



International Association of Geomorphologists  
*Association Internationale des Géomorphologues*



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Indian Institute of Geomorphologists (IGI)

## ABSTRACTS VOLUME



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## Table of Contents

### MESSAGES

- International Association of Geomorphologists, <i>Prof. Eric Fouache, President</i> .....	41
- Indian Institute of Geomorphologists (IGI), India, <i>Prof. Savindra Singh, President</i> .....	42
- International Association of Geomorphologists, <i>Prof. Sunil Kumar De, Secretary General</i> .....	43-44
INTERNATIONAL ASSOCIATION OF GEOMORPHOLOGISTS : <i>Executive Committee (2013-1027)</i> .....	45
INDIAN INSTITUTE OF GEOMORPHOLOGISTS (IGI) : <i>Office Bearers of the Executive Council, 2017</i> .....	45-46
ORGANIZING COMMITTEE: <i>9th INTERNATIONAL CONFERENCE ON GEOMORPHOLOGY</i> .....	46-49
SESSIONS AND CO-CHAIRS .....	50-51

### ABSTRACTS FOR PLENARY SESSIONS

<b>Keynote Speech: Geomorphology and Society</b> , <i>Prof. Michael Crozier, Victoria University of Wellington, New Zealand</i> .....	54
<b>Plenary Lecture-1: Applications of geospatial technology in geomorphology: historical review and future perspectives</b> , <i>Prof Takashi Oguchi, University of Tokyo, Kashiwa, Japan</i> .....	54
<b>Prof. S. R. Basu Memorial Plenary Lecture-2: Geomorphology: My Way</b> , <i>Prof. Morgan De Dapper, Ghent University, Department of Geography, Research Unit 'Regional Geomorphology &amp; Geo-archaeology' Belgium</i> .....	55
<b>Plenary Lecture-3: Applied geomorphological investigations using the trenching technique. Sinkholes, faults, landslides, floods</b> , <i>Prof. Francisco Gutierrez, University of Zaragoza, Spain</i> .....	55-56
<b>Plenary Lecture-4: Equilibrium theory, evolution and least action principle; factors determining self-adjustment in Geomorphology and Earth's fluvial stratigraphic record</b> , <i>Prof. Gerald C. Nanson, University of Wollongong, NSW 2519, He Qing Huang, Chinese Academy Sciences, Beijing, China</i> .....	56-57
<b>Plenary Lecture-5: Indian Geomorphology : Past, Present and Future</b> , <i>Prof. Savindra Singh, Department of Geography, University of Allahabad, Allahabad, India</i> .....	57
<b>Plenary Lecture-6: Rivers in the Humid Tropics</b> , <i>Prof. Avijit Gupta, School of Earth and Environmental Sciences University of Wollongong, Australia, Centre for Remote Imaging, Sensing and Processing National University of Singapore, Singapore</i> .....	57-58
<b>Plenary Lecture-7: Geomorphology, disaster risk reduction &amp; policy making: on the road to Sendai</b> , <i>Prof. Irasema Alcántara-Ayala, Institute of Geography, UNAM</i> .....	58

### ABSTRACTS FOR ORAL PRESENTATION

#### S1 : THEORETICAL GEOMORPHOLOGY ..... 60-65

<b>ABSTRACT: 17 : SHOULD THEORY IN GEOMORPHOLOGY TAKE HUMAN IMPACTS AND HUMAN AGENCY SERIOUSLY?</b> , <i>Olav Slaymaker<sup>1</sup>, University Of British Columbia, Vancouver, British Columbia, Canada</i>	
<b>ABSTRACT NUMBER: 143 : THE MORPHOLOGY OF TRANSITION ZONES IN MOUNTAIN REGIONS</b> , <i>Gennady Baryshnikov*, Altai State University, Barnaul, Altai Region, Russian Federation</i>	
<b>ABSTRACT NUMBER: 165 : GOETHE'S MORPHOLOGICAL METHOD AND ITS INFLUENCE IN GEOMORPHOLOGY</b> , <i>Maira Ferraz<sup>1</sup>, IFSP/UNICAMP, Matão/Campinas, São Paulo, Brazil;<sup>2</sup> UNICAMP, Campinas, São Paulo, BRAZIL</i>	
<b>ABSTRACT NUMBER: 204 : GEOMORPHOLOGY AND SOCIETY: A POLITICAL-ECONOMIC INTERPRETATION OF EARTHSCAPES</b> , <i>Lakshminarayan Satpati, Department of Geography, University of Calcutta, Kolkata, West Bengal, India</i>	
<b>ABSTRACT NUMBER: 240 : ON THE SCALE-DEPENDENCY AND MECHANICAL PRECONDITIONING OF PARAGLACIAL ROCK SLOPE INSTABILITY – CONCEPTUAL CONSIDERATIONS FROM MODELLING, FIELD AND LABORATORY STUDIES</b> , <i>Karoline Messenzehl, University of Bonn, Bonn, Germany</i>	
<b>ABSTRACT NUMBER: 412 : UNDERSTANDING GEOMORPHIC THRESHOLD THROUGH EMPIRICAL STUDIES</b> , <i>Ramkrishna Maiti, Vidyasagar University, Midnapore, West Bengal, India</i>	
<b>ABSTRACT NUMBER: 469 : CHARACTERISING AUTOGENIC AND ALLOGENIC CONTROLS OF CHANNEL AVULSION USING HIGH RESOLUTION CHRONOLOGY OF FLUVIAL FAN STRATIGRAPHY IN NW GANGES BASIN</b> , <i>Ajit Singh, Department of Earth Science and Engineering, Imperial College London, London, United Kingdom</i>	
<b>ABSTRACT NUMBER: 472 : CAUSES AND MECHANISMS OF SEDIMENTATION IN THE LOWER REACH OF THE RUPNARAYAN RIVER, WEST BENGAL, INDIA</b> , <i>Swapan Maiti, Nayagram P.R.M. Govt. College, Midnapur, West Bengal, India</i>	



**ABSTRACT NUMBER: 530 : THE GEOMORPHIC CELL: A BASIS FOR STUDYING HYDRO-GEOMORPHIC CONNECTIVITY,** Ronald Pöppel, *University Of Vienna, Vienna, Austria*

**ABSTRACT NUMBER: 544 : PROCESS INTERPRETATION USING FRACTAL DIMENSION: A CASE STUDY FROM THE NWHIMALAYA,** Ramendra Sahoo, *Indian Institute of Technology Gandhinagar, Gandhinagar, Gujarat, India*

**ABSTRACT NUMBER: 621 : CONCEPTS AND MODELS FOR THE GROUND THERMAL REGIME AS A TOOL TO UNDERSTAND GEOMORPHOLOGICAL PROCESSES AND LANDSCAPE DEVELOPMENT IN COLD MOUNTAIN ENVIRONMENTS,** Bernd Etzelmüller, *University Of Oslo, Oslo, Oslo, Norway*

**THEME: S2 : APPLIED GEOMORPHOLOGY ..... 65-69**

**ABSTRACT NUMBER: 4 : SEISMIC GEOMORPHOLOGY FOR HYDROCARBON EXPLORATION,** Sunjay Sunjay, *Geophysics, BHU, Varanasi, Uttar Pradesh, India*

**ABSTRACT NUMBER: 126 : UNDERSTANDING THE SHIFTING BEHAVIOUR OF RIVER KOSI: STEERING TOWARDS A MORE RATIONAL HYPOTHESIS,** Vilakshna Parmar, *Indian Institute Of Technology Delhi, New Delhi, Delhi, India*

**ABSTRACT NUMBER: 163 : THE ANTHROPOGENIC-URBAN GEOMORPHOLOGY OF NEWSUBURBS, EAST OF GREATER CAIRO, EGYPT,** Amr Saleem, *Ain Shams University, Cairo, Egypt*

**ABSTRACT NUMBER: 254 : UAV BASED SOIL EROSION MONITORING FOR SOIL PROTECTION,** Delia Maendli, *University Of Basel, Basel, Switzerland*

**ABSTRACT NUMBER: 321 : MORPHOSCUPTURAL AND MORPHO-STRUCTURAL UNITS AND ENVIRONMENTAL SENSITIVITY IN SÃO-PAULO-STATE COASTAL AREA,** Marisa, *University Of São Paulo, São Paulo, Brazil*

**ABSTRACT NUMBER: 401 : DESIGNING NATURAL RIVERS: THE NEW CHALLENGES OF BUILDING MINING RIVER DIVERSIONS,** Ian Rutherford, *School Of Geography, University Of Melbourne, Carlton, VIC, Australia*

**ABSTRACT NUMBER: 505 : TREE RINGS AS A SOURCE OF DATA FOR LANDSLIDE HAZARD IDENTIFICATION AND MAPPING (WESTERN CARPATHIAN MTS, POLAND),** Ireneusz Malik, *University Of Silesia In Katowice, Faculty Of Earth Sciences, Katowice*

**ABSTRACT NUMBER: 537 : NEW LESSONS FROM AN OLD LANDSLIDE: WHY THE VAIONT LANDSLIDE WAS MISUNDERSTOOD,** Alan Dykes, *Kingston University, Kingston Upon Thames, Surrey, United Kingdom*

**ABSTRACT NUMBER: 652 : FLOOD MANAGEMENT AND PLANNING,** Mukta Raje, *S.P.G. College, Mihrawan, Jaunpur, Uttar Pradesh, India*

**THEME: S3 : GEOMORPHIC PROCESSES IN COUPLED HUMAN AND NATURAL SYSTEMS ..... 70-74**

**ABSTRACT NUMBER: 31 : RIVER SEDIMENT EXTRACTION AND DRYING WELLS: A HUMAN INDUCED HYDROMORPHOLOGICAL THREATS IN THE PIEDMONT REGION OF DARJEELING HIMALAYAS,** Lakpa Tamang, *University Of Calcutta, Kolkata, West Bengal, India*

**ABSTRACT NUMBER: 72 : EMERGENT PROPERTIES OF FLOOD DISASTERS: TOWARDS THEORY,** Robert Wasson, *Institute Of Water Policy, National University of Singapore, Singapore*

**ABSTRACT NUMBER: 247 : CHARACTERISTICS OF THE 2016 FLOOD FOCUSING ON FLUVIAL TOPOGRAPHY AND FLOOD IMPACT ON LOCAL COMMUNITIES IN THE OMOTO RIVER BASIN, NORTHEASTERN JAPAN,** Naoko Nagumo, *International Centre for Water Hazard and Risk Management (ICHARM), PWRI, Tsukuba, Ibaraki, Japan*

**ABSTRACT NUMBER: 397 : CHANGE OR PERSISTENCE? THE IMPACT OF LAND USE CHANGES ON GEOMORPHIC SYSTEMS IN DEPOPULATED AREAS (SUDETY MTS. CASE STUDY),** Agnieszka Latocha, *University of Wroclaw, Wroclaw, Poland*

**ABSTRACT NUMBER: 498 : RIVERBANK EROSION, GEOMORPHOLOGICAL CHANGE, AND MIGRATION EXPERIENCES IN MAJULI, ASSAM: A CASE STUDY,** Avijit Sahay, *University of Allahabad, Allahabad, Uttar Pradesh, India*

**ABSTRACT NUMBER: 685 : VULNERABLE OR RESILIENT? LOCAL NARRATIVES OF ADAPTATION IN THE LANDSLIDE PRONE**

**HILLS OF KURSEONG: A POLITICAL ECOLOGY PERSPECTIVE,** Samayita Bandyopadhyay, *Oklahoma State University, Stillwater, Oklahoma, United States*

**ABSTRACT NUMBER: 705 : GEOMORPHOLOGY IN THE ANTHROPOCENE,** Andrew GOUDIE, *Oxford University, Oxford, Oxon, United Kingdom*

**ABSTRACT NUMBER: 716 : IMPACTS OF NATURAL AND HUMAN DRIVERS ON THE MORPHOLOGY OF TIDALLY INFLUENCED DELTAS OVER MULTI-DECADAL TIMESCALES,** Balaji Angamuthu, *SECON Ltd, Bengaluru, Karnataka, India*



**ABSTRACT NUMBER: 722 : HYBRID APPROACH TO MODELLING CENTURY-SCALE CHANGES IN THE SPATIAL DISTRIBUTION OF STORMSURGE FLOOD RISK**, [Jon French](#), *University College London (UCL), London, United Kingdom*

**ABSTRACT NUMBER: 742 : THE CHALLENGE OF URBAN FLOOD RISK AND THE GEOMORPHOLOGY OF “SPONGE CITIES”**, [David Higgitt](#), *Beijing Jiaotong University (Lancaster College), Weihai, Shandong, China*

**THEME: S4 : GEOMORPHOLOGICAL RESOURCES ..... 74-75**

**ABSTRACT NUMBER: 404 : A GEOMORPHOLOGICAL APPROACH TO ASSESS LAND SUITABILITY OF KARHA RIVER BASIN USING GIS**, [Virendra Nagarale](#), *S.N.D.T. Women's University Mumbai, Pune, Maharashtra, India*

**ABSTRACT NUMBER: 506 : TALUS CONES AS GEOMORPHOLOGICAL SITES FOR GRAFTING ARTIFICIAL GLACIERS IN THE HINDUKUSH KARAKORAM(PAKISTAN)**, [Lasafamlturrizaga](#), *University of Goettingen, Göttingen, Niedersachsen, Germany*

**ABSTRACT NUMBER: 762 : GEOMORPHOLOGICAL MAPPING OF SANJAI RIVER BASIN, JHARKHAND, INDIA**, [Swapna Saha](#), *National Atlas and Thematic Mapping Organisation, Kolkata, West Bengal, India*

**THEME: S5 : VOLCANIC GEOMORPHOLOGY ..... 76-78**

**ABSTRACT NUMBER: 21 : CALDERA KSUDACH (KAMCHATKA): MAIN FEATURES OF THE HYDROGRAPHIC NETWORK DEVELOPMENT**, [Ekaterina Lebedeva](#), *Institute Of Geography RAS, Moscow, Moscow, Russian Federation*

**ABSTRACT NUMBER: 25 : ASSESSING THE VULNERABILITY OF VOLCANIC ERUPTION ON THE JOS AND BIU PLATEAU, NIGERIA: USING GIS**, [Hauwa Mohammed Aliyu](#), *Centre For Geodesy And Geodynamics, Toro, Bauchi, Nigeria*

**ABSTRACT NUMBER: 316 : DYNAMIC EVOLUTION OF THE 1888 RITTER FLANK COLLAPSE AND ASSOCIATED MASS MOVEMENTS**, [Aaron Micallef](#), *Marine Geology & Seafloor Surveying, Department of Geosciences, University Of Malta, Msida, Malta*

**ABSTRACT NUMBER: 562 : RIVER INCISION RATES IN VOLCANIC TERRAINS**, [Moshe Inbar](#), *Department of Geography and Environmental Studies, University Of Haifa, Haifa, Israel*

**ABSTRACT NUMBER: 595 : GEOLOGICAL AND GEOMORPHOLOGICAL CHARACTERISTICS OF OBSIDIAN IN BINGÖL VOLCANIC AREA (EASTERN ANATOLIA-TURKEY)**, [Ebru Akköprü](#), *Van Yüzüncü Yil University, Van, Kampüs, Turkey*

**THEME: S6 : KARST GEOMORPHOLOGY ..... 78-81**

**ABSTRACT NUMBER: 49 : DETECTION AND CHARACTERIZATION OF SAGGING SINKHOLES BY TRENCHING IN A SITE SELECTED FOR A CRITICAL INFRASTRUCTURE**, [Francisco Gutierrez](#), *University of Zaragoza, Zaragoza, Zaragoza, Spain*

**ABSTRACT NUMBER: 51 : SUBSIDENCE ACTIVITY IN SINKHOLES INFERRED BY TRENCHING, GPR AND ERI. EVAPORITE KARST OF THE FLUVIA VALLEY, NE SPAIN**, [Ivan Fabregat González](#), *Departamento de Ciencias de la Tierra, University of Zaragoza, Zaragoza, Spain*

**ABSTRACT NUMBER: 140 : STUDY ON THE EXTRACTION OF TERRAIN ELEMENTS BASED ON DEM IN KARST FENGLIN AND FENGCONG**, [Yang Xianwu](#), *Key Laboratory Of Virtual Geographic Environment Of Ministry Of Education, Nanjing Normal University, Nanjing, Jiangsu, China*

**ABSTRACT NUMBER: 230 : OBJECT-BASED IMAGE ANALYSIS OF GYPSUM DOLINES USING LIDAR ELEVATION DATA TO REFINE ALPINE LANDSCAPE EVOLUTION IN VORARLBERG, AUSTRIA**, [Arie Seijmonsbergen](#), *University of Amsterdam, Amsterdam, Noord Holland, Netherlands*

**ABSTRACT NUMBER: 269 : EPIKARST HYDROLOGY - AN INSIGHT FROM THE CROATIAN CAVE MONITORING**, [Nina Lončar](#), *Department of Geography, Center for Karst and Coastal Research, University of Zadar, Zadar, Croatia*

**ABSTRACT NUMBER: 373 : CORROSION RATES IN THE MIXED ZONE OF UNDERWATER LITTORAL CAVES (MALLORCA, BALEARIC ISLANDS, WESTERN MEDITERRANEAN)**, [Lluís Gomez-Pujol](#), *Earth Sciences Research Group, University of the Balearic Islands, Palma, Illes Balears, Spain*

**ABSTRACT NUMBER: 632 : GEOMORPHIC WORK IN KARST LANDSCAPES AND EVOLUTION OF CAVE SYSTEMS IN SOUTHERN INDIA: IMPLICATIONS FOR CLIMATE AND ENVIRONMENTAL STUDIES**, [Narayana A.C.](#), *Centre for Earth & Space Sciences, University of Hyderabad, Hyderabad, Andhra Pradesh, India*

**THEME: S7 : ANTHROPOCENE GEOMORPHOLOGY ..... 82-85**

**ABSTRACT NUMBER: 118 : HUMAN INTERFERENCES ON FLUVIAL SYSTEM: A STUDY OF RIVER MAHANANDA IN DARJEELING DISTRICT, WEST BENGAL**, [Pompi Sarkar](#), *University Of North Bengal, Siliguri, West Bengal, India*

**ABSTRACT NUMBER: 205 : HYDRO-GEOMORPHIC PERSPECTIVE OF URBAN RENEWAL: SELECTED EXAMPLES**



FROMKOLKATA, Lakshminarayan Satpati, Department of Geography, University of Calcutta, Kolkata, West Bengal, India

**ABSTRACT NUMBER: 206: SILENT KILLER : ARSENIC CONTAMINATION IN WEST BENGAL, A CASE STUDY OF BARUIPUR BLOCK, SOUTH 24 PARGANAS DISTRICT, WEST BENGAL, INDIA**, Karabi Das, University Of Calcutta, Kolkata, West Bengal, India

**ABSTRACT NUMBER: 271 : ASSESSING THE REHABILITATION POTENTIAL OF FLOODPLAINS: CASE STUDY OF THE LOWER DRAVA PLAIN IN HUNGARY**, Dénes, University Of Pécs, Pécs, Baranya, Hungary

**ABSTRACT NUMBER: 344 : IS ANTHROPOCENE GEOMORPHOLOGY DIFFERENT FROM FORMER GEOMORPHOLOGY?** Antonio Cendrero, University Of Cantabria, Santander, Cantabria, Spain

**ABSTRACT NUMBER: 376 : A SPATIAL ANALYSIS OF MASS MOVEMENT EVENTS ON TABLE MOUNTAIN, CAPE TOWN, SOUTH AFRICA**, Michael Meadows, University of Cape Town, Rondebosch, Western Cape, South Africa

**ABSTRACT NUMBER: 377 : BUILDING BEYOND LAND: AN OVERVIEW OF COASTAL LAND RECLAMATION IN 15 GLOBAL MEGACITIES**, Michael Meadows, University of Cape Town, Rondebosch, Western Cape, South Africa

**ABSTRACT NUMBER: 488 : UNTANGLING THE ANTHROPOCENE IN NEW ZEALAND: ANALYZING A VERY LONG TERM EXPERIMENT**, John Wainwright, Durham University, Department of Geography, Durham, United Kingdom

**ABSTRACT NUMBER: 746 : THE CO-EVOLUTION OF GEOMORPHOLOGY AND SOCIETY IN THE ANTHROPOCENE: SEDIMENT FLUX IN A HIGH ALPINE HYDROELECTRIC POWER SYSTEM: RESULTS FROM THE SEDFATE PROJECT**, Stuart Lane, <sup>1</sup>University Of Lausanne, Institute of Earth Surface Dynamics, Lausanne, Vaud, Switzerland

**THEME: S8 : GEOMORPHOLOGICAL OUTREACH ..... 86-87**

**ABSTRACT NUMBER: 88 : DUNE ECOSYSTEM RESTORATION ON A HIGHLY IMPACTED BEACH: ANALYSING LAND USE/ COVER, SPECIES DIVERSITY AND SEDIMENT TRANSPORT AT NORTHWEST BEACH, POINT PELEE NATIONAL PARK, CANADA**, Mary-Louise Byrne, Geography and Environmental Studies, Wilfrid Laurier University, Waterloo, Ontario, Canada

**ABSTRACT NUMBER: 160, MAKING THE MESSAGE SIMPLE : OUTREACH RELATED TO A WORLD HERITAGE SITE NOMINATION FOR A TECTONIC PROCESS SEEN THROUGH A LANDSCAPE**, Cécile Olive-garcia, Conseil Departemental Du Puy De Dome, Clermont-ferrand, Puy De Dome, France

**ABSTRACT NUMBER: 603 : UNRAVELING GLACIAL LAKE OUTBURST FLOOD GEOMORPHOLOGY: AN EXERCISE ON JOKULHLAUP LANDSCAPE INTERPRETATION IN ICELAND**, Greta Wells, University Of Texas At Austin, Austin, Texas, United States

**ABSTRACT NUMBER: 625 : CAUSES FOR THE DEVELOPMENT OF CHAMBAL BADLANDS, INDIA**, Vimal Singh, Department Of Geology, University Of Delhi, Delhi, India

**ABSTRACT NUMBER: 645 : TECTONO- GEOMORPHIC EVOLUTION OF RAVINE AND ITS EROSION RATE ESTIMATION IN THE MARGINAL GANGA PLAIN, INDIA**, Rupa Ghosh, Wadia Institute Of Himalayan Geology, Dehradun, Uttarakhand, India

**THEME: S9 : BIO-GEOMORPHOLOGY ..... 88-91**

**ABSTRACT NUMBER: 30 : WHITE-SAND VEGETATION OF AMAZONIAN LOWLANDS TRIGGERED BY LATE PLEISTOCENE-HOLOCENE GEOMORPHOLOGICAL PROCESSES**, Dilce de Fatima Rossetti, Inpe, São Jose Dos Campos, Sp, Brazil

**ABSTRACT NUMBER: 57 : RIPARIAN PLANT RESPONSE AND EFFECT TRAITS: A BETTER PREDICTION OF BIOGEOMORPHIC EVOLUTIONARY TRAJECTORIES OF ALLUVIAL BARS?** Borbála Hortobágyi, <sup>1</sup>Université Clermont Auvergne, CNRS, GEOLAB, Clermont-Ferrand, France

**ABSTRACT NUMBER: 82 : LIFE ENCROACHING ROCKS – DENDROGEOMORPHOLOGICAL EVIDENCE OF BIOMECHANICAL WEATHERING CAUSED BY TREE ROOTS**, Lukasz Pawlik, Pedagogical University Of Cracow, Krakow, Poland

**ABSTRACT NUMBER: 225 : BIOLOGICAL SOIL CRUSTS MICROMORPHOLOGY ALONG AN ARID ALLUVIAL FAN IN NORTHEASTERN IRAN**, Adel Sepehr, Dept. of Desert and Arid Zone Management, Ferdowsi University of Mashhad, Mashhad, Khorasan-razavi, Iran

**ABSTRACT NUMBER: 372 : CLOSING THE CIRCLE: SEAGRASS BERM DEPOSITION AND DISMANTLING AND BEACH SHORELINE PROTECTION AT MEDITERRANEAN MICROTIDAL SEMI-EXPOSED BEACHES**, Lluís Gomez-Pujol, University of the Balearic Islands, Earth Sciences Research Group (Geology and Paleontology "Guillem Colom"), Department of Biology, Palma, Illes Balears, Spain

**ABSTRACT NUMBER: 792 : LAND SURFACE FEATURES AND DISTRIBUTION OF WILDLIFE – CASE STUDY OF MUSK DEER IN DACHIGAM NATIONAL PARK, KASHMIR (J&K)**, Mudasir Ali, S.P. College, Cluster University of Srinagar, Srinagar, Jammu & Kashmir, India



**THEME: S10 :WEATHERING, SOILS AND REGOLITH ON DIFFERENT TIME SCALES ..... 91-99**

**ABSTRACT NUMBER: 11 : POTENTIAL THRESHOLD RESPONSE IN TAFONI DEVELOPMENT: AN ALTERNATIVE APPROACH TO CAVERNOUS ROCK DECAY,** Kaelin Groom, *University Of Arkansas, Parker, Colorado, United States*

**BSTRACT NUMBER: 44 : GEOMORPHIC EVOLUTION OF BHAWAL GARH: A PEDOGENIC APPROACH,** Rajib Kumar Saha, *Geological Survey of Bangladesh, Dhaka, Bangladesh*

**ABSTRACT NUMBER: 96 : SOIL FORMATION IN THE SOUTHEASTERN TRANSBAIKALIA IN THE HOLOCENE,** Olga Bazhenova, *Sochava Institute Of Geography Siberian Branch Russian Academy Of Sciences, Irkutsk, Irkutskaya Oblast, Russian Federation*

**ABSTRACT NUMBER: 106 : GEOMORPHOLOGICAL-PEDOLOGICAL EVOLUTION OF CUESTA ESCARPMENT FOOTHILLS IN SOUTHEASTERN TROPICAL BRAZIL,** Fernando Nadal Junqueira Villela, *University Of Sao Paulo, São Paulo, Brazil*

**ABSTRACT NUMBER: 123 : QUANTIFYING CHANGES IN NEAR-SURFACE SOIL MOISTURE AND TEMPERATURE DURING PRESCRIBED FIRE UNDER THREE FUEL LOADS,** Michael Slattery, *Texas Christian University, Fort Worth, Texas, United States*

**ABSTRACT NUMBER: 164 : FERRICRETE GENESIS IN THE NORTHWEST OF PARANÁ STATE (BRAZIL),** Leonardo Santos, *Department Of Geography - Federal University Of Paraná, Curitiba, Paraná, Brazil*

**ABSTRACT NUMBER: 306 : AEOLIAN PEDOGENIC CHARACTERISTICS OF TERTIARY LIMESTONE NEAR PORT CAMPBELL, VICTORIA AUSTRALIA—MARINE OR PEDOGENIC?** Xiuming Liu, *Fujian Normal University, Fuzhou, Fujian, China*

**ABSTRACT NUMBER: 307 : TUDY ON THE ORIGIN OF THICK LATERITE ON DECCAN PLATEAU, INDIA,** Xiuming Liu, *Fujian Normal University, Fuzhou, Fujian, China*

**ABSTRACT NUMBER: 366 : CAVES IN CAVES: EVOLUTION OF POST-DEPOSITIONAL MACROHOLES IN STALAGMITES,** Nurit Shtober-Zisu, *University of Haifa, Haifa, Israel; <sup>2</sup>McMaster University, Hamilton, Ontario, Canada*

**ABSTRACT NUMBER: 367 : POST-FIRE GEOMORPHIC RESPONSE IN MEDITERRANEAN CARBONATES HILLSLOPES,** Nurit Shtober-Zisu, *University of Haifa, Haifa, Israel*

**ABSTRACT NUMBER: 436 : WEATHERING OF BEDROCKS, FORMATION OF HARDPAN CALCRETES IN THE THAR DESERT, WESTERN RAJASTHAN: STRAIGRAPHIC MARKER HORIZONS,** Hema Achyuthan, *Anna University, Chennai, Tamil Nadu, India*

**ABSTRACT NUMBER: 509 : GEOMORPHOLOGICAL AND REGOLITH MAPPING IN PARTS OF WAJRAKARUR KIMBERLITE FIELD, ANANTAPUR DISTRICT, SOUTHERN INDIA,** Ramesh Chandra Phani Pothuri, *Cyient Limited, Hyderabad, Telangana, India*

**ABSTRACT NUMBER: 573 : LITHOLOGICAL AND CLIMATIC CONTROLS ON CHEMICAL DENUDATION IN SMALL WATERSHEDS OF THE WESTERN INDIA,** Ravi Kant Prasad, *IIT Gandhinagar, Gandhinagar, Gujarat, India*

**ABSTRACT NUMBER: 657 : UNSCIENTIFIC INTERFERENCE WITH PEDO-GEOMORPHIC PRINCIPLES AND ITS IMPACT ON CROP PRODUCTION IN BARDDHAMAN OF WEST BENGAL, INDIA,** Biswaranjan Mistri, *University of Burdwan, Burdwan, West Bengal, India*

**ABSTRACT NUMBER: 670 : THE RELATION OF FERRICRETE AND PEDOLOGICAL SYSTEMS WITH THE LANDSCAPE EVOLUTION IN MARACÁÍ – SP (BRAZIL),** Grace Alves, *Department of Geography, Federal University Of Bahia, Salvador, Bahia, Brazil*

**ABSTRACT NUMBER: 765 : LANDSCAPE EVOLUTION MODEL ON ANCIENT RELIEF IN TROPICAL AREA,** Cristina Augustin, *IGC-UFMG, Belo Horizonte, Minas Gerais, Brazil*

**ABSTRACT NUMBER: 766 : SLOPE AND WATER TABLE DYNAMIC AT SEMI ARID AREA – BRAZIL,** Cristina Augustin, *IGC-UFMG, Belo Horizonte, Minas Gerais, Brazil*

**THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS ..... 99-109**

**ABSTRACT NUMBER: 109 : ANALYSIS OF HYDROGEOMORPHOLOGICAL CHARACTERISTICS AND NATURAL DISASTER PREVENTION: DEBRIS FLOW IN PALMITAL RIVER, APIÁI MUNICIPALITY, SÃO PAULO / BRAZIL, 2014,** Gilberto Lima, *Serviço Geológico do Brasil, São Paulo, Brazil*

**ABSTRACT NUMBER: 116 : COASTAL CLIFFS, GIANT ROCKSLIDES AND LATE QUATERNARY TRANSGRESSIONS OF THE BLACK SEA ALONG THE SOUTHERN CRIMEA,** Tomas Panek, *University Of Ostrava, Ostrava, Czech Republic*

**ABSTRACT NUMBER: 173 : GEOSPATIAL REVIEW AND VALIDATION OF VARIOUS PREDICTION MODELS FOR THE LANDSLIDE SUSCEPTIBILITY MAPPING IN DARJEELING HIMALAYA,** Chalantika Laha Salui, *Indian Institute Of Engineering Sciences And Technology, Shibpur, Haora, West Bengal, India*

**ABSTRACT NUMBER: 231 : ESCARPMENT RETREAT IN TABLELANDS – DOES IT ALWAYS REQUIRE CATASTROPHIC MASS MOVEMENTS? NEW FACTS AND ALTERNATIVE SCENARIO FROM THE STOŁOWE MOUNTAINS TABLELAND, SW POLAND,** Filip Duszyński, *University of Wrocław, Wrocław, Lower Silesia, Poland*



**ABSTRACT NUMBER: 250 : INTERACTION OF EXOGENOUS PROCESSES IN GULLY FORMATION, DEVELOPMENT AND FILLING IN THE SIBERIA (RUSSIA),** Yury Ryzhov, V.B. Sochava Institute Of Geography SB RAS, Irkutsk, Irkutsk Region, Russian Federation

**ABSTRACT NUMBER: 253 : INTERRELATIONSHIP OF TECTONICS, PRECIPITATION AND LANDSLIDES, NORTHWEST HIMALAYA, INDIA,** Vipin Kumar, Wadia Institute Of Himalayan Geology, Dehradun, Uttarakhand, India

**ABSTRACT NUMBER: 277 : ANALYSIS AND MONITORING OF SUPERFICIAL EROSION PROCESS IN DIFFERENT VEGETATION COVER IN AMAZONIAN ENVIRONMENT - ACRE – BRAZIL,** Waldemir Santos, Federal University of Acre, Rio Branco, Acre, Brazil;

**ABSTRACT NUMBER: 333 : PRESENTING LOGISTIC REGRESSION-BASED LANDSLIDE SUSCEPTIBILITY RESULTS,** Luigi Lombardo, Physical Sciences and Engineering (PSE) Division, King Abdullah University of Science and Technology, Thuwal, Saudi Arabia, Saudi Arabia

**ABSTRACT NUMBER: 351 : ANTHROPOGENIC AND CLIMATOGENETIC IMPACT ON THE LANDSLIDES IN LESSER HIMALAYAN BELT OF J&K: DISTRIBUTION, CHARACTERISTICS AND MANAGEMENT,** Anju Gupta, Kurukshetra University, Kurukshetra, Haryana, India

**ABSTRACT NUMBER: 386 : LITHOLOGY AND GEOMORPHIC CONTROL ON SLOPE STABILITY IN KONKAN AREAS OF MAHARASHTRA, INDIA,** Sudhakar Pardeshi, Department Of Geography, Savitribai Phule Pune University, Pune, Maharashtra, India

**ABSTRACT NUMBER: 389 : LANDSLIDE SUSCEPTIBILITY MAPPING ON MACRO SCALE- A CASE STUDY FROM IDUKKI DISTRICT OF KERALA, INDIA,** Sajeev R, Geological Survey Of India, India

**ABSTRACT NUMBER: 402 : ANALYSIS OF THE GEOMORPHIC EFFECTS OF AN EXTREME PRECIPITATION EVENT ON A SMALL ALPINE MEADOW CATCHMENT, SOUTHERN SIERRA NEVADA, CALIFORNIA USA,** Louis Scuderi, University of New Mexico, Albuquerque, New Mexico, United States

**ABSTRACT NUMBER: 430 : POSTGLACIAL FAN EVOLUTION IN THE UPPER RHONE VALLEY, SWITZERLAND – GRADUAL OR CATASTROPHIC?** Jan Henrik Blöthe, University of Bonn, Bonn, Germany; 2University of Wollongong, Wollongong, Australia

**ABSTRACT NUMBER: 496 : RAPID REWORKING AND REACTIVATION OF MASS MOVEMENTS BY GULLY EROSION IN THE MANGAHEU CATCHMENT, EAST COAST REGION, NORTH ISLAND, NEW ZEALAND,** Thomas Parkner, University of Tsukuba, Tsukuba, Ibaraki, Japan

**ABSTRACT NUMBER: 504 : CAN LOW-MAGNITUDE EARTHQUAKES ACT AS A TRIGGERING FACTOR FOR LANDSLIDE ACTIVITY? EXAMPLES FROM THE WESTERN CARPATHIAN MTS, POLAND,** Małgorzata Wistuba, University of Silesia in Katowice, Faculty of Earth Sciences – Centre for Polar Studies KNOW, Katowice, Silesian Province, Poland

**ABSTRACT NUMBER: 538 : THE IMPORTANCE OF RAINFALL AND GROUNDWATER DATA FOR LANDSLIDE HAZARD ASSESSMENTS DEMONSTRATED BY NEW ANALYSES OF THE VAIONT LANDSLIDE USING A REALISTIC FAILURE SURFACE GEOMETRY,** Alan Dykes, Kingston University, Kingston Upon Thames, Surrey, United Kingdom

**ABSTRACT NUMBER: 604 : MORPHOLOGICAL ASSESSMENT OF SHALLOW LANDSLIDES IN GURUTUBA BASIN, SÃO PAULO STATE, BRAZIL,** Camila Carou, University of São Paulo, Sao Paulo, Brazil

**ABSTRACT NUMBER: 605 : LITHOLOGICAL SUSCEPTIBILITY ASSESSMENT OF MASS MOVEMENTS IN THE SERRA DO MAR, SÃO PAULO STATE, BRAZIL,** Maria Rita Pelegrin de Oliveira, University Of São Paulo, Sao Paulo, Brazil

**ABSTRACT NUMBER: 607 : PHYSIOGRAPHIC MODELING WITH 3D SIMULATION SOFTWARE AS A SUBSIDY TO RETRO-ANALYSIS STUDIES OF MASS MOVEMENTS: APPLICATION IN MOUNTAIN AREA OF STATE OF SÃO PAULO, BRAZIL,** Claudia Vanessa Dos Santos Corrêa, Unesp/ São Paulo State University, Rio Claro, São Paulo State, Brazil

**ABSTRACT NUMBER: 687 : DEBRIS FLOWS AND LONG-TERM DENUDATION RATES IN THE SERRA DO MAR/SP, BRAZIL,** Maria Carolina Villaça Gomes, State University of Santa Catarina, Florianópolis, Santa Catarina, Brazil

**ABSTRACT NUMBER: 768 : THE OCCURRENCE AND SUSCEPTIBILITY TO MASS MOVEMENT IN THE WESTERN SAN JUAN MOUNTAINS, COLORADO: A 3-D MAPPING APPROACH,** Kaytan Kelkar, Texas A&M University, Texas, United States

**THEME: S12 : PALAEOHYDROLOGY AND FLUVIAL ARCHIVES - HYDROLOGICAL EXTREME AND CRITICAL EVENTS (HEX).....110-116**

**ABSTRACT NUMBER: 102 : ARE ALLUVIAL FAN SEDIMENTATION AND EROSION PATTERNS CONTROLLED BY AFRICAN HUMID PERIOD CLIMATE DYNAMICS (CAPE VERDE ISLANDS, OFFSHORE WEST AFRICA)?** Martin Stokes, Earth Sciences, Plymouth University, Plymouth, Devon, United Kingdom

**ABSTRACT NUMBER: 132 : READING PALAEOHYDROLOGICAL INFORMATION FROM MODERN AND ANCIENT ALLUVIAL FAN ARCHIVES IN ARID SETTINGS: THE ATACAMA DESERT, NORTHERN CHILE,** Anne Mather, School of Geography, Earth and Environmental Sciences, Plymouth University, Plymouth, Devon, United Kingdom



**ABSTRACT NUMBER: 146 : STORM-GENERATED HOLOCENE AND HISTORICAL PALAEOFLOODS IN NEW ZEALAND,** [Ian Fuller](#), *Massey University, Palmerston North, Manawatu-Wanganui, New Zealand*

**ABSTRACT NUMBER: 175 : RUN-UP SEDIMENTS AS (PALAEO-)HYDRAULIC INDICATOR,** [Juergen Herget](#), *Department of Geography, Bonn, NRW, Germany*

**ABSTRACT NUMBER: 360 : PALAEO- HYDROLOGICAL EXTREME EVENTS FROM THE INDUS AND ZANSKAR RIVER SYSTEM, LADAKH HIMALAYA,** [Poonam Chahal](#), *H.N.B. Garhwal University, Srinagar Garhwal, Uttrakhand, India*

**ABSTRACT NUMBER: 393 : RECONSTRUCTION OF PALEO-DROUGHT CONDITIONS ASSOCIATED WITH MONSOON SYSTEM IN MAKRAN, IRAN,** [Tayebeh Akbari Azirani](#), *Shahid Beheshti University, Tehran, Iran*

**ABSTRACT NUMBER: 415 : SENSITIVITY AND RESPONSES OF THE CHER RIVER (RÉGION CENTRE, FRANCE) TO CLIMATE VARIABILITY AND HUMAN PRESSURE,** [Anaëlle Vayssièrè](#), *Université de Paris<sup>1</sup> Panthéon Sorbonne, Laboratoire de Géographie Physique, LGP CNRS-UMR 8591, Paris, France*

**ABSTRACT NUMBER: 422 : ESTIMATION OF FLOOD DISCHARGE TO REJUVENATE THE EARLIER CHANNELS- A STUDY ON LOWER DAMODAR BASIN, WEST BENGAL, INDIA,** [Hirak Mahata](#), *Vidyasagar University, Midnapore, West Bengal, India*

**ABSTRACT NUMBER: 478 : DIRECT CATCHMENT RESPONSE TO THE LAST QUATERNARY CLIMATE TRANSITION: DRIVERS AND RATES OF SURFACE PROCESSES IN INTRAMONTANE BASINS OF THE SOUTHERN PYRENEES, SW EUROPE,** [Kurt Martin Stange](#), *University of Bremen, Bremen, Germany*

**ABSTRACT NUMBER: 526 : FLOOD PHASES DURING THE LAST 5500 BP (CA 4350 CAL. BC) - THE COURSE AND CORRELATION IN THE EASTERN CARPATHIAN FORELAND,** [Piotr Gębica](#), *University of Information Technology and Management, Rzeszów, Podkarpackie voivodeship, Poland*

**ABSTRACT NUMBER: 542 : ALLUVIAL MEGAFANS OF EUROPE: MORPHOLOGIES, ARCHITECTURES AND FORMATION PHASES,** [Alessandro Fontana](#), *University of Padova, Padova, Italy*

**ABSTRACT NUMBER: 647 : LUMINESCENCE DATES FROM LOWER GANGETIC PLAIN, INDIA AND ITS IMPLICATIONS FOR QUATERNARY EVOLUTION OF THE WESTERN BENGAL BASIN-FILL,** [Sujoy Bandyopadhyay](#), *Department of Geography, The University of Burdwan, Bardhaman, West Bengal, India*

**ABSTRACT NUMBER: 788 : QUATERNARY ENVIRONMENTAL CHANGES IN THE EAST GOBI DESERT: PALEOHYDROLOGICAL EVIDENCE,** [Hongwei Li](#), *School of Earth Sciences, Zhejiang University, Hangzhou, Zhejiang, China*

**THEME: S13 : FLUVIAL PROCESS AND LANDFORMS.....116-134**

**ABSTRACT NUMBER: 42 : DEGENERATING DISTRIBUTARIES IN THE UPPER GANGA DELTA, INDIA: EVIDENCES FROM MEANDER CUT-OFFS,** [Sayantan Das](#), *Department of Geography, Dum Dum Motijheel College, Kolkata, West Bengal, India*

**ABSTRACT NUMBER: 86 : CHANGING PATTERN OF CHANNEL MORPHOLOGY OF ALAKNANDA RIVER AND ITS IMPACT ON LOCAL ENVIRONMENT IN SRINAGAR VALLEY (GARHWAL HIMALAYA),** [Sapna Semwal](#), *D.B.S College Dehradun, Dehradun, Uttarakhand, India*

**ABSTRACT NUMBER: 103 : INSIGHTS INTO QUATERNARY FLUVIAL LANDSCAPE DEVELOPMENT IN NW AFRICA USING RIVER TERRACES,** [Martin Stokes](#), *Earth Sciences, Plymouth University, Plymouth, Devon, United Kingdom*

**ABSTRACT NUMBER: 119 : MORPHOLOGIC EVOLUTION AND SEDIMENT DYNAMICS IN A LOW-ENERGY RIVER IN A CONTEXT OF DAM REMOVAL: THE YERRES RIVER IN THE SEINE CATCHMENT,** [Luc Michler](#), *Prodig Laboratory, Paris, France*

**ABSTRACT NUMBER: 125 : UNDERSTANDING THE GENESIS OF 2008 KOSI FLOODS: COULD KOSI BED MORPHODYNAMICS BE ITS PROBABLE CAUSE?** [Vilakshna Parmar](#), *Indian Institute Of Technology Delhi, New Delhi, India*

**ABSTRACT NUMBER: 141 : FLOOD HYDROLOGY OF THE MAHI RIVER: WESTERN INDIA,** [Pramodkumar Hire](#), *HPT Arts and RYK Science College, Nashik, Maharashtra, India*

**ABSTRACT NUMBER: 142 : ESTIMATION OF THE ROCK RESISTIVITY OF THE PAR RIVER USING SCHMIDT HAMMER REBOUND VALUES,** [Archana Patil](#), *RNC Arts, JDB Commerce and NSC Science College, Nashik, Maharashtra, India*

**ABSTRACT NUMBER: 158 : RIVER BANK EROSION AND MEANDER MIGRATION IN LOWER DISANG RIVER, ASSAM,** [Kashmiri Begum](#), *Department of Geography, North-Eastern Hill University, Shillong, Meghalaya, India*

**ABSTRACT NUMBER: 174 : HYDROLOGICAL DIS-CONNECTIVITY IN A SEMI-ARID LOESS COVERED AREA,** [Aaron Yair](#), *Hebrew University of Jerusalem, Jerusalem, Israel*

**ABSTRACT NUMBER: 210 : BANK EROSION IN AN ANDEAN PÁRAMO ECOSYSTEM: ASSESSING THE POTENTIAL FOR FLUVIAL EXPORT OF ORGANIC CARBON,** [Derek Martin](#), *Appalachian State University, Boone, Nc, United States*

**ABSTRACT NUMBER: 280 : SOIL EROSION, SUSPENDED SEDIMENT INFLOW/OUTFLOW AND CHANNEL DEGRADATION/ AGGRADATION IN THE MORA DHANSIRI RIVER BASIN, ASSAM, INDIA,** [Rana Sarmah](#), *Pandu College, Guwahati, Assam, India*

**ABSTRACT NUMBER: 285 : A MULTIDISCIPLINARY APPROACH TO RECONSTRUCTING HOLSTEINIAN OXBOW ON THE PIEDMONT FAN AT KRZCZONÓW, SUDETC FORELAND, SE POLAND,** [Lucyna Wachecka-Kotkowska](#), *University of Lodz, Faculty of Geography, Department of Geomorphology and Palaeogeography, Lodz, Lodzkie, Poland*

**ABSTRACT NUMBER: 332 : INFERRING MORPHOLOGICAL CHANGES IN THE ADIGE/ETSCH RIVER DURING THE LAST TWO MILLENNIA: INTEGRATING GEOMORPHIC, GEOARCHEOLOGICAL AND GEOPHYSICAL APPROACHES,** [Vittoria Scorpio](#), *Free University Of Bozen-Bolzano, Bolzano, Italy*

**ABSTRACT NUMBER: 349 : LONG-TERM IMPACTS OF HYDRAULIC MINING SEDIMENT IN THE SIERRA NEVADA, CALIFORNIA: A MASSIVE ANTHROPOGENIC SEDIMENTATION EVENT REVISITED,** [Allan James](#), *University South Carolina, Columbia, South Carolina, United States*

**ABSTRACT NUMBER: 357 : SEDIMENT TRANSPORT, RIVER CHANNEL CHANGE AND RIVER REGIME IN THE LOWER YELLOW RIVER: A RATIONAL ANALYSIS,** [Yuanxu Ma](#), *Institute Of Remote Sensing And Digital Earth, Chinese Academy Of Sciences, Beijing, China*

**ABSTRACT NUMBER: 361 : MORPHOLOGICAL CHARACTERISTICS OF A RIVER CONFLUENCE: A CASE STUDY OF RIVER PRAVARA IN MAHARASHTRA,** [Maya Unde](#), *Ahmednagar College, Savitribai Phule Pune University, Ahmednagar, Maharashtra, India*

**ABSTRACT NUMBER: 398 : ESTIMATING BEDLOAD TRANSPORT IN A LARGE GRAVEL-BED RIVER USING THE VIRTUAL VELOCITY APPROACH,** [Nicola Surian](#), *University of Padova, Padova, Italy*

**ABSTRACT NUMBER: 424 : SHORT-TERM CHANNEL ADJUSTMENTS OF THE SELE RIVER (SOUTHERN ITALY),** [Alessio Valente](#), *Sannio University, Benevento, BN, Italy*

**ABSTRACT NUMBER: 426 : SEDIMENT DYNAMICS IN EPHEMERAL CHANNELS,** [Janet Hooke](#), *University of Liverpool, Liverpool, Merseyside, United Kingdom*

**ABSTRACT NUMBER: 439 : IMPLICATIONS OF MORPHOLOGICAL CHARACTERISTICS AND LITHOLOGY ON GULLY DEVELOPMENT: A CASE STUDY OF GARHBETA BADLANDS, WEST BENGAL, INDIA,** [Atrayee Biswas](#), *University Of Calcutta, Kolkata, West Bengal, India*

**ABSTRACT NUMBER: 463 : RIVER LONG PROFILE AND STREAM POWER ANALYSIS TO MAP SPATIAL VARIABILITY IN GEOMORPHIC PROCESSES ALONG MAJOR RIVERS OF PENINSULAR INDIA,** [Sonam Sonam](#), *Indian Institute of Technology Gandhinagar, Gandhinagar, Gujarat, India*

**ABSTRACT NUMBER: 497 : ISO AND META-CHRONICAL TERRACES AND THEIR EXPRESSION ON THE FORMATION OF THE MIDDLE REACH OF THE YELLOW RIVER,** [Ke Zhang](#), *Sun Yat-sen University, Guangzhou, Guangdong, China*

**ABSTRACT NUMBER: 502 : POST-FLOOD PERIOD SERIAL GEOMORPHIC ANALYSIS (POPSEGA) AND RECENT CHANNEL PLANFORM EVOLUTION OF A BRAIDED-WANDERING RIVER,** [Anna Kidová](#), *Institute of Geography Slovak Academy of Sciences, Bratislava, Slovakia*

**ABSTRACT NUMBER: 568 : INCISIONAL RIVER AVULSIONS: PROGRESS IN UNDERSTANDING THEIR DISTRIBUTION, LENGTH, AND FREQUENCY,** [Ian Rutherford](#), *School Of Geography, University Of Melbourne, Carlton, VIC, Australia*

**ABSTRACT NUMBER: 612 : LATE QUATERNARY AGGRADATION AND INCISION OF INDUS RIVER: ROLE OF CLIMATE AND TECTONICS,** [Anil Kumar](#), *Wadia Institute Of Himalayan Geology, Dehradun, Uttarakhand, India*

**ABSTRACT NUMBER: 614 : ASSESSMENT OF FLOW VELOCITY AND BANK EROSION OF THE PUTHIMARI RIVER OF ASSAM, INDIA,** [Pankaj Roy](#), *North-eastern Hill University, Shillong, Meghalaya, India*

**ABSTRACT NUMBER: 620 : WHAT CONTROLS CHANNEL WIDTH IN AN INTERMONTANE VALLEY ALONG THE NW HIMALAYA?** [Sukumar Parida](#), *Department Of Geology, University Of Delhi, Delhi, India*

**ABSTRACT NUMBER: 631 : DIFFERENCES BETWEEN WANDERING AND BRAIDING RIVERS,** [He Qing Huang](#), *Institute Of Geographical Sciences And Natural Resources Research, Chinese Academy Of Sciences, Chaoyang District, Beijing, China*

**ABSTRACT NUMBER: 633 : MODELLING FLUVIAL GEOMORPHIC RESPONSES TO HUMAN PERTURBATIONS,** [Jorge Ramirez](#), *University Of Bern, Bern, Switzerland*

**ABSTRACT NUMBER: 638 : THE LOWER LOIRE RIVER FLOODPLAIN FORMATION: A MULTI-SCALED APPROACH TO CHARACTERIZE LANDFORMS, PROCESSES AND DRIVERS EVOLUTION ON THE LONG-TERM (LAST 10**

**MILLENNIUMS) (VAL D'AUTHION, FRANCE),** [Cyril Castanet](#), *Université Paris 8 Vincennes-Saint-Denis, UMR CNRS 8591 LGP - Laboratoire de Géographie Physique, Environnements Quaternaires et Actuels, Meudon, France*

**ABSTRACT NUMBER: 678 : SPATIO-TEMPORAL ASSESSMENT OF FLUVIAL CHANGES AND THEIR IMPACTS: A CASE STUDY OF SANGAM, ALLAHABAD CITY, INDIA,** [Ashwajeet Chaudhary](#), *Department of Geography, University of Allahabad, Allahabad, Uttar Pradesh, India*

**ABSTRACT NUMBER: 682 : GEOMORPHOMETRY AND STAGES OF LANDFORM DEVELOPMENT IN A CENTRAL HIMALAYAN DRAINAGE BASIN,** [Manisha Tripathi](#), *Kumaun University Nainital, Nainital, Uttarakhand, India*



**ABSTRACT NUMBER: 713 : IMPACT OF CHANNEL MORPHOLOGY ON JHELM RIVER FLOODING IN KASHMIR VALLEY, NW HIMALAYAS, INDIA, [Mannan Bashir Wani](#), Aligarh Muslim University, Uttar Pradesh, India**

**ABSTRACT NUMBER: 715 : GEOMORPHIC ASSESSMENT AND SPATIAL DISTRIBUTION OF SEDIMENT AND MINING METAL STORAGE IN CHANNEL AND FLOODPLAIN DEPOSITS IN BIG RIVER, OLD LEAD BELT, SOUTHEAST MISSOURI (USA), [Robert Pavlowsky](#), Missouri State University, Springfield, Missouri, United States**

**ABSTRACT NUMBER: 745 : RIVERS UNDER TEMPERATE VALLEY GLACIERS, [Stuart Lane](#), University Of Lausanne, Institute of Earth Surface Dynamics, Lausanne, Vaud, Switzerland**

**ABSTRACT NUMBER: 757 : MEANDER GEOMETRY IN THE INTERFLUVES AREA BETWEEN BURHI DIHING AND NOA DIHING RIVER, ASSAM, INDIA, [Santanu Patnaik](#), Rajiv Gandhi University, Itanagar, Arunachal Pradesh, India**

**ABSTRACT NUMBER: 771 : ASSESSMENT OF CONTROL FACTORS AND SENSITIVITY OF A RIVER CHANNEL TO CHANGES BASED ON A COMBINATION OF HISTORICAL AND FIELD DATA, DOROGNE RIVER (SW FRANCE), [Fabien Boutault](#), ECOGÉA, 352 avenue Roger Tissandié, 31600 Muret, Haute-Garonne, France**

**THEME: S14 : LARGE RIVERS ..... 135-140**

**ABSTRACT NUMBER: 78 : DRYLAND FLUVIAL SEDIMENTOLOGY FROM THE MODERN LUNI RIVER, THAR DESERT, WESTERN INDIA, [Paul Carling](#)**

**ABSTRACT NUMBER: 97 : SUSTAINABLE MANAGEMENT OF LARGE RIVERS USING A GEOMORPHIC TEMPLATE: A CASE STUDY OF THE GANGA RIVER, INDIA, [Rajiv Sinha](#), Indian Institute of Technology Kanpur, Kanpur, Uttar Pradesh, India**

**ABSTRACT NUMBER: 171 : HOW CAN WE BETTER UNDERSTAND THE WATER TRANSFER PROJECT OF THE CHANGJIANG RIVER? AN ESTUARINE PERSPECTIVE, [Zhongyuan Chen](#), East China Normal University, Shanghai, China**

**ABSTRACT NUMBER: 242 : IMPACT OF RECENT CHANNEL DYNAMISM ON LAND USES IN THE INTER-FLUVIAL ZONES IN MIDDLE GANGA PLAIN, [V A V Raman](#), Shaheed Bhagat Singh College, University of Delhi, New Delhi, India**

**ABSTRACT NUMBER: 248 : DIFFERENT DYNAMIC PROCESS OF FLUID MUD DURING NEAP AND SPRING TIDE OF THE DRY SEASON IN THE CHANGJIANG ESTUARY TURBIDITY ZONE, [Li Maotian](#), East China Normal University, Shanghai, China**

**ABSTRACT NUMBER: 260 : MORPHODYNAMIC STUDY OF THE FLUVIAL ISLANDS IN LARGE ANABRANCHING RIVERS, [Emmanuele Gautier](#), University Paris 1 - CNRS Physcal Geography Lab., Paris, France;**

**ABSTRACT NUMBER: 276 : RIVER'S QUICK RESPONSE TO SEA LEVEL CHANGES FROM ONE THOUSAND KILOMETERS AWAY, [Yantian Xu](#), School of Earth Sciences, China University Of Geosciences, Wuhan, Hubei, China**

**ABSTRACT NUMBER: 330 : HYDRODYNAMIC AND MORPHOLOGICAL UNDERSTANDING OF THE BRAHMAPUTRA RIVER, INDIA: CHALLENGES AND EXPERIENCES, [Vinay Chembolu](#), Indian Institute Of Technology Guwahati, Guwahati, Assam, India**

**ABSTRACT NUMBER: 337 : AMAZONIAN WHITE WATER RIVERS SPATIAL PATTERNS OF SUSPENDED SEDIMENT TRANSPORT, [Otávio Montanher](#), Maringá State University, Maringá, Paraná, Brazil**

**ABSTRACT NUMBER: 434 : BEDROCK RIVER INCISION AND LOESS DEPOSITION RESPONSE TO BASIN CONNECTION OF THE SANMEN GORGE, THE YELLOW RIVER, NORTH CHINA, [Hao Liang](#), School of Earth Science and Engineering, Sun Yat-sen University, Guangzhou, Guangdong, China**

**ABSTRACT NUMBER: 477 : LARGE MONSOONAL RIVERS: A NEW PERSPECTIVE FROM THE SEDIMENTARY SINK, [Liviú Giosan](#), Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, United States**

**ABSTRACT NUMBER: 482 : COSMOGENIC BURIAL AGES OF THE EARLY PHASE EVOLUTION OF THE JINSHAAN YELLOW RIVER, CHINA, [Zhongyun Li](#), School Of Earth Science And Engineering, Sun Yat-sen University, Guangzhou, Guangdong, China**

**THEME: S15 : INTEGRATED RIVER MANAGEMENT ..... 141-145**

**ABSTRACT NUMBER: 45 : COMBINED CONTRIBUTION OF ACTIVE RFID TECHNOLOGY, TIME LAPSE CAMERA AND DTM FOR THE MONITORING OF THE HAUT-DRAC RIVER RESTORATION (SOUTHERN ALPS, FRANCE), [Guillaume Brousse](#), University of Paris-diderot (Paris 7), UMR 8586 (PRODIG), Paris, France**

**ABSTRACT NUMBER: 46 : HYDROMORPHOLOGICAL MONITORING OF A SEDIMENT REPLENISHMENT OPERATION: THE CASE OF THE SAINT-SAUVEUR DAM IN THE BUËCH RIVER (SOUTHERN ALPS, FRANCE), [Guillaume Brousse](#), University of Paris-diderot (Paris 7), UMR 8586 (PRODIG), Paris, France**

**ABSTRACT NUMBER: 65 : INTEGRATING ECOLOGICAL RESPONSE TO FINE BED SEDIMENT INTO ENVIRONMENTAL FLOW ASSESSMENTS, [Kate Rowntree](#), Rhodes University, Grahamstown, Eastern Cape, South Africa**



**ABSTRACT NUMBER: 145 : INTEGRATING GEOMORPHOLOGY AND ECOLOGY FOR RESILIENT RIVER ENGINEERING,** [Ian Fuller](#), *Massey University, Palmerston North, Manawatu-Wanganui, New Zealand*

**ABSTRACT NUMBER: 192 : RAINWATER MANAGEMENT FOR CAPACITY BUILDING FOR THE ENVIRONMENTALLY VULNERABLE LOCAL COMMUNITIES OF POLDER-LIKE SUNDARBAN ISLANDS IN INDIA- SELECTED CASE STUDIES,** [Anwasha Haldar](#), *Department Of Geography, University Of Calcutta, Kolkata, West Bengal, India*

**ABSTRACT NUMBER: 416 : ANTHROPOGENIC TRANSFORMATIONS OF LOW ENERGY RIVERS IN NORMANDY; GEOMORPHOLOGICAL LEGACY OF AN HISTORICAL MANAGEMENT OF THE SEULLES RIVER,** [Axel Beauchamp](#), *Universite De Caen Normandie, Caen, Normandie, France*

**ABSTRACT NUMBER: 778 : ASSESSING THE IMPACT OF LANDUSE/LANDCOVER CHANGE ON STREAMFLOW AND SEDIMENT YIELD USING A DISTRIBUTED HYDROLOGIC MODEL,** [Sreedevi S.](#), *IIT Bombay, Mumbai, Maharashtra, India*

**ABSTRACT NUMBER: 779 : COMPARISON OF CONCEPTUAL RAINFALL-RUNOFF MODELS FOR WATER RESOURCES ASSESSMENT IN A RIVER BASIN,** [Aiswarya Kunnath-Poovakka](#), *Department of Civil Engineering, Indian Institute of Technology Bombay, Mumbai, Maharashtra, India*

**ABSTRACT NUMBER: 780 : ASSESSING LAND USE/LAND COVER CHANGE ON STREAMFLOW AND SEDIMENT YIELD IN A WESTERN GHAT RIVER BASIN IN INDIA,** [Rakesh Kumar Sinha](#), *IDP in climate studies, Indian Institute of Technology Bombay, Powai, Mumbai, Maharashtra, India*

**THEME: S16 : COASTAL GEOMORPHOLOGY AND MANAGEMENT ..... 145-155**

**ABSTRACT NUMBER: 22 : INTEGRATED GEOINFORMATICS APPROACH TO COASTAL HABITAT VULNERABILITY MAPPING ALONG THE SOUTHWEST COAST OF KANYAKUMARI, INDIA,** [S. Kaliraj](#), *<sup>1</sup>ESSO - National Centre for Earth Science Studies (NCESS), Thiruvananthapuram, Kerala, India*

**ABSTRACT NUMBER: 35 : RECONSTRUCTION OF PALEO-TOPOGRAPHY OF THE EASTERN PART OF LOMBOK ISLAND (INDONESIA) BEFORE THE AD 1257 ERUPTION OF SAMALAS VOLCANO,** [Bachtiar Wahyu Mutaqin](#), *Faculty of Geography, Universitas Gadjah Mada, Sekip Utara, Bulaksumur, Indonesia*

**ABSTRACT NUMBER: 66 : REVIEW OF DELTA GEOMORPHOLOGICAL CHANGES CONSIDERING CHANGES IN GEOCHEMISTRY OF SEDIMENTARY FACIES (CASE STUDY: ARVANDRUD DELTA, SOUTHWEST OF IRAN),** [Maryam Rahmati](#), *2Tarbiat Modares University, Tehran, Iran*

**ABSTRACT NUMBER: 74 : THE DICHOTOMY BETWEEN VULNERABILITY AND PROTECTION MEASURES: A FRAMEWORK FOR DEVELOPING CROSS-CUTTING PERSPECTIVES OF COASTAL DUNE MANAGEMENT,** [Dipanjan Das Majumdar](#), *Jadavpur University, Kolkata, West Bengal, India*

**ABSTRACT NUMBER: 91 : CONCEPTUAL MODELS FOR NATURAL MECHANISMS OF SEDIMENT BYPASSING AT THE TIDAL INLETS ALONG THE KONKAN COAST OF MAHARASHTRA, INDIA,** [Anargha A Dhorde](#), *Department of Geography, Nowrosjee Wadia College,(affiliated to S.P. Pune University), Pune, Maharashtra, India*

**ABSTRACT NUMBER: 203 : APPLICATION OF DIFFERENT BEACH MANAGEMENT TOOLS FOR THE PROMOTION OF TOURISM DEVELOPMENT AND CONSERVATION OF COASTAL RESOURCES OF SOUTH ANDAMAN,** [Swagata Bera](#), *Vidyasagar University, Midnapore, West Bengal, India*

**ABSTRACT NUMBER: 208, PALEOGEOMORPHOLOGY OF THE URMIA LAKE (NORTH WEST OF IRAN) IN QUATERNARY,** [Alireza Salehipourmilani](#), *Faculty of Earth Sciences,Shahid Beheshti University, Tehran, Iran*

**ABSTRACT NUMBER: 216 : THE CONCEPTION OF THE DEVELOPMENT OF THE COASTAL ZONE OF THE SUBARCTIC SEAS IN THE TRANSITION OF AVERAGE DAILY TEMPERATURES TO THE FREEZING VALUES,** [Viktor Afanasev](#), *Institute of Marine Geology and Geophysics" FEB RAS, Yuzhno-sakhalinsk, Sakhalin, Russian Federation*

**ABSTRACT NUMBER: 237 : RESILIENCE DEVELOPMENT FOLLOWING STORM-INDUCED CHANGE TO A PREVIOUSLY MANAGED UK COASTAL GRAVEL-BARRIER,** [Julian Orford](#), *Queen's University, Belfast, Northern Ireland, United Kingdom*

**ABSTRACT NUMBER: 318 : THE DEPOSITION OF RED SAND DUNES AT FUJIAN COASTAL, CHINA ON RESPONSE OF THE LAST INTERGLACIAL EAST ASIAN MONSOON CHANGES,** [Mingtong Yu](#), *School Of Geographical Sciences, Fujian Normal University, Fuzhou, Fujian, China*

**ABSTRACT NUMBER: 322 : EFFECT FACTORS AND CLASSIFICATIONS OF PLANFORM GEOMETRY OF ARC-SHAPED BEACHES,** [Zhiqiang Li](#), *Department of Ocean Engineering,Guangdong Ocean University, Zhanjiang, Guangdong, China*

**ABSTRACT NUMBER: 342 : INFLUENCE OF SYSTEM CONTROLS ON THE HOLOCENE GEOMORPHIC EVOLUTION OF A RAPIDLY-INFILLED INCISED-VALLEY SYSTEM: THE LOWER MANAWATU VALLEY, NORTH ISLAND NEW ZEALAND,** [Alastair Clement](#), *Massey University, Palmerston North, Palmerston North, New Zealand*

**ABSTRACT NUMBER: 356 : PAN-EUROPEAN MAPPING OF COASTAL EROSION AND ACCRETION: DEVELOPING EMODNET COASTAL RESILIENCE DATA,** [Cherith Moses](#), *University Of Sussex, Falmer, Brighton, East Sussex, United Kingdom*

**ABSTRACT NUMBER: 405 : COASTAL VULNERABILITY AND MANAGING STRATEGIES: A CASE STUDY ON PARTS OF COASTAL DISTRICTS OF SOUTH ANDAMAN ISLAND, INDIA, [Swati Ghosh](#), Vidyasagar University, Medinipore, West Bengal, India**

**ABSTRACT NUMBER: 452 : USING COMMERCIAL DRONE FOR MAPPING ECOLOGICAL PHASE SHIFTS ON THE CORAL REEFS OF SOUTHERN FAAFU ATOLL, REPUBLIC OF THE MALDIVES, [Luca Fallati](#), University Of Milano - Bicocca, Milano, Italy;**

**ABSTRACT NUMBER: 453 : PALAEOENVIRONMENTAL 3D RECONSTRUCTION OF THE LATE HOLOCENE EVOLUTION OF THE NATURAL RESERVE AND MARINE PROTECTED AREA OF TORRE GUACETO (BRINDISI, ITALY), [Giuseppe Mastronuzzi](#), University of Bari, Dipartimento di Scienze della Terra e Geoambientali, Bari, Italy**

**ABSTRACT NUMBER: 454 : MODELLING THE SEA FLOOD SCENARIO FOR FOUR ITALIAN COASTAL PLAINS FOR 2100 ACCORDING TO THE START PROJECT, [Giuseppe Mastronuzzi](#), Dipartimento di Scienze della Terra e Geoambientali, University "Aldo Moro", Bari, Italy**

**ABSTRACT NUMBER: 523 : HYDRODYNAMIC BEHAVIOR OF TIDAL INLET SYSTEMS: A COMPARATIVE STUDY OF JALDHA AND PICHABONI INLET, PURBA MEDINIPUR, WEST BENGAL. [Sayan Mandal](#), Sarojini Naidu College for Women, Kolkata, West Bengal, India**

**ABSTRACT NUMBER: 665 : GROWTH PATTERNS AND MORPHODYNAMIC FEEDBACKS RECORDED IN DANUBE DELTA EVOLUTION, [Alfred Vespremeanu-Stroe](#), University of Bucharest, Bucharest, Romania**

**ABSTRACT NUMBER: 755 : THE ROLE OF RAPID DEGLACIATION AND PARAGLACIAL SEDIMENT FLUXES IN CONTROLLING THE POST-LITTLE ICE AGE EVOLUTION OF HIGH ARCTIC COASTAL SYSTEMS, [Matt Strzelecki](#), University Of Wroclaw, Wroclaw, Dolnoslaskie, Poland**

**THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY..... 155-164**

**ABSTRACT NUMBER: 29 : PROVENANCE, TRANSPORT AND MIXING OF TAKLAMAKAN DESERT SAND, [Qida Jiang](#), Institute Of Geology And Geophysics, Chinese Academy of Sciences, Beijing, China**

**ABSTRACT NUMBER: 81 : CYCLIC CHANGES OF LANDFORM UNDER THE IMPACT OF FLUVIAL-AEOLIAN INTERACTION, [Baoli Liu](#), Xiamen University, Xiamen, Fujian, China**

**ABSTRACT NUMBER: 258 : AEOLIAN-ACCUMULATIVE COMPLEX SARYKUM AS A UNIQUE GEOMORPHIC OBJECT OF RUSSIA: STRUCTURE, ORIGIN AND AGE OF ITS SANDS, [Artem V. Gusarov](#), Kazan Federal University, Kazan, Russian Federation**

**ABSTRACT NUMBER: 273 : REVISING AND EXTENDING LATE QUATERNARY DUNE ACCUMULATION HISTORIES IN THE THAR DESERT, INDIA, [Aayush Srivastava](#), University Of Oxford, Lucknow, Uttar Pradesh, India**

**ABSTRACT NUMBER: 284 : FORMATIVE TRIGGERS IN ALLUVIAL PLAINS OF THE BORBOREMA HIGHLANDS, NORTHEASTERN BRAZIL, [Rodrigo de Freitas Amorim](#), Federal University of Brazil, Natal, Rio Grande do Norte, Brazil**

**ABSTRACT NUMBER: 290 : EOLIAN LANDSCAPE EVOLUTION CONTROLLED BY SEDIMENT AVAILABILITY SINCE LGM IN THE HULUNBUIR SANDY LAND, NORTHEAST CHINA, [Peng Liang](#), Institute of Geology and Geophysics, Chinese Academy of Sciences, Beijing, China**

**ABSTRACT NUMBER: 336 : CATCHMENT CONNECTION CONTROLS MEGA-LAKE EVOLUTION ON THE CENTRAL TIBETAN PLATEAU, [Chang Huang](#), School of Earth Sciences, China University of Geosciences, Wuhan, Hubei, China**

**ABSTRACT NUMBER: 374 : A SELF-ORGANIZING MAPS APPROACH TO MERGE EXPERT BASED KNOWLEDGE AND SPATIAL DATA ANALYSIS TO PREDICT SOIL AND LANDFORM PROPERTIES IN DESERT ENVIRONMENTS, [Fabio Iwashita](#), Geosciences Dept, Los Andes University, Bogota, D.C., Colombia**

**ABSTRACT NUMBER: 379 : GEOMORPHOLOGICAL IMPLICATIONS DUE TO CLIMATE-TECTONIC IMPACTS IN THE FRAGILE COLD ARID DESERT OF LADAKH, TRANS-HIMALAYA, INDIA DURING THE LATE QUATERNARY, [Binita Phartiyal](#), Birbal Sahni Institute Of Palaeosciences, Lucknow, Uttar Pradesh, India**

**ABSTRACT NUMBER: 429 : RECONSTRUCTING THE QUATERNARY SEDIMENTATIONS OF TSAGAAN SUVARGA FORMATION IN SOUTHERN MONGOLIA, [A. Orkhonselenge](#), Laboratory of Geochemistry & Geomorphology, School of Arts & Sciences, National University Of Mongolia, Ulaanbaatar, Mongolia**

**ABSTRACT NUMBER: 447 : PATTERNED VEGETATION OF THE AUSTRALIAN DRYLANDS: WHAT DO WE KNOW AND WHAT KNOWLEDGE GAPS REMAIN? [David Dunkerley](#), Monash University, Melbourne, VIC, Australia**

**ABSTRACT NUMBER: 450 : ESTIMATING BLOWN SAND ENTERING INTO THE NINGXIA-INNER MONGOLIA YELLOW RIVER DURING 1981~2014, [Xiaoyang Wu](#), College of Environmental Science And Engineering, Peking University, Beijing, China**

**ABSTRACT NUMBER: 566 : GEOCHEMICAL CHARACTERISTICS OF A LOESS PROFILE IN NORTHWEST CHINA, [Jiancheng Kang](#), Shanghai Normal University, Shanghai, China**

**ABSTRACT NUMBER: 569 : LATE HOLOCENE GEOMORPHIC EVOLUTION BY MINERAL COMPOSITION AT A DRIED LAKE PLAYA, Maliheh Pourali, Ferdowsi University of Mashhad, Mashhad, Khorasan Razavi, Iran**

**ABSTRACT NUMBER: 675 : CONNECTING THE DOTS: THE POSSIBLE LONG DISTANCE IMPACTS OF KALAHARI DUNE MOBILIZATION, Paolo D'odorico, University of California, Berkeley, Berkeley, California, United States**

**ABSTRACT NUMBER: 694 : INITIAL FORMATION OF SAND SEAS IN NORTHERN CHINA: FROM GEOMORPHOLOGICAL PERSPECTIVE, Xiaoping Yang, School Of Earth Sciences, Zhejiang University, Hangzhou, Zhejiang, China**

**ABSTRACT NUMBER: 733 : DESERTIFICATION AS EVIDENCED FROM CHANGING PASTURE LANDS ECOLOGY- A CASE STUDY IN INDIAN DESERT, Azizur Rahman Siddiqui, University Of Allahabad, Allahabad, Uttar Pradesh, India**

**ABSTRACT NUMBER: 751 : RECONSTRUCTING DESERT DUNEFIELD ACCUMULATION HISTORIES: A NEW APPROACH USING CHRONOMETRIC DATA, David Thomas, University Of Oxford, Oxford, Oxon, United Kingdom**

**ABSTRACT NUMBER: 789 : DUNEFIELDS OF PATAGONIA, Alejandro Montes, Centro Austral De Investigaciones Cientificas-conicet, Ushuaia, Tierra Del Fuego, Argentina**

**ABSTRACT NUMBER: 793 : BLOWING IN THE WIND: EVENTFUL HISTORY OF A THAR DESERT DUNE, RAJASTHAN, Martin Williams, University of Adelaide, Glenalta, South Australia, Australia**

**THEME: S18 : TROPICAL GEOMORPHOLOGY ..... 164-166**

**ABSTRACT NUMBER: 36 : GRAIN SIZE CHARACTERISTICS OF INTRA-FORMATIONAL CONGLOMERATE EXPOSED ALONG TYRSAD AND WEILOI AREA OF MEGHALAYA,INDIA, Kulhi-u Mero, Noth Eastern Hill University, Shillong, Meghalaya, India**

**ABSTRACT NUMBER: 39 : AN INTRODUCTION OF MORPHOLOGY AND PEDOLOGY OF TILLA-LUNGA TOPOGRAPHY, INDIA, Subhajit Sen, Tripura University, Agartala, Tripura, India**

**ABSTRACT NUMBER: 334 : PEDO-GEOMORPHOLOGY OF THE HILL REGION OF PURULIA DISTRICT, WEST BENGAL, INDIA AND ITS INFLUENCE ON LULC, Arindam Sarkar, University Of Calcutta, Kolkata, West Bengal, India**

**ABSTRACT NUMBER: 492 : SOIL-GEOMORPHOLOGY RELATIONSHIP IN ETCHPLAIN OF BRAZILIAN CENTRAL PLATEAU, Vinicius Vasconcelos, University Of Brasília, Brasília, DF, Brazil**

**ABSTRACT NUMBER: 688 : USING COSMOGENIC NUCLIDE <sup>10</sup>BE METHOD IN SANDSTONE KARST AREA IN THE SOUTHEASTERN OF AMAZONIAN REGION (BRAZIL): LIMITS AND POSSIBILITIES, Helen Nébias Barreto, Federal University of Maranhão, São Luís, Maranhão, Brazil**

**THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY ..... 167-179**

**ABSTRACT NUMBER: 18, HIGH-FREQUENCY HOLOCENE GLACIAL CHRONOSTRATIGRAPHIES IN THE HIMALAYAN-TIBETAN OROGEN OFFER INSIGHT INTO PAST SHIFTS OF EARTH'S THERMAL EQUATOR AND COEVAL CHANGES IN THE SOURCES OF MOISTURE, Sourav Saha, University Of Cincinnati, Cincinnati, Ohio, United States**

**ABSTRACT NUMBER: 24 : AN ATTEMPT TO IMPROVE DATING OF PERIGLACIAL LANDFORMS IN HIGH MOUNTAIN ENVIRONMENTS USING SCHMIDT-HAMMER EXPOSURE-AGE DATING, Stefan Winkler, University Of Würzburg, Würzburg, Bavaria, Germany**

**ABSTRACT NUMBER: 71 : THE VARIABILITY AND UNIQUENESS OF CIRQUES IN THE SCHLADMINGER TAUERN (EASTERN ALPS, AUSTRIA): A MORPHOMETRIC ANALYSIS, Christine Embleton-Hamann, University of Vienna, Department of Geography, Wien, Austria**

**ABSTRACT NUMBER: 136 : DRAINAGE RE-ORGANIZATION AT THE SE MARGIN OF THE SCANDINAVIAN ICE SHEET, NW RUSSIA, Andrei Panin, Institue of Geography RAS, Moscow, Russia**

**ABSTRACT NUMBER: 196 : GLACIAL GEOMORPHOLOGY AND GLACIER EVOLUTION OF MOUNT ARARAT/AĞRI DAĞI (EASTERN ANATOLIA, TURKEY), Roberto Sergio Azzoni, Dept of Environmental Science and Policy - University of Milan, Milan, Italy**

**ABSTRACT NUMBER: 310 : GLACIER DYNAMICS IN THE CHANGME KHANGPU BASIN, SIKKIM HIMALAYA (INDIA) SINCE 1974 TO 2016, Manasi Debnath, North Eastern Hill University, Shillong, Meghalaya, India**

**ABSTRACT NUMBER: 327 : GLACIER ADVANCES AND SURGES IN THE HINDU KUSH-KARAKORAM MOUNTAINS (PAKISTAN): GEOMORPHOLOGICAL EVIDENCES FROM THE LATEROGLACIAL SEDIMENT ENVIRONMENT, Lasafam Iturrizaga, University of Goettingen, Göttingen, Niedersachsen, Germany**

**ABSTRACT NUMBER: 339 : THERMAL EROSION IN THE PRO GLACIAL OF THE GEPATSCHFERNER GLACIER, EASTERN EUROPEAN ALPS, Sabine Kraushaar, Universtiy Of Vienna, Vienna, Austria**

**ABSTRACT NUMBER: 409 : RECESSION PATTERN AND GEOMORPHOLOGICAL CHANGES OF MENTHOSA GLACIER, LAHAUL HIMALAYA (INDIA), Vijendra Kumar Pandey, Jawaharlal Nehru University, New Delhi, India**

**ABSTRACT NUMBER: 445, DEBRIS COVER EVOLUTION AS A FACTOR OF MORPHOLOGICAL CHANGES OF THE**



**DJANKUAT GLACIER, CAUCASUS**, [Victor Popovnin](#), *Moscow State University, Moscow, Russian Federation*

**ABSTRACT NUMBER: 461 : CRYO-CONDITIONING OF LANDSCAPE EVOLUTION REVISITED**, [Ivar Berthling](#), *Department of Geography, Norwegian University Of Science And Technology, Trondheim, Norway*

**ABSTRACT NUMBER: 462 : SAFEGUARDING AND SUSTAINING LONG RECORDS OF SURFACE DISPLACEMENT MEASUREMENTS ON PERIGLACIAL SORTED CIRCLES**, [Ivar Berthling](#), *Department Of Geography, Norwegian University Of Science And Technology, Trondheim, Norway*

**ABSTRACT NUMBER: 485 : MORPHODINAMICS OF GLACIAL AND PERIGLACIAL ENVIRONMENTS AND RELATED HAZARDS: CASE STUDIES IN THE MOUNTAINS OF NORTHERN ITALY AND WESTERN CANADA**, [Marco Giardino](#), *University Of Torino - Earth Science Dept., Torino, TO, Italy*

**ABSTRACT NUMBER: 540 : THE POSSIBLE GEOMORPHOLOGICAL EVIDENCES OF PALAEO-SURGES**, [Osip Kokin](#), *Moscow State University, Moscow, Russian Federation*

**ABSTRACT NUMBER: 567 : POST-GLACIAL ROCK-SLOPE FAILURES IN ICELAND: SPATIAL DISTRIBUTION, TEMPORAL PATTERN AND TRIGGERING FACTORS**, [Denis Mercier](#), *Paris-sorbonne University and CNRS (ENeC), Paris, France*

**ABSTRACT NUMBER: 570 : SURFACE MORPHOLOGY, INTERNAL STRUCTURE AND WATER STORAGE CAPACITIES OF ROCK GLACIERS IN THE DRY CENTRAL ANDES OF ARGENTINA (30-33°S)**, [Christian Halla](#), *University of Bonn, Bonn, Germany*

**ABSTRACT NUMBER: 648 : SORTED PATTERNED GROUND IN SLOVENIAN KARST CAVES**, [Jaroslav Obu](#), *University Of Oslo, Oslo, Norway*

**ABSTRACT NUMBER: 680 : THE POSSIBLE GEOMORPHOLOGICAL EVIDENCES OF THE GLACIAL PALAEO-SURGES**, [Osip Kokin](#), *Moscow State University, Moscow, Russian Federation*

**ABSTRACT NUMBER: 693 : SURGE GLACIERS IN THE KARAKORAM: DISTRIBUTION AND CHARACTERISTICS**, [Rakesh Bhambri](#), *Centre For Glaciology, Wadia Institute Of Himalayan Geology, Dehra Dun, Uttarakhand, India*

**ABSTRACT NUMBER: 721 : STRESS PATTERN IN THE GLACIERS AND ITS RELATIONSHIP WITH THE ICE THICKNESS AND BEDROCK SLOPE – A CASE STUDY FROM SVALBARD ARCTIC**, [Ashit Kumar Swain](#), *Geological Survey Of India, Gangtok, Sikkim, India*

**ABSTRACT NUMBER: 743 : LANDSCAPE ANALYSIS AND GEOMORPHOLOGICAL MAPPING FOR INVESTIGATING THE INTERACTION OF CLIMATE CHANGES AND CRUSTAL THERMO-MECHANIC VARIATIONS IN DRIVING EAST ANTARCTIC GLACIAL HISTORY SINCE LATE CENOZOIC**, [Carlo Baroni](#), *Dipartimento di Scienze della Terra, University of Pisa, Pisa, Italy*

**ABSTRACT NUMBER: 744 : HOW DO PARAGLACIAL PROCESSES RESPOND TO RAPID ALPINE GLACIER RECESSION?**, [Stuart Lane](#), *University Of Lausanne, Institute of Earth Surface Dynamics, Lausanne, Vaud, Switzerland*

**ABSTRACT NUMBER: 770 : GLACIER AREA CHANGE IN THE JANKAR CHHU WATERSHED, CHANDRABHAGA BASIN, NW HIMALAYA BETWEEN 1971 AND 2016 USING SENTINEL 2A, LANDSAT AND CORONA KH- 4B IMAGERY**, [Suresh Das](#), *Centre for the Study of Regional Development (CSR), Jawaharlal Nehru University, New Delhi, India*

**ABSTRACT NUMBER: 791 : PRESENT LANDSCAPE DEVELOPMENT AND GEO-RISKS IN THE THERMOKARST AREAS OF CENTRAL YAKUTIA, NE SIBERIA**, [Jiri Chlachula](#), *Laboratory for Palaeoecology, Tomas Bata University, Zlin, Moravia, Czech Republic*

**ABSTRACT NUMBER: 794 : GLACIAL GEOMORPHOLOGY OF CHIRRIPO NATIONAL PARK, COSTA RICA**, [Adolfo Quesada Román](#), *Geographical Sciences School, Universidad Nacional de Costa Rica*

**THEME: S20 : MOUNTAIN GEOMORPHOLOGY..... 179-184**

**ABSTRACT NUMBER: 16 : DEVELOPMENTS IN MOUNTAIN GEOMORPHOLOGY OVER THE LAST DECADE**, [Olav Slaymaker](#), *University Of British Columbia, Vancouver, British Columbia, Canada*

**ABSTRACT NUMBER: 129 : COMBINING GEOMORPHIC AND DENDROGEOMORPHIC INDICES WITH NUMERICAL MODELING FOR EVALUATION OF SNOW AVALANCHE ACTIVITY (TATRA MTS., POLAND)**, [Zofia Janina Rączkowska](#), *Institute of Geography and Spatial Organisation, Polish Academy of Sciences, Poland*

**ABSTRACT NUMBER: 138 : THE CHANGING HIMALAYAN FOOTHILL GEOMORPHOLOGY AND ITS INFLUENCE ON HYDROGEOLOGY: A CASE STUDY IN A PART OF EASTERN HIMALAYA, INDIA**, [Monjil Rajkonwar](#), *Department Of Applied Geology, Dibrugarh University, Dibrugarh, Assam, India*

**ABSTRACT NUMBER: 299 : TALLI SETHI ROCKSLIDE: AN INVESTIGATION OF STRUCTURAL CONTROL ON ROAD-INDUCED ROCKSLIDE, CENTRAL LESSER HIMALAYA**, [Vinita Joshi](#), *Department of Geography, Kumaun University, Nainital, Uttarakhand, India*

**ABSTRACT NUMBER: 313 : HILLSLOPE HYDROLOGICAL CONDITIONS ALONG DISTURBED SLOPES ON SIWALIKS OF ARUNACHAL HIMALAYA**, [Santanu Patnaik](#), *Rajiv Gandhi University, Itanagar, Arunachal Pradesh, India*



**ABSTRACT NUMBER: 324 : EVOLUTION OF LANDFORMS AND SLOPE INSTABILITY ALONG MAIN CENTRAL THRUST IN CENTRAL HIMALAYA (UPPER REACHES OF SARJU WATERSHED),** Anita Pande, *Department of Geography, Kumaun University, Nainital, Uttarakhand, India*

**ABSTRACT NUMBER: 433 : AN INVESTIGATION OF ROAD-INDUCED LANDSLIDES IN PARKHA WATERSHED, CENTRAL LESSER HIMALAYA,** Rekha Deolia, *Kumaun University Nainital, Nainital, Uttarakhand, India*

**ABSTRACT NUMBER: 503 : SPATIAL ANALYSIS OF MASS WASTING INDUCED SURFACE CHANGES AND RELATED GEO-INDICATORS IN TRANS-HIMALAYA: A STUDY IN LOWER PIN VALLEY, LAHAUL AND SPITI,** V.A.V Raman, *Shaheed Bhagat Singh College, University Of Delhi, New Delhi, India*

**ABSTRACT NUMBER: 586 : MOBILITY OF LANDSLIDES AND PERMAFROST DEGRADATION REVEALED BY MOLARDS: TWO CASE STUDIES IN NORTHERN ICELAND,** Costanza Morino, *School of Environment, Earth and Ecosystem Sciences, The Open University, Milton Keynes, United Kingdom*

**ABSTRACT NUMBER: 615 : ASSESSING FLASH FLOOD SUSCEPTIBLE RIVER REACHES FROM LONGITUDINAL PROFILE – A CASE STUDY FROM THE GANGA RIVER, INDIA,** Rahul Devrani, *School Of Environmental Sciences (SES), Jawaharlal Nehru University, New Delhi, India*

**ABSTRACT NUMBER: 622 : ROCK WALL PERMAFROST ACROSS NORWAY – MONITORING, DISTRIBUTION MODELLING AND GEOMORPHOLOGICAL IMPLICATIONS,** Bernd Etzelmüller, *University Of Oslo, Oslo, Norway*

**THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY ..... 185-193**

**ABSTRACT NUMBER: 20 : MODELLING THE EFFECT OF ARTISANAL GOLD MINING ON PARTS OF THE LANDSCAPE OF ILESA SCHIST BELT, SOUTHWESTERN, NIGERIA,** Olawale Oluwafemi, *Centre for Geodesy and Geodynamics, Toro, Bauchi, Nigeria*

**ABSTRACT NUMBER: 90 : ESTIMATION OF ACTIVE TECTONIC INDEX USING ANALYTICAL HIERARCHICAL PROCESS (AHP) THROUGH GEOINFORMATICS,** Snehasish Ghosh, *Earthquake Research Cell, Faculty of Engineering & Technology, SRM University, Kattankulathur, Tamil Nadu, India*

**ABSTRACT NUMBER: 121 : AUTOMATIC APPROACH TO TYPICAL LOCATION-BASED FUZZY CLASSIFICATION OF SLOPE POSITIONS,** Cheng-zhi Qin, *Institute Of Geographic Sciences And Natural Resources Research, Chinese Academy Of Sciences, Beijing, Beijing, China*

**ABSTRACT NUMBER: 124 : MORPHOTECTONIC AND NEOTECTONIC EVIDENCES IN DWARAHAT BASIN UTTARAKHAND INDIA USING REMOTE SENSING & GIS TECHNIQUES,** Ajay Kumar Taloor, *<sup>1</sup>Department of Remote Sensing & GIS, University of Jammu, Jammu, Jammu & Kashmir, India*

**ABSTRACT NUMBER: 169 : DIRECT GRAIN SIZE MAPPING FROM LOW-COST SUAS: A PROOF-OF-CONCEPT,** Patrice Carbonneau, *Durham University, Durham, United Kingdom*

**ABSTRACT NUMBER: 202 : FIRST WORLD WAR LANDFORMS CLASSIFICATION OF THE VERDUN BATTLEFIELD USING AIRBORNE LIDAR AND MULTIVARIATE ANALYSIS,** Rémi De Matos Machado, *Université Paris-Diderot (Paris 7) – UMR 8586 PRODIG, Paris, France*

**ABSTRACT NUMBER: 267 : THE ROLE OF MORPHOTECTONICS IN GULLY FORMATION: TWO CASE STUDIES IN SEMIARID AREAS,** Geraldine Queneherve, *University Of Tuebingen, Tuebingen, BW, Germany*

**ABSTRACT NUMBER: 314 : A SPATIO-TEMPORAL ANALYSIS OF CHANNEL MIGRATION USING REMOTE SENSING, FIELD INVESTIGATION AND GIS TECHNIQUES: THE KAMENG RIVER (LOWER REACH), INDIA,** Chandan Pradhan, *Research Scholar, Civil Engineering Department, IIT Guwahati, Guwahati, Assam, India*

**ABSTRACT NUMBER: 358 : INVENTORY AND RECENTLY INCREASING GLOF SUSCEPTIBILITY OF GLACIAL LAKES IN SIKKIM, EASTERN HIMALAYA,** Suruchi Aggarwal, *Department of Geography, Delhi School of Economics, University Of Delhi, Delhi, India*

**ABSTRACT NUMBER: 370 : IDENTIFICATION OF GROUND WATER PROSPECT IN BARA TAHSIL OF ALLAHABAD DISTRICT BASED ON HYDRO-GEOMORPHOLOGICAL ANALYSIS USING SATELLITE IMAGERY,** Deeksha Mishra, *Research Scholar, Department of Geography, University of Allahabad, Allahabad, Uttar Pradesh, India*

**ABSTRACT NUMBER: 383 : HYDRO-GEOMORPHOLOGY OF THE TAMIRAPARANI RIVER BASIN: IMPLICATIONS ON THE MANAGEMENT OF GROUNDWATER RESOURCES UNDER CHANGING CLIMATIC CONDITIONS,** S.Magesh N, *Anna University, Chennai, Tamil Nadu, India*

**ABSTRACT NUMBER: 531 : MERGING TOPOGRAPHICAL AND SAR DATA FOR IMPROVED PROBABILISTIC FLOOD MAPPING,** Stefan Schlaffer, *American University Of Armenia, Yerevan, Armenia*

**ABSTRACT NUMBER: 539 : EFFECTS OF SENSOR SPATIAL RESOLUTION ON GLACIER VOLUME ESTIMATION USING**





**MULTIPLATFORM DATA: A CASE STUDY OF CHHOTA SHIGRI GLACIER**, Manish Pandey, *School Of Environmental Sciences, Jawaharlal Nehru University, New Delhi, India*

**ABSTRACT NUMBER: 555 : USE OF HIGH-RESOLUTION MODELS FOR GULLY EROSION MONITORING A CASE STUDY FROM PAG ISLAND (CROATIA)**, Nina Lončar, *Department of Geography, Center for Karst and Coastal Research, University of Zadar, Zadar, Croatia*

**ABSTRACT NUMBER: 594 : PLANFORM CHANGE IN DHALAI RIVER, TRIPURA, INDIA**, Saheli Bhattacharjee, *Department of Geography, Calcutta University, Kolkata, West Bengal, India*

**ABSTRACT NUMBER: 646 : CHANNEL PLANFORM DYNAMICS AND STABILITY ASSESSMENT OF RAMGANGA RIVER USING REMOTE SENSING AND GIS**, Ashwani Kumar Agnihotri, *Indian Institute Of Technology (BHU) Varanasi, Varanasi, Uttar Pradesh, India*

**ABSTRACT NUMBER: 699 : TOPOGRAPHIC SIGNATURE OF HIGH INTENSITY DENUDATION PROCESSES IN COMPLEX LANDSCAPES**, Hazel Faulkner, *Middlesex University, London, United Kingdom*

**ABSTRACT NUMBER: 776 : TEMPORAL VARIATION OF VEGETATION CHANGE IN GANGOTRI AND GORI GANGA VALLEY OF CENTRAL WESTERN HIMALAYA, UTTARAKHAND**, Tripti Jayal, *State Climate Change Center, Dehradun, Uttarakhand, India*

**THEME: S22 : QUANTITATIVE GEOMORPHOLOGY AND MODELING..... 194-199**

**ABSTRACT NUMBER: 170 : REVISITING THE DRIVERS OF HYDRAULIC GEOMETRY AT REACH SCALE IN THE HYDROGRAPHIC NETWORK**, Maxime Morel, *Irstea Lyon-Villeurbanne, Villeurbanne, France*

**ABSTRACT NUMBER: 272 : ON THE ACCURACY OF STRUCTURE FROM MOTION (SFM) METHOD FOR GRAIN SCALE MONITORING OF FLUVIAL SURFACES**, Seyed Hossein Mohajeri, *Islamic Azad University, Science And Research Branch, Tehran, Iran*

**ABSTRACT NUMBER: 311 : RELATIONSHIP BETWEEN LANDFORM AND VEGETATION IN PANNA AREA, MADHYA PRADESH**, Pranamee Gogoi, *Rajiv Gandhi University, North Lakhimpur, Assam, India*

**ABSTRACT NUMBER: 362 : AUTOMATED LANDFORM CLASSIFICATION OF BHIMBETKA AREA, MP AND ITS CORRELATES WITH SETTLEMENT AND LANDUSE**, Jenson Pangging, *International Geomorphology Conference, Itanagar, Arunachal Pradesh, India*

**ABSTRACT NUMBER: 363 : APPLICATION OF SWAT MODEL TO PREDICT SOIL LOSS FROM MIDDLE TAPI BASIN, WESTERN DECCAN, INDIA**, Veena Joshi, *Savitribai Phule Pune University, Pune, Maharashtra, India*

**ABSTRACT NUMBER: 364 : FOURIER BASED SIMPLIFIED SHAPE ANALYSIS FOR GEOMORPHIC CURVES**, Vaibhava Srivastava, *Department Of Geology, Banaras Hindu University, Varanasi, Uttar Pradesh, India*

**ABSTRACT NUMBER: 382 : ASSESSING THE FLOOD HAZARD POTENTIAL OF UPPER JHELMUM BASIN, NW KASHMIR HIMALAYA**, Shabir Ahmad, *University Of Kashmir, Srinagar, Jammu And Kashmir, India*

**ABSTRACT NUMBER: 443 : IDENTIFYING NONLINEAR GROUND DISPLACEMENT TRENDS IN BUCHAREST (ROMANIA) BASED ON INSAR**, Iuliana Armas, *University of Bucharest, Faculty of Geography, Department of Geomorphology-Pedology-Geomatics, Nicolae Balcescu 1, Sector 1, Bucharest, Romania*

**ABSTRACT NUMBER: 494 : DTM RESOLUTION INFLUENCE ON MODELLING SLOPE INSTABILITY**, Tiago Martins, *Federal University of Pernambuco, Recife, PE, Brazil*

**ABSTRACT NUMBER: 515 : FUZZY LOGIC APPLICATIONS FOR GEOMORPHOLOGICAL STUDIES**, R. C Pathak, *ICOER, Pune, Maharashtra, India*

**ABSTRACT NUMBER: 598 : METRICS FOR COMPARISON OF GEOMORPHOLOGICAL LANDSCAPE EVOLUTION MODELS**, Marco Van De Wiel, *Coventry University, Coventry, Warwickshire, United Kingdom*

**ABSTRACT NUMBER: 634 : SIMULATING THE EFFECT OF CHECK DAMS ON LANDSCAPE EVOLUTION AT CENTENNIAL TIME SCALES**, Jorge Ramirez, *University Of Bern, Bern, Switzerland*

**THEME: S23 : GEOMORPHOLOGICAL MAPPING..... 199-204**

**ABSTRACT NUMBER: 70 : IDENTIFICATION OF LINEAMENTS AND GEOMORPHIC FEATURES BY USING DIFFERENT DEM DATA PRODUCTS IN SATPURA-PURNA BASIN, WESTERN VIDARBHA, INDIA**, Prashant Magar, *PG Dept of Geography, Government Vidarbha Institute Of Science & Humanities, Amravati, Maharashtra, India*

**ABSTRACT NUMBER: 134 : BGS GEOMORPHOLOGICAL MAPPING SOLUTIONS AND SEMI-AUTOMATIC APPROACHES TRANSFERABLE BETWEEN TERRESTRIAL TO MARINE ENVIRONMENT**, Joana Gafeira, *British Geological Survey, Edinburgh, Scotland, United Kingdom*



**ABSTRACT NUMBER: 236 : HIGH-RESOLUTION RIVER LANDSCAPE MAPPING BY UAV TECHNOLOGY AND COMPARISON WITH TRADITIONAL FIELD MAPPING: CASE STUDY OF BELÁ RIVER REACH, SLOVAKIA, Miloš Rusnák, Institute of Geography Slovak Academy of Sciences, Bratislava, Slovakia**

**ABSTRACT NUMBER: 252 : RESEARCH AND PERSPECTIVES ON GEOMORPHOLOGY IN CHINA: FOUR DECADES IN RETROSPECT, Weiming Cheng, IGSNRR, Beijing, China**

**ABSTRACT NUMBER: 266 : GEOMORPHOLOGICAL AND LITHOLOGICAL MAPPING IN A SEMI-ARID ENVIRONMENT, Geraldine Queneherve, University Of Tuebingen, Tuebingen, BW, Germany**

**ABSTRACT NUMBER: 549 : MULTI-LEVEL DIGITAL GEOMORPHOLOGICAL MAPPING USING ORTHOPHOTOS, LIDAR- AND UAV-DERIVED INFORMATION, Arie Seijmonsbergen, University of Amsterdam, Noord Holland, Netherlands**

**ABSTRACT NUMBER: 565 : A GEOMORPHOLOGICAL CHARACTERISATION OF RAVINE AND ITS DYNAMICS: THE STUDY OF A SEMI-ARID CHAMBAL, INDIA, Padmini Pani, Jawaharlal Nehru University, New Delhi, India**

**ABSTRACT NUMBER: 589 : INDUCED CHANGES IN SLOPE MORPHOLOGY, SOIL PROPERTIES AND GULLY EXPANSION FROM TRAIL DEVELOPMENT AND ANTHROPOGENIC FOOTPRINT ACROSS A LATERITIC BADLAND GEOMORPHOSITE, Rajarshi Dasgupta, East Calcutta Girls' College, Kolkata, West Bengal, India**

**ABSTRACT NUMBER: 767 : SURFICIAL GEOLOGY AND GEOMORPHOLOGY OF THE WESTERN SAN JUAN MOUNTAINS, COLORADO, Kaytan Kelkar, Texas A&M University, Texas, United States**

**ABSTRACT NUMBER: 783 : MORPHOMETRICAL-MORPHOSTRUCTURAL SUBDIVISION OF THE WESTERN CARPATHIANS (SLOVAKIA) BY OBJECT-BASED IMAGE ANALYSIS (OBIA), Peter Bandura, Comenius University in Bratislava, Bratislava, Slovakia**

**THEME: S24 : GEOMORPHOLOGY AND ALLIED DISCIPLINES: MUTUAL CONTRIBUTIONS FOR THE PROGRESS OF INTEGRATED ENVIRONMENTAL AND DISASTER STUDIES..... 204-209**

**ABSTRACT NUMBER: 154 : FLOODPLAIN MAPPING AND VULNERABILITY OF KASHMIR VALLEY USING HEC-RAS AND ARCGIS : A CASE STUDY OF UPPER RIVER JHELMUM, KASHMIR INDIA, Hakim Farooq Ahmad, Dept. of Geography, University Of Kashmir, Srinagar, Jammu And Kashmir, India**

**ABSTRACT NUMBER: 209 : EVALUATION OF SPATIAL AND TEMPORAL DRYNESS CHARACTERISTICS IN TURKEY AND THEIR POSSIBLE IMPACTS ON SOIL DEGRADATION, Haim Kutiel, University Of Haifa, Haifa, Israel**

**ABSTRACT NUMBER: 304 : OBJECTIVE AND SUBJECTIVE REALITY: AN INTEGRATIVE RESEARCH ON NATURAL HAZARDS EVENTS AND PERCEPTION IN ALPINE VALLEYS, Florian Ortner, University of Graz, Department of Geography and Regional Science, Graz, Austria**

**ABSTRACT NUMBER: 345 : EVALUATING LAND USE CHANGES AND GEO-HYDROLOGICAL RESPONSE IN SMALL MEDITERRANEAN CATCHMENTS WITH OUTSTANDING CULTURAL AND NATURAL VALUES, Francesco Faccini, University of Genoa, Genoa, Italy**

**ABSTRACT NUMBER: 413 : RAIN WATER HARVESTING IN THE DROUGHT PRONE REGION- A WATERSHED SCALE STUDY IN BANKURA DISTRICT OF WEST BENGAL, Moumita Moitra Maiti, Raja N.L. Khan Women's College, Midnapore, West Bengal, India**

**ABSTRACT NUMBER: 418 : ENVIRONMENTAL INFLUENCE ON AGRICULTURE: A STUDY OF WEST BENGAL, Anwesha Banerjee, Vidyasagar University, Midnapore, West Bengal, India**

**ABSTRACT NUMBER: 419 : WATER LOGGING AND LAND USE - A DIALECTIC RELATIONSHIP: STUDY ON CHUNDIA RIVER BASIN, WEST BENGAL, Surajit Mondal, Vidyasagar University, Midnapore, West Bengal, India**

**ABSTRACT NUMBER: 421, LONG-TERM MULTIDISCIPLINARY INVESTIGATIONS ALONG THE NW COAST OF MALTA (CENTRAL MEDITERRANEAN SEA), Mauro Soldati, Department of Chemical and Geological Sciences, University of Modena and Reggio Emilia, Modena, Italy**

**ABSTRACT NUMBER: 456 : LONGTIME: AN INTERDISCIPLINARY PROJECT TO EVALUATE THE LONG TERM IMPACT OF ANCIENT AMERINDIAN SETTLEMENTS ON GUIANESE FORESTS AND ITS CONSEQUENCES FOR BIODIVERSITY CONSERVATION, Jeanne Brancier, CNRS Guyane - USR LEEISA / Micromorphological Team INRAP Grignon - ADEPRINA, Cayenne, French Guiana, France**

**ABSTRACT NUMBER: 564 : GEOMORPHOLOGICAL CHANGES DUE TO ANTHROPIC ACTIVITY IN THE HIGHLY URBANIZED FLOODPLAINS OF SMALL LIGURIAN MEDITERRANEAN BASINS (ITALY), Francesco Faccini, University of Genoa, Genoa, Italy**

**THEME: S25 : FUTURE EARTH: RESEARCH FOR GLOBAL SUSTAINABILITY..... 209-210**

**ABSTRACT NUMBER: 493 : CHALLENGES OF A PRESENT-DAY AND FUTURE LANDSLIDE RISK ASSESSMENT AT NATIONAL SCALE IN ROMANIA, Alexandru Mihai Micu, Institute of Geography, Romanian Academy, Bucharest, Romania**



**ABSTRACT NUMBER: 712 : AN ACCOUNT OF CLIMATIC OSCILLATIONS IN FRAGILE GEOMORPHOLOGICAL SETTINGS OF HIMALAYAN FOOTHILLS, INDIA, Koyel Sam, Dept. Of Geography, The University Of Burdwan, Burdwan, West Bengal, India**

**THEME: S26 : CONNECTIVITY IN GEOMORPHOLOGY ..... 210-215**

**ABSTRACT NUMBER: 83 : CONNECTIVITY RESPONSE UNITS: A CLUSTERING-BASED APPROACH FOR ASSESSMENT OF HYDROLOGICAL CONNECTIVITY OF A WETLAND (KAABAR TAL, NORTH BIHAR PLAINS, INDIA), Manudeo Singh, Indian Institute Of Technology Kanpur, Kanpur, Uttar Pradesh, India**

**ABSTRACT NUMBER: 131 : BEDROCK STRUCTURAL CONTROL ON CATCHMENT-SCALE CONNECTIVITY AND SEDIMENT SUPPLY TO TRIBUTARY-JUNCTION ALLUVIAL FANS IN THE HIGH ATLAS MOUNTAINS OF MOROCCO, Anne Mather, Plymouth University, Plymouth, Devon, United Kingdom**

**ABSTRACT NUMBER: 232 : MULTITEMPORAL APPROACH TO MEASUREMENT COARSE SEDIMENT CONNECTIVITY (CASE STUDY OF A BRAIDED-WANDERING RIVER), Milan Lehotský, Institute of Geography, Slovak Academy of Sciences, Bratislava, Slovakia**

**ABSTRACT NUMBER: 353 : SPATIAL NON-CONTINUITY OF HYDROLOGICAL AND ECOLOGICAL PROCESSES IN ARID AND SEMI-ARID HILLSLOPES, Hanoch Lavee, Bar-ilan University, Ramat-Gan, Israel**

**ABSTRACT NUMBER: 425 : INFLUENCES ON CONNECTIVITY IN FLUVIAL SYSTEMS AND THEIR EFFECTS ON STRATEGIES AND GOALS OF SUSTAINABLE LAND AND WATER MANAGEMENT, Janet Hooke, University of Liverpool, Liverpool, United Kingdom**

**ABSTRACT NUMBER: 516 : POTENTIAL INTERACTION BETWEEN TRANSPORT AND STREAM NETWORKS OVER ALLUVIAL RIVER BASIN, Suwendu Roy, University Of Kalyani, Kalyani, West Bengal, India**

**ABSTRACT NUMBER: 529 : DEFINING FUNDAMENTAL UNITS IN HYDRO-GEOMORPHIC CONNECTIVITY RESEARCH: A WETLAND EXAMPLE USING REMOTE SENSING DATA, Ronald Pöppel, University of Vienna, Vienna, Austria**

**ABSTRACT NUMBER: 574 : 1950 AD: THE GREAT ACCELERATION OF EROSION AND SEDIMENT FLUX? Anthony Foucher, Laboratoire GéoHydrosystèmes Continentaux (GéHCO), E.A 6293, Université F. Rabelais de Tours, Faculté des Sciences et Techniques, Tours, France**

**ABSTRACT NUMBER: 575 : SEDIMENT FLUXES AND PROCESSES IN A LOWLAND AGRICULTURAL CATCHMENT, Sébastien Salvador-blanes, EA 6293 Géohydrosystèmes Continentaux (GéHCO) - Université François Rabelais de Tours, Tours, France**

**ABSTRACT NUMBER: 692 : GETTING THE RIGHT PICTURE: A DETAILED SEDIMENT BUDGET FOR AN ABANDONED TERRACED AND GULLIED HILLSLOPE, Erik Cammeraat, IBED-Ecosystem and Landscape Dynamics, University Of Amsterdam, Amsterdam, Noord Holland, Netherlands**

**THEME: S27 : SEDIMENT BUDGETS (IAG-WG SEDIBUD)..... 215-220**

**ABSTRACT NUMBER: 213 : HUMAN IMPACT ON SUSPENDED SEDIMENT LOAD IN A SMALL CARPATHIANS CATCHMENT DURING THE YEARS 1970-2010, Malgorzata Kijowska-Strugala, Polish Academy of Sciences, Institute of Geography and Spatial Organization, Research Station in Szymbark, Szymbark, PL, Poland**

**ABSTRACT NUMBER: 224 : ASSESSING THE HYDROGEOMORPHOLOGICAL FUNCTIONING OF A SMALL ALPINE CATCHMENT BY APPLYING A SEDIMENT BUDGET ANALYSIS: THE PEYNIN SUB-CATCHMENT (UPPER-GUIL CATCHMENT, SOUTHERN FRENCH ALPS), Benoit Carlier, Université Paris-Diderot (Paris 7), Sorbonne Paris Cité, UMR 8586 PRODIG, Paris, France**

**ABSTRACT NUMBER: 259 : QUANTITATIVE ASSESSMENT OF EROSION/SEDIMENTATION RATE TRENDS IN, DIFFERENT SCALES: PROBLEMS AND POSSIBILITIES (BY THE EXAMPLE OF THE EAST-EUROPEAN PLAIN), Artem V. Gusarov, Kazan Federal University, Institute of Environmental Sciences, Kazan, Russian Federation**

**ABSTRACT NUMBER: 481 : ENVIRONMENTAL SIGNIFICANCE OF SEDIMENT GRAIN SIZE FROM THE HOLOCENE GREAT RANN BASIN AT THE WESTERN CONTINENTAL MARGIN OF INDIA, Abhishek Kumar, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat, India**

**ABSTRACT NUMBER: 490 : SEDIMENT BUDGET OF THE OPAK RIVER CATCHMENT FOUR YEARS AFTER THE 2010 LARGE VOLCANIC EVENT OF THE MERAPI (INDONESIA), Frédéric Gob, Université Paris 1 - Laboratoire de Géographie Physique de Meudon, Meudon, Hauts de Seine, France**

**ABSTRACT NUMBER: 587 : MULTI-TEMPORAL LIDAR DATASETS REVEALING DIFFERENT STYLES OF DEBRIS FLOW TRIGGERING AND EVOLUTION IN THE WESTFJORDS OF ICELAND, Costanza Morino, School of Environment, Earth and Ecosystem Sciences, The Open University, Milton Keynes, United Kingdom**

**ABSTRACT NUMBER: 639 : SPATIO-TEMPORAL VARIATION OF SEDIMENT GRAIN SIZE OF RIVER TISTA, Kausik Ghosh, Vidyasagar University, Midnapore, West Bengal, India**



**ABSTRACT NUMBER: 640 : IMPACTS OF CLIMATE CHANGES AND ENVIRONMENTAL CONTROLS ON SEDIMENT FLUXES THROUGHOUT THE HOLOCENE EPOCH IN MOUNTAIN CATCHMENTS OF EASTERN CANADA, [Daniel Germain](#), *Université du Québec à Montréal, Montreal, Quebec, Canada***

**ABSTRACT NUMBER: 695 : ASSESSING IMPACTS OF EXTREME RAINFALL EVENTS ON SUSPENDED SEDIMENT EVACUATED FROM GLACIERS OF UPPER GANGA BASIN, GARHWAL HIMALAYA, [Amit Kumar](#), *Centre for Glaciology, Dehradun, Uttarakhand, India***

**ABSTRACT NUMBER: 697 : CONTROLS ON THE FORMATION AND ABANDONMENT OF THE TISTA MEGAFAN (WEST BENGAL, INDIA), A MAJOR TRANSIENT SEDIMENT TRAP IN THE HIMALAYAN SOURCE TO SINK SYSTEM, [Pieter van der Beek](#), *Université Grenoble Alpes, Grenoble, France***

**ABSTRACT NUMBER: 749 : LABORATORY EXPERIMENTS TO PREDICT EVOLUTION OF SEDIMENT SIZE DISTRIBUTIONS BY ABRASION AND FRAGMENTATION IN TRANSPORT, [Leonard Sklar](#), *San Francisco State University, San Francisco, California, United States***

**THEME: S28 : TROPICAL RIVERS (IAG-WG) ..... 221-224**

**ABSTRACT NUMBER: 61 : FIRE, FLOODS AND FOREST: IMPACT ON INDIAN RIVERS OF THE TOBA SUPER- ERUPTION, [Martin Williams](#), *University of Adelaide, Adelaide, South Australia, Australia***

**ABSTRACT NUMBER: 435 : HOLOCENE ALLUVIAL RECORDS OF THE NORTHEAST-MONSOON DOMINATED RIVERS OF SOUTH INDIA, [Hema Achyuthan](#), *Anna University, Chennai, Tamil Nadu, India***

**ABSTRACT NUMBER: 519 : CONTROLS ON PROCESS-FORM WITHIN A LOW-RELIEF LANDSCAPE, [Adeyemi Olusola](#), *Osun State University, Osogbo, Osun State, Nigeria***

**ABSTRACT NUMBER: 703 : A GEOMORPHOLOGICAL ASSESSMENTS OF THE DISTRIBUTION OF SEDIMENT SINKS ALONG THE LOWER AMAZON RIVER, [Edward Park](#), *Earth Observatory Of Singapore, Nanyang Technological University, Singapore***

**ABSTRACT NUMBER: 710 : ARE SEDIMENT LOADS OF INSULAR SOUTH EAST ASIA OVERESTIMATED? - CLUES FROM BORNEO, [Edgardo Latrubesse](#), *University of Texas at Austin, Austin, Texas, United States***

**ABSTRACT NUMBER: 711 : THE PARADOX OF LARGE ALLUVIAL RIVERS: EQUILIBRIUM AND FLOODPLAINS EVOLUTION, [Edgardo Latrubesse](#), *University of Texas at Austin, Austin, Texas, United States***

**ABSTRACT NUMBER: 732 : HOW OLD IS THE COURSE OF THE NIGER RIVER AT BAMAKO, MALI? [N'dji Dit Jacques Dembele](#), *FHG/USSGB, Bamako, Bamako District, Mali***

**ABSTRACT NUMBER: 775 : MATERIAL FLUX DYNAMICS IN A HEADWATER CATCHMENT IN NORTHERN THAILAND: HYSTERESIS, HIGH YIELDS, AND HOT SPOTS, [Alan D Ziegler](#), *National University Of Singapore, Singapore***

**THEME: S29 : GEOMORPHOLOGY OF ROCKY COASTS (IAG-WG)..... 224-229**

**ABSTRACT NUMBER: 115 : HARD ROCK CLIFF EROSION IN BRITTANY (FRANCE): IMPACT OF SUBAERIAL AND MARINE AGENTS AND PROCESSES ON ROCK MICRO-FRACTURING, [Katja Laute](#), *Université de Bretagne Occidentale, IUEM, CNRS, UMR LETG, Technopôle Brest-Iroise, Plouzané, Finistère, France***

**ABSTRACT NUMBER: 200 : RECENT PROGRESS IN ROCKY COAST SYSTEMS EVOLVING IN POLAR ENVIRONMENTS, [Matt Strzelecki](#), *Institute of Geography and Regional Development, University Of Wroclaw, Wroclaw, Poland***

**ABSTRACT NUMBER: 214 : SOUTHERN CALIFORNIA COASTAL CLIFF RESPONSE TO THE 2015-2016 EL NINO, [Adam Young](#), *Scripps Institution of Oceanography, UC San Diego, La Jolla, California, United States***

**ABSTRACT NUMBER: 217 : THE EROSION OF THE SHORE PLATFORM RAISED BY THE COSEISMIC COASTAL UPLIFT AS A RESULT OF THE NEVELSK EARTHQUAKE OF 2007, MW = 6.2, [Viktor Afanasev](#), *Institute of Marine Geology and Geophysics FEB RAS, Yuzhno-sakhalinsk, Sakhalin, Russian Federation***

**ABSTRACT NUMBER: 226 : 45 YEARS OF SHORE PLATFORM RESEARCH AT KAIKOURA - AN UPLIFTING EXPERIENCE, [Wayne Stephenson](#), *University Of Otago, Dunedin, Otago, New Zealand***

**ABSTRACT NUMBER: 355 : EROSION OF COHESIVE SHORELINES: NEW INSIGHTS FROM 10 YEARS OF PLATFORM DOWNWEARING MEASUREMENTS; LONDON CLAY, KENT COASTLINE, UK, [Cherith Moses](#), *University Of Sussex, Falmer, Brighton, East Sussex, United Kingdom***

**ABSTRACT NUMBER: 423 : FORMS AND PROCESSES OF ROCKY CLIFFS IN THE PONZA ISLAND COAST (ITALY), [Alessio Valente](#), *Sannio University, Benevento, BN, Italy***

**ABSTRACT NUMBER: 500 : MECHANISMS AND CONTROLS OF SHORE PLATFORM DOWN-WEARING, [Zuzanna Swirad](#), *Department of Geography, Durham University, Durham, United Kingdom***



**ABSTRACT NUMBER: 512 : LINKING NEARSHORE AND ONSHORE EVIDENCE FOR EXTREME WAVE IMPACTS ON ROCKY SHORES IN MALTA,** [Derek Mottershead](#), *University of Portsmouth, Portsmouth, Hampshire, United Kingdom*

**ABSTRACT NUMBER: 660 : INFLUENCE OF SHORE PLATFORM AND ITS GEOMORPHOLOGY ON COASTAL EROSION RATE OF BEACH TERRACES, SOUTH SHORE OF THE ST-LAWRENCE ESTUARY, CANADA,** [Caroline Pinsonnault](#), *Chaire de recherche en géoscience côtière, Laboratoire de dynamique et de gestion intégrée des zones côtières (LDGIZC), Center for Northern Studies, Université du Québec à Rimouski, Rimouski, Quebec, Canada*

**THEME: S30 : SUBMARINE GEOMORPHOLOGY (IAG-WG)..... 220-235**

**ABSTRACT NUMBER: 7 : SUBMARINE LANDSLIDE INFLUENCES ON THE DEVELOPMENT AND MORPHOLOGY OF 'EMPTY BUCKET' VERSUS 'FULL BUCKET' VARIETIES OF PACIFIC ATOLLS,** [James Terry](#), *Zayed University, Dubai, United Arab Emirates*

**ABSTRACT NUMBER: 135 : GEOMORPHOMETRIC CHARACTERISATION OF POCKMARKS ACROSS THE EUROPEAN GLACIATED MARGIN BY A USING GIS-BASED SEMI-AUTOMATED TOOLBOX,** [Joana Gafeira](#), *British Geological Survey, Edinburgh, Scotland, United Kingdom*

**ABSTRACT NUMBER: 157 : SHAPING MECHANISMS AND LONG-TERM EVOLUTION OF SUBMARINE CANYONS. LESSONS TAKEN FROM FIELD, NUMERICAL AND EXPERIMENTAL STUDIES,** [David Amblas](#), *Scott Polar Research Institute - University Of Cambridge, Cambridge, United Kingdom*

**ABSTRACT NUMBER: 308 : GRAVITY DRIVEN SEDIMENT TRANSPORT ALONG THE NW-AFRICAN CONTINENTAL MARGIN,** [Sebastian Krastel](#), *Kiel University, Kiel, Germany*

**ABSTRACT NUMBER: 317 : TOPOGRAPHICALLY-DRIVEN METEORIC GROUNDWATER: AN IMPORTANT GEOMORPHIC AGENT?** [Aaron Micallef](#), *Marine Geology & Seafloor Surveying, Department of Geosciences, University Of Malta, Msida, Malta*

**ABSTRACT NUMBER: 380 : A NEW GENETIC CLASSIFICATION AND MAPPING APPROACH FOR LITTORAL TO ABYSSAL FEATURES ON THE AUSTRALIAN MARGIN,** [Rachel Nanson](#), *Geoscience Australia, Symonston, Act, Australia*

**ABSTRACT NUMBER: 518 : DIRECT MEASUREMENT OF THE IMPACT OF SUBMARINE GRAVITY FLOWS ON SEAFLOOR MORPHOLOGY: PRELIMINARY RESULTS OF THE MONTEREY COORDINATED CANYON EXPERIMENT,** [C.K. Paull](#), *Mbari, Moss Landing, California, United States*

**ABSTRACT NUMBER: 601 : ROV-BORNE MICRO-BATHYMETRY REVEALS THE ROLE OF REEF FRAMEWORK- FORMING COLD-WATER CORALS IN SHAPING THE NORTH-EASTERN IONIAN MARGIN FROM LATE PLEISTOCENE TO PRESENT TIME,** [Alessandra Savini](#), *University of Milano Bicocca, Dept of Earth and Environmental Sciences, Milano, Italy*

**ABSTRACT NUMBER: 676 : SUBMARINE CHANNEL MORPHOLOGICAL SCALING RELATIONSHIPS: A PREDICTOR FOR ARCHITECTURAL HETEROGENEITY AND A COMPARISON TO SUBAERIAL/RIVER SCALING RELATIONSHIPS,** [Zane Jobe](#), *Colorado School Of Mines, Golden, CO, United States*

**ABSTRACT NUMBER: 681 : THE LEVANTINE MARGIN DURING THE MESSINIAN SALINITY CRISIS: SLUMPS, INCISIONS, TECTONICS AND MORE,** [Liran Ben Moshe](#), *University Of Haifa, Haifa, Israel*

**ABSTRACT NUMBER: 683 : MASS WASTING EVIDENCES ON A SMOOTH SEAFLOOR RIDGE OF THE SOUTH WEST INDIAN RIDGE; 28°S – 64°E,** [Mariacristina Prampolini](#), *National Council of Research - Institute for Marine Sciences, Bologna, Italy*

**ABSTRACT NUMBER: 784 : MULTIBEAM BATHYMETRIC MAPPING OF SUBMARINE CANYONS OFF VISAKHAPATNAM, EASTERN CONTINENTAL MARGIN OF INDIA,** [VP Mahale](#), *National Institute Of Oceanography, Panaji, Goa, India*

**THEME: S31 : LANDFORM ASSESSMENT FOR GEODIVERSITY: GENERAL GEOMORPHOLOGY, GEODIVERSITY, GEOCONSERVATION (IAG-WG) ..... 236-341**

**ABSTRACT NUMBER: 76 : THE MUSTANG GRABEN (NEPAL HIMALAYAS): LANDFORMS DIVERSITY AND DYNAMICS VS. ECONOMIC DEVELOPMENT. OPPORTUNITIES OR THREAT TO GEODIVERSITY?** [Monique Fort](#), *University Paris Diderot - CNRS UMR 8586 PRODIG, Paris, Ile-de-France, France*

**ABSTRACT NUMBER: 161 : THE GEODIVERSITY OF PROCESSES AND LANDFORMS: HOW CAN THEY BE INTEGRATED AT WORLD HERITAGE LEVEL?** [Cécile Olive-garcia](#), *Conseil Departemental Du Puy De Dome, Clermont- ferrand, Puy De Dome, France*

**ABSTRACT NUMBER: 229 : EXPLORING GEODIVERSITY OF ISLANDS IN RELATION TO TECTONIC SETTING AND AGE,** [Arie Seijmonsbergen](#), *University of Amsterdam, Amsterdam, Noord Holland, Netherlands*

**ABSTRACT NUMBER: 293 : GEOMORPHOLOGICAL LANDSCAPE IN THE NORTHERN MOROCCO REGION: INVENTORY OF GEOMORPHOSITE, EVALUATION, MAPPING AND VALORIZATION,** [Alilou Mohamed Rida](#), *University Of Abdelmaled Assadi, Tetouan, Tanger, Tetouen El Hoceima, Morocco*



**ABSTRACT NUMBER: 346 : MAN-MADE LANDFORMS AND GEODIVERSITY WITHIN OLD GENOA CITY (ITALY): AN UNIQUE AND COMPLEX GEOMORPHOLOGICAL LANDSCAPE IN MEDITERRANEAN AREA, [Francesco Faccini](#), *University of Genoa, Genoa, Italy***

**ABSTRACT NUMBER: 484 : ASSESSMENT AND ENHANCEMENT OF GEODIVERSITY IN THE PIEMONTE REGION (ITALY): “FROM ROCKS TO STONES, FROM LANDFORMS TO LANDSCAPES”, [Marco Giardino](#), *University of Torino - Earth Science Dept., Torino, Italy***

**ABSTRACT NUMBER: 610 : EVIDENCES OF QUATERNARY ENVIRONMENTAL CHANGES IN THE AREA OF KANCHENJUNGA BIOSPHERE RESERVE IN SIKKIM HIMALAYA AND OUR STRATEGY FOR MANAGEMENT, [Guru Prasad Chattopadhyay](#), *Visva-Bharati University, Santiniketan, West Bengal, India***

**ABSTRACT NUMBER: 700 : GEOPARK AS A LINK BETWEEN GEOMORPHOLOGY AND SOCIETY, [Jiun-Chuan Lin](#), *Department of Geography, National Taiwan University, Taipei, Taiwan***

**ABSTRACT NUMBER: 709 : TIMELINE MAP FOR ANALYZING TRENDS IN THE USE OF GEODIVERSITY ASSESSMENT METHODS, [Zbigniew Zwolinski](#), *Adam Mickiewicz University in Poznan, Poznan, Poland***

**ABSTRACT NUMBER: 740 : EVALUATION OF ANTHROPOGENIC DEGRADATION OF PEATLANDS FROM THE VIEWPOINT OF THEIR OCCURRENCE AND GEODIVERSITY. CASE STUDY OF PEATLAND IN THE POLISH CARPATHIAN MOUNTAINS, [Adam Łajczak](#), *Pedagogical University, Institute Of Geography, Krakow, Malopolska, Poland***

**ABSTRACT NUMBER: 741 : TIMBERLINE AS A LINK JOINING AREAS OF VARIOUS GEODIVERSITY IN MOUNTAIN ENVIRONMENT. CASE STUDY OF BABIA GÓRA MASSIF, WESTERN CARPATHIANS, [Adam Łajczak](#), *Pedagogical University, Institute Of Geography, Krakow, Malopolska, Poland***

**THEME: S32 : PLANETARY GEOMORPHOLOGY (IAG-WG) ..... 242-245**

**ABSTRACT NUMBER: 195 : ALTERNATING GLACIAL AND GULLY EROSION ON MARS, [Susan Conway](#), *CNRS, UMR6112 Laboratoire de Planetologie et Geodynamique de Nantes, Nantes, France***

**ABSTRACT NUMBER: 239 : SEDIMENTATION OF FINE PARTICLE CLOUDS IN WATER ON MARS, [Nikolaus J. Kuhn](#), *University Of Basel, Basel, Switzerland***

**ABSTRACT NUMBER: 268 : ALLUVIAL FANS ON MARS: FROM ORBITAL DATA TO GROUND TRUTH, [Nicolas Mangold](#), *LPG/Univ Nantes/CNRS, Nantes, France***

**ABSTRACT NUMBER: 326 : AN IN-SITU INVESTIGATION OF THE EFFECT OF IMPACT PROCESSES ON ROCK BREAKDOWN USING SUB-MM RESOLUTION DEMS AT METEOR CRATER, ARIZONA, [Ankit Verma](#), *Trinity College Dublin, College Green, Dublin, Ireland***

**ABSTRACT NUMBER: 560 : VARIATION OF MORPHOLOGICAL CHARACTERISTICS OF LIGHT-TONED MATERIALS IN VALLES MARINERIS, MARS: INSIGHTS INTO THE DEPOSITION, DIAGENESIS, AND POST-DEPOSITIONAL CONDITIONS, [Ranjan Sarkar](#), *Indian Institute of Technology Bombay, Mumbai, Maharashtra, India***

**ABSTRACT NUMBER: 571 : A KARSTIC ORIGIN FOR THE NORTH POLAR LAKES REVEALS A SOLUBLE TITAN, [Rajani Dhingra](#), *University Of Idaho, Moscow, Idaho, United States***

**ABSTRACT NUMBER: 588 : GEOMORPHOLOGY OF CRATER FLOOR IMPACT MELT DEPOSITS ON THE MOON: INSIGHTS INTO THE IMPACT CRATERING PROCESS, [Deepak Dhingra](#), *Indian Institute of Technology Kanpur, Kanpur, Uttar Pradesh, India***

**THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION) ..... 245-256**

**ABSTRACT NUMBER: 13 : LATE PLEISTOCENE-HOLOCENE GEOMORPHOLOGY AND CLIMATE OF THE MOGAN BASIN (CENTRAL ANATOLIA), TURKEY, [Faruk Ocakoğlu](#), *Eskişehir Osmangazi University, Eskişehir, Turkey***

**ABSTRACT NUMBER: 111 : GEOMORPHOLOGICAL PROCESSES, IN RELICT LANDSCAPE OF TECTONIC TERRACES IN DAGHMAR-DIBBAB COASTAL AREA, (NE OMAN), [Kosmas Pavlopoulos](#), *Paris Sorbonne University Abu Dhabi, Geography and Planning Department, Abu Dhabi, United Arab Emirates***

**ABSTRACT NUMBER: 150 : MORPHOSTRATIGRAPHIC CONSTRAINTS VERSUS THERMOCHRONOLOGICAL DATA. LESSONS FROM GEOMORPHOLOGICAL STUDIES IN NORTHEAST BRAZIL, [Jean-pierre Peulvast](#), *University Of Paris-sorbonne, Paris, Île De France, France***

**ABSTRACT NUMBER: 153 : CONSISTENCY OF DRAINAGE PATTERN WITH STRAIN PORTIONING ACROSS HIMALAYA, [M. Sultan Bhat](#), *Department of Geography, University of Kashmir, Srinagar, Jammu And Kashmir, India***

**ABSTRACT NUMBER: 159 : A GLOBAL FRAMEWORK FOR VALUING AND COMPARING TECTONIC GEOMORPHOLOGICAL SITES, [Cécile Olive-garcia](#), *Conseil Departemental Du Puy De Dome, Clermont-ferrand, Puy De Dome, France***

**ABSTRACT NUMBER: 189 : ALLUVIAL RIVERS AND RESPONSE OF ACTIVE TECTONICS: A CASE STUDY ON THE KHARI RIVER SYSTEM, WESTERN BENGAL BASIN, EASTERN INDIA, Subhankar Bera, Department of Geography, University of Kalyani, Kalyani, West Bengal, India**

**ABSTRACT NUMBER: 241 : MORPHOTECTONIC STUDIES IN EARTHQUAKE SWARM ACTIVITY PRONE SW SAURASHTRA, WESTERN INDIA, Naimisha Vanik, Department of Geology, The M. S. University of Baroda, Vadodara, Gujarat, India**

**ABSTRACT NUMBER: 261 : GEOMORPHIC SIGNATURES OF POSSIBLE CAUSATIVE FAULT IN EARTHQUAKE SWARM ACTIVITY PRONE AREA, NORTHERN SAURASHTRA, WESTERN INDIA, Prabhuti Tiwari, M.S. University Of Baroda, Vadodara, Gujarat, India**

**ABSTRACT NUMBER: 265 : VARIABILITY OF NEOTECTONIC ACTIVITY ALONG THE SEGMENTED NARMADA-SON FAULT (NSF): EVIDENCE FROM GEOMORPHOLOGY AND LATE QUATERNARY SEDIMENTS, Deepak Maurya, M. S. University of Baroda, Vadodara, Gujarat, India**

**ABSTRACT NUMBER: 279 : MORPHOTECTONIC STUDY IN AND AROUND AIZAWL, MIZORAM, INDIA, Raghupratim Rakshit, Department Of Applied Geology, Dibrugarh University, Dibrugarh, Assam, India**

**ABSTRACT NUMBER: 281 : STREAM RESPONSE TO ACTIVE TECTONIC DEFORMATION OF THE SUB-HIMALAYAN WEDGE: INFERENCES ON GEOLOGICAL STRUCTURE, TECTONICS AND SEISMIC HAZARD, Hitander Singh Gill, Centre for Advanced Study in Geology, Panjab University, Chandigarh, India**

**ABSTRACT NUMBER: 329 : PALAEOSEISMOLOGICAL INVESTIGATION ALONG THE BACK THRUST OF HFT, SOAN DUN, NORTHWEST HIMACHAL HIMALAYA, INDIA, Girish Kothiyari, Institute Of Seismological Research, Gandhinagar, Gujarat, India**

**ABSTRACT NUMBER: 371 : TECTONIC GEOMORPHOLOGY OF THE KALAHARI, Frank Eckardt, University Of Cape Town, Cape Town, Western Cape, South Africa**

**ABSTRACT NUMBER: 378 : RECOGNITION OF ACTIVE STRIKE-SLIP FAULTING FROM OFFSET RIVER CHANNELS: THE QINGCHUAN FAULT, THE NORTHEASTERN SEGMENT OF THE LONGMEN SHAN FAULT ZONE, CHINA, Zhou Lin, Zhejiang University, Hangzhou, Zhejiang, China**

**ABSTRACT NUMBER: 466 : TECTONIC AND CLIMATIC CONTROL ON THE EVOLUTION OF THE INTERMONTANE KANGRA BASIN, NW HIMALAYA, Saptarshi Dey, Indian Institute Of Technology Gandhinagar, Gandhinagar, Gujarat, India**

**ABSTRACT NUMBER: 548 : LATE QUATERNARY ACTIVITY WITHIN THE MARIÁNSKÉ LÁZNĚ FAULT ZONE AS REVEALED BY TRENCHING SURVEY; CHEB BASIN, BOHEMIAN MASSIF (CZECH REPUBLIC), Petra Štěpančíková, Institute Of Rock Structure And Mechanics, Czech Academy, v.v.i. Of Sciences, Prague 8, Czech Republic**

**ABSTRACT NUMBER: 596 : LATE QUATERNARY TECTONICS OF THE PAMIR-TIAN SHAN CONVERGENCE ZONE, NW CHINA, Jessica Ann Thompson Jobe, Institute of Tectonics Studies, University of Texas El Paso, El Paso, Texas, United States**

**ABSTRACT NUMBER: 613 : ESTIMATING RELATIVE RATES OF UPLIFT AND EROSION ON THE MAIN FRONTAL THRUST, CENTRAL HIMALAYA, USING THE INTEGRAL METHOD OF CHANNEL PROFILE ANALYSIS, Ananya Divyadarshini, Department Of Geology, University Of Delhi, Delh, India**

**ABSTRACT NUMBER: 651 : “POP-UP” LIKE REJUVENATION OF SATPURA RANGE CAUSING SEISMICITY IN CENTRAL INDIAN CRATON? - A STUDY WITH TECTONIC GEOMORPHOLOGICAL APPROACHES, Dipanjan Bhattacharjee, Indian Institute Of Technology Gandhinagar, Gandhinagar, Gujrat, India**

**ABSTRACT NUMBER: 656 : GEOMORPHOLOGICAL INDICATORS OF NEOTECTONIC DEFORMATION ALONG THE EASTERN HIMALAYAN FOOTHILLS: CASE STUDIES FROM TWO AREAS IN WEST BENGAL AND ARUNACHAL PRADESH, INDIA, Chandreyee Goswami, University Of Calcutta, Kolkata, West Bengal, India**

**ABSTRACT NUMBER: 718 : ALLUVIAL TERRACES OF THE CHEL RIVER VALLEY, FOOTHILLS OF DARJEELING HIMALAYA, INDIA: IMPRINTS OF GEOMORPHIC AND TECTONIC PROCESSES, Rimpal Kar, Geological Survey of India, Hyderabad, Telengana, India**

**ABSTRACT NUMBER: 782 : PHYSICALLY-BASED SEGMENTATION OF THE LAND SURFACE FOR MORPHOTECTONIC ANALYSIS, Jozef Minar, Comenius University in Bratislava, Bratislava, Slovakia**

**ABSTRACT NUMBER: 787 : MORPHOTECTONIC OF REGOLITH LANDSURFACES IN CAMEROON (CENTRAL AFRICA): WEIGHTING THE EVIDENCES OF LATE CRETACEOUS UPLIFT AND CLIMATIC DEEP WEATHERING AND STRIPPING, Mathieu Momo Nouazi, University of Dschang, Dschang, Western Region, Cameroon**

**THEME: S33-A : TECTONIC GEOMORPHOLOGY OF KACHCHH BASIN ..... 256-260**

**ABSTRACT NUMBER: 246 : SCARP DEVELOPMENT AND NEOTECTONIC RESPONSE OF UPLIFT INDUCED EROSIONAL LANDSCAPE ALONG THE SEISMICALLY ACTIVE KACHCHH MAINLAND FAULT (KMF), WESTERN INDIA, Mohamedharoon Shaikh, The Maharaja Sayajirao University of Baroda, Vadodara, Gujarat, India**

**ABSTRACT NUMBER: 328 : EVOLUTION OF DRAINAGE IN RESPONSE TO BRITTLE - DUCTILE DYNAMICS AND SURFACE PROCESSES IN KACHCHH RIFT BASIN, WESTERN INDIA, Girish Kothiyari, Institute Of Seismological Research, Gandhinagar, Gandhinagar, Gujarat, India**

**ABSTRACT NUMBER: 406 : ODDS OF EARTHQUAKE HAZARD IN KACHCHH: REVEALED BY THE TECTONIC GEOMORPHOLOGY OF KACHCHH,** [Siddharth Prizomwala](#), Institute Of Seismological Research, Gandhinagar, Gujarat, India

**ABSTRACT NUMBER: 458 : COASTAL GEOMORPHOLOGY OF THE KACHCHH, WESTERN INDIA: ROLE OF TECTONICS AND SEDIMENT DISPERSAL SYSTEM,** [Nilesh Bhatt](#), *The M. S. University Of Baroda, Vadodara, Gujarat, India*

**ABSTRACT NUMBER: 636 : ROLE OF IGNEOUS BODIES IN SHAPING THE PRESENT DAY LANDSCAPE OF KACHCHH BASIN-WESTERN INDIA,** [Anil Chavan](#), *Dept. Of Earth And Env. Science, K.S.K.V. Kachchh University, Bhuj, Gujrat, India*

**ABSTRACT NUMBER: 644 : MORPHOTECTONIC EVIDENCES OF RECENT TECTONIC ACTIVITY ALONG WESTERN KACHCHH MAINLAND FAULT, WESTERN INDIA,** [Ketan Chaskar](#), *KSKV Kachchh University, Bhuj, Gujarat, India*

**ABSTRACT NUMBER: 649 : GEOMORPHOLOGY OF ACTIVE INTRA-PLATE AND PASSIVE MARGIN KACHCHH BASIN IN WESTERN INDIA,** [Mahesh Thakkar](#), *KSKV Kachchh University, Bhuj, Gujarat, India*

**ABSTRACT NUMBER: 658 : CLIMATE OVERPRINTS TECTONICS ON OPENING EPIGENETIC GORGE IN CRETACEOUS FLUVIAL SANDSTONE OF KACHCHH, WESTERN INDIA,** [Kaustubh Sane](#), *KSKV Kachchh Univeristy, Bhuj, Gujarat, India*

**ABSTRACT NUMBER: 667 : DEVELOPMENT OF QUATERNARY LANDSCAPE ALONG MEDIAN HIGH ACROSS KACHCHH BASIN:WESTERN INDIA,** [Gaurav Chauhan](#), *K.S.K.V. Kachchh University, Bhuj, Gujarat, India*

**ABSTRACT NUMBER: 671 : TECTONIC GEOMORPHOLOGY ALONG THE WESTERN SEGMENT OF SOUTH WAGAD FAULT, KACHCHH: WESTERN INDIA,** [Veerindra Kumar](#), *K.S.K.V. Kachchh University, Bhuj, Gujarat, India*

**THEME: S34 : GEOARCHAEOLOGY (IAG-WG)..... 261-270**

**ABSTRACT NUMBER: 6 : ANCIENT QUARRIES AS INDICATORS OF PALAEOGEOGRAPHICAL EVOLUTION OF WESTERN NAXOS ISLAND (CYCLADES),** [Niki Evelpidou](#), *National And Kapodistrian University Of Athens, Zografou, Athens, Greece*

**ABSTRACT NUMBER: 15 : LATE QUATERNARY GEOMORPHOLOGY, CLIMATE AND HUMAN INTERACTIONS IN THE KUREYŞLER AREA (KÜTAHYA, W CENTRAL ANATOLIA), TURKEY: PRELIMINARY FINDINGS,** [Faruk Ocakoğlu](#), *Eskişehir Osmangazi University, Department of Geology, Eskişehir, Turkey*

**ABSTRACT NUMBER: 68 : SHELL MOUND FORMATION PROCESSES: A GEOARCHAEOLOGICAL PERSPECTIVE,** [Patricia Fanning](#), *Macquarie University, Macquarie University, NSW, Australia*

**ABSTRACT NUMBER: 181 : THE LATE HOLOCENE GEOMORPHOLOGY AND GEOARCHAEOLOGY OF MAYA WETLAND AGROECOSYSTEMS IN GLOBAL CONTEXTS,** [Timothy Beach](#), *University Of Texas At Austin, Austin, Texas, United States*

**ABSTRACT NUMBER: 244 : TROPICAL GEOARCHAEOLOGY AND ITS ROLE IN ASSESSING PALEOENVIRONMENTS AND SOIL FORMATION PROCESSES: GEOMORPHOLOGY, PEDOLOGY AND ARCHAEOLOGICAL SITES IN SE BRAZIL,** [Astolfo Araujo](#), *Museum of Archaeology and Ethnology - University of São Paulo, São Paulo, Brazil*

**ABSTRACT NUMBER: 325 : THE ENVIRONMENTAL EVOLUTION OF THE TRADE SITE OF KOTA CINA, IN NORTH SUMATRA (INDONESIA), BETWEEN THE XITH AND THE XIVTH CENTURIES AD,** [Yohan Chabot](#), *Laboratory of Physical Geography UMR CNRS 8591, University Paris 1 Pantheon-Sorbonne, Paris, France*

**ABSTRACT NUMBER: 340 : THE BATTLEFIELD GEOMORPHOLOGY OF ANCIENT THERMOPYLAE (CENTRAL GREECE),** [Konstantinos Vouvalidis](#), *Aristotle University Of Thessaloniki, Thessaloniki, Greece*

**ABSTRACT NUMBER: 348 : BENTHIC FORAMINIFERAL RECORDS OF MIDDLE-LATE HOLOCENE COASTAL PLAINS IN THE AEGEAN SEA (GREECE): A REVIEW,** [Olga Koukousioura](#), *Aristotle University Of Thessaloniki, Thessaloniki, Greece*

**ABSTRACT NUMBER: 352 : COASTAL ZONE PALAEOGEOGRAPHICAL RECONSTRUCTION OF MOLYVOTI PENINSULA ANCIENT SETTLEMENT, N. AEGEAN SEA, GREECE,** [Georgios Syrides](#), *Aristotle University Of Thessaloniki, Thessaloniki, Greece*

**ABSTRACT NUMBER: 375 : IDENTIFICATION AND STUDY OF LONG-TERM CULTIVATED SOILS IN SEMI-ARID ENVIRONMENT: CONSTRUCTION OF A PEDO-SEDIMENTARY AND GEOCHEMICAL REFERENCE COLLECTION (OASIS OF MASAFI, UNITED ARAB EMIRATES),** [Sophie Costa](#), *Université Côte D'Azur - CEPAM/CNRS - UMR 7264, Nice, Alpes Maritimes, France*

**ABSTRACT NUMBER: 387 : WHAT FIELD WORK AS "EXPERT KNOWLEDGE" BRINGS TO THE SOURCING STUDIES? CASE OF OBSIDIAN FROM NEMRUT VOLCANO AND ALATEPE VOLCANIC AREA. SESSION S34 GÉOARCHÉOLOGIE,** [Anne-kyria Robin](#), *University Pantheon-sorbonne Paris 1, Meudon, Idf, France*

**ABSTRACT NUMBER: 390 : LATE HOLOCENE RELATIVE SEA-LEVEL CHANGE AND CLIMATE CHANGE IN THE NORTHERN ADRIATIC (CROATIA),** [Sanja Faivre](#), *Faculty of Science, Department of Geography, Zagreb, Croatia*

**ABSTRACT NUMBER: 455 : A GEOARCHAEOLOGICAL APPROACH OF THE RAINFOREST LANDSCAPE EVOLUTION UNDER PRE-COLUMBIAN IMPACT: THE EXAMPLE OF RING-DITCH SITES (MONTAGNES COURONNÉES) IN FRENCH GUIANA,** [Jeanne Brancier](#), *CNRS Guyane - USR LEEISA / Micromorphological Team INRAP Grignon - ADEPRINA, Cayenne, French Guiana, France*

**ABSTRACT NUMBER: 487 : INTEGRATING GIS, TRENCH MAPS, LIDAR AND ARCHAEOLOGICAL APPROACH FOR THE WWI**





**LANDSCAPES SURVEY OF THE CHAMPAGNE FRONT (FRANCE), Pierre Taborelli, Université De Reims - GEGENAA, Reims, 57 rue Pierre Taittinger, BP 30, France**

**ABSTRACT NUMBER: 637 : HYDROLOGICAL AND SOCIO-ENVIRONMENTAL DYNAMICS IN SUBTROPICAL MAYA LOWLANDS: ALLUVIAL GEOARCHAEOLOGICAL APPROACH OF THE WETLANDS (BAJOS) AROUND NAACHTUN DURING THE LAST 4 MILLENNIUMS (PETEN, GUATEMALA), Cyril Castanet, Université Paris 8 Vincennes Saint-Denis - UMR CNRS 8591 LGP - Laboratoire de Géographie Physique, Environnements Quaternaires et Actuels, Meudon, France**

**ABSTRACT NUMBER: 661 : NEOTECTONICS INFLUENCE ON BABADAG AND ENISALA SETTLEMENTS SINCE ANTIQUITY (SOUTHERN DANUBE DELTA), Luminita Preoteasa, University of Bucharest, Bucharest, Romania**

**ABSTRACT NUMBER: 686 : CONTRIBUTIONS OF THE GEOMORPHOLOGY ON THE SPATIAL ORGANIZATION OF THE NEOLITHIC HYPOGEA : THE EXAMPLE OF “MARAIS DE SAINT-GOND”, Thibaud Damien, Université de Reims Champagne-Ardenne, GEGENAA, REIMS, Marne, France**

**ABSTRACT NUMBER: 730 : RELATIVE SEA LEVEL CHANGES AND HUMAN OCCUPATION DURING HOLOCENE IN ABU DHABI, UNITED ARAB EMIRATES, Damien Arhan, Paris-Sorbonne, Paris, France**

**ABSTRACT NUMBER: 772 : ENVIRONMENTAL CHANGES IN BACTRIA SOGDIANA AND MARGIANA (CENTRAL ASIA, AFGHANISTAN, UZBEKISTAN, TURKMENISTAN) FROM NEOLITHIC TO THE LATE BRONZE AGE : INTERACTION WITH HUMAN OCCUPATION, Eric Fouache, University Paris Sorbonne Abu Dhabi, UMR 8185, Abu Dhabi, United Arab Emirates**

**THEME: S35 GEOMORPHOLOGICAL HAZARDS AND RISKS (IAG-WG): RISK MITIGATION THROUGH NEW TECHNIQUES UNDER THE CHALLENGES OF ENVIRONMENTAL CHANGES..... 270-276**

**ABSTRACT NUMBER: 12 : MODELING OF MASS MOVEMENTS RISK AND ASSESSMENT BY GIS. CASE OF AIN EL HAMMAM AREA, BASIN OF TIZI-OUZOU, (ALGERIA), Mohamed Said Guettouche, Univesity Of Sciences And Technology Houari Boumediene, Algeria**

**ABSTRACT NUMBER: 28 : CONTRIBUTION OF NUMERICAL MODELLING IN THE RISK MITIGATION IN BUJUMBURA / BURUNDI: CASE OF THE 'BANANA TREE' LANDSLIDE ALONG THE KANYOSHA RIVER, Leonidas Nibigira, Environment and Geohazards, Department of Geology, University of Liege, LIEGE, Belgium**

**ABSTRACT NUMBER: 40 : HUMAN INTERVENTION ON FLUVIAL HAZARDS: A CASE STUDY OF THE NAGAVALI RIVER ALONG THE RAYAGADA DISTRICT, ORISSA, Shreya Bandyopadhyay, Maharaja Nandakumar Mahavidyalaya, Nandakumar, Purba Medinipur, West Bengal, India**

**ABSTRACT NUMBER: 93 : SIMULATION OF GEOMORPHIC PROCESS CHAINS IN MOUNTAIN AREAS: PROGRESS AND CHALLENGES, Martin Mergili, Institute of Applied Geology, University of Natural Resources and Life Sciences (BOKU), Vienna, Austria**

**ABSTRACT NUMBER: 263 : LAND USE/COVER AND CLIMATE CHANGE EFFECTS ON STREAMFLOW AND SEDIMENT YIELD: A CASE STUDY OF KAN BASIN, IRAN, Zahra Sedighifar, Kharazmi University, Tehran, Iran**

**ABSTRACT NUMBER: 323 : THE LANDSLIDE OF AGRIGENTO HILL CASE HISTORY: DATA COLLECTION AND ANALYSIS, Vincenzo Liguori, Dicam - University Of Palermo, Palermo, Italy**

**ABSTRACT NUMBER: 331 : GEOMORPHIC EFFECTS OF EXTREME FLOODS ON RIVER CHANNELS: THE SEPTEMBER 2015 EVENT IN THE NURE RIVER CATCHMENT (NORTHERN ITALY), Vittoria Scorpio, Free University Of Bozen-Bolzano, Bolzano, Italy;**

**ABSTRACT NUMBER: 474 : GEOMORPHOLOGICAL APPROACH FOR HAZARD ANALYSIS OF SINABUNG VOLCANO ERUPTION IN KARO NORTH SUMATRA INDONESIA, Dwi Wahyuni Nurwihastuti, Universitas Negeri Medan/Medan State University, Medan, Sumatera Utara, Indonesia**

**ABSTRACT NUMBER: 480 : INTEGRATED APPROACH TO ASSESS VULNERABILITY AS A MEANS TOWARDS QUANTIFYING LANDSLIDE CONSEQUENCES AT A NATIONAL LEVEL (ROMANIA), Dan Balteanu, Institute of Geography, Romanian Academy, Bucharest, Romania**

**ABSTRACT NUMBER: 761 : LANDSLIDE RISK ZONING AT A MACRO SCALE USING ANALYTICAL HIERARCHICAL PROCESS, Swagatam Bhowmik, Geological Survey Of India, Kolkata, West Bengal, India**

**THEME: S36 : GEOMORPHOSITES AND GEOTOURISM (IAG-WG) ..... 276-282**

**ABSTRACT NUMBER: 27 : SUSTAINABLE CULTURAL HERITAGE THROUGH ENGAGEMENT OF LOCAL COMMUNITIES PROJECT (SCHEP), WADI RUM, JORDAN: A TRAINING PROGRAM ASSESSING GEOLOGIC STABILITY OF ROCK ART AND GEOTOURISM MANAGEMENT, Casey Allen, Western Governors University, Salt Lake City, UT, United States**

**ABSTRACT NUMBER: 60 : GEODIVERSITY AT THE CHAPADÃO DO DIAMANTE AREA. A RICH HYDROLOGICAL GEOMORPHOSITE REGION IN MINAS GERAIS STATE – BRAZIL, Silvio Carlos Rodrigues, Universidade Federal De Uberlândia, Uberlândia, MG, Brazil**



**ABSTRACT NUMBER: 133 : MAN MADE LANDSCAPE ON THE ISLAND OF USHANT, FROM THE LATE BRONZE AGE TO PRESENT, Hervé Regnaud, Université Rennes 2, Rennes, France**

**ABSTRACT NUMBER: 139 : CLASSIFICATION AND GEO-CODING OF GEOMORPHOSITES IN INDIA, Vishwas Kale, Formerly at SP Pune University, Pune, Maharashtra, India**

**ABSTRACT NUMBER: 162 : THE UPHILL EXPERIENCE OF NOMINATING A LANDSCAPE OF WORLD HERITAGE, Cécile Olive-Garcia, Conseil Departemental Du Puy De Dome, Clermont-ferrand, Puy De Dome, France**

**ABSTRACT NUMBER: 234 : THE IMPORTANCE OF DETAILED GEOLOGICAL AND GEOMORPHOLOGICAL MAPPING FOR THE MANAGEMENT OF TOURIST AREA: CASE STUDY OF A NATURAL RESERVE OF EMILIA APENNINES (NORTHERN ITALY), Doriano Castaldini, University Of Modena And Reggio Emilia, Modena, Italy**

**ABSTRACT NUMBER: 298 : GEOMORPHOSITES ASSESSMENT FOR THE DEVELOPMENT OF GEO-TOURISM IN NORTH AND MIDDLE ANDAMAN'S, INDIA, Kavita Arora, Shaheed Bhagat Singh College, University Of Delhi, New Delhi, India**

**ABSTRACT NUMBER: 396 : INTEGRATING GEOLOGICAL AND INDUSTRIAL HERITAGE FOR THE REHABILITATION OF DISMISSED QUARRY AREAS IN THE NORTHERN APENNINES, ITALY, Vittoria Vandelli, University Of Modena And Reggio Emilia, Modena, Italy**

**ABSTRACT NUMBER: 471 : THE PLACE OF THE GEOMORPHOSITES IN THE INVENTORY, THE PROTECTION AND THE VALORIZATION OF THE GEOHERITAGE IN THE AUVERGNE-RHÔNE-ALPES REGION (FRANCE), Fabien Hoblea, EDYTEM CNRS Université Savoie Mont Blanc, Le Bourget du Lac, Savoie, France**

**ABSTRACT NUMBER: 545 : MAPPING GEOHERITAGE ON THE OFFICIAL ITALIAN GEOMORPHOLOGICAL MAPS: A PROPOSAL FROM THE ITALIAN SCIENTIFIC COMMUNITY, Paola Coratza, Department of Chemical and Geological Sciences, University of Modena and Reggio Emilia, Modena, Italy**

**ABSTRACT NUMBER: 623 : GEOMORPHOLOGY AND GEOHERITAGE PROMOTION ISSUES IN SEORAKSAN MOUNTAINS, KOREA, Piotr Migoń, Institute Of Geography And Regional Development, University Of Wroclaw, Wroclaw, Dolnośląskie, Poland**

**ABSTRACT NUMBER: 668 : GEOMORPHOSITES OF KACHCHH: AN APPROACH FOR GEOTOURISM IN WESTERN INDIA, Gaurav Chauhan, K.S.K.V. Kachchh University, Bhuj, Gujarat, India**

**ABSTRACT NUMBER: 790 : GEOMORPHOLOGY AND GEO-HERITAGE OF EAST KAZAKHSTAN, Jiri Chlachula, Laboratory for Palaeoecology, Tomas Bata University, Zlin, Moravia, Czech Republic**

**THEME: S37 : DANXIA GEOMORPHOLOGY (IAG-WG) ..... 282-283**

**ABSTRACT NUMBER: 41 : ANALYZING SURFACE CHANGES OF BADLAND SEDIMENTS DURING WEATHERING: A NEW APPROACH USING IMAGE ANALYSES, Yan Luobin, Sun Yat-sen University, Guangzhou, Guangdong, China**

**ABSTRACT NUMBER: 219 : EVALUATION OF DANXIA LANDFORM TOURISM RESOURCES IN HUOSHAN MOUNTAIN, GUANGDONG PROVINCE, Zaijian Yuan, Guangdong Institute Of Eco-environment Technology, Guangzhou, Guangdong, China**

**THEME: S38 : EXTREME EVENTS IN GEOMORPHOLOGY ..... 283-285**

**ABSTRACT NUMBER: 77 : EFFECT OF A QUATERNARY METEORITE IMPACT IN INDO-CHINA ON THE SURFACE SEDIMENTARY RECORD, Paul Carling, University of Southampton, Southampton, Hampshire, United Kingdom**

**ABSTRACT NUMBER: 80 : GEOMORPHOLOGICAL RESPONSE AND DAMAGE RESULTING FROM THE APRIL-MAY 2015 EARTHQUAKE SEQUENCE IN SOLUKHUMBU DISTRICT (NEPAL), Monique Fort, University Paris Diderot - CNRS UMR 8586 PRODIG - ANR-13-SENV-0005-02-PRESHINE, Paris, France**

**ABSTRACT NUMBER: 432 : FLOOD, VILLAGE TRANSFORMATION, AND MYTHS, Su Bing Chang, National Taiwan Normal University, Taipei, Taiwan**

**ABSTRACT NUMBER: 486 : INVESTIGATING THE ROLE OF LARGE RUNOFF EVENTS IN (RE)SETTING SUSPENDED SEDIMENT SUPPLIES IN WATERSHEDS IN NORTHEASTERN UNITED STATES, Jaclyn Cockburn, University of Guelph, Dept of Geography, Guelph, Ontario, Canada**

**THEME: S39 : LAND DEGRADATION AND HAZARDS IN A CHANGING ENVIRONMENT ..... 285-293**

**ABSTRACT NUMBER: 47 : WIND - THE UNNOTICED CLIMATIC ELEMENT IN SOIL EROSION MODELLING, Edmore Kori, University Of Venda, Thohoyandou, Limpopo, South Africa**

**ABSTRACT NUMBER: 52 : SOIL DEGRADATION IN THE ISLAND OF SARDINIA (ITALY): A STATE-OF-THE-ART, Andrea Vacca, Department Of Chemical And Geological Sciences, University Of Cagliari, Cagliari, Italy**

**ABSTRACT NUMBER: 63 : ESTIMATION OF VOLUME OF SEDIMENTS PRODUCED BY LANDSLIDES AND SOIL EROSION AND THEIR IMPACT ON THE HYDRO-MORPHOLOGICAL CHARACTERISTICS ON THE LACHUNG RIVER, Sudatta Wadadar, North-Eastern Hill University, Shillong, Meghalaya, India**

**ABSTRACT NUMBER: 94 : AGRICULTURAL LAND DEGRADATION IN SOUTHERN SIBERIA, Olga Bazhenova, Sochava Institute Of Geography Siberian Branch Russian Academy Of Sciences, Irkutsk, Irkutskaya Oblast, Russian Federation;**

**ABSTRACT NUMBER: 100 : ROLE OF TOPOGRAPHY AND CULTIVATION IN SOIL DEGRADATION OF THE MEGHALAYA PLATEAU IN NORTH-EAST INDIA, Pawel Prokop, Department of Geoenvironmental Research, Institute of Geography and Spatial Organization, Polish Academy of Sciences, Jana 22, 31-018 Kraków, Poland**

**ABSTRACT NUMBER: 101 : LAND DEGRADATION IN THE TSITSA CATCHMENT, SOUTH AFRICA: A COMPLEX WEB OF HAZARD, HISTORY AND HOPE, Kate Rowntree, Rhodes University, Grahamstown, EC, South Africa**

**ABSTRACT NUMBER: 130 : GEOMORPHOLOGICAL AND SEDIMENTOLOGICAL INDICATORS OF LAND DEGRADATION (MEGHALAYA PLATEAU, NE INDIA), Zofia Janina Rączkowska, Department of Geoenvironmental Research, Institute of Geography and Spatial Organization, Polish Academy of Sciences, Kraków, Poland**

**ABSTRACT NUMBER: 238 : IN-FILLED RESERVOIRS SERVING AS SEDIMENT ARCHIVES TO ANALYSE SOIL ORGANIC CARBON EROSION – A CASE STUDY FROM THE KAROO RANGELANDS, Nikolaus J. Kuhn, University Of Basel, Basel, Switzerland**

**ABSTRACT NUMBER: 347 : DYNAMICS AND PATTERNS OF LAND-LEVELLING FOR AGRICULTURAL RECLAMATION OF EROSIONAL BADLANDS IN CHAMBAL VALLEY (MADHYA PRADESH, INDIA), Padmini Pani, Jawaharlal Nehru University, New Delhi, India**

**ABSTRACT NUMBER: 369 : EFFECTS OF POST-FIRE MANAGEMENT PRACTICES ON EROSION RESPONSE AND VEGETATION RECOVERY – MT. CARMEL, ISRAEL, Lea Wittenberg, University Of Haifa, Haifa, Israel**

**ABSTRACT NUMBER: 384 : SOIL EROSION ON AGRICULTURAL LAND ASSOCIATED TO EXTREME BLIZZARD CONDITIONS WITHIN NORTH-EASTERN ROMANIA, Lilian Niacsu, Alexandru Ioan Cuza University of Iasi, Iasi, Romania**

**ABSTRACT NUMBER: 561 : BOULDER MOBILITY IN EXTREME FLASH FLOODS- CASE STUDIES IN THE JORDAN RIVER (ISRAEL) AND AMBATO RIVER (CATAMARCA, ARGENTINA), Moshe Inbar, Department of Geography and Environmental Studies, University Of Haifa, Haifa, Israel;**

**ABSTRACT NUMBER: 591 : A MODEL FOR DEGRADATION OF KOBRESIA PYGMAEA TURFS ON HILLSLOPES, Gregory Okin, UCLA, Los Angeles, California, United States; 2UC Berkeley, Berkeley, California, United States**

**ABSTRACT NUMBER: 642 : APPLICATION OF SAR INTERFEROMETRY IN MONITORING MINING SUBSIDENCE IN AN AROUND RANIGANJ COAL MINE, WEST BENGAL, INDIA, Kazi Hifajat, Department of Geography, Lady Brabourne College, University of Calcutta, Kolkata, West Bengal, India**

**ABSTRACT NUMBER: 723 : NEW GEOMORPHOLOGY OF INDIA CAUSED BY HYPER URBANIZATION, Neeraj Suhag, Jamia Millia Islamia, New Delhi, India**

**ABSTRACT NUMBER: 725 : ENVIRONMENTAL IMPACTS AND ECOLOGICAL IMBALANCES IN ALLUVIAL GEOMORPHOLOGY OF GREAT GANGETIC PLAINS: A CASE STUDY OF BRICK KILNS, Pradeep Kumar Singh, M.M.Post-Graduate College, Kalakankar, Pratapgarh, Uttar Pradesh, India**

**ABSTRACT NUMBER: 748 : GEOSPATIAL APPROACH FOR LANDSLIDE INVENTORY AND SUSCEPTIBILITY MAPPING ALONG TONS VALLEY, GARHWAL HIMALAYA, UTTARAKHAND, INDIA, Vikram Sharma, Indian Institute of Remote Sensing, Dehradun, Uttarakhand, India**

**THEME: S40 : YOUNG GEOMORPHOLOGISTS' SESSION ..... 293-297**

**ABSTRACT NUMBER: 19 : QUANTITATIVE ROCKFALL RISK ANALYSIS BASED ON LANDFORM CLASSIFICATION, Guruh Samodra, Faculty Of Geography, Universitas Gadjah Mada., Sleman, Yogyakarta, Indonesia**

**ABSTRACT NUMBER: 33 : LANDSLIDE DISASTER RISK IN THE URBAN AREA OF TEZIUTLÁN, PUEBLA, MÉXICO: BUILDING EXPOSURE THROUGH TIME, Noemi Sharon Ruiz-Cortés, National Autonomous University of Mexico, University City, Mexico City, Mexico**

**ABSTRACT NUMBER: 34 : PROGRESS OF GEOMORPHOLOGICAL RESEARCH IN INDIA IN 21ST CENTURY, Pramod Kumar Pandey, University of Allahabad, Allahabad, Uttar Pradesh, India**

**ABSTRACT NUMBER: 176 : FORMATION OF LANDSLIDE DAMED LAKE IN THE KANAKA RIVER, SIKKIM HIMALAYA, INDIA, Kapil Ghosh, Calcutta University, Kolkata, West Bengal, India**

**ABSTRACT NUMBER: 180 : MORPHODYNAMICS AND ANABRANCHING PATTERN OF BRANCO RIVER, NORTHERN AMAZONIA, Edipo Henrique Cremon, IFG, Goiania, Goiás, Brazil**

**ABSTRACT NUMBER: 338 : ESTIMATING SUSPENDED SEDIMENT CONCENTRATION BY USING HISTORICAL LANDSAT**

**5 DATASET: EXPERIENCES BASED ON TWO SOUTH AMERICAN LARGE RIVER BASINS, AMAZON AND PARANÁ,** Otávio Cristiano Montanher, *Maringá State University, Maringá, Paraná, Brazil*

**ABSTRACT NUMBER: 441 : FLUVIAL DISCONTINUITY AND ITS IMPLICATIONS TO GEODIVERSITY IN AN ALLUVIAL MEANDERING RIVER: THE PEIXE RIVER, BRAZIL,** Eduardo Morais, *Universidade Estadual De Maringá, Maringá, Paraná, Brazil*

**ABSTRACT NUMBER: 297 : RESEARCH ON IMPACT OF TOURISM ACTIVITIES FOR DUNE LANDSCAPE ON DESERT TOURISM AREA—SHAPOTOU SLIDING SAND IN NINGXIA AS AN EXAMPLE,** Lilongtang Lilongtang, *School of Resources and Environment, Ningxia University, Yinchuan, China*

#### ABSTRACTS FOR POSTER PRESENTATION

**THEME: S1 : THEORETICAL GEOMORPHOLOGY .....299**

**ABSTRACT NUMBER: 227 : THE ROOTS OF FUNDAMENTAL CONCEPTS OF GEOMORPHOLOGY IN THE AL-BIRUNI'S THOUGHTS,** MAHDIEH GHAYOOR BOLORFROSHAN, *Ferdowsi University Of Mashhad, Mashhad, Khorasan Razavi, Iran*

**ABSTRACT NUMBER: 499 : TECTONIC PROCESSES - SEISMICITY INDEX TA: A NEW INDEX FOR EVALUATING THE DEGREE OF TECTONIC ACTIVITY AND ASSESSING SEISMIC HAZARD,** Dimitrios Ntokos, *National Technical University of Athens, Athens, Athens, Greece*

**THEME: S2 : APPLIED GEOMORPHOLOGY ..... 300-301**

**ABSTRACT NUMBER: 177 : GEOMORPHOLOGICAL DYNAMICS OF THE CAMAQUÃ RIVER DELTA (BRAZIL),** Adriano Luís Simon, *Pelotas Federal University, Pelotas, Rio Grande Do Sul, Brazil*

**ABSTRACT NUMBER: 320 : MASS MOVEMENTS OF DIFFERING MAGNITUDE AND FREQUENCY IN A DEVELOPING HIGH-MOUNTAIN AREA OF THE MOXI BASIN, HENGDUAN MTS, CHINA – A TREE-RING BASED HAZARD ASSESSMENT,** Ireneusz Malik, *University of Silesia in Katowice, Faculty of Earth Sciences – Centre for Polar Studies KNOW, Katowice, Silesian Province, Poland*

**ABSTRACT NUMBER: 606 : THE ROLE OF GEOINDICATORS IN ASSESSING GEOMORPHOLOGICAL IMPACTS OF HIGHWAYS – A CASE STUDY IN SÃO PAULO, BRAZIL,** Juliana da Costa Mantovani, *Universidade De São Paulo, São Paulo, São Paulo, Brazil*

**ABSTRACT NUMBER: 758 : EVALUATING THE LIQUEFACTION HAZARD IN AXIOS BASIN, THESSALONIKI BASED ON DETAILED GEOMORPHOLOGICAL MAPPING,** Olga Koukousioura, *Aristotle University Of Thessaloniki, Thessaloniki, Thessaloniki, Greece*

**THEME: S3 : GEOMORPHIC PROCESSES IN COUPLED HUMAN AND NATURAL SYSTEMS ..... 302-307**

**ABSTRACT NUMBER: 99 : IMPACT OF THE LARGE TEA PLANTATIONS DEVELOPMENT ON LANDSCAPE OF THE EASTERN HIMALAYAN PIEDMONT,** Paweł Prokop, *Department of Geoenvironmental Research, Institute of Geography and Spatial Organization, Polish Academy of Sciences, Jana 22, 31-018 Krakow, Poland*

**ABSTRACT NUMBER: 228 : PRELIMINARY RESEARCH DATA OF FLUVIAL EVOLUTION AND HUMAN IMPACT. A GEOMORPHOLOGICAL AND NEOTECTONIC APPROACH ON PEIROS RIVER, NORTHWESTERN PELOPONNESE, GREECE,** Leonidas Stamatopoulos, *University Of Patras, Department of Geology, Patras, Achaia, Greece*

**ABSTRACT NUMBER: 303 : NATURAL HAZARDS AND THE NORMATIVE SIGNIFICANCE OF EXPECTATIONS IN PROTECTING ALPINE COMMUNITIES,** Florian Ortner, *University of Graz, Department of Geography and Regional Science, Graz, , Austria*

**ABSTRACT NUMBER: 403 : SELF-ORGANIZATION OF ANTHROPIC OCCUPATION IN THE BRAZILIAN CERRADO LANDSCAPE,** Antonio Felipe Couto Junior, *University of Brasília, Brasília, DF, Brazil*

**ABSTRACT NUMBER: 411 : INTERVENTION ON ESTUARINE PROCESS AND ITS IMPACTS IN INDIAN SUNDARBANS,** Ramkrishna Maiti, *Vidyasagar University, Midnapore,, West Bengal, India*

**ABSTRACT NUMBER: 528 : A CONCEPTUAL CONNECTIVITY FRAMEWORK FOR UNDERSTANDING GEOMORPHIC CHANGE IN COUPLED HUMAN-GEOMORPHIC SYSTEMS,** Ronald Pöppel, *University Of Vienna, Vienna, Austria*

**ABSTRACT NUMBER: 547 : LAND SYSTEM ANALYSIS AND LAND MANAGEMENT PLAN FOR KABANI RIVER BASIN, WAYANAD DISTRICT, KERALA, INDIA,** Vandana. M., *Sree Sankaracharya University Of Sanscrit, Kalady, Kerala, India*

**ABSTRACT NUMBER: 577 : INVESTIGATING THE BUFFERING CAPACITY OF MOUNTAIN COMMUNITIES TO SOCIO-ECONOMIC AND NATURAL HAZARD SHOCKS,** Margreth Keiler, *University of Bern, Institute of Geography, Bern, Switzerland*

**ABSTRACT NUMBER: 579 : GEOMORFOMETRY AND URBAN PLANNING: CORRELATION BETWEEN FORMS OF RELIEF**



**AND EROSION IN THE FEDERAL DISTRICT – BRAZIL**, Karla Maria Silva de Faria, *Universidade Federal De Goiás, Goiânia, Goiás, Brazil*

**ABSTRACT NUMBER: 674 : RAIN-TRIGGERED LAHARS ASSESSMENT OF THE 2014 KELUD VOLCANO ERUPTION, EAST JAVA (INDONESIA)**, Syamsul Bachri, *Department Of Geography, State University Of Malang, Malang, East Java, Indonesia*

**ABSTRACT NUMBER: 731 : EMERGING WASTELANDING PROCESSES IN ALLUVIAL GEOMORPHOLOGY OF TONS BASIN, INDIA**, Sheo Prakash Agnihotri, *Madan Mohan Malviya Post- Graduate College, Kalakankar, Pratapgarh, U. P., Pratapgarh, Uttar Pradesh, India*

**ABSTRACT NUMBER: 750 : GEOMORPHIC CONSTRAINTS TO URBAN DEVELOPMENT IN NATIONAL CAPITAL TERRITORY OF DELHI (INDIA)**, Naveen Chandra Singh, *MMH (PG) College, Ghaziabad, Ghaziabad, Uttar Pradesh, India*

**THEME: S5 : VOLCANIC GEOMORPHOLOGY .....308**

**ABSTRACT NUMBER: 559 : INITIATION AND RECESSION OF THE FLUVIAL KNICKPOINTS: A CASE STUDY FROM THE YALU RIVER–WANGTIAN'E VOLCANIC REGION, NORTHEASTERN CHINA**, Huiping Zhang, *Institute Of Geology, China Earthquake Administration, Beijing, Beijing, China*

**ABSTRACT NUMBER: 689 : METHOD APPROACHES ABOUT VOLCANIC GAS RISK ANALYSIS AND RISK MODELLING STUDIES**, Ergin Canpolat, *Kağıthane Cengizhan Anadolu Highschool, Istanbul, Istanbul, Turkey*

**THEME: S6 : KARST GEOMORPHOLOGY ..... 309-310**

**ABSTRACT NUMBER: 50 : SINKHOLES IN A HYPOGENE GYPSUM KARST. THE CASE OF SANT MIQUEL VALLEY, NE SPAIN**, Ivan Fabregat González, *Departamento de Ciencias de la Tierra; University of Zaragoza, C/ Pedro Cerbuna, 12; 50009 Zaragoza, Spain*

**ABSTRACT NUMBER: 223 : THE SITUATION AND CHARACTERISTIC OF KARST LANDFORM AND WATER AND SOIL LOSS IN NORTHERN GUANGDONG**, Muning Zhuo<sup>1\*</sup>, *Guangdong Institute Of Eco-environment Technology, Guangdong, China*

**ABSTRACT NUMBER: 643 : THE EFFECT OF CARBONATE FORMATION ON SINKHOLES AROUND THE LAR DAM, NORTHWEST OF TEHRAN**, Mehrnoosh Ghadimi, *University Of Tehran, Tehran, Enghelab, Iran*

**ABSTRACT NUMBER: 702 : AN EXAMPLE OF POLYGENETIC GEOMORPHOLOGIC DEVELOPMENT (KARST-GLACIAL-TECTONICS) ON MUNZUR MOUNTAINS: KEPIR CAVE-ELBABA SPRING KARSTIC SYSTEM**, Zeynel Çiğdem<sup>1\*</sup>, *Munzur University, Tunceli, Turkey*

**THEME: S7 : ANTHROPOCENE GEOMORPHOLOGY .....311**

**ABSTRACT NUMBER: 593 : LANDSCAPE ANALYSIS AND MILK PRODUCTION IN BRAZIL**, Nathalia Costa, *Universidade De Brasília, Sobradinho, Df, Brazil*

**ABSTRACT NUMBER: 724 : WATER IN THE URBAN & RURAL AREAS: AN OVERVIEW OF NEW LANDFORMS WITH INTEGRATED WATER MANAGEMENT**, Neeraj Suhag, *Jamia Millia Islamia, Sonapat, Haryana, India*

**THEME: S9 : BIO-GEOMORPHOLOGY .....311-314**

**ABSTRACT NUMBER: 55 : WHAT DO MICROBES 'DO' ON ROCKS? INITIAL APPLICATION OF COMMUNITY LEVEL PHYSIOLOGICAL PROFILING (CLPP) IN BIOGEOMORPHOLOGY**, Martin Andrew Coombes, *School of Geography and the Environment, University Of Oxford, Oxford, Oxfordshire, United Kingdom*

**ABSTRACT NUMBER: 388 : DISTRIBUTION OF THE UPPER LIMIT OF POSIDONIA OCEANICA MEADOW IN RELATION WITH WAVE INDUCED HYDRODYNAMICS IN MEDITERRANEAN BEACHES**, Sandro De Muro<sup>1\*</sup>, *University of Cagliari, Department of Chemical and Geological Sciences, Cagliari, Cagliari, Italy*

**ABSTRACT NUMBER: 501 : REE-RING BASED DATING OF LANDSLIDES: THE NOISE/SIGNAL RATIO**, Karel Šilhán, *University Of Ostrava, Ostrava, Moravskoslezský Kraj, Czech Republic*

**ABSTRACT NUMBER: 584 : GEOMORPHOLOGICAL AND BIOLOGICAL INFLUENCE ON SOIL  $\delta^{13}C$  AND  $\delta^{15}N$  ALONG A CATENA IN THE CENTRAL BRAZILIAN PLATEAU**, Fabio Santos, *Universidade de Brasília, Brasília, Distrito Federal, Brazil*

**ABSTRACT NUMBER: 592 : POTENTIAL INFLUENCE OF RELIEF DISSECTION IN SOIL  $\delta^{15}N$  VALUES OF WESTERN PAULISTA PLATEAU, SOUTHEASTERN BRAZIL**, Ray Alves, *University Of Brasilia, Brasília, Distrito Federal, Brazil*

**ABSTRACT NUMBER: 739 : BIOCHEMICAL WEATHERING AND DUST ACCRETION DETECTED IN COMPLEX ROCK VARNISH FROM THE DRY VALLEYS (ANTARCTICA)**, Andrea Zerboni, *Dipartimento di Scienze Della Terra "A. Desio", Università degli Studi di Milano, Milano, Italy*



**THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS ..... 314-321**

**ABSTRACT NUMBER: 117 : ENORMOUS DEEP-SEATED GRAVITATIONAL SLOPE DEFORMATION OF FLYSCH MONOCLINAL RIDGE: LARGE-SCALE SACKUNG AND GRAVITATIONAL TRANSPRESSION IN OUTER WESTERN CARPATHIANS, Tomas Panek, University Of Ostrava, Ostrava, Czech Republic, Czech**

**ABSTRACT NUMBER: 183 : EFFECT OF INJECTED SEDIMENT CONCENTRATION ON RED SOIL EROSION AND FLOW HYDRAULICS, Guo Tailong, Guangdong Key Laboratory of Agricultural Environmental Pollution Integrated Control, Guangdong Institute of Eco-environment Technology, the Tianhe District, Guangzhou, 510650, P. R. China**

**ABSTRACT NUMBER: 315 : APPLICATION OF PAP/RAC FOR MAPPING FORMS OF SOIL EROSION IN THE CATCHMENT OF ASIF GHZAF CENTRAL HIGH ATLAS , MOROCCO, Nadia ENNAJI, University of sultan moulay slimane of Letters and Human Sciences, Beni Mellal, beni mellal -khnifra, Morocco**

**ABSTRACT NUMBER: 319 : RELIEF EVOLUTION OF LANDSLIDE SLOPES RECONSTRUCTED FROM DEM BASED ON AIRBORNE LIDAR DATA (SUDETEN MTS, POLAND), Malgorzata Wistuba, University of Silesia in Katowice, Faculty of Earth Sciences – Centre for Polar Studies KNOW, Katowice, Silesian Province, Poland**

**ABSTRACT NUMBER: 368 : TUFA DEPOSITS SHELTERED BY INLAND NOTCHES AS INDICATORS OF QUATERNARY DENUDATION RATES, Nurit Shtober-Zisu, University of Haifa, Haifa, Israel**

**ABSTRACT NUMBER: 444 : REGIONAL SOIL PARAMETERS ANALYSIS IN THE SHALLOW LANDSLIDE MODEL: APPLICATION IN THE SERRA DO MAR (BRAZIL), Roberto Gomes, Universidade De Brasilia, Brasilia, Distrito Federal, Brazil;**

**ABSTRACT NUMBER: 446 : THE INFLUENCE OF GEOLOGICAL AND MORPHOLOGICAL SETTINGS ON SHALLOW LANDSLIDES, SERRA DO MAR, BRAZIL, Helen Cristina Dias, Universidade De São Paulo, São Paulo, São Paulo, Brazi**

**ABSTRACT NUMBER: 448 : MORPHOMETRIC PARAMETERS ASSESSMENT AND DEBRIS FLOW MAGNITUDE IN BRAZIL, Vivian Cristina Dias, University of Sao Paulo, Sao Paulo, Sao Paulo, Brazil**

**ABSTRACT NUMBER: 534 : EVALUATION OF LANDSLIDE ACTIVITY USING TERRESTRIAL LASER SCANNING, Zofia Janina Rączkowska, Polish Academy of Sciences, Institute of Geography and Spatial Organisation, Dept of Geoenvironmental Research, 31-018 Cracow, Św. Jana str. 22, Poland**

**ABSTRACT NUMBER: 535 : RECONSTRUCTION OF LARGE LANDSLIDES MOVEMENTS BASED ON DENDRO-GEOMORPHOLOGICAL METHOD (SAWICKI LANDSLIDE EXAMPLE IN THE BESKID NISKI MTS), Zofia Janina Rączkowska, Polish Academy of Sciences, Institute of Geography and Spatial Organization, Dept of Geoenvironmental Research, 31-018 Cracow,, Św. Jana Str. 22, Poland**

**ABSTRACT NUMBER: 546 : MORPHOMETRIC ANALYSIS AND EVOLUTION OF BADLANDS IN THE EMILIA APENNINES (NORTHERN ITALY), Paola Coratza, Department of Chemical and Geological Sciences, University of Modena and Reggio Emilia, Modena, Italy**

**ABSTRACT NUMBER: 551 : THERMOMECHANICAL CONTROLS ON ROCKFALL FREQUENCY AND MAGNITUDE (SWISS ALPS) – INTEGRATING DEDUCTIVE ROCKWALL SURVEYS INTO ABDUCTIVE TALUS APPROACHES, Karoline Messenzehl, University Of Bonn, Oxford, Oxfordshire, United Kingdom**

**ABSTRACT NUMBER: 729 : THE ROLE OF SOIL GRANULOMETRY IN THE DEVELOPMENT OF SHALLOW LANDSLIDES IN THE SERRA DO MAR STATE OF SÃO PAULO, Rebeca Coelho, Universidade de São Paulo, São Paulo, São Paulo, Brazil**

**ABSTRACT NUMBER: 785 : CHARACTERIZATION AND MAPPING OF MASS MOVEMENT HAZARDS IN THE BAMBOUTO CALDERA (CAMEROUN VOLCANIC LINE): A CONTRIBUTION FOR THE MITIGATION OF ASSOCIATED RISKS, Ghislain Zangmo Tefogoum, University Of Maroua, Maroua, Far North Region, Cameroon**

**THEME: S12 : PALAEOHYDROLOGY AND FLUVIAL ARCHIVES - HYDROLOGICAL EXTREME AND CRITICAL EVENTS (HEX)..... 321-322**

**ABSTRACT NUMBER: 414 : POSTGLACIAL CHANGES IN FLUVIAL MORPHOLOGIES OF THE UPSTREAM LOIRE CATCHMENT AND THE MIDDLE CHER RIVER VALLEY, Anaëlle Vayssièrè, Université Paris 1 Panthéon-Sorbonne, Laboratoire de Géographie Physique, LGP CNRS-UMR 8591, Paris, France**

**ABSTRACT NUMBER: 440 : LATE HOLOCENE EVOLUTION OF FLUVIAL SYSTEM IN SOUTHERN INDIA, TAMIL NADU: AN APPROACH FOR PALAEOFLOOD RECONSTRUCTION, Maha Dev, Indian Institute of Science Education and Research Kolkata, Kalyani, Nadia, West Bengal, India**

**ABSTRACT NUMBER: 468 : LUMINESCENCE CHRONOLOGY OF PALAEOFLOODS IN UPPER CAUVERY BASIN: IMPLICATIONS TO HOLOCENE CLIMATE RECONSTRUCTION, Kartika Goswami, Dept. of Earth Sci., Indian Institute of Science Education And Research, Kolkata, West Bengal, India**

**THEME: S13 : FLUVIAL PROCESS AND LANDFORMS..... 323-336**

**ABSTRACT NUMBER: 79 : ARTIFICIAL OPEN CHANNELS AS TOPOGRAPHICAL SIGNATURES AND THEIR IMPLICATIONS ON THE HYDROGEOMORPHOLOGICAL DYNAMICS OF RIVER BASINS, Renato Emanuel Silva, <sup>1</sup>Federal University of Uberlândia/ CAPES Scholarship, Uberlândia, Minas Gerais, Brazil**

**ABSTRACT NUMBER: 120 : GEOMORPHIC HAZARDS ASSOCIATED WITH RIVER CHANNEL PROCESSES - MANIFESTATION, FREQUENCY, MAGNITUDE, Chernov Alexey, Moscow State University, Department of Geography, Moscow, Moscow, Russian Federation**

**ABSTRACT NUMBER: 122 : ASSESSING THE GEOMORPHIC AND ECOLOGIC RESPONSE OF A RESTORED STREAM IN A COMPENSATORY MITIGATION BANK PROJECT, NORTH-CENTRAL TEXAS, USA, Michael Slattery, Texas Christian University, Fort Worth, Texas, United States**

**ABSTRACT NUMBER: 137 : LATE GLACIAL TO HOLOCENE MORPHOSEDIMENTARY EVOLUTION IN THE LOWER VALLEY OF THE HÉRAULT RIVER, NORTHWESTERN MEDITERRANEAN, Jean-Philippe Degeai, CNRS, Montpellier, France**

**ABSTRACT NUMBER: 155 : CHANNEL HEAD LOCATION IN SMALL CATCHMENT IN MONSOON CLIMATE, Eliza Placzkowska, Institute of Geography and Spatial Organization, Polish Academy of Sciences, Krakow, Poland**

**ABSTRACT NUMBER: 156 : CONTEMPORARY EVOLUTION OF HEADWATER VALLEYS IN A MOUNTAIN ENVIRONMENT (WESTERN TATRAS, POLAND), Eliza Placzkowska, Institute of Geography and Spatial Organization, Polish Academy of Sciences, Krakow, Poland**

**ABSTRACT NUMBER: 167 : ABOUT THE RESULTS LONG-TERM MONITORING OF GULLY EROSION IN UDMURT REPUBLIC, RUSSIA, Maria Zaytseva, Dept of Ecology and Nature management, Udmurt State University, Udmurt Republic, Russian Federation**

**ABSTRACT NUMBER: 168 : TRENDS IN THE DEVELOPMENT OF GULLY EROSION ON THE RUSSIAN PLAIN, Maria Zaytseva, Dept of Ecology and Nature management, Udmurt State University, Udmurt Republic, Russian Federation**

**ABSTRACT NUMBER: 190 : THE EROSION'S BELTS ON THE PLOWED SLOPES OF THE RIVER BASINS (BASED ON THE EXAMPLE OF THE RUSSIAN PLAIN), Oleg Yermolaev, Department Of The Landscape Ecology, Institute Of Ecology And Environmental Sciences , Kazan Federal University, Kazan, Tatar Republic, Russian Federation**

**ABSTRACT NUMBER: 191 : TRENDS IN THE DEVELOPMENT OF GULLY EROSION ON THE RUSSIAN PLAIN, Oleg Yermolaev, Dept Of The Landscape Ecology, Institute Of Ecology And Environmental Sciences , Kazan Federal University, Kazan, Tatar Republic, Russian Federation**

**ABSTRACT NUMBER: 215 : QUANTITATIVE AND QUALITATIVE ANALYSIS OF RELATIVE TECTONIC ACTIVITY OF NORTHWESTERN GREECE, Dimitrios Ntokos, National Technical University of Athens, Athens, Athens, Greece**

**ABSTRACT NUMBER: 249 : FORMATION STAGES OF THE TARBAGATAYKA RIVER VALLEY (WESTERN TRANSBAIKALIA) IN THE LATE GLACIAL AND HOLOCENE, Yury Ryzhov, Irkutsk Scientific Center SB RAS, Irkutsk, Irkutsk Region, Russian Federation**

**ABSTRACT NUMBER: 289 : PHYSICAL CHARACTERISTICS AND FLOW MEASUREMENT IN SPRINGS OF THE SÃO FRANCISCO RIVER IN SERRA DA CANASTRA, MINAS GERAIS-BRAZIL, Giliander Allan Silva, Federal University Of Uberlândia, Uberlândia, MG, Brazil**

**ABSTRACT NUMBER: 442 : SURVEY AND SYSTEMATIZATION OF HYDROMORPHOLOGICAL PARAMETERS FOR CHARACTERIZATION AND EVALUATION OF THE DIVERSITY OF RIVER CHANNEL PATTERNS IN THE XINGU RIVER BASIN, Juliana De Paula Silva, State University of Maringá, Maringá, Paraná, Brazil**

**ABSTRACT NUMBER: 464 : RATIO OF BED LOAD TO TOTAL SEDIMENT LOAD IN RIVERS, Sang Deog, Gangneung- Wonju National University, Gangneung, Gangwon, South Korea**

**ABSTRACT NUMBER: 507 : PLANFORM CHARACTERISTICS AND DEVELOPING LEVEL OF INTERCHANNEL WETLANDS IN A GRAVEL-BED ANASTOMOSING RIVER, MAQU REACH OF THE UPPER YELLOW RIVER, Suiji Wang, Institute Of Geographic Sciences And Natural Resources Research, Chinese Academy of Sciences, Beijing, China**

**ABSTRACT NUMBER: 522 : RESPONSE OF BHUKI BASIN TO CLIMATE DURING THE MID-PLEISTOCENE PERIOD WITHIN THE KACHCHH MAINLAND, WESTERN INDIA, Subhash Bhandari, K.S.K.V. Kachchh University, Bhuj, Bhuj, Gujarat, India**

**ABSTRACT NUMBER: 557 : THE HYDROGEOCHEMICAL STUDY OF VARZAGAN PLAIN, Hamid Sadigh, Islamic Azad University, Maragheh Branch, Maragheh, Iran, Maragheh, East Azerbaijan, Iran**

**ABSTRACT NUMBER: 583 : ANALYSIS OF CHANNEL PATTERN CHANGES IN THE COASTAL PLAIN OF GILAN, IRAN, Somaïyeh Khaleghi, Shahid Beheshti University, Tehran, Tehran, Iran**

**ABSTRACT NUMBER: 616 : ROLE OF GEOMORPHIC PROCESSES ON EVOLUTION OF VALLEY-FILL DEPOSITS IN DIFFERENT REACHES OF THE ALAKNANDA RIVER BASIN, Rahul Devrani, School Of Environmental Sciences (SES), Jawaharlal Nehru University, New Delhi, India**

**ABSTRACT NUMBER: 617 : PREDOMINANT LITHOLOGICAL OVER CLIMATIC CONTROL ON THE VARIABILITY OF LANDSCAPE CHARACTERISTICS IN TECTONICALLY PASSIVE WESTERN GHAT, Shantamoy Guha, Earth Sciences Discipline, Indian Institute of Technology, Gandhinagar, Gandhinagar, Gujarat, India**

**ABSTRACT NUMBER: 655 : SLOPE-AREA AND SLOPE-DISTANCE CHANNEL STEEPNESS INDICES YIELD ANALOGOUS RESULTS FOR A HIGH-RELIEF POST-OROGENIC LANDSCAPE, Daniel Peifer Bezerra, University of Glasgow, Glasgow, United Kingdom**

**ABSTRACT NUMBER: 663 : THE ROLE OF INHERENT BASIN CHARACTERISTICS IN DEFINING FLUVIAL RESPONSE TO CHANGED FLUX REGIME IN GLACIATED SUB-BASINS, NORTHWEST HIMALAYAS, L. Sardine Varay, Department of Geology, Delhi University, Delhi, Delhi, India**

**ABSTRACT NUMBER: 696 : THE UPPER HOLOCENE IN ITAPICURU RIVER BASIN (BRAZIL): PROPOSITION OF SCENARIO FOR THE LOWER COURSE AND COASTAL PLAIN, Kleber Lima, UNICAMP, Campinas, São Paulo, Brazil**

**ABSTRACT NUMBER: 698 : SEMIAUTOMATIC IDENTIFICATION OF ALLUVIAL FORMS ON THE WARTA RIVER FLOODPLAIN, POLAND, Małgorzata Mazurek, Adam Mickiewicz University in Poznań, Poznań, Great Poland, Poland**

**ABSTRACT NUMBER: 737 : STRATIGRAPHIC CHARACTERIZATION AND GRANULOMETRIC ANALYSIS OF MARGINAL SEDIMENTS IN THE COASTAL SECTION OF THE TRÊS BARRAS RIVER, SOUTHERN BRAZIL, AND RELATIONSHIP WITH FLUVIAL DYNAMICS, Fabiano Oliveira, Federal University of Parana, Curitiba, Parana, Brazil**

**ABSTRACT NUMBER: 752 : IDENTIFYING VULNERABILITY ZONES IN A TECTONICALLY ACTIVE RIVER CATCHMENT: RUAMAHANGA RIVER, WAIRARAPA, NEW ZEALAND, Ian Fuller, Massey University, Palmerston North, Manawatu- Wanganui, New Zealand**

**ABSTRACT NUMBER: 760 : LATE QUATERNARY EVOLUTION OF FLUVIAL TERRACES IN MIDDLE TISTA VALLEY, DARJEELING-SIKKIM HIMALAYAS: INSIGHT INTO PALAEOCLIMATE AND TECTONICS, Atul Kumar Singh, Indian Institute Of Science Education And Research Kolkata, Nadia, West Bengal, India**

**THEME: S14 : LARGE RIVERS ..... 336-337**

**ABSTRACT NUMBER: 110 : DETERMINING FLOOD-PRONE REGIONS OF KARAJ BY USE SCS CURVE NUMBER METHOD, Fatemeh Dadfar, Private sector, Karaj, Alborz, Iran**

**ABSTRACT NUMBER: 184 : DEFORMATION OF THE AMUR RIVER CHANNEL UNDER THE CATASTROPHIC FLOOD OF 2013, Vladimir Kim, Institute of Water and Ecological Problems Far Eastern Branch Russian Academy of Science, Khabarovsk, Khabarovsk Krai, Russian Federation**

**THEME: S15 : INTEGRATED RIVER MANAGEMENT ..... 337-338**

**ABSTRACT NUMBER: 37 : ASSESSMENT OF WATER QUALITY IN PRE MONSOON & POST MONSOON SEASONS OF RANIKHOLA RIVER AND ITS TRIBUTARIES, SIKKIM, INDIA, Sarmistha Mallick, North Eastern Hill University, Shillong, Meghalaya, India**

**ABSTRACT NUMBER: 197 : IMPACT OF CLIMATE VARIABILITY AND HUMAN INTERFERENCE ON FLUVIAL GEOMORPHOLOGY IN THE DAMODAR VALLEY, INDIA DURING ANTHROPOCENE, Prasanta Kumar Ghosh, The University of Burdwan, Burdwan, West Bengal, India**

**ABSTRACT NUMBER: 514 : A GEOMORPHOLOGICAL STUDY OF SUBERNREKHA - A DYING RIVER, R. C Pathak, ICOER, Wagholi, Pune, Maharashtra, India; 2SIG-Symboisis Institute of Geoinformatics, Pune, Maharashtra, India**

**ABSTRACT NUMBER: 582 : INCORPORATION OF GEOMORPHIC CRITERIA TO DEFINE ENVIRONMENTAL FLOW IN A HIMALAYAN RIVER, YAMUNA RIVER SYSTEM, INDIA, Nupur Bawa Chakraborty, Geological Survey Of India, Agartala, Tripura, India**

**THEME: S16 : COASTAL GEOMORPHOLOGY AND MANAGEMENT ..... 339-345**

**ABSTRACT NUMBER: 59 : SOCIETY'S RESPONSE TO A COMPLEX GEOMORPHIC ENVIRONMENT OF THE BENGAL COASTAL REGIME, Arindam Chattopadhyay, NIL, BERHAMPORE, WEST BENGAL, India**

**ABSTRACT NUMBER: 220 : SIGNIFICANCE OF THE DISCOVERY OF A SEA ERODED LANDFORM IN QIXINGGANG OF GUANGZHOU, Bin Huang, Guangdong Institute of Eco-environment Science & Technology, Guangzhou, Guangdong, China**

**ABSTRACT NUMBER: 359 : KEY CHALLENGES AND FUTURE DIRECTIONS FOR RECONSTRUCTING HOLOCENE RELATIVE SEA-LEVEL CHANGES IN THE NEW ZEALAND REGION, Alastair Clement, Massey University, Palmerston North, Palmerston North, New Zealand**

**ABSTRACT NUMBER: 399 : LATE HOLOCENE GEOMORPHIC EVOLUTION OF THE LIVADI COASTAL PLAIN, GULF OF ARGOSTOLI, CEPHALONIA ISLAND, WESTERN GREECE, Efthimios Karymbalis, Department of Geography, Harokopio University, GR-17671 Kalithea, Athens, Greece**



**ABSTRACT NUMBER: 410 : ESTIMATION OF DRAINAGE DEGRADATION IN THE RECLAIMED PART OF INDIAN SUNDARBANS, Rakesh Bera, Vidyasagar University, Midnapore., West Bengal, India**

**ABSTRACT NUMBER: 517 : EVOLUTION OF RELATIVE SEA LEVEL IN OKINAWA, JAPAN THROUGH THE USE OF BEACHROCKS, Niki Evelpidou, National And Kapodistrian University of Athens, Zografou, Athens, Greece**

**ABSTRACT NUMBER: 554 : PHYSICO-CHEMICAL ATTRIBUTES OF THE HOLOCENE SEDIMENTS IN THE EASTERN SUBARNAREKHA COASTAL REGION, Pritam Kumar Santra, Department of Geography, University of Calcutta, Kolkata, West Bengal, India**

**ABSTRACT NUMBER: 563 : UNRAVELLING POSSIBLE CLIMATIC AND/OR SEISMIC SIGNALS PRESERVED IN COASTAL SAND DUNES AND AROUND MODERN LAKE WAIRARAPA, NORTH ISLAND, NEW ZEALAND, Alastair Clement, Massey University, Palmerston North, Palmerston North, New Zealand**

**ABSTRACT NUMBER: 581 : VARIATION IN BEACH PROFILE AND RELATED TEXTURAL CHARACTERISTICS OF SEDIMENT IN MANDARMANI COASTAL TRACT, EAST MEDINIPUR, WEST BENGAL, Sujata Dutta, West Bengal State University, Kolkata, West Bengal, India**

**ABSTRACT NUMBER: 619 : LANDFORM CHANGES ALONG THE KACHCHH COAST LINE: A POSSIBLE IMPACT OF STORMS, Hitesh Patel, Government Engineering College, Palanpur, Palanpur, Gujarat, India**

**ABSTRACT NUMBER: 662 : THE MORPHODYNAMICS OF THE SF. GHEORGHE (DANUBE) WAVE DOMINATED RIVER MOUTH BAR (2004-2017), Florin Zăinescu, University Of Bucharest, Bucharest, , Romania**

**ABSTRACT NUMBER: 673 : COASTAL GEOMORPHOLOGICAL EVOLUTION OF CAUVERY DELTA DURING HOLOCENE AND LATE PLEISTOCENE, Krishnan Sivakumar, Department of Geology, National College, Tiruchirappalli, Tamil Nadu, India**

**ABSTRACT NUMBER: 717 : ROLE OF SEDIMENT TRANSPORT AND LONGSHORE DRIFT IN FORMATION OF GORGAN SPIT IN SOUTH COAST OF THE CASPIAN SEA, Babak Najafiha, Geological Survey of Iran, Tehran, Iran**

**ABSTRACT NUMBER: 720 : COASTAL GEOMORPHOLOGY: MAJOR PROBLEMS FACED BY THE COMMUNITY ALONG THE KARNATAKA COAST AND THEIR MANAGEMENT, Katihally Jayappa, Mangalore University, Mangalore, Karnataka, India**

**ABSTRACT NUMBER: 763 : ANALYSIS OF COMPACTION DIFFERENCES AND MATERIAL COMPOSITION BETWEEN COASTAL PLAINS OF THE NORTH (TRIMMED) AND SOUTH (OPEN) LITTORAL, IN SÃO PAULO STATE, Marisa Fierz, University Of São Paulo, São Paulo, São Paulo, Brazil**

**THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY..... 345-349**

**ABSTRACT NUMBER: 56 : RELATIONS OF DEGRADED RIVERINE DUNEFIELDS IN SEMIARID ZONES TO OVER-EXPLOITATION OF GROUNDWATER: WITH THE CASES FROM THE KORQIN SANDY LAND, NORTHEAST CHINA, Guang Han, College of Resources and Environmental Sciences, Hunan Normal University, Changsha, Hunan, China**

**ABSTRACT NUMBER: 245 : THE USE OF CONVERGING EVIDENCE TO ASCERTAIN THE ORIGIN OF DESERT SAND, Beneah Daniel Odhiambo, University Of Venda, Thohoyandou, Limpopo, South Africa**

**ABSTRACT NUMBER: 270 : THE ROLE OF GEOMORPHOLOGICAL FACTORS IN THE FORMATION OF K- AND LI-RICH BRINE DEPOSITS IN ARID QAIDAM BASIN, CHINA, Junqing Yu, Qinghai Institute Of Salt Lakes, Chinese Academy Of Sciences, Xining, Qinghai Province, China**

**ABSTRACT NUMBER: 282 : GEOCHEMICAL EVIDENCE FOR THE PROVENANCE OF AEOLIAN SANDS IN THE ORDOS DESERTS, NORTH CHINA, Qianqian Liu, <sup>1</sup>Institute Of Geology And Geophysics, Chinese Academy Of Sciences, Beijing, Beijing, China**

**ABSTRACT NUMBER: 312 : IDENTIFICATION OF AEOLIAN LOESS DEPOSITS ON THE INDO-GANGETIC PLAIN (INDIA) AND THEIR SIGNIFICANCE, Mingming Ma, Institute of Geography, Fujian Normal University, Fuzhou, Fujian, China**

**ABSTRACT NUMBER: 476 : IDENTIFICATION AND CHARACTERISATION OF MICRO LANDFORM FEATURES AS CLUE TO RECENT DESERTIFICATION PROCESSES IN INDIA'S ARID ZONE, Pratap Chandra Moharana, ICAR- Central Arid Zone Research Institute, Jodhpur, Rajasthan, India**

**ABSTRACT NUMBER: 483 : AEOLIAN SAND FIELD WITHIN AN INTRAMOUNTAIN BASIN, QINGHAI-TIBETAN PLATEAU: SAND SOURCE AND DEPOSITION CONTROLS, Hanlin Jiang, College of Environmental Science and Engineering, Key Laboratory of Water and Sediment Sciences, Ministry of Education, Peking University, Haidian District, Beijing, China**

**ABSTRACT NUMBER: 533 : MODERN AEOLIAN PROCESSES AND LANDFORMS OF THE VILYUI RIVER BASIN (CENTRAL YAKUTIA), Maria Pavlova, Melnikov Institute Of Permafrostology Siberian Branch Of Russian Academy Of Science, Yakutsk, Republic Sakha (Yakutia), Russian Federation**

**THEME: S18 : TROPICAL GEOMORPHOLOGY ..... 349-350**

**ABSTRACT NUMBER: 89 : ANALYSIS OF ORGANIC MATTER, TEXTURE AND CEC OF SURFACE MATERIALS ON BRAZILIAN CERRADO SLOPES UNDER RECOVERY STAGE, Fabiana Cristina Dos Santos, Federal University Of Uberlandia, Uberlândia, Minas Gerais, Brazil**

**ABSTRACT NUMBER: 590 : URBANIZATION INDUCED THREAT TO GEOHERITAGE IN WEST BENGAL, EASTERN INDIA: A CASE STUDY OF THE KHOAI, NEAR SHANTINIKETAN, Rajarshi Dasgupta, East Calcutta Girls' College, Kolkata, West Bengal, India**

**THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY ..... 350-361**

**ABSTRACT NUMBER: 3 : GPR SIGNAL AND IMAGE PROCESSING FOR GEOMORPHOLOGICAL ANALYSIS, Sunjay Sunjay, Geophysics, BHU, Varanasi 221005 India, Varanasi, Up, India**

**ABSTRACT NUMBER: 67 : DISCOVERY OF AN EARLIER PLEISTOCENE GLACIATION IN BODUIZANGBU VALLEY, SOUTHEASTERN TIBET, Shangzhe Zhou, South China Normal University, School of Geography Science, Guangzhou, Guangdong Province, China**

**ABSTRACT NUMBER: 84 : TWO NEW CONTRIBUTIONS TO TURKEY'S GLACIAL GEOMORPHOLOGY: ŞAHINTAŞI GLACIER (MUNZUR MOUNTAINS) AND KARADAĞ (WESTERN TAURUS), Cihan Bayrakdar, Istanbul University, Istanbul, Turkey**

**ABSTRACT NUMBER: 92 : GEOMORPHOLOGICAL FORCING OF PROGLACIAL LAKE DYNAMICS IN MOUNTAIN AREAS, Martin Mergili, Department of Geography and Regional Research, University of Vienna, Vienna, Vienna, Austria**

**ABSTRACT NUMBER: 198 : CONTROL OF SEA LEVEL TEMPERATURE AND ATMOSPHERE VAPOUR CONTENT ON MODERN AND LGM SNOWLINES AT GLACIERS OF CENTRAL HIMALAYAN, INDIA, Tanuj Shukla, Center for Glaciology, Wadia Institute Of Himalayan Geology, Dehradun, Uttarakhand, India**

**ABSTRACT NUMBER: 199 : EXTREME PROCESSES SHAPING ARCTIC COASTS – IMPACT OF TSUNAMIS AND ICEBERG-ROLL EVENTS ON GREENLAND COASTAL SYSTEMS, Matt Strzelecki, Institute of Geography and Regional Development, University Of Wroclaw, Wroclaw, , Poland**

**ABSTRACT NUMBER: 211 : SEDIMENTOLOGICAL CHARACTERIZATION OF SUSPENDED SEDIMENTS EVACUATED FROM DEBRIS-COVERED CHORABARI GLACIER, GARHWAL HIMALAYA, INDIA, Anupam Anand Gokhale, Centre for Glaciology, Wadia Institute Of Himalayan Geology, Dehradun - 248001, Uttarakhand, India**

**ABSTRACT NUMBER: 251 : PALEOCRYOGENESIS, SOIL FORMATION AND DEVELOPMENT OF EROSION PROCESSES IN THE WESTERN TRANSBAIKALIA FOREST-STEPPE LANDSCAPES (EASTERN SIBERIA, RUSSIA) DURING THE LATE GLACIAL AND THE HOLOCENE, Yury Ryzhov, V.B. Sochava Institute Of Geography SB RAS, Irkutsk, Irkutsk Region, Russian Federation**

**ABSTRACT NUMBER: 275 : REFLECTION OF ENVIRONMENTAL CONDITIONS IN THE INTERNAL STRUCTURE OF TALUS SLOPES: THE EXAMPLES FROM SW SPITSBERGEN AND POLISH TATRA MOUNTAINS, Krzysztof Senderak, University of Silesia, Faculty of Earth Sciences, Department of Geomorphology, Sosnowiec, Poland**

**ABSTRACT NUMBER: 278 : MAPPING ON GLACIER SURFACE FACIES OF NY ALESUND IN SVALBARD USING HIGH RESOLUTION SATELLITE REMOTE SENSING DATA AND GIS TECHNIQUE, Manoj Kumar Patley, Bharathidasan University, Tiruchirappalli, Tamil Nadu, India**

**ABSTRACT NUMBER: 301 : SOUTHERN CARPATHIANS PERMAFROST PROBABILITY MAP, Flavius Sorin Sirbu, West University Of Timisoara, Timisoara, Timis, Romania**

**ABSTRACT NUMBER: 302 : THE GEOMORPHOLOGICAL CHARACTERISTICS OF ROCK GLACIERS AND PROTALUS RAMPARTS IN THE RILA AND PIRIN MOUNTAINS, Brigitte Magori, West University Of Timisoara, Timisoara, Timis, Romania**

**ABSTRACT NUMBER: 341 : INFERRING GLACIER SUMMER MASS BALANCE FROM TREE-RINGS IN RHAETIAN ALPS (ITALY), Riccardo Cerrato, University of Pisa-Scuola di Dottorato Regionale in Scienze della Terra, Pis , Italy**

**ABSTRACT NUMBER: 354 : THE CHARACTERISTICS AND FORMING PROCESS OF GLACIAL PERIPHERAL MORAINES AT GONGBA GLACIERS IN MT. GONGGA, CHINA, Jiancheng Kang, Shanghai Normal University, Shanghai, Shanghai, China**

**ABSTRACT NUMBER: 395 : GLACIERS' FLUCTUATIONS IN THE ITALIAN ALPS DURING THE LAST GLACIAL CYCLE: A LITERATURE REVIEW, Vittoria Vandelli, University of Modena and Reggio Emilia, Modena, Italy**

**ABSTRACT NUMBER: 460 : A 10-YEAR SERIES OF SURFACE KINEMATICS OF PERIGLACIAL SORTED CIRCLES FROM SFM CLOSE-RANGE PHOTOGRAMMETRY, Ivar Berthling, Department Of Geography, Norwegian University Of Science And Technology, Trondheim, Norway**

**ABSTRACT NUMBER: 467 : IN SITU 10BE EXPOSURE AGES DOCUMENT A DOUBLE GLACIERS RESPONSE TO YOUNGER DRYAS IN THE UPPER PEIO VALLEY (RHAETIAN ALPS, ITALY), Stefano Casale, Dipartimento di Scienze della Terra - Università di Pisa, Pisa , Italy**



**ABSTRACT NUMBER: 470 : GEOMORPHOLOGICAL EVOLUTION OF THE CHANGLA BASIN, LADAKH, NW TRANS HIMALAYA, INDIA DURING LATE QUATERNARY, Priyanka Joshi, Birbal Sahni Institute Of Palaeosciences, 53, University Road, Lucknow, Uttar Pradesh, India**

**ABSTRACT NUMBER: 473 : RECENT GLACIERS VARIATIONS IN ALTA VALTELLINA (ORTLES-CEVEDALE GROUP, ITALIAN ALPS): QUANTITATIVE ANALYSIS OF AN ACCELERATED GLACIAL DECLINE DURING THE LAST 60 YEARS, Simona Gennaro, University of Pisa-Scuola di Dottorato Regionale in Scienze della Terra, Pisa, Italy**

**ABSTRACT NUMBER: 553 : QUATERNARY GLACIAL CHRONOLOGY AND ITS DRIVING FACTOR IN THE MONSOON INFLUENCED REGIONS OF THE HIMALAYA-TIBETAN OROGEN, Pinkey Bisht, Wadia Institute Of Himalayan Geology, Dehradun, Uttarakhand, India**

**ABSTRACT NUMBER: 650 : EVOLUTION OF IMJA, LOWER BARUN AND THULAGI GLACIAL LAKE AND ITS GEOMORPHOLOGICAL RELATIONSHIP, Umesh Haritashya, University Of Dayton, Dayton, OH, United States**

**ABSTRACT NUMBER: 701 : RECONSTRUCTING GLACIER CHANGE POST LITTLE ICE AGE (LIA) IN THE NORTH- WESTERN HIMALAYA, INDIA: AN OVERVIEW AND SPECIFIC EXAMPLES, Pritam Chand, Jawaharlal Nehru University, New Delhi, Delhi, India**

**ABSTRACT NUMBER: 714 : GLACIAL-GEOMORPHOLOGY AND VALLEY DEVELOPMENT; A CASE STUDY OF THE THAJWAS GLACIER VALLEY, KASHMIR HIMALAYAS, INDIA, Omar Jaan, University Of Kashmir, Srinagar, Jammu & Kashmir, India**

**THEME: S20 : MOUNTAIN GEOMORPHOLOGY ..... 362-364**

**ABSTRACT NUMBER: 212 : ASSESSMENT OF THE SHORE ABRASION SIZE IN A MOUNTAIN RESERVOIR (POLISH CARPATHIANS), Malgorzata Kijowska-Strugala, Polish Academy of Sciences, Institute of Geography and Spatial Organization, Research Station in Szymbark, Szymbark, PL, Poland**

**ABSTRACT NUMBER: 479 : GEOMORPHOLOGICAL MAPPING OF VAL PIANA (ADAMELLO-PRESANELLA GROUP, RHAETIAN ALPS): FROM MULTI-TEMPORAL ANALYSIS TO DEBRIS FLOWS SUSCEPTIBILITY, Maria Cristina Salvatore, University of Pisa, Dipartimento di Scienze della Terra, Pisa, Italy**

**ABSTRACT NUMBER: 602 : HYPOMETRIC AND DRAINAGE NETWORK ANALYSIS OF THE EASTERN CORDILLERA OF THE COLOMBIAN ANDES, Andres Cala, Universidad De Los Andes, Bogota, Cundinamarca, Colombia**

**ABSTRACT NUMBER: 627 : VULNERABILITY ASSESSMENT OF FLOOD HAZARDS IN THE TECTONICALLY ACTIVE BASINS USING SRTM DATA AND GIS IN THE EASTERN PART OF ARUNACHAL PRADESH, INDIA, Swapna Acharjee<sup>1</sup>, State Remote Sensing Application Centre, Department of Science and Technology, Government of Arunachal Pradesh, Itanagar, Arunachal Pradesh, India**

**ABSTRACT NUMBER: 666 : ROCKWALLS MORPHOMETRY AND DISTRIBUTION IN THE ROMANIAN CARPATHIANS: CONTROLS OF LITHOLOGY, TOPOGRAPHY AND FROST WEATHERING PATTERNS, Alfred Vespremeanu-Stroe, University of Bucharest, Bucharest, Bucharest, Romania**

**THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY ..... 364-373**

**ABSTRACT NUMBER: 23 : APPRAISAL OF LANDSLIDES TRAJECTORIES AND VULNERABILITY MAPPING IN JOS SOUTH LGA : USING REMOTE SENSING AND GIS, Nyofa Shitta, National Space Research And Development Agency, Toro, Bauchi, Nigeria**

**ABSTRACT NUMBER: 43 : EVALUATION OF GLACIAL LAKES EXPANSION AND PROBABILISTIC VOLUME ESTIMATION BY DIFFERENT TECHNIQUES IN CHHOMBU CATCHMENT OF UPPER TISTA BASIN, SIKKIM HIMALAYAS, Arindam Chowdhury, Department of Geography, North Eastern Hill University (NEHU), Shillong, Meghalaya, India**

**ABSTRACT NUMBER: 127 : DEVELOPMENT OF WATER POTENTIAL ZONE (WPZ) FOR GAD WATERSHED, INDIA - AN INTEGRATED GEOMORPHOLOGICAL AND GEOINFORMATICS APPROACH, Sandeep Mahajan, Department of Civil Engineering, Faculty of Engineering & Technology, SRM University, Kattankulathur, Tamil Nadu, India**

**ABSTRACT NUMBER: 147 : HYDROMORPHOLOGICAL STUDY OF DHAMANI RIVER SUB-BASIN USING REMOTE SENSING AND GIS TECHNIQUES, Chandrakant Gurav, Department of Geology, Dyanopasak College, Parbhani-431 401 Maharashtra India, Parbhani, Maharashtra, India**

**ABSTRACT NUMBER: 207 : DIFFERENCES BETWEEN SPECTRAL ANGLE MAPPER AND EUCLIDEAN DISTANCE CLASSIFIERS IN LANDFORM MAPPING, João Paulo Sena-Souza, Graduate Program of Environmental Sciences - University of Brasília, Planaltina, Federal District, Brazil**

**ABSTRACT NUMBER: 262 : ANALYSIS SPATIOTEMPORAL LAND USE/COVER DYNAMICS USING REMOTE SENSING IMAGERY AND GIS TECHNIQUES, Zahra Sedighifar, Kharazmi University, Tehran, Iran**



**ABSTRACT NUMBER: 286 : DETERMINATION OF THE BOUNDARY BETWEEN THE MID-EUROPEAN LOWLANDS AND THE POLISH HIGHLANDS IN THE LIGHT OF THE CONFORMITY OF PROFILES ALONG FOSSIL AND CONTEMPORARY SURFACES, Lucyna Wachecka-Kotkowska, <sup>1</sup>University of Lodz, Faculty of Geography, Department of Geomorphology and Palaeogeography, Lodz , Poland**

**ABSTRACT NUMBER: 287 : GEOTECHNICAL CHARACTERIZATION OF THE SITE ALONG ROODBAR HIGHWAY, Hamid Sadigh, Islamic Azad University, Maragheh Branch, Maragheh, Iran, Maragheh, East Azerbaijan, Iran**

**ABSTRACT NUMBER: 288 : LOCATING OF UNDERGROUND DAMS WITH USING REMOTE SENSING & GIS (CASE STUDY: MAKEKAN), Hamid Sadigh, Islamic Azad University, Maragheh Branch, Maragheh, Iran**

**ABSTRACT NUMBER: 431 : GEOMORPHOLOGICAL UNITS AS NATURAL BOUNDARY TO LAND COVER CHANGE ASSESSMENT, Glauber Neves, University of Brasilia - UnB, Planaltina, Distrito Federal, Brazil**

**ABSTRACT NUMBER: 459 : MORPHOMETRIC ANALYSIS OF PACHNAI RIVER BASIN, ASSAM (INDIA) USING GEOSPATIAL TOOLS, Dandeswar Boro, Cotton College State University, Guwahati, Assam, India**

**ABSTRACT NUMBER: 491 : LANDFORM FRAGMENTATION ANALYSIS IN DIFFERENT ETCHPLANTION STAGES, Vinicius Vasconcelos, University of Brasilia, Brasilia, DF, Brazil**

**ABSTRACT NUMBER: 585 : DRAINAGE DYNAMICS SYSTEM ANALYSIS DUE TO THE URBANIZATION PROCESS IN THE DEVELOPMENT OF EROSION PROCESSES, Anesmar Olineo de Albuquerque, Universidade De Brasilia, Brasilia, Distrito Federal, Brazil**

**ABSTRACT NUMBER: 609 : COMPARISON OF LANDSLIDES HAZARD MAPS PRODUCED FROM DIGITAL TERRAIN MODELS GENERATED FROM LIDAR DATA AND DIGITAL AREA PHOTOGRAPHS, Argélica Saiaka Luiz, Universidade de Brasilia - UNB, Brasilia, Distrito Federal, Brazil**

**ABSTRACT NUMBER: 690 : PREDICTION OF LANDUSE-LANDCOVER CHANGES IN THE FLOOD-PRONE AREAS OF DOMBIVALI TOWNSHIP, MAHARASHTRA, Deepali Gadkari, Department Of Geography, University Of Mumbai, Kalina, Santacruz (E), Mumbai, Maharashtra, India**

**ABSTRACT NUMBER: 727 : DEVELOPING OPEN-ACCESS E-LEARNING MATERIALS FOR GIS EDUCATION RELATED TO TERRAIN ANALYSIS, Hiroyuki Yamauchi, Center for Spatial Information Science, The University of Tokyo, Kashiwa-shi, Chiba, Japan**

**ABSTRACT NUMBER: 735 : RELATIONSHIPS BETWEEN COASTAL SAND DUNE VEGETATION AND LANDFORMS BASED ON ALS AND UAV-SFM PHOTOGRAMMETRY: TOTTORI SAND DUNES, SOUTHWEST JAPAN, Takashi Oguchi, Univ. Tokyo, Kashiwa, Chiba, Japan**

**ABSTRACT NUMBER: 736 : EROSION RATES WITH RELATION TO TECTONIC ACTIVITY, Takashi Oguchi, Univ. Tokyo, Kashiwa, Chiba, Japan**

**ABSTRACT NUMBER: 759 : EFFECT OF THE NEOTECTONICS ON THE DRAINAGE SYSTEM IN THE PIEDMONT OF THE DARJEELING-SIKKIM HIMALAYAS, NORTH BENGAL, INDIA, Atul Kumar Singh, Indian Institute Of Science Education And Research Kolkata, Nadia, West Bengal, India**

**THEME: S22 : QUANTITATIVE GEOMORPHOLOGY AND MODELING.....374**

**ABSTRACT NUMBER: 417 : ESTIMATING DISCHARGE FROM SUB-BASINS OF THE GANGA RIVER- A SWAT BASED ANALYSIS, Suman Bera, Vidyasagar University, Midnapore, West Bengal, India**

**ABSTRACT NUMBER: 599 : RELATIONS BETWEEN TIME VARIABILITY OF HYDRO-SEDIMENTARY RESPONSES, CLIMATIC SIGNALS AND CATCHMENT CHARACTERISTICS USING A LANDSCAPE EVOLUTION MODEL (CAESAR- LISFLOOD), Marco Van De Wiel, Coventry University, Coventry, Warwickshire, United Kingdom**

**THEME: S23 : GEOMORPHOLOGICAL MAPPING ..... 375-380**

**ABSTRACT NUMBER: 10 : GEOMORPHOLOGICAL MAPPING OF THE REGION OF NEPENTHES MNSAE, MARS. EVIDENCE OF AN ANCIENT SEA, Francisco Gutierrez, Universidad de Zaragoza, Zaragoza, Spain**

**ABSTRACT NUMBER: 107 : TOPOMORPHOLOGICAL SURVEY USING ANALOGICAL AND DIGITAL TECHNIQUES, Fernando Nadal Junqueira Villela, University Of Sao Paulo, São Paulo, Sao Paulo, Brazil**

**ABSTRACT NUMBER: 128 : DETAILED OFFSHORE SEAFLOOR MAPPING AS THE BASIC METHOD IN IDENTIFICATION AND ASSESSMENT OF ENVIRONMENTAL CONDITIONS, Kazimierz Szeffler, Maritime Institute In Gdańsk, Gdańsk, Pomorskie, Poland**

**ABSTRACT NUMBER: 194 : OBJECT-BASED APPROACH FOR GULLY FEATURE MAPPING IN THE HILLY LOESS PLATEAU REGION OF CHINA USING HIGH-RESOLUTION IMAGERY AND DEM, Hu Ding, School of Geographic Science, Nanjing Normal University, Nanjing, Jiangsu, China**



**ABSTRACT NUMBER: 201 : BOMB CRATERS MAPPING AND QUANTIFICATION ON THE VERDUN BATTLEFIELD (1914-1918, FRANCE),** Rémi De Matos Machado, *Université Paris-Diderot (Paris 7) – UMR 8586 PRODIG, Paris, France*

**ABSTRACT NUMBER: 257 : GEOMORPHOLOGY AND MAPPING OF THE VOURAIKOS BASIN, NORTH PELOPONNESUS, GREECE,** Dimitris Vandarakis, *Harokopio University, Kallithea (Athens), Attica, Greece*

**ABSTRACT NUMBER: 291 : SURFACE RUNOFF COEFFICIENT OF HYDROGRAPHIC BASINS ACCORDING TO PHYSIOGRAPHIC COMPARTMENTATION,** Claudia Vanessa Dos Santos Corrêa, *Universidade Estadual Paulista "Júlio De Mesquita Filho" Unesp, Rio Claro, São Paulo, Brazil*

**ABSTRACT NUMBER: 296 : SEMI-AUTOMATED GEOMORPHOLOGICAL MAPPING FROM A DIGITAL TERRAIN MODEL APPLIED TO THE CHAPADÃO DO DIAMANTE, SERRA DA CANASTRA, MG-BRAZIL,** Thallita Isabela Silva Martins Nazar, *Federal University Of Uberlândia, Uberlândia, Minas Gerais, Brazil*

**ABSTRACT NUMBER: 449 : GEOMORFOLOGY OF THE BRAZILIAN CERRADO - REPRESENTATION OF THE RELIEF BY MEANS OF GEOMORFOMETRIC PARAMETERS,** Gervásio Barbosa Soares Neto, *Instituto Federal de Brasília, Brasília, Distrito Federal, Brazil*

**ABSTRACT NUMBER: 600 : THE GEOMORPHOLOGY AND SOILS OF THE LETABA FLUVIAL TERRACES, SOUTH AFRICA,** Marco Van De Wiel, *Coventry University, Coventry, Warwickshire United Kingdom*

**ABSTRACT NUMBER: 618 : GEOMORPHIC FEATURES OF GRANITE TORS - ROCK CONTROL AND CARTOGRAPHIC REPRESENTATION, WEST SUDETES, POLAND,** Aleksandra Michniewicz, *University Of Wroclaw, Institute of Geography and Regional Development, Wroclaw, Dolnośląskie, Poland*

**ABSTRACT NUMBER: 706 : DIGITAL GEOMORPHOLOGICAL MAPPING IN POLAND,** Zbigniew Zwolinski, Adam Mickiewicz University in Poznan, *Poznan, Poznan, Poland*

**THEME: S27 : SEDIMENT BUDGETS (IAG-WG SEDIBUD)..... 380-384**

**ABSTRACT NUMBER: 53 : STUDIES ON THE MORPHOCLIMATE AND CONTEMPORARY MORPHODYNAMICS OF THE BOREAL HOMLA DRAINAGE BASIN SYSTEM IN MIDDLE NORWAY (TRØNDELAG),** Achim Alfred Beylich, *Geological Survey of Norway (NGU), Trondheim, Norway*

**ABSTRACT NUMBER: 54 : KEY ACTIVITIES AND OUTCOMES OF THE I.A.G./A.I.G. SEDIBUD (SEDIMENT BUDGETS IN COLD ENVIRONMENTS) PROGRAM (2005 - 2017),** Achim A. Beylich, *Geological Survey of Norway (NGU), Trondheim, Norway*

**ABSTRACT NUMBER: 108 : SOIL EROSION AND SEDIMENT YIELD MODELING FOR THE GANGA RIVER SYSTEM USING RUSLE AND SDR BASED APPROACH,** Somil Swarnkar, *Department of Earth Sciences, Indian Institute Of Technology Kanpur, Kanpur, Uttar Pradesh, India*

**ABSTRACT NUMBER: 114 : ANALYSIS OF THE SPATIO-TEMPORAL VARIABILITY OF POSTGLACIAL ROCKFALL ACTIVITY IN WESTERN NORWAY,** Katja Laute, *Université de Bretagne Occidentale, IUEM, CNRS, UMR LETG, Technopôle Brest-Iroise, Plouzané, Finistère, France*

**ABSTRACT NUMBER: 641 : THE ZOOGEOMORPHOLOGICAL IMPACT OF SNOW VOLE (CHIONOMYS NIVALIS) IN SUBALPINE PRAIRIES OF PARÂNG MOUNTAINS, SOUTHERN CARPATHIANS, ROMANIA,** Daniel Germain, *University of Quebec at Montreal, Montreal, Quebec, Canada*

**ABSTRACT NUMBER: 654 : PROVENANCE STUDY OF RIVER SEDIMENTS FROM SIKKIM-DARJEELING HIMALAYA; UNDERSTANDING SOURCE TO SINK RELATION,** Imtinungla Pongener, *Sikkim University, Gangtok, Sikkim, India*

**ABSTRACT NUMBER: 708 : SOURCE-TO-MAINSTEM: LINK BETWEEN GEOCHEMISTRY OF DEPOSITS AND HYDROCHEMISTRY OF STREAM WATERS, BRØGGERDALEN, NW SPITSBERGEN,** Zbigniew Zwolinski, Adam Mickiewicz University in Poznan, *Poznan, Poznan, Poland*

**THEME: S28 : TROPICAL RIVERS (IAG-WG) ..... 384-387**

**ABSTRACT NUMBER: 172 : UNDERSTANDING PLANFORM DYNAMICS FOR RIVER MANAGEMENT: A CASE STUDY OF THE KOSI RIVER IN NORTH BIHAR PLAINS, INDIA,** Kanchan Mishra, *Indian Institute of Technology, Kanpur., Kanpur, Uttar Pradesh, India*

**ABSTRACT NUMBER: 628 : PRELIMINARY EVALUATION OF PEAK DISCHARGE REDUCTION IN FLUVIAL MEANDRIC SYSTEMS, RIVER RIBEIRA DE IGUAPE, BRAZIL,** Yuri Veneziani, *University Of São Paulo, São Paulo, São Paulo, Brazil*

**ABSTRACT NUMBER: 704 : BACKWATER EFFECT ON SUSPENDED SEDIMENT TRANSPORT PATTERNS IN THE LOWER MADEIRA RIVER, BRAZIL,** Edward Park, *Earth Observatory Of Singapore, Nanyang Techological University, Singapore, Singapore*

**ABSTRACT NUMBER: 747 : MORPHOMETRIC DIFFERENCES OF LARGE ALLUVIAL FANS AND MEGAFANS,** Moulay Anwar Sounny-Slitine, *University of Texas, Austin, Texas, United States*



**ABSTRACT NUMBER: 773 : NEW PIECES FOR THE GEOLOGICAL PUZZLE OF THE FORMATION OF AMAZONIAN RIVERS SINCE THE LATE NEOGENE: COUPLING LUMINESCENCE AND COSMOGENIC NUCLIDE DATING, [Fabiano N Pupim](#), Department of Environmental Science, Universidade Federal de Sao Paulo, Diadema, SP, Brazil**

**THEME: S29 : GEOMORPHOLOGY OF ROCKY COASTS (IAG-WG)..... 387-392**

**ABSTRACT NUMBER: 756 : RAUK - FORGOTTEN WITNESS OF HOLOCENE SEA-LEVEL CHANGES AND DEVELOPMENT OF BALTIC ROCKY COASTS - PROJECT CONCEPT AND PILOT RESULTS, [Matt Strzelecki](#), University Of Wroclaw, Wroclaw, Dolnoslaskie, Poland**

**THEME: S30 : SUBMARINE GEOMORPHOLOGY (IAG-WG)..... 387-392**

**ABSTRACT NUMBER: 9 : MATHEMATICAL MORPHOLOGY FOR SEISMIC IMAGING AND INTERPRETATION, [Sunjay Sunjay](#), Geophysics, BHU, Varanasi 221005 India**

**ABSTRACT NUMBER: 112 : MARINE GEOMORPHOLOGY AND ENVIRONMENTAL STATUS OF ELEFSIS BAY AND INNER SARONIKOS GULF, GREECE, [Kosmas Pavlopoulos](#), Paris Sorbonne University Abu Dhabi, ABU DHABI, ABU DHABI, United Arab Emirates**

**ABSTRACT NUMBER: 309 : IMPACT OF BENTHIC ORGANISMS ON SUB-CM SCALE SEAFLOOR MICROTOPOGRAPHY, [Sebastian Krastel](#), Kiel University, Kiel, , Germany**

**ABSTRACT NUMBER: 343 : HE GRAHAM BANK (SICILY CHANNEL, CENTRAL MEDITERRANEAN SEA): SEAFLOOR SIGNATURES OF TECTONIC AND VOLCANIC CONTROLS, [Daniele Spatola](#), University Of Malta, Msida, Msida, Malta**

**ABSTRACT NUMBER: 381 : APPLICATION OF A NEW GENETIC CLASSIFICATION AND SEMI-AUTOMATED MAPPING APPROACH IN THE PERTH SUBMARINE CANYON, AUSTRALIA, [Rachel Nanson](#), Geoscience Australia, Canberra, ACT, Australia**

**ABSTRACT NUMBER: 543 : INCISED VALLEYS OF THE NORTHERN ADRIATIC SHELF: A WINDOW ON THE LATE-QUATERNARY FLUVIAL AND COASTAL EVOLUTION, [Alessandro Fontana](#), University of Padova; CoNISMa, Padova, Italy**

**ABSTRACT NUMBER: 550 : TRANSITION OF A SLOPE-CONFINED TO A SHELF-INCISED SUBMARINE CANYON ON THE ACTIVE CONTINENTAL MARGIN OF RHODES ISLAND, SE GREECE, [Georgios Angelos Chatiris](#), Hellenic Centre for Marine Research/Institute of Oceanography, Anavissos, Attica, Greece**

**ABSTRACT NUMBER: 629 : GEOMORPHOMETRY AS A TOOL TO ESTIMATE VOLUME AND DISTRIBUTION OF CORALLIGENOUS HABITATS ALONG THE APULIAN CONTINENTAL SHELF, [Fabio Marchese](#), University Of Milano- Bicocca, Milan, Milan, Italy**

**ABSTRACT NUMBER: 630 : TESTING THE USE OF UNMANNED AERIAL VEHICLE AND STRUCTURE FROM MOTION TECHNIQUE FOR ACQUISITION OF ULTRA-SHALLOW WATER BATHYMETRIC DATA, [Fabio Marchese](#), University Of Milano-Bicocca, Milan, Italy**

**ABSTRACT NUMBER: 684 : SUBMARINE GEOMORPHOLOGY OF THE STRAIT OF OTRANTO (SOUTHERN ADRIATIC, MEDITERRANEAN SEA), [Mariacristina Prampolini](#), National Council of Research - Institute for Marine Sciences, Bologna, Bologna, Italy**

**THEME: S31 : LANDFORM ASSESSMENT FOR GEODIVERSITY: GENERAL GEOMORPHOLOGY, GEODIVERSITY, GEOCONSERVATION (IAG-WG)..... 392-394**

**ABSTRACT NUMBER: 149 : MAPPING "GEODIVERSITY HOTSPOTS" AT A REGIONAL SCALE: A GIS-BASED INTEGRATED APPROACH WITH APPLICATION TO THE CEARÁ STATE (BRAZIL), [Jean-Pierre Peulvast](#), Univ Paris- Sorbonne, UFR de Géographie, Paris, Île de France, France**

**ABSTRACT NUMBER: 178 : GEOMORPHOLOGICAL MAPPING AND GEODIVERSITY: STUDY AT THE MINAS DO CAMAQUÃ GEOSITE PROTECTION AREA (BRAZIL), [Adriano Simon](#), Pelotas Federal University, Pelotas, Rio Grande Do Sul, Brazil**

**ABSTRACT NUMBER: 274 : AUTOMATIC RECOGNITION OF LOESS LANDFORMS BASED ON RANDOM FOREST METHOD, [Wufan Zhao](#), Key Laboratory of Virtual Geographic Environment, Nanjing Normal University, Nanjing, Jiangsu, China**

**ABSTRACT NUMBER: 707 : GEODIVERSITY ASSESSMENT OF THE SŁUPSK BANK, BALTIC SEA, [Zbigniew Zwolinski](#), Adam Mickiewicz University in Poznan, Poznan, Poland**

**ABSTRACT NUMBER: 728 : LANDSCAPP: A NEW TOOL FOR A SHARED KNOWLEDGE OF TERRITORIAL GEODIVERSITY, [Francesca Lugerì](#), Ispra/unicam, Roma, Italy**

**THEME: S32 : PLANETARY GEOMORPHOLOGY (IAG-WG)..... 394-397**

**ABSTRACT NUMBER: 283 : MARTIAN VALLEY NETWORKS: ESTIMATION OF FLUVIAL EROSION RATE DURING EARLY MARS FROM MARS EXPRESS HRSC DATA, [Veronique Ansan](#), LPGnantes - UMR Cnrs 6112, Nantes, France, France**



**ABSTRACT NUMBER: 300 : MASS WASTING FEATURES IN JUVENTAE CHASMA, MARS: CLUES FROM DEBRIS FLOWS IN LADAKH, INDIA,** Pragya Singh, *Indian Institute of Technology, Bombay, Mumbai, Maharastra, India*

**ABSTRACT NUMBER: 635 : FLUVIO GEOMORPHIC SET-UP OF SYRIA PLANUM PROVENANCE IN SYRIA- THAUMASIA, MARS,** Anil Chavan, *Dept. Of Earth And Env. Science, K.S.K.V. Kachchh University, Bhuj, Bhuj, Gujarat, India*

**ABSTRACT NUMBER: 753 : FACTORS CONTROLLING RECENT ROCKFALLS ON MARS,** Susan Conway, *CNRS UMR6112 Laboratoire de Planetologie et Geodynamique de Nantes, Nantes, Loire Atlantique, France*

**ABSTRACT NUMBER: 754 : HIGH RESOLUTION TOPOGRAPHY AND NUMERICAL SIMULATIONS OF LANDSLIDES ON MARS,** Susan Conway, *CNRS UMR6112 Laboratoire de Planetologie et Geodynamique de Nantes, Nantes, Loire Atlantique, France*

**ABSTRACT NUMBER: 764 : GROUND SHEAR STRENGTH MEASUREMENTS USING LUNAR ROVER WHEELS,** Nikolaus J. Kuhn, *University Of Basel, Basel, Switzerland*

**THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION) ..... 397-409**

**ABSTRACT NUMBER: 48 : QUANTITATIVE ASSESSMENT OF NEOTECTONIC EFFECT ON LANDFORM, DRAINAGE AND SEDIMENT IN DARJEELING HIMALAYAS,** Sunipa Mandal, *Jadavpur University, Kolkata, West Bengal, India*

**ABSTRACT NUMBER: 64 : ESTIMATING THE GEOSTATIC UPLIFT OF EASTERN SHORE OF THE HORMUZ STRAIT (IRAN) THROUGH DATING OF MARINE TERRACES,** Mojtaba Yamani, *University of Tehran, Tehran, Iran*

**ABSTRACT NUMBER: 85 : TECTONIC CONTROL ON THE CHANNEL PATTERN OF ALAKNANDA RIVER IN SRINAGAR VALLEY (GARHWAL HIMALAYA),** Devi Datt Chauniyal, *H.N.B. Gharwal University, Srinagar, Srinagar, Uttarakhand, India*

**ABSTRACT NUMBER: 98 : EVIDENCE FOR QUATERNARY DISPLACEMENTS IN THE TRANS YAMUNA SEGMENT OF THE DOON VALLEY IN NW HIMALAYA: IMPLICATIONS FOR EARTHQUAKE HAZARD ASSESSMENT,** Swakangkha Ghosh, *Wadia Institute of Himalayan Geology, Dehradun, Uttarakhand, India*

**ABSTRACT NUMBER: 113 : DRAINAGE NETWORK EVOLUTION, ACTIVE TECTONICS, GRAVITATIONAL MASS MOVEMENTS: SPATIO-TEMPORAL CAUSAL RELATIONS IN A SECTOR OF THE NORTHERN APENNINES OF ITALY,** Francesco Troiani, *Department of Earth Sciences, Sapienza University of Rome, Rome, Italy*

**ABSTRACT NUMBER: 144 : MORPHOEVOLUTION OF THE SEYMAREH RIVER VALLEY IN THE TECTONICALLY ACTIVE ZAGROS MTS. (IRAN): PREDISPOSING FACTORS AND GEOMORPHIC RESPONSE TO THE LARGEST LANDSLIDE ON EARTH SURFACE,** Marta Della Seta, *Sapienza Università di Roma - Dipartimento di Scienze della Terra, Rome, Italy*

**ABSTRACT NUMBER: 182 : APATITE FISSION TRACK (AFT) LOW TEMPERATURE THERMOCHRONOLOGY CONSTRAINTS ON THE TECTONIC-GEOMORPHIC HISTORY OF THE GRAMPIAN HIGHLAND AREA-SCOTLAND,** Awara M.Amin, *University of Glasgow, Glasgow, Scotland, United Kingdom*

**ABSTRACT NUMBER: 233 : TOPOGRAPHIC METRICS OF TRANSIENT STREAM NETWORKS FOR THE DETECTION OF THE DEFORMATION STYLE OF ACTIVE NORMAL FAULTS: THE CASE OF CITTANOVA FAULT (CALABRIA, SOUTHERN ITALY),** Edoardo Peronace, *Dipartimento Di Scienze Della Terra, Sapienza University Of Rome, Roma, Rm, Italy*

**ABSTRACT NUMBER: 256 : STUDY OF NEOTECTONICS IN AND AROUND DIKRONG RIVER, ASSAM-ARUNACHAL PRADESH,** Archana Singh, *Dibrugarh University, Dibrugarh, Assam, India*

**ABSTRACT NUMBER: 264 : TECTONIC GEOMORPHOLOGY OF THE SIHOR FAULT, EASTERN SAURASHTRA, WESTERN INDIA,** Akash Padmalal, *M. S. University of Baroda, Vadodara, Gujarat, India*

**ABSTRACT NUMBER: 391 : SIGNATURES OF MORPHOTECTONIC ACTIVITIES IN WESTERN UPLAND MAHARASHTRA AND KONKAN REGION, INDIA,** Sumit Das, *Department of Geography, Savitribai Phule Pune University, Pune, Maharashtra, India*

**ABSTRACT NUMBER: 392 : COMPARATIVE STUDY OF LISH AND GISH RIVER SEDIMENTS, SIKKIM-DARJEELING HIMALAYA; A TECTONIC GEOMORPHOLOGICAL APPROACH,** Krity Rai, *Sikkim University, Gangtok, East Sikkim, India*

**ABSTRACT NUMBER: 465 : ASSESSING THE CONTROL OF VARIABLE SEDIMENT ROUTING ON REGIONAL TECTONIC SETTING: A PERFECT SETTING TO DISENTANGLE THE COMPLEXITY,** Saptarshi Dey, *Indian Institute Of Technology Gandhinagar, Gandhinagar, Gujarat, India*

**ABSTRACT NUMBER: 495 : TEESTA RIVER RESPONSE TO NEOTECTONIC ACTIVITY; SEDIMENTOLOGICAL STUDY OF RIVER DEPOSITS, NEAR RANGPO, SIKKIM, INDIA,** Ananda Badekar, *Sikkim University, Gangtok, Sikkim, India*

**ABSTRACT NUMBER: 510 : RELATIONSHIP BETWEEN LANDSLIDE AND ACTIVE TECTONIC ZONES, (CASE STUDY:JAJROOD WATERSHED, IRAN),** Parivash Karami, *Kharazmi University Of Tehran Iran, Theran, Iran*

**ABSTRACT NUMBER: 511 : TECTONIC GEOMORPHOLOGY OF CENTRAL ALBORZ RANGES (IRAN)AN INITIATIVE TOWARDS SEISMIC HAZARD ASSESSMENT,** Parivash Karami, *Kharazmi University Of Tehran Iran, Theran, Iran*

**ABSTRACT NUMBER: 521 : TECTONIC INFLUENCE ON THE LONGITUDINAL PROFILE OF ALAMARVDASHT RIVER, SOUTH OF IRAN,** Hadi Karimi, *Kharazmi University Of Tehran, Tehran, Iran*



**ABSTRACT NUMBER: 524 : GEOMORPHOLOGICAL EXPLANATION OF SWAMPS ON THE BARAK VALLEY, NE INDIA, Nandita Dutta, Assam State Disaster Management Authority, Guwahati, Assam, India**

**ABSTRACT NUMBER: 525 : EXTRACTION OF RIDGES ORDERS FROM DEM TO EVALUATE OF ACTIVE TECTONICS IN CENTRAL ALBORZ MOUNTAINS, Abolghasem Goorabi, University Of Tehran, Tehran, Tehran, Iran**

**ABSTRACT NUMBER: 556 : MORPHOTECTONIC STUDY OF THE GANG RIVER BASIN, WEST KAMENG, ARUNACHAL PRADESH, INDIA, Raghupratim Rakshit, Dept. Of Applied Geology, Dibrugarh University, Dibrugarh, Assam, India**

**ABSTRACT NUMBER: 597 : MORPHOTECTONICS OF A TILTED BLOCK (ORLICKIE – BYSTRZYCKIE MOUNTAINS BLOCK, SUDETES, CENTRAL EUROPE) - WHAT STREAM LONGITUDINAL PROFILES AND VALLEY MORPHOLOGY TELL, Milena Różycka, Institute of Geography and Regional Development, University of Wrocław, Wrocław, Poland**

**ABSTRACT NUMBER: 624 : WATER DIVIDE POSITION AND DRAINAGE PATTERN DIVERSITY IN REGIONAL MORPHOTECTONIC ANALYSIS – A STUDY FROM THE SUDETES, CENTRAL EUROPE, Piotr Migoń, Institute Of Geography And Regional Development, University Of Wrocław, Wrocław, Dolnośląskie, Poland**

**ABSTRACT NUMBER: 672 : TECTONIC CONTROL ON DRAINAGE EVOLUTION AND DEVELOPMENT IN THE SOUTHEASTERN SEGMENT OF PIR PANJAL RANGE, Bashir Ahmad, Department of Geology, Nawakadal School Safakadal, Srinagar, J&K/Kashmir, India**

**ABSTRACT NUMBER: 719 : MUD VOLCANOES OF MAKRAN COAST, IRAN, Keramat Nezhadafzali, University, Jiroft, Kerman, Iran**

**ABSTRACT NUMBER: 726 : THE INFLUENCE OF LUOTIAN DOME UPLIFTS ON THE EASTERN JUSHUI DRAINAGE PATTERN, Jietao Wang, Wuhan Center Of China Geological Survey, Wuhan, Hubei, China**

**THEME: S33-A : TECTONIC GEOMORPHOLOGY OF KACHCHH BASIN ..... 409-412**

**ABSTRACT NUMBER: 179 : THE ROLE OF THE CLIMATE AND HILLSLOPE GEOMETRY IN THE EROSION PROCESSES IN THE CONTINENTAL MARGIN OF SOUTHEAST BRAZIL, Daniel Henrique De Souza, Universidade Estadual Paulista, Rio Claro, São Paulo, Brazil**

**ABSTRACT NUMBER: 365 : TECTONIC IMPACT ON EPHEMERAL RIVERS, AS APPREHENDED BY GEOMORPHIC INDICES WITHIN NW KACHCHH MAINLAND, KACHCHH, INDIA, Madhavi Dabhi, Department of Earth and Environmental Science, KSKV Kachchh University, Bhuj, Gujarat, INDIA**

**ABSTRACT NUMBER: 407 : DRYLAND FLUVIAL RESPONSE TO LATE QUATERNARY CLIMATE, TECTONIC AND SEA LEVEL CHANGES FROM SOUTHERN KACHCHH MAINLAND, WESTERN INDIA: INSIGHTS FROM OPTICAL CHRONOLOGY, SEDIMENTOLOGY AND GEOCHEMISTRY, Archana Das, Institute Of Seismological Research, Gandhinagar, Gujarat, India**

**ABSTRACT NUMBER: 408 : PROVENANCE AND PATHWAYS OF THE MODERN AND LATE HOLOCENE SEDIMENTS OF THE CENTRAL AND WESTERN GREAT RANN OF KACHCHH, WESTERN INDIA, Nisarg Makwana, Department of Earth and Environmental Science, KSKV, Kachchh University, Bhuj, Gujarat, India**

**ABSTRACT NUMBER: 428 : GEOMORPHIC EVIDENCE OF ACTIVE TECTONICS ALONG ISLAND BELT FAULT, KACHCHH: WESTERN INDIA, Rakesh Bhagora, KSKV Kachchh University, Bhuj, Gujarat, India**

**ABSTRACT NUMBER: 669 : TRANSVERSE FAULT SYSTEMS AND THEIR SIGNIFICANCE IN KACHCHH RIFT BASIN: WESTERN INDIA, Chintan Vedpathak, K.S.K.V. Kachchh University, Bhuj, Gujrat, India**

**THEME: S34 : GEOARCHAEOLOGY (IAG-WG)..... 412-414**

**ABSTRACT NUMBER: 187 : THE ENVIRONMENTAL CHANGE AND HUMAN LIFE IN PREHISTORIC TIMES BASED ON THE BANGUDAE PETROGLYPHS ALONG TAEHWA RIVER IN ULSAN-SI, SOUTH KOREA, Sangill Hwang; Kyungpook National University, Daegu, Buk-gu, South Korea**

**ABSTRACT NUMBER: 188 : THE SPATIAL DISTRIBUTION OF THE ANCIENT ‘LIAOZE’ ALONG THE LIAO RIVER AND SHORELINE CHANGE SINCE THE MIDDLE HOLOCENE AROUND LIAODONG BAY IN CHINA, Sangill Hwang, Kyungpook National University, Daegu, Buk-gu South Korea**

**ABSTRACT NUMBER: 400 : OPTICALLY STIMULATED LUMINESCENCE DATING OF SHELL MIDDEN LAYERS FROM UMHLANGA ROCKS, NATAL NORTH COAST, SOUTH AFRICA, Efthimios Karymbalis, Department of Geography, Harokopio University, GR-17671 Kalithea, Athens, Attica, Greece**

**ABSTRACT NUMBER: 532 : GEOARCHAEOLOGICAL APPROACHES TO THE PALAEOLITHIC SURFACE ARTEFACT DISTRIBUTIONS AND HOMININ LANDSCAPE USE IN SW SAUDI ARABIA, Patricia Fanning, Macquarie University, Macquarie University, NSW, Australia**





**THEME: S35 GEOMORPHOLOGICAL HAZARDS AND RISKS (IAG-WG): RISK MITIGATION THROUGH NEW TECHNIQUES UNDER THE CHALLENGES OF ENVIRONMENTAL CHANGES..... 414-416**

**ABSTRACT NUMBER: 186 : STUDY ON THE RELATION BETWEEN SEDIMENT-RELATED DISASTERS AND WEATHER CONDITION FACTORS,** Tomoyuki Tsunoda, *Fujitsu Laboratories Ltd., Kawasaki, Kanagawa, Japan*

**ABSTRACT NUMBER: 451 : WOE MODEL BASED PREDICTION OF SUBSIDENCE OVER THE UNDERGROUND COAL MINES,** Abhijit Manna, *Vidyasagar University, Midnapore, West Bengal, India*

**ABSTRACT NUMBER: 541 : EVALUATING THE 4 NOVEMBER 2015 FLASH FLOOD DISASTER- A CASE STUDY IN WADI A-NATRUN AND WADI AL-FARIGH DEPRESSIONS, WESTERN DESERT, EGYPT,** Amr Saleem, *Ain Shams University, Cairo, Cairo, Egypt*

**ABSTRACT NUMBER: 572 : VULNERABILITY ASSESSMENT OF BUILDINGS TO DEBRIS FLOW THROUGH THE METHOD PTVA (PAPATHOMA TSUNAMI VULNERABILITY ASSESSMENT) APPLIED IN SERRA DO MAR, BRAZIL,** Luzia Matos, *University Of São Paulo (USP), São Paulo, São Paulo, Brazil*

**ABSTRACT NUMBER: 691 : AN ASSESSMENT OF ADMINISTRATIVE BLOCK-WISE FLOOD VULNERABILITY INDEX IN THE ERSTWHILE DISTRICT OF JALPAIGURI, WEST BENGAL, INDIA,** Moitrayee Das, *Chandernagore College, Kolkata, West Bengal, India*

**ABSTRACT NUMBER: 738 : FLOOD FREQUENCY ANALYSIS OF PACHNOI RIVER, ASSAM (INDIA),** Jamini Mahanta, *Cotton College State University, Guwahati, Dibrugarh, Assam, India*

**THEME: S36 : GEOMORPHOSITES AND GEOTOURISM (IAG-WG) ..... 416-418**

**ABSTRACT NUMBER: 420 : GEOMORPHOSITE RECOGNITION AND ASSESSMENT IN NORTHERN MALTA (MEDITERRANEAN SEA): A TOOL FOR SUSTAINABLE TOURISM DEVELOPMENT,** Mauro Soldati, *Department of Chemical and Geological Sciences, University of Modena and Reggio Emilia, Modena, Italy*

**ABSTRACT NUMBER: 475 : GEOPARK OF TOBA CALDERA AS EDUCATIONAL ASPECTS OF GEOMORPHOSITES IN NORTH SUMATRA INDONESIA,** Dwi Wahyuni Nurwihastuti, *Universitas Negeri Medan/Medan State University, Medan, Sumatera Utara, Indonesia*

**ABSTRACT NUMBER: 626 : GEOMORPHOLOGICAL FEATURES OF ARUNACHAL PRADESH, INDIA: A CASE STUDY OF TAWANG AND WEST KAMENG DISTRICTS (POTENTIAL GEOMORPHOSITES),** Swapna Acharjee, *State Remote Sensing Application Centre, Department of Science and Technology, Government of Arunachal Pradesh, Arunachal Pradesh, India*

**ABSTRACT NUMBER: 653 : GEOMORPHOSITES AS A VALUABLE RESOURCE BASE FOR TOURISM DEVELOPMENT: A CASE STUDY OF JHARKHAND (PALIMPSESTS TOPOGRAPHIC MUSEUM IN INDIA),** Jitendra Shukla, *Department Of Geography, Ranchi University, Ranchi, Ranchi, Jharkhand, India*

**ABSTRACT NUMBER: 786 : THE GEOMORPHOSITES OF LEFO AND SANTA-MBU CALDERAS (BAMENDA VOLCANO, CAMEROON VOLCANIC LINE): ASSETS FOR POTENTIAL GEOPARK DEVELOPMENT,** Ghislain Zangmo Tefogoum, *University Of Maroua, Maroua, Far North Region, Cameroon*

**THEME: S37 : DANXIA GEOMORPHOLOGY (IAG-WG) ..... 419-422**

**ABSTRACT NUMBER: 58 : RESEARCH ON AESTHETIC CHARACTERISTICS AND LANDSCAPE VALUE OF THE DANXIA LANDFORMS IN LANGSHAN, HUNAN PROVINCE, CENTRAL CHINA,** Jingbao Li, *College Of Resources And Environmental Sciences, Hunan Normal University, Changsha, Hunan, China*

**ABSTRACT NUMBER: 222 : THE CHARACTERISTICS OF DANXIA GEOMORPHOLOGY AND SOCIAL APPLICATION IN HEYUAN, GUANGDONG,** Muning Zhuo<sup>1</sup>, *Guangdong Key Laboratory of Agricultural Environmental Pollution Integrated Control, Guangdong Institute Of Eco-Environment Technology, Guangzhou, Guangdong, China*

**ABSTRACT NUMBER: 255 : CHARACTERISTICS AND SPATIAL-TEMPORAL DISTRIBUTION OF SOIL EROSION IN SHENZHEN,** Junjie Li, *Guangdong Institute of Eco-Environmental Science & Technology, Guangzhou, Guangdong, China*

**ABSTRACT NUMBER: 294 : MORPHOLOGICAL CHARACTERISTICS OF DANXI LANDFORM IN QINGHAI-TIBET PLATEAU,** Yishan Liao<sup>1</sup>, *Guangdong Institute Of Eco-Environmental Science & Technology, Guangzhou, Guangdong, China*

**ABSTRACT NUMBER: 295 : THE PRELIMINARY STUDY OF MICRO DANXIA GEOMORPHOLOGY,** Dingqiang Li, *Guangdong Institute Of Eco-Environment Technology, Guangzhou, Guangdong, China*

**ABSTRACT NUMBER: 305 : THE PROBLEMS OF REDBEDS DESERTIFICATION IN THE HUMID REGION OF SOUTHERN CHINA,** Peng Hua, *Sun Yat-sen University, Guangzhou, Guangzhou, China*



**THEME: S38 : EXTREME EVENTS IN GEOMORPHOLOGY ..... 422-423**

**ABSTRACT NUMBER: 26 : MAPPING EARTH TREMOR VULNERABILITY IN NIGERIA,** Salamatu Abdullahi, Centre For Geodesy and Geodynamics, Toro, Bauchi, Nigeria

**ABSTRACT NUMBER: 95 : EXTREME GEOMORPHOLOGICAL EVENTS IN THE BAIKAL REGION,** Olga Bazhenova, Sochava Institute Of Geography Siberian Branch Russian Academy Of Sciences, Irkutsk, Irkutskaya Oblast, Russian Federation

**ABSTRACT NUMBER: 677 : CALIBRATION AND EVALUATION OF FLOOD FORECASTING USING WRF-HYDRO SYSTEM,** Soumendu Chatterjee, Presidency University, College Street, West Bengal, India

**THEME: S39 : LAND DEGRADATION AND HAZARDS IN A CHANGING ENVIRONMENT ..... 423-424**

**ABSTRACT NUMBER: 104 : PROGETTO GEOSOGIE: INTEGRATED STUDIES ON RAINFALL THRESHOLDS AND SUSCEPTIBILITY TO LANDSLIDES IN SARDINIA (ITALY),** Stefano Loddo, CFD RAS - Regione Autonoma Della Sardegna, Cagliari, Sardinia, Italy

**ABSTRACT NUMBER: 513 : IMPACT OF PRECIPITATION AND LAND USE CHANGES ON SOIL EROSION IN SMALL CARPATHIAN CATCHMENT,** Malgorzata Kijowska-Strugala, Polish Academy of Sciences, Research Station in Szymbark, Szymbark, PL, Poland

**ABSTRACT NUMBER: 527 : THE IMPACT OF LAND USE ON STREAM CHANNELS IN THE MARGIN OF THE DARJEELING HIMALAYAS IN INDIA,** Pawel Prokop, Institute of Geography and Spatial Organization, Polish Academy of Sciences, Krakow, Malopolska, Poland

**THEME: S40 : YOUNG GEOMORPHOLOGISTS' SESSION ..... 425-426**

**ABSTRACT NUMBER: 32 : TERRAIN ANALYSIS USING GEOMORPHIC AND SEDIMENTARY INDICATORS ; A CASE STUDY OF HAZARIBAGH PLATEAU , JHARKHAN, INDIA,** Pramod Kumar Pandey, UNIVERSITY OF ALLAHABAD, ALLAHABAD, Uttar Pradesh, India

**ABSTRACT NUMBER: 438 : CONTROLS OF ANTHROPOGENIC ACTIVITIES ON THE STREAM POWER DISTRIBUTION OF THE DAMODAR RIVER, INDIA,** Sumantra Biswas, Centre for the Study of Regional Development, Jawaharlal Nehru University, New Delhi, Delhi, India

**ABSTRACT NUMBER: 578 : QUATERNARY DOME-LIKE RELIEF IN THE NORTHERN PARAÍBA BASIN, NORTHEASTERN BRAZIL,** Fabio Corrêa Alves, National Institute For Space Research, INPE, São José Dos Campos, São Paulo, Brazil

**ABSTRACT NUMBER: 781 : APPLICATION OF SWAT AND GEOWEPP MODEL IN PREDICTING THE IMPACT OF STONE BUNDS ON THE GEOMORPHOLOGY, RUNOFF AND EROSION PROCESSES IN ETHIOPIAN HIGHLANDS,** Nigus Demelash Melaku Melaku, University of Natural Resources and Life Sciences, Vienna, Austria



# International Association of Geomorphologists

## Association Internationale des Géomorphologues

(IAG/AIG)

**Prof. Eric Fouache**  
President

### MESSAGE

This is a great pleasure to welcome you at the 9th International Conference on Geomorphology of the International Association of Geomorphologists (AIG/IAG), held in New Delhi at Vigyan Bhawan from 6 to 11 November 2017.

I would like to congratulate the organizing committee, and the scientific committee, for the quality of the scientific program, excursions and sessions, that has been established under the main theme of this conference "Geomorphology and Society". India, as a vast country, is a real laboratory to our discipline and our exchanges promise to be rich.

At a time when the temptations to withdraw from oneself dominate the world, the mission of the International Scientific Associations like ours, is to affirm the interest of openness to others and the collective enrichment that constitutes an open and tolerant world!

Those values are ours at the 9th International Conference of Geomorphology.

You are all welcome!

Namaste !

**Eric Fouache**  
Vice-Chancellor  
Paris-Sorbonne University Abu Dhabi  
&  
President AIG/IAG



**Indian Institute Of Geomorphologists (IGI)**  
**Department of Geography, Allahabad University,**  
**Allahabad - 211002, Uttar Pradesh, India**

**Prof. Savindra Singh**  
President

MESSAGE

It is a matter of pride that the Indian Institute of Geomorphologists is hosting the 9th International Conference of Geomorphology (9th ICGG) at this historical Vigyan Bhawan, New Delhi.

I take this opportunity to extend a very warm welcome to all the participants coming from different parts of the world.

The Indian Institute of Geomorphologists (IGI) aims to promote researches on methodological advancement in the field of geomorphology in India. The idea of forming an association was conceived from International Conference on Geomorphology and Environment held during Jan 17 to 21, 1987 under my Convenership in the Department of Geography, University of Allahabad. After long discussion for two days regarding the name and logo of the association, its goals and objectives, mode of formation, constitution etc. were finally decided to call a general house meeting of all the delegates on January 19, 1987 to finalise the modalities. Ultimately the general house agreed that the name and logo should be Indian Institute of Geomorphologists and IGI respectively. The following objectives were formulated.

1. To bring the entire earth scientists dealing with geomorphology and allied disciplines on a common platform under the banner of IGI.
2. To hold annual conferences in different places of the country,
3. To publish a research journal entitled Indian journal of Geomorphology now it is Journal of Indian Geomorphology,
4. To coordinate researches being carried out on geomorphology and allied disciplines in different universities and laboratories in the country,
5. To encourage young research scholars doing researches in geomorphology by giving awards and certificates,
6. To give more emphasis on researches related to human society and its welfare such as environmental geomorphology, urban geomorphology, environmental hazards and disasters and their management on different spatial and temporal scales etc.

Most of the above mentioned goals and objectives of the IGI have been fulfilled. Till now 29 annual conferences of the IGI with different focal themes have been organised at different Universities and Institutes in India.

The publication of Journal of Indian Geomorphology is smooth and updated. The present volume is a memoir of one of our friend of the Polish Academy of Sciences, Prof. Leszek Starkel. The family of IGI has grown rapidly with its life members exceeded to 557. It has been observed that young Geomorphologists are coming very fast and they are doing quality researches in the field of geomorphology in India. All the life members have contributed much in the growth and progress of this organization.

I wish the conference a grand success under the dynamic leadership of Professor Sunil Kumar De, Convener of this conference and all the Core, Organizing and Scientific Committee Members.

**Prof. Savindra Singh**  
Vice-Chancellor  
President, Indian Institute of Geomorphologists (IGI)  
&  
Chairman, 9th ICG



# International Association of Geomorphologists

## Association Internationale des Géomorphologues

(IAG/AIG)

**Prof. Sunil Kumar De**  
Secretary General

### MESSAGE

Respected Dignitaries on the Dias, Geomorphologists from different dots of the World, ladies and Gentlemen,

On behalf of the Organizing Committee of the 9th International Conference on Geomorphology (9th ICG) as well as from the Indian Institute of Geomorphologists (IGI) I welcome all the leaned participants and dignitaries to this historic capital city of India, New Delhi and to this historic venue Vigyan Bhawan. This is for the first time that the International Conference on Geomorphology is being held in India. The International Geographical Congress of the IGU was held 50 years before, in the year 1968 in this same Hall of Vigyan Bhwan.

I thank all of the Executive Committee Members of the International Association of Geomorphologists (IAG/AIG) to give us an opportunity to hold this memorable Conference in India. This conference is being jointly organized by the Indian Institute of Geomorphologists and the North-Eastern Hill University, Shillong.

India is a vast country having long heritage of science and culture. The country has amazing geomorphological diversity from north to the south and from east to the west with the lofty Himalayan mountain chain in the north, Indian Ocean in the south, desert in the west and plateau in the east. The country also possesses the biggest delta (Bengal Delta) in the world.



Mankind today is facing scores of environmental problems because of overpopulation and increasing pressure on natural resources. Human beings try to impede the spontaneous rhythm of nature by utilizing resources for making their life more hospitable. Lack of awareness often creates imbalance and obstructs the natural functioning of the normal geomorphic processes. The Earth's climate too is predicted to change as human activities are altering the natural environment. Nature always tries to balance itself but is unable to do so due to excessive intervention into the natural systems. the net result is experienced as hazards that may assume proportions of disasters. The effects of such human activities are seen in the form of accelerated soil erosion and in increased frequency of natural hazards – flood, desertification, salinisation, siltation, landslide, shrinking glaciers, rising sea level and depleting ground water.

Keeping this perspective in mind, the theme of the 9th International Conference on Geomorphology is selected as 'Geomorphology and Society'. In the conference, the role of geomorphology on society as well as the societal role in preserving the geomorphological balance and heritage will be discussed.

As many as 740 accepted abstracts (474 oral and 266 posters) were received and have been distributed among 40 subthemes of the conference including 1 (one) Key-Note Lectures, 7 Plenary Lectures, IAG-EGU Joint Session, IGU Commission Sessions, IAG Working Group Sessions and Young Geomorphologists session. Since a few subthemes attracted inadequate number of abstracts some of the sessions have been merged. To accommodate all the oral presentations 6 parallel sessions will be held regularly. 2 pre-conference, 3 mid-conference, 5 post-conference field trips are going to be organized although the proposals were more. One IAG-EGU Intensive Course on 'Geomorphology Field Training in tectonically active mountain regions' for the Young Geomorphologists is going to be held in Dehra Dun. I can assure you that all of the field trips will be exciting.

On behalf of the Organizing Committee I am glad to inform you that this time 37 numbers of Young Geomorphologists have been awarded Scholarship for taking part in this conference out of which 23 Scholarships have been offered by the International Association of Geomorphologists (IAG/AIG), 2 Scholarships by the International Permafrost Association (IPA), 2 Scholarships by the **Italian Association of Physical Geography and Geomorphology (AIGeo)** and **10 Scholarships by the 9th ICG Organizing Committee.**

We are thankful to the Geological Survey of India (GSI), Beta Analytic, Springer Publishing Company and Cambridge University Press for according their kind help through advertisement and contributing for exhibitions. I gratefully




acknowledge the financial support rendered by Science and Engineering Research Board (SERB, DST), Govt. of India; Ministry of Earth Sciences, Govt. of India, Defence Research and Development Organization (DRDO), Govt. of India; Council of Scientific and Industrial Research (CSIR), India; Indian Space Research Organization (ISRO) and Geological Survey of India to organize this 9th International Conference on Geomorphology.

From the core of my heart I wish to place on record our heartfelt thank to all the Core Committee, Organizing Committee and Scientific Committee Members. Since the preparation of the bidding proposal till organizing this memorable event today, all of the members have generously extended their ungrudging support to organize this conference in a befitting manner. I will only mention some names: Prof. Savindra Singh, President of the IGI and the Chairman of the Organizing Committee, who has always inspired us; Prof. V. S. Kale and Prof. Sunando Bandyopadhyay, who have meticulously managed all the technical aspects starting from editing of the financial proposals to preparation of this abstract volume and finalizing the academic programme; Dr. Amal Kar, who has edited 6 tour guide books with tremendous care and Prof. M. N. Kaul, who edited 1 book. Prof. H. S. Sharma and Prof. N. Chandrasekar have guided us at every moment and we have immensely benefited from their long and rich experience. The Scientific Committee Members have helped us in many ways both academically and promoting this Conference internationally, that will be difficult to enumerate.


How can I forget the tireless works of all the officials of the Thomas Cook (India) Ltd.? On behalf of the Organizing Committee I am indeed thankful to Mr. Rajendra Kumar, Mr. Goutam Loadh, Mr. Dharmesh Kumar, Mr. Ranjeet Kumar, Ms. Gunjan Suri, Ms. Mayuri Mishra, Ms. Ichhapurak Kaur and Mr. Amulya Ratan for their professional help from the very beginning starting from the website preparation till the materialization of the conference. All of them has been very humble and hard working.

Last but not the least, hats off to those personalities, who have encouraged, and helped us despite long distance that separated us to ensure successful organization of this conference.

I hope you will enjoy your stay in this historical capital city of Delhi with your native food, beverages and outing.



**Sunil Kumar De**  
Convener, 9th ICG



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**9th International Conference on Geomorphology**  
**Vigyan Bhawan, New Delhi, INDIA**  
**6-11 November, 2017**

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# 9th International Conference on Geomorphology

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The International Geological Congress (IGC), considered to be the Olympics of Geological Sciences is going to be organized in India after a gap of 56 years. 36<sup>th</sup> IGC, a global platform to advance the cause of Earth Sciences is being hosted by the Ministry of Mines [MoM] and the Ministry of Earth Sciences [MoES], Government of India with active support from the Indian National Science Academy and science academies of co-host neighboring countries, viz. Bangladesh, Nepal, Pakistan and Sri Lanka. The Congress is being organized by an autonomous organization, the 36<sup>th</sup> International Geological Congress. The Geological Survey of India is the nodal organization for this event.

The country with mighty Himalayas and its glaciers, icy peaks, deep gorges and vast alluvial plains, cold and warm deserts, mangroves, rain forests and mesmerizing sun drenched beaches, each with its own unique enticing geology has attracted the world since ages. The sub-continent offers everything from Archaean crustal nuclei to present day volcanism which is a must see for geo-tourist bugs.

The Indian sub-continent with its unique diversity of terrain and people invites the world Geoscientific community to converge in India during the 36<sup>th</sup> session of IGC at Delhi in year 2020. The Congress with theme **GEOSCIENCE: The Basic Science for Sustainable Future** will be offering an opportunity to collaborate for developing Geoscience for a better tomorrow.

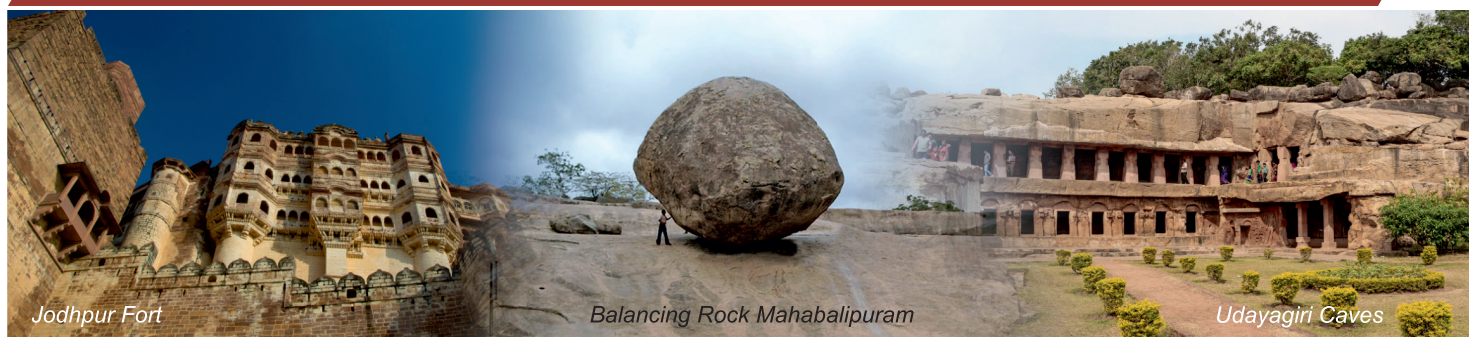
The 36<sup>th</sup> Session of IGC will typically cover the entire gamut of Geoscience with its themes and will have all geologically important sites packaged for Field Excursions. This Congress driven by dictum 'Science for all and not for Profit' aims to make it affordable and accessible for students, young researchers and geoscientists from underdeveloped countries through its unique Geohost Program and a special youth Geohost program for International Union of Geological Sciences (IUGS) member countries.

Visit 36<sup>th</sup> International Geological Congress

**Stand (3 & 4)**

**1<sup>st</sup> Floor, Vigyan Bhawan**

Make sure you are in India for 36<sup>th</sup> IGC to experience the Mystic Continent with all its flavor and above all its unique geology!



Jodhpur Fort

Balancing Rock Mahabalipuram

Udayagiri Caves

**36<sup>th</sup> International Geological Congress**  
2 - 8, March, 2020  
Delhi, INDIA

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ABSTRACTS FOR  
PLENARY SESSIONS

## GEOMORPHOLOGY AND SOCIETY

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**Prof. Michael Crozier**

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“It seems to us a supreme irony that geomorphology must have started as applied ‘science’ which the intellectuals of the period of enlightenment then converted into a ‘pure’ science, and that only now, in our present wisdom, are we again beginning to use it in a practical way as an applied science.” This prescient statement was made almost 25 years ago by Walker and Grabau in their book ‘The Evolution of Geomorphology’.

In this address, I argue that the **‘present wisdom then’** has even more validity and more urgency today. Society is at a moment in history where more people than ever are confronted by the destructive forces of nature as well as the consequences of the overuse of resources, brought about ultimately by the pressure of burgeoning global population.

Population pressure and attendant resource demands have tipped our climate and ocean systems into unprecedented rates of change. And that change is being manifest through intensified weather systems, leading to amplified droughts and heat waves, and increased rainfall intensities, resulting in enhanced soil erosion and landslide activity as well as accelerated inundation and coastal erosion. In support of these postulates, I draw on demonstrated trends in global natural disasters and case studies illustrating the geomorphic impact of human intervention.

Geomorphologists have a unique perspective and a comprehensive tool box of methodologies and techniques that can aid in reducing the negative outcomes of the human footprint. To fulfil an effective role, these attributes need to be applied to the dynamics and interrelationships within earth systems. Understanding how systems respond to the global drivers of accelerating climate change and intensifying human activity has become critical. We need to be able to identify the thresholds of system stability in response to human intervention - the tipping points, and the outcomes of exceedence. We need to know the elasticity (resilience) of systems and the negative and positive feedbacks. Only then are we equipped to recognize the capability and constraints of the land, its suitability for human activities and the limits set by the natural environment. This unique geomorphic approach can contribute significantly to resolving the issues confronting society. But we need to be proactive in engaging with society so that our science is not only heard but incorporated into policy and planning for the benefit of all people.

**Keywords:** geomorphology; society; human impact

### Plenary Lecture -1

## APPLICATIONS OF GEOSPATIAL TECHNOLOGY IN GEOMORPHOLOGY: HISTORICAL REVIEW AND FUTURE PERSPECTIVES

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Quantitative landform analysis using geospatial technology is one of the most popular topics in today’s geomorphology. It has a long background history. Traditional geomorphology in the 19th Century relied on field surveys to describe landforms and surficial deposits. In the early 20th Century, aerial photos became available, enabling the production of topographic maps with contour lines using photogrammetry. Such maps became important sources of geomorphological information, including manually-derived geomorphometric data. In the mid-20th Century, statistical analysis of geomorphometric parameters such as the number and length of streams and slope angle became a method of quantitative geomorphology, although it depended on tedious manual work. Increasing availability of computers and digital elevation models (DEMs) since the 1960s allowed more efficient derivation and analysis of geomorphometric data. This trend was accelerated after the introduction of geographical information systems (GIS) to geomorphology in the early 1990s. Since then some major advances have been made. For example, 1) resolution of available DEMs has significantly improved thanks to modern remote sensing technology, enabling the detection and analysis of subtle topographic features; 2) analysis of geomorphometric data along with other environmental data such as geology and vegetation has become easier, providing deeper understanding of factors controlling landform development; and 3) newer mathematical or statistical models including artificial intelligence have been employed to better explain geomorphological phenomena. Although these historical advances are significant, they might have made geomorphology more technical than scientific. For example, some geomorphologists today are also considered to be excellent surveyors with tools including drones, terrestrial laser scanners, and GPS devices, but their main research outcomes may be high-resolution topographic data and information about their errors, with relatively limited geomorphological reasoning. This presentation reviews the history of morphometry and geospatial data in geomorphology, describes current status and existing problems, and provides some future perspectives.



## Prof. S. R. Basu Memorial Plenary Lecture -2

### GEOMORPHOLOGY: MY WAY

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#### Prof. Morgan De Dapper

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Research Unit 'Regional Geomorphology & Geo-archaeology' Belgium  
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## Plenary Lecture -3

### APPLIED GEOMORPHOLOGICAL INVESTIGATIONS USING THE TRENCHING TECHNIQUE. SINKHOLES, FAULTS, LANDSLIDES, FLOODS

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#### Prof. Francisco Gutierrez

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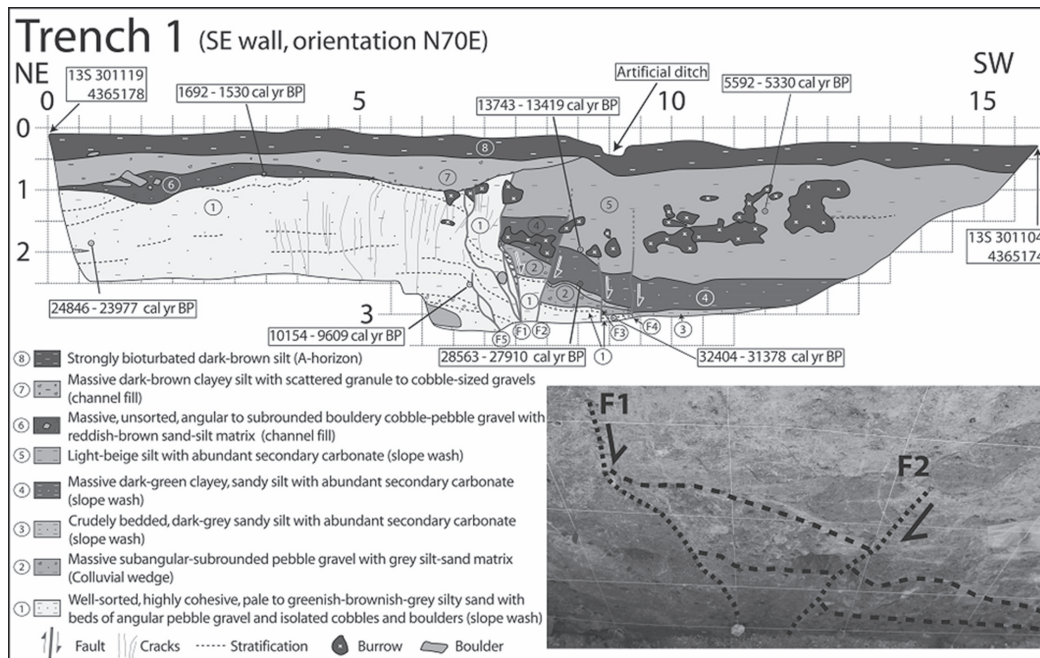
The trenching technique involves the excavation of trenches at specific sites selected on the basis of geomorphic criteria. The resulting artificial exposures allow the detailed investigation of shallow deposits (stratigraphic trenches) and/or recent deformation structures (structural trenches). Trenching has been mainly applied in paleoseismological investigations aimed at characterising active faults and assessing their seismogenic potential. However, it can be also used to investigate other hazardous geomorphic processes that involve the deformation of the ground surface, including landslides, sacking, gravitational faults, sinkholes and earth fissures. The analysis of the stratigraphic and structural relationships exposed in structural trenches (retrodeformation analysis) in combination with geochronological data provide a great deal of information of relevance for hazard assessment: (1) precise location of structures; (2) deformation style; (3) kinematic regime (progressive vs. episodic); (4) strain magnitude and rate; (5) recurrence and timing of surface deformation episodes, particularly the most recent event. The methodology and its usefulness in applied geomorphology will be illustrated through a number of case studies, including large landslides in reservoirs, sacking attributable to paleoseismic activity, normal and flexural-slip gravitational faults, active sinkholes affecting human structures or located at sites selected for critical structures, fissures induced by groundwater withdrawal. Knowledge on the past behaviour of the deformation phenomena may be used as objective data for hazard and risk assessment and the design of mitigation measures. Trenches may be highly useful in Quaternary and palaeoenvironmental investigations, providing excellent exposures for understanding the architecture of the deposits, performing high-resolution stratigraphic and sedimentological studies, and collecting sampling. Some examples of stratigraphic trenches will be also presented (paleolakes, eolian deposits, paleoflood records).



Trench dug in a sacking trough in the Pyrenees



Trenching investigation in paleolakes associated with tufa mounds, Pyrenees



Trench dug across a flexural-slip fault scarp related to evaporite dissolution (Grand Hogback Monocline, Rocky Mountains, Colorado)

#### Plenary Lecture -4

### EQUILIBRIUM THEORY, EVOLUTION AND LEAST ACTION PRINCIPLE; FACTORS DETERMINING SELF-ADJUSTMENT IN GEOMORPHOLOGY AND EARTH'S FLUVIAL STRATIGRAPHIC RECORD

Prof. Gerald C. Nanson

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A fascinating characteristic of alluvial rivers is that they self-adjust. If a channel is too wide it narrows, too steep it meanders or braids, too fast and it roughens its boundary. In short, rivers evolve to minimise their action, but how do they 'know' to do this? Until recently no universal agreement for a philosophical or scientific methodological framework has been proposed to guide the study of fluvial geomorphology. Least action principle (LAP) provides a new paradigm for river research by identifying the attractor state controlling river channel evolution. It is the theoretical basis of variational mechanics and is exemplified in rivers in the form of maximum flow efficiency (MFE), linking major advances in theoretical physics to fluvial geomorphology, hydraulic engineering and sedimentology. LAP explains that alluvial rivers self-adjust (evolve) towards an optimum state whereby they do the work imposed upon them by transporting their sediment load using the least amount of energy (i.e. they adopt MFE). Because of Earth's continuing tectonics

and abundant runoff, most rivers are significantly overpowered. They create dynamic-equilibrium forms to shed excess energy and maximise their stability. A few are underpowered and adjust their form to conserve energy, disperse and deposit excess sediment and remain relatively stable. Very few rivers occupy the 'Goldilocks zone' where the valley and energy gradients are equal. Some examples of this last type are illustrated from the ancient, barely-eroding surface of the arid Australian continent. Bedforms in rivers are of two types; those that create roughness to consume surplus energy and those that minimise roughness and store surplus load. LAP explains profound biases in Earth's surviving stratigraphic record. Meanders are an energy-shedding mechanism and sequester little sediment; all known sequences are <50m thick. In contrast, low-energy braided and anabranching systems have no excess energy so dominate Earth's stratigraphic record by sequestering sediment piles over a kilometre in thickness and up to several hundred kilometres wide. LAP provides a universal, rational explanation for why alluvial rivers strategically evolve to change their width/depth ratios, planforms, bedforms and erosion or deposition to achieve stable equilibrium in response to changing externally-imposed sediment loads and energy conditions.

**Key words:** Least action; equilibrium theory; geomorphological evolution; self-adjustment; alluvial stratigraphy

#### Plenary Lecture -5

### INDIAN GEOMORPHOLOGY : PAST, PRESENT AND FUTURE

**Prof. Savindra Singh**

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The development of geomorphological researches in India has passed through several distinct phases to attain its present status of field-based geomorphology e.g. periods of descriptive geomorphology, regional geomorphology, quantitative geomorphology, process geomorphology, applied and environmental geomorphology, and field-based geomorphology. The Period of Descriptive Geomorphology from Runnel's work in 1781 on Ganges and Brahmaputra to 1950 was devoted to the descriptions of the structure and origin of the Himalayas, Indo-Gangetic Plains and parts of foreland of Indian Peninsula. The second period of Regional Geomorphology from 1950 to 1970 was confined to the description of different physiographic regions of Peninsular India, mainly Chotanagpur Plateau and Maharashtra Plateau based on topographical maps, district gazetteers, memoirs and records of Geological Society of India and limited field work.

The post-21st IGU Congress period (the 21st International Geographical Congress was held in 1968 in New Delhi, India) witnessed an upsurge in geomorphological researches by Indian geoscientists in the fields of fluvial, arid, glacial, structural and quantitative geomorphology wherein morphometric techniques were widely used (Savindra Singh and S. S. Ojha, 1996). Most of works on form-geomorphology were still based on information derived from topographical maps, limited use of satellite images and field studies. The salient aspects of geomorphic researches between 1950 and 1970 were related to subjective explanation of landforms on the lines of Davisian model of landscape evolution.

The post-1st ICG Conference at Manchester in 1985 and 1st International Conference on Geomorphology and Environment and establishment of Indian Institute of Geomorphologists (IGI) at Allahabad in 1987 witnessed increased enthusiasm in the study of causal relationships between landforms and processes based on field instrumentation and measurement of processes at shorter spatial and temporal scales. Significant works were done in determining palaeofloods; monitoring of processes of gully erosion sedimentation and ravination in different regions; experimentation of geomaterials of gully erosion; wave generation and coastal erosion; instrumentation and measurement of glacial processes mainly ablation and retreat of the Himalayan glaciers; instrumentation and measurement of landslides in Darjeeling Himalayas; monitoring of sea beach processes along the western coasts; development of models of sea waves and coastal erosion in laboratories; monitoring of spatio-temporal changes of landscapes in Sundarban areas of West Bengal; monitoring of impacts of human activities on geomorphic processes and landform changes, and climate changes and desertification in Rajasthan etc.

In spite of overdominance of human geography in Indian Universities the scientific studies of different aspects of modern geomorphology by geographers, geologists, marine scientists etc. have bright future in India.

#### Plenary Lecture -6

### RIVERS IN THE HUMID TROPICS

**Prof. Avijit Gupta**

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The tropics are an area of radiative surplus, bounded by anticyclonic circulations near the 30° latitudes. About half of the tropical land surface is humid. A number of rivers in the humid tropics display similar forms and functions following seasonal climatic characteristics. The differences among the rivers, however, can be attributed commonly to regional lithology and relief which control

the sediment. The expectations are based on a limited number of investigations, as fluvial studies in the tropics were not common until the last several decades. Very few rivers were studied beyond mapping, and commonly the exoticness of rivers was studied; good for idiosyncratic observations, not generalisation. Most studies were carried out by engineers on rivers heavily utilised by resident population. The picture that emerged was of discrete and different rivers in spite of the process-based approach which revolutionised fluvial geomorphology since the 1950s.

Given the large areal coverage of the tropics and transfer of considerable sediments to deltas and coastal seas, the limited role of humid tropical rivers in constructing theoretical fluvial geomorphology is surprising, especially regarding effects of seasonality and frequent high-magnitude floods to transfer huge amount of stored sediment. The tropical rivers were modified in the Quaternary, and afterwards by anthropological alteration. It is likely that the effect of current climate changes will accelerate certain fluvial processes and modify tropical rivers.

We explore (1) the common riverine physiography and processes in the tropics, and (2) the possible changing characteristics of the tropical rivers. We may need to modify our teaching and research on rivers in the seasonal tropics.

*Keyword:* tropical rivers; channel forms; sediment; effect of climate change

### Plenary Lecture -7

## GEOMORPHOLOGY, DISASTER RISK REDUCTION & POLICY MAKING: ON THE ROAD TO SENDAI

**Prof. Irasema Alcántara-Ayala**

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As a follow up of the Hyogo Framework for Action, the Sendai Framework for Disaster Risk Reduction was established in 2015. It aims at achieving "the substantial reduction of disaster risk and losses in lives, livelihoods and health and in the economic, physical, social, cultural and environmental assets of persons, businesses, communities and countries" by "Preventing new and reducing existing disaster risk through the implementation of integrated and inclusive economic, structural, legal, social, health, cultural, educational, environmental, technological, political and institutional measures that prevent and reduce hazard exposure and vulnerability to disaster, increase preparedness for response and recovery, and thus strengthen resilience" (UNISDR, 2015).

Identifying and addressing disaster risk drivers is required for reducing existing and avoiding the creation of new risks. Demographic growth, social deterioration, environmental degradation, climate change, patterns of land use - both urban and rural -, and lack of or poor urban development are among the main drivers of risk.

It is well documented that land use changes can lead to a series of processes that exacerbate disaster risk and disasters. Therefore, understanding the likely impact of geomorphic processes in addition to those induced by anthropogenic activities on the landscape are very significant for disaster risk reduction. Nonetheless, although it is clear that science has contributed to a major extent to the understanding of geomorphological and other type of hazards and different aspects of vulnerability and exposure, there is still a major gap between science and policy making with regard to disaster risk management. In this paper, attention is given to some of the key challenges for the implementation of the Sendai Framework for Disaster Risk Reduction.

*Keywords:* geomorphology, disaster risk reduction, policy making, Sendai Framework



ABSTRACTS FOR  
ORAL PRESENTATION



THEME: S1 : THEORETICAL GEOMORPHOLOGY

ABSTRACT NUMBER: 17

## SHOULD THEORY IN GEOMORPHOLOGY TAKE HUMAN IMPACTS AND HUMAN AGENCY SERIOUSLY?

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Theoretical geomorphology has traditionally focussed on modelling the geophysical behaviour of geomorphic systems. Drivers of change are identified and/or complexity and self-organization are appealed to when cause and effect relationships are obscure. Immanence is assumed and contingency is either ignored or accommodated with difficulty. The geomorphology of the 21st. Century is increasingly influenced by human impacts, which have become important drivers of geomorphic change. Such impacts are modelled sufficiently effectively to produce satisfactory predictions. The new challenge is the role of human agency: value systems, policy decisions and radical uncertainty with respect to geomorphic outcomes. Can we continue to rely on exclusively geophysical theory or do we need new hermeneutics and/or socially critical models to provide more flexible alternative predictions of future geomorphic responses? The answer to this question is not self-evident but the future of our discipline may be at stake. Arguments for and against exclusively geophysical theory will be reviewed.

**Keyword:** theory; geomorphology; immanence; contingency; human impacts; human agency; prediction; uncertainty.

THEME: S1 : THEORETICAL GEOMORPHOLOGY

ABSTRACT NUMBER: 143

## THE MORPHOLOGY OF TRANSITION ZONES IN MOUNTAIN REGIONS

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Transition zone is a part of the Earth's surface, located between tectonically active mountain ranges and foothills, with minimal manifestation of neotectonic movements and with structural characteristics of low mountains. The need for transition zones arises from the line leveling of multidirectional tectonic movements that result in the development of the general morphology of those areas. Due to selective denudation of intrusive rocks, peculiar relief of dome - and -ring morphostructures is formed here; in combination with planation surfaces covered by waste mantle. Altitudes of transition zones generally reach 1000 m above sea level. Transition zones are located in all mountain regions of the world.

Virtually all known gold deposits of the Asian continent are spatially confined in the transition zones. In America, as well as in Australia, the same tendency is traced. The African continent is of exceptional interest for the study. Here are the most ancient world known, developed about 5000 years ago, the gold deposits of Egypt, Ethiopia and Southern Rhodesia. The known diamond continental deposits also reveal the same geographical distribution.

Another important aspect in the transition zones identification is the possibility of establishing a scheme in the Paleolithic monuments distribution and highlighting the connections between the human origin and the area morphology. The geographical distribution mapping of such monuments around the world, revealed almost the complete coincidence of these locations with the transition zone of mountain systems. Thus the ancient man and his descendants, with their physiological characteristics, could not live without endless consequences for themselves for an infinitely long time on the terrain with absolute elevations above 1000 m.

**Keyword:** transition zone; dome, ring morphostructure



THEME: S1 : THEORETICAL GEOMORPHOLOGY

ABSTRACT NUMBER: 165

## GOETHE'S MORPHOLOGICAL METHOD AND ITS INFLUENCE IN GEOMORPHOLOGY

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Nowadays Goethe's method about geology and geomorphology is put aside in history and philosophy of science studies and also for the practices and application developed for those sciences. However the Goethe's view about natural phenomenon especially concerning geology and geomorphology can contribute for a more integrative view of the facts, once Goethe created a method of analyze for the natural sciences which can be apply for those branches. The method of Goethe is known as morphological method and it is very widespread in botany, though its application goes beyond this field, because as a natural scientist he has engaged to geology and geomorphology as well.

In order to understand his method is also important highlight his view of nature, which was thought as a whole, organic and harmonious, because his analyses had as premises to start from the whole to understand the parts. According to him the comprehension of the particular phenomenal is only passageway for the whole.

Applying Goethe's morphological method the scientist is considered an observer of nature and he should look at nature free of judgments and pre-established concepts, because the phenomenal that happen in nature will disclose and it will be possible to understand them. In this way, his method did not organize or classified, but it develop and realize, such development should made effective for the observer in contact within the phenomenal. So the observer should be attentive not only with the external characteristics but should make an effort to reach the knowledge of the internal characteristics.

Considering those facts Goethe looked for uncover the formation of Earth's surface and tried to establish a base law that could be apply for understanding all the rocks formation. The method of Goethe could be explored for current geomorphology in order to contribute for more integrative studies.



THEME: S1 : THEORETICAL GEOMORPHOLOGY



ABSTRACT NUMBER: 204

## GEOMORPHOLOGY AND SOCIETY: A POLITICAL-ECONOMIC INTERPRETATION OF EARTHSCAPES

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The term 'earthscapes' supposes to identify a piece of the earth's surface holistically, either having predominant natural elements or being heavily altered by anthropogenic process. Anthropocene epoch is considered as a distinct geological age to recognize human beings as a prominent agent of irreversible landscape development to mark the intricate relationship between geomorphology and human society. The relationship has been very dynamic and can be interpreted in terms of political-economic perspective of human history. The contemporary earthscape is definitely an accumulation of anthropogenic built-up elements produced due to continuous change in land use and land cover for agriculture, mining, industries, urbanization, etc. The so called progress of human civilization bears several testimonies of exploitation of natural landscape by men over the last few centuries to necessitate conservation of the natural elements within the man-made cultural landscapes in the recent times. The feudal and colonial tyranny practically robbed the nature and also the people surviving on the natural resources. Degradation of natural landscape due to irrational and/ or over utilization was the ultimate outcome. The post-colonial period and also the recent globalization of trade and commerce have facilitated world-wide redevelopment of landscapes with much emphasis on high-intensive agriculture, destructive mining, imbalanced hydro-geomorphic environment, unsustainable urban-industrial growth, etc. Huge increase of population, especially in the global South, and significant shift in occupation pattern from primary engagements to tertiary service sector have promoted artificial landscaping, which in many of the cases have been found to be socially exclusive favouring the limited number of wealthy people. This review paper, based on analysis of existing literatures and information, is an attempt to address issues concerning geomorphology and society for human development through sustainable resources management particularly of the developing countries of the tropics, like India..

**Keyword:** Geomorphology and society, Political-economy of earthscape, Anthropocene



THEME: S1 : THEORETICAL GEOMORPHOLOGY

ABSTRACT NUMBER: 240

ON THE SCALE-DEPENDENCY AND MECHANICAL PRECONDITIONING  
OF PARAGLACIAL ROCK SLOPE INSTABILITY –  
CONCEPTUAL CONSIDERATIONS FROM MODELLING, FIELD AND LABORATORY STUDIES

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Today, the paraglacial concept is commonly used in geomorphology as a framework for investigating the reworking of postglacial sediments, particularly in fluvial systems. Within this 'sediment-dominated' research focus, however, the concept has rarely been applied from a rock mechanical perspective in the context of rock slope instability. The paraglacial response of deglaciated bedrock has not been well-explored, either theoretically and empirically, despite the fact that it is the key source of the paraglacial sediment cascade and poses significant natural hazards in mountain valleys.

Here we apply the paraglacial concept of Church and Ryder to high-alpine bedrock terrain undergoing glacier retreat. We address three spatiotemporal levels of paraglacial rockwall failures by linking recent findings from (i) valley-scale logistic regression and machine learning models, (ii) rockwall-scale geotechnical and temperature surveys and (iii) micro-scale rock weathering experiments of freeze-thaw and thermal cycling.

We propose a conceptual model in which permafrost degradation after glacier retreat determines the spatiotemporal clustering of paraglacial rock slope instabilities with highest peaks in recently deglaciated upper basins. For the valley-scale (i), we assume two contrasting, mechanically preconditioned scenarios of paraglacial rockwall adjustment. Dependent on the rock mass strength and the tectonically-derived dip direction of joints, the intensity and timing of paraglacial failures may evolve either exponentially or linearly. At the scale of individual rockwalls (ii), however, different kinematic conditions and depth-varying frost cracking intensities may lead to complex magnitude-frequency patterns that overlay the total, higher-scale declining rate. We discuss whether the lowest failure rates and flake-like detachments during the late-paraglacial period could be linked to a permafrost-free, but likely micro-scale weathering regime of freeze-thaw and thermal cycling (iii). We hypothesise that the final adjustment of deglaciated rockwalls to non-glacial strength conditions is inherently pre-defined by the micro-scale bedrock fracturing and can differ highly between anacinal and cataclinal rock slopes.

THEME: S1 : THEORETICAL GEOMORPHOLOGY

ABSTRACT NUMBER: 412

UNDERSTANDING GEOMORPHIC THRESHOLD THROUGH EMPIRICAL STUDIES

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Close observation, continuous monitoring and experiments reveal that geomorphic processes become active only after the major controlling factors attain their critical (threshold) values. Study on debris slide for a duration of 6 years showed that slopes are not changing continuously but slides suddenly after attaining threshold height (5m), steepness (21°) and critical rain (95mm). Plot experiment under different exposure condition shows that erosion starts after receiving 4mm/hr rain that are sufficient to generate threshold stress. Channel bed scouring also started after the threshold shear stress has been achieved due to critical constriction and reduction of W/D ratio. Close monitoring, observation and experiment help in understanding exact time, condition and mechanism of such catastrophic changes for the sake of robust explanation and effective management.

**Keywords:** Monitoring; Experiments; Threshold; Episodic Change



THEME: S1 : THEORETICAL GEOMORPHOLOGY

ABSTRACT NUMBER: 469

## CHARACTERISING AUTOGENIC AND ALLOGENIC CONTROLS OF CHANNEL AVULSION USING HIGH RESOLUTION CHRONOLOGY OF FLUVIAL FAN STRATIGRAPHY IN NW GANGES BASIN

Ajit Singh<sup>1\*</sup>; Sanjeev Gupta<sup>1</sup>; Rajiv Sinha<sup>2</sup>; Alexander Densmore<sup>3</sup>; Jan-Pieter Buylaert<sup>4</sup>; Suneel Kumar Joshi<sup>2</sup>; Kristina Thomsen<sup>4</sup>; Andrew Murray<sup>5</sup>; Philippa Mason<sup>1</sup>; Wout van Dijk<sup>3</sup>; Andrew Carter<sup>6</sup>; Mayank Jain<sup>4</sup>

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The distribution of sandbodies in ancient fluvial successions represents the history of channel avulsion during the development of fluvial fan stratigraphy. This can be interpreted in terms of sedimentary evolution of fluvial fans in response to autogenic and allogenic controls on channel avulsions. However precise field estimates of dimensions and distribution of sandbodies both in space and time is challenged not only by the discontinuous archive of fluvial records but also by vast regional extent of fluvial fans. Here, we report the results of a detailed analysis of late Quaternary fluvial fan systems formed by the major Himalayan rivers, the Sutlej and Yamuna, in the northwestern Indo-Gangetic basin in NW India. We used nine sediment cores ~50 m deep to map the spatial distribution of channel sand bodies deposited by these rivers and develop a chronostratigraphic model for the fluvial succession. Discontinuous channel sand bodies are separated by floodplain fines that show evidence of pedogenesis and mark the end of episodes of channel aggradation. We obtained 46 optically stimulated luminescence (OSL) dates through the fan stratigraphy to bracket the timing of channel-filling episodes, and their spatial distribution. Mapping of sand bodies coupled with chronostratigraphic constraints permits reconstruction of channel migration patterns and their timing across parts of the Sutlej-Yamuna fans. Chronostratigraphy permits temporal correlation with published measures of monsoon variability. Our results show that much of the fan stratigraphy is characterised by channel sand bodies that show variation in age with spatial position along the transect suggesting that the stratigraphic record of the fan was built by avulsing fluvial channels. However, in the upper part of the succession, the OSL results reveal the presence of a major incised valley fill eroded into the fan stratigraphy. The scale and timing of valley incision are suggestive of climatic control on fan evolution.

THEME: S1 : THEORETICAL GEOMORPHOLOGY

ABSTRACT NUMBER: 472

## CAUSES AND MECHANISMS OF SEDIMENTATION IN THE LOWER REACH OF THE RUPNARAYAN RIVER, WEST BENGAL, INDIA

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Continuous sedimentation and development of shoal area creates varieties of detrimental problems like, drainage decay, deterioration of navigability, unavailability of water resources, water storage and resultant flood, river bank erosion, loss of settlements and properties and social dislocation in the lower reach of the Rupnarayan River. The present study attempts to explain the causes and mechanisms of sedimentation in the lower reach in a holistic approach. Depth of river is measured by echo sounder and the water velocity is measured by digital current meter. Density of water and sediment is tested in the laboratory of Indian Institute of Technology (IIT), Kharagpur. Textural characteristics of sediment are identified by sieving technique. Available and Critical shear stress have been calculated following DuBoys (1879) and Shield (1936) formula. Sedimentation in this river is the result of combined interaction of riverine and marine processes. Channel asymmetry, channel diversification and separation of flow, seasonal variation of water discharge during high and low tide, tidal asymmetry and associated fluctuation of shear stress are the main causative and controlling factors of sedimentation. Tidal asymmetry increases from downstream (2 hours at Geonkhali) to upstream (6 hours at Kolaghat) which indicates that high tide

is shorter and stronger than low tide. Shear stress during swifter and stronger high tide is more than in slower and weaker low tide. The available shear stress, during low tide is less than the critical shear stress for entrainment of sediment and this is found to be the main cause of sedimentation in the area under study, especially in non-monsoon season when this deviation becomes maximum.

**Keywords:** Causes and mechanisms of sedimentation; flow separation; tidal asymmetry; available and critical shear stress

*THEME: S1 : THEORETICAL GEOMORPHOLOGY*

**ABSTRACT NUMBER: 530**

## **THE GEOMORPHIC CELL: A BASIS FOR STUDYING HYDRO-GEOMORPHIC CONNECTIVITY**

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Connectivity is an important concept for understanding the transport of water and sediments in hydro-geomorphic systems. Any attempt to measure connectivity within a system requires a set of entities (i.e. fundamental units or FUs) to be defined that permit the connectivity amongst them to be quantified. Here we propose the geomorphic cell as such an entity. We provide a means to identify these cells, define a terminology for describing cell state, and identify the pathways of connections to and from cells (connecteins). Geomorphic cells are conceptualized as structural entities made up of land elements with similar hydro-geomorphic potential determined by factors that influence its capability to store and transfer water and sediment (e.g. topography, land cover/vegetation, soil type), while the actual cell state depends on the degree of water saturation and sediment availability.

**Keywords:** Connectivity; Fundamental unit; landscape structure and function; complexity

*THEME: S1 : THEORETICAL GEOMORPHOLOGY*

**ABSTRACT NUMBER: 544**

## **PROCESS INTERPRETATION USING FRACTAL DIMENSION: A CASE STUDY FROM THE NW HIMALAYA**

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Landscape morphology in the Himalaya has a strong imprint of the Himalayan tectonics along with surface processes. Knowledge of fractal dimension of the landscape improves our understanding about the role of these forcings on its space filling capacity. Tectonics brings about some remarkable changes in the land surface shape, such as steeply incised valleys, which increases fractal dimension of the landscape. The objective of our work is to find a relation between the relative tectonic activity, underlying lithology and the fractal dimension of the surface, in Kangra reentrant, NW Himalaya. We have used the semi-variogram method for estimating the fractal dimension, which has been implemented in Python. The analysis was carried out using digital elevation model (1 arcsec), provided by SRTM. The dimensions were estimated for a number of square boxes (100 by 100 pixel), traversing the whole area, and later interpolated to give a thematic map for the entire reentrant. Fractal dimension was found to be well correlated with the relative tectonic activity. Additionally, our results indicated a negative correlation between the fractal dimension and rock erodibility. For homogenous lithology (for ex. Siwaliks in sub Himalayas), estimated fractal dimension is around 2.6-2.7 in regions under tectonic influence, whereas it is closer to 2 in not so tectonically active regions. Hence, given similar lithology, we found the fractal dimension to be a more efficient and accurate index for process-form relations, especially the relative tectonic activity of a region, as it explains the regional variability of land surface elevation, unlike other indices, which assume the elevation to be an aleatory/stochastic variable. Additionally it brings forth the scale dependence of topographic roughness, which may give an indication of different physical processes acting at several scales.

**Keywords:** Fractal dimension; Index of relative tectonic activity; Scale (in)dependence



THEME: S1 : THEORETICAL GEOMORPHOLOGY

ABSTRACT NUMBER: 621

## CONCEPTS AND MODELS FOR THE GROUND THERMAL REGIME AS A TOOL TO UNDERSTAND GEOMORPHOLOGICAL PROCESSES AND LANDSCAPE DEVELOPMENT IN COLD MOUNTAIN ENVIRONMENTS

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The role of the ground thermal regime on geomorphological processes in settings associated to steep slopes has received considerable attention in the past. It is evident from recent studies that e.g. rock walls have a profound effect on the thermal regime in mountain sides, a.o. influencing rock wall stability, weathering regimes and glacier-permafrost interaction in space and time. This presentation discusses the importance of the thermal regime in space and time on geomorphological processes in steep slopes. We combine direct observations of air, ground and rock wall temperatures with numerical simulations using a 2D transient thermal model (CryoGRID 2D). We analyze how thermal gradients in rock walls or coastal cliffs may influence important geomorphological processes related to weathering, talus developments, material accumulation and ice aggregation in coarse material. On longer time scales permafrost dynamics associated with glaciation and deglaciation phases, may have influenced the development and stability of large-scale valley systems.

THEME: S2 : APPLIED GEOMORPHOLOGY

ABSTRACT NUMBER: 4

## SEISMIC GEOMORPHOLOGY FOR HYDROCARBON EXPLORATION

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Quantitative seismic geomorphology (QSG) is a new direction in the analysis of seismic data . Partial differential equation(PDE) and wavelet transform are employed for seismic image processing and interpretation for geomorphological studies. Application of seismic geomorphology and stratigraphy of depositional elements in deep-water settings, detailed seismic interpretation and analysis of key stratal discontinuities- Seismic incision features interpreted as channels, Continental Slope and Base-of-slope Systems, for Frontier Hydrocarbon Exploration, Arctic petroleum systems, seismic geomorphology applications to hydrocarbon exploration and production 3-D Seismic Geomorphology of a Deepwater Slope Channel System, Imaging Elements of Depositional Systems from Shelf to Deep Basin using 3D Seismic Data, etc are need of hydrocarbon industry. 3D seismic data can play a vital role in hydrocarbon exploration and development especially with regard to mitigating risk associated with presence of reservoir, source, and seal facies. Such data can afford direct imaging of depositional elements, which can then be analyzed using seismic geomorphology and seismic stratigraphy to yield predictions of lithologic distribution, insights to compartmentalization, and identification of stratigraphic trapping possibilities. Interpretation Techniques can be employed to extract stratigraphic insights from seismic data. These include: time slices; flattened time slices (i.e., horizon slices); reflection attribute mapping; interval attribute mapping; sub-volume detection (i.e., opacity rendering), and voxbody picking. 3D seismic data to characterize the geomorphology and stratigraphy of deep-water depositional elements and infer process of deposition where appropriate. The following depositional elements will be discussed: turbidity flow leveed channels; overbank sediment waves and levees; frontal splays or distributary-channel complexes; crevasse-splay complexes, and debris-flow channels, lobes, and sheets. Exploration activities along continental margins which contains the shelf and deep water parts of these dynamic systems, imaging them to a high level of detail, allowing high-resolution mapping of depositional sequences and depositional elements and fluid flow phenomena, which help constrain the presence of petroleum systems.



THEME: S2 : APPLIED GEOMORPHOLOGY

ABSTRACT NUMBER: 126

## UNDERSTANDING THE SHIFTING BEHAVIOUR OF RIVER KOSI: STEERING TOWARDS A MORE RATIONAL HYPOTHESIS

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Kosi is one of the most enigmatic rivers on account of its course hyperkinesis which lends the river its characteristic course instability and frequent morphological avulsions forming the world's largest morphological alluvial fan. Many theories have been advanced to explain this aberrant but anomalous propensity to shift course and these may be grouped into two broad categories namely (i) Autocyclic processes, and (ii) Tectonics processes.

Autocyclic processes allude to the natural phenomenology of upland erosion and sediment deposition and arguably, the latter theory has been the more dominant viewpoint amongst researchers and other investigators in their quest to explain the observed migration of the Kosi. A serious drawback, however, has been its failure to explain the recorded preferential westward translation of the river.

The paper presents a credible and an encompassing metaphysical hypothesis to explain the geomorphological evolution of Kosi's course and is supported by a detailed examination of available topographical maps, footprints of paleo-channels and historical literature. Critical review of traditional viewpoints with a plausible argument for the river migration is also presented. Additionally, imperativeness of a better understanding of the complex morphodynamics of Kosi basin as an aid for implementing river training and/or management initiatives is also highlighted by implication.

The authors also propose that Kosi's migration and its geomorphological evolution may be a response to underlying multi-scale basin processes including neo-tectonic movements and causing a westward creeping, limited extent upheaval. The result is a transverse tilt in the river base that exaggerates its western bank cutting rate.

**Keywords:** Kosi; course instability; alluvial megafan; morphodynamics; paleochannels

THEME: S2 : APPLIED GEOMORPHOLOGY

ABSTRACT NUMBER: 163

## THE ANTHROPOGENIC-URBAN GEOMORPHOLOGY OF NEW SUBURBS, EAST OF GREATER CAIRO, EGYPT

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The Great Cairo is one of the largest urban clusters in the world. It is composed of three interlocked cities including Cairo City. By the last two decades, many new suburbs have been constructed eastward of Cairo City. These settlements are found in the desert. Many previous studies deal with urban growth in GC. However, the urban geomorphology perspective is poorly studied. The current study aims to investigate urbanization in Cairo suburbs and the impacts on the landscape and geomorphology.

A series of optical satellite images are utilized to quantify land-cover changes in 2000-2017. Detailed field studies were carried. These allow (1) for checking remotely sensed data; (2) for observing of human-induced landforms; and (3) to determine hazardous spots. The current study focuses on two cases as follows:

- Madinty residence was founded by 2008. It is located about 30 km of Cairo City. Buildings and asphalt subsidence are frequently recorded there. For example in the Golf heights district 20 villas are being restored. Satellite image monitoring shows that the two residential districts within Madinty are located on an old quarry. This engineering failure is mainly attributed to the occurrence of subsurface clay deposits and misuse of water inside gardens and golf courses.
- New Cairo Capital is being under construction. It includes a new governmental administrative area, cultural center, sports center, and residence districts. The site of a new capital occupies large drainage basins. By the last few months a dramatic change of natural landscape and drainage system have been observed. A Sentinel2 dataset combined with field observations show severe modification of drainage basins due to the expansion of infrastructure and new roads. For example, large areas of interwadi deposits are bulldozed. Many of trunk streams are positively leveled and blocked.

**Keywords:** Cairo; Urban Geomorphology; Hazards; Remote Sensing

THEME: S2 : APPLIED GEOMORPHOLOGY

ABSTRACT NUMBER: 254

## UAV BASED SOIL EROSION MONITORING FOR SOIL PROTECTION

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Since 2017, regional governments in Switzerland have to monitor soil erosion and take action when non-sustainable rates of erosion are exceeded. UAV acquired imagery offers the potential to support this task. In this study, a small UAV was used to map rills and crusted areas after a snowmelt/rainfall event in February 2017. In total, four fields were mapped at resolutions ranging from 0.4 cm to 2.61 cm. DEMs generated from the acquired images illustrated the potential of UAVs to document erosion, including rough estimates of soil loss in rills.

The study also raises several questions regarding the legal and administrative framework of erosion monitoring using UAVs. Most obviously, DEMs have limited accuracy what affects the associated estimation of soil loss. Furthermore, when a long-term average loss is seen as a limit, a single observation, even when above the limit for one year, may not be legally sufficient to take action. The occurrence of rills alone was also not necessarily a sign of non-sustainable soil management in our study because runoff often appears to be generated outside cropland. A further issue is the frequency of the monitoring, ranging from regular mapping of all areas at risk, to just documenting erosion after it occurred. The difference between the two would presumably lead to different technical approaches when images are acquired, with the former requiring larger UAVs and at least a partially automated rill detection algorithm. The latter, on the other hand, relies on a network of observers.

Overall, our study showed that UAVs have a great potential in applied soil erosion monitoring. However, procedures that enable a legally sound use still require further definition to complete the assessment of the potential of this new tool.

THEME: S2 : APPLIED GEOMORPHOLOGY

ABSTRACT NUMBER: 321

## MORPHOSCUPTURAL AND MORPHO-STRUCTURAL UNITS AND ENVIRONMENTAL SENSITIVITY IN SÃO-PAULO-STATE COASTAL AREA.

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Brazil has more than 8 thousand kilometers of coastline in the South Atlantic. Among the geological and geomorphological coastal area characteristics is the orogenic chain of the Atlantic, with emphasis on Serra do Mar, formed about 225 Ma, after intense tectonic and erosive processes. The coastal area has rugged rocks on the escarpment, and, in the coastal plains, unconsolidated sands. Environmental fragility is directly associated with material resistance. In principle, the coastal plains present the least resistance of materials as well as greater environmental fragilities. The objective of this study is to identify these differences along this plain in São Paulo state, with the use of accessible methodologies and material physical / chemical analysis. From the relief subdivision proposed by Ab'saber (1969) for Quaternary surveys, the sequence follows: 1- topographic compartmentalization in large geomorphological units (morpho-structures) defined by lithology, Ross (1992). Morpho-sculptures more recently sculpted by exogenous processes. 2- Surface structure analysis of the landscape, chrono-geology, and the first interpretative propositions on sequence of Quaternary paleo-climatic and morphoclimatic processes. 3- Landscape Physiology in order to understand the morphoclimatic and pedogenic processes, in full action. As concerns differences in material resistance, a correlation was established with Brunsdén & Thornes (1979), who consider intertidal plains, river plains, and beaches as fast, fragile response subsystems. Slower response subsystems would be associated with the higher relief forms, where matter and energy inputs and outputs are less intense corresponding to the formations highlighted in the relief in altimetric and more distant direct-input terms, such as sea level variations, as tidal-level wave oscillation. The highest points of material resistance, points of high soil organic matter (SOM - 90%), and iron (27%) contents as well as intense hardness, contrary to the hypothesis all coastal plain presents unconsolidated material and high fragility.

**Keywords:** Morpho-structure; Morpho-sculpture; Geology; Geomorphology; Environmental Fragility

THEME: S2 : APPLIED GEOMORPHOLOGY

ABSTRACT NUMBER: 401

DESIGNING NATURAL RIVERS:  
THE NEW CHALLENGES OF BUILDING MINING RIVER DIVERSIONS

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Numerous rivers are diverted for large mining operations. The stream is diverted, either around the mining pit to avoid flooding, or is diverted entirely away to allow access to ore. In Australia alone there many hundreds of these diversions, with some being tens of kilometres long. In the past these diversions have been nothing more than engineered trenches, but rapid erosion, and multiple failures, mean that standards of design have improved greatly. Regulators now demand that the diverted channel should essentially mimic the morphology of the original channel. This means (a) that geomorphologists are now working alongside engineers in the detailed design of these diversions, and (b) that these diversions now represent among the largest river restoration experiments on earth. Little is written in the literature about these vast experiments because the projects can be commercially sensitive. In this talk we review the exciting developments, and challenges, in this field of applied fluvial geomorphology.

**Keywords:** fluvial, river, mining, diversions, restoration

THEME: S2 : APPLIED GEOMORPHOLOGY

ABSTRACT NUMBER: 505

TREE RINGS AS A SOURCE OF DATA FOR LANDSLIDE  
HAZARD IDENTIFICATION AND MAPPING (WESTERN CARPATHIAN MTS, POLAND)

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Landslide activity is a common threat for inhabitants and infrastructure of mountain regions. Various methods and engineering solutions are applied to identify landslide hazard. Dendrochronology, although increasingly popular, is used rather for basic research than for solving practical issues. In our study we aim to use tree rings (i.e. ring eccentricity) as a source of data for landslide hazard mapping. Stems of trees growing on active landslides are tilted and bent which influences radial growth and structure of wood. Thus landslide activity is recorded year-by-year in annual rings of trees. Using dendrochronology we have dated landslide events in 950 sampling sites distributed throughout the Milówka administrative district (98,3 km<sup>2</sup>, Western Carpathian Mts, Poland) where landslides caused significant material losses in the past. Sites were distributed both on landslides and on slopes devoid of any landslide relief (based on airborne LiDAR data). In each site we have sampled 1-3 *Picea abies* and *Abies alba* trees, depending on the availability of healthy trees. Tree-ring widths were measured in samples taken from up- and downslope sides of stems. Measurement results were recalculated into per cent eccentricity index and landslide events were dated (method after Wistuba et al., 2013). Average frequency of landsliding in each sampling site was calculated. Results were used to develop various maps of landslide activity and hazard, including interpolated maps (IDW, Krigging and Topo-to-Raster). Maps of average landslide activity and hazard were combined with contemporary distribution of infrastructure (housing areas, public buildings, roads, etc.) and plans of spatial development of the area under study. The most vulnerable and hazardous areas have been outlined. Study conducted for the Milówka district demonstrates that dendrochronology is a promising and efficient approach for detecting and mapping landslide hazard, not only at the limited spatial scale of a single slope but also for larger areas.

THEME: S2 : APPLIED GEOMORPHOLOGY

ABSTRACT NUMBER: 537

## NEW LESSONS FROM AN OLD LANDSLIDE: WHY THE VAIONT LANDSLIDE WAS MISUNDERSTOOD

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The Vaiont landslide of 1963 provides an early example of 'engineering geomorphology' applied to a major infrastructure project. The Vaiont Dam Project Director employed a geologist, Edoardo Semenza, to investigate possible landslide hazards and associated risks arising from the planned reservoir. Semenza used field observations of geomorphological and geological features to develop a hypothesis that subsequent investigations were used to test. He interpreted a variety of geological outcrops, sediment juxtapositions and landform units as being the result of a very large ancient landslide that had previously blocked the Vaiont gorge. Having formed this hypothesis, he then misinterpreted borehole evidence and accidentally created the 'chair' shaped failure surface for which the landslide is famous but which does not actually exist.

Critical to site investigations for major engineering projects are: (i) an adequate appreciation of the range of geological and geomorphological processes that may have produced the present site conditions, and (ii) a good understanding of how different elements of a site may interact to affect its future state in response to a wide range of short-term changes imposed by engineers or natural events. Semenza was constrained by the extent of relevant scientific and technical knowledge at the time and a lack of scientific evidence to support his interpretations of his observations. The risk of a large landslide and a resulting wave were correctly identified but incorrectly assessed.

Three major lessons can be identified from the Vaiont case. Firstly, field evidence alone can be misinterpreted. Secondly, the minds of investigators must remain open to all possibilities and not be influenced by seeking to prove a specific theory. Thirdly, arising from the above, adequate site investigations are necessary if correct interpretations and a reliable ground model are to be developed prior to any detailed planning for a project.

**Keywords:** landslide, Vaiont, ground model

THEME: S2 : APPLIED GEOMORPHOLOGY

ABSTRACT NUMBER: 652

## FLOOD MANAGEMENT AND PLANNING

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In India, the areas prone to flood are well known with every monsoon. Undulating topography, heavy and concentrated rainfall are primarily responsible for such hazard, but unscientific and unplanned usage of land, deforestation, haphazard and uncontrolled urbanization and construction works increases frequency and magnitude of such hazard. The recent devastating floods of Mumbai, Srinagar and Chennai were the eye opener for us and provide lesson to concern persons/organizations to diminish the flood hazard.

In the present paper an attempt has been made to analyze the causes to such hazards. Heavy rainfall normally during in the end of monsoon season are important cause of flood hazard. Apart from this deforestation and hence untamed flow surface runoff is responsible for excessive soil erosion. This leads siltation in the riverbed. Excessive settlement, transport and construction in the river catchment area are other causes of increasing flood hazard.

For present study data has been collected from relevant areas and appropriate statistical methods were used to those. Keeping in view all the facts mentioned above the present study tries to examine the various issues related to flood hazard and suggests – properly to check flood hazard and damages of life, land and property.

THEME: S3 : GEOMORPHIC PROCESSES IN COUPLED HUMAN AND NATURAL SYSTEMS

ABSTRACT NUMBER: 31

## RIVER SEDIMENT EXTRACTION AND DRYING WELLS: A HUMAN INDUCED HYDRO-MORPHOLOGICAL THREATS IN THE PIEDMONT REGION OF DARJEELING HIMALAYAS

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After 1980s, the river sediment extraction increased drastically in the piedmont region of Darjeeling Himalaya as demand for construction materials from the urban centers and population dependent on these extraction activities increased. The impacts of sediment extraction have not only degraded the fluvio-geomorphic system of the region but also the socio-environmental impacts like lowering of ground water level, human occupancy of flood plains, etc are increasing in areas adjacent to river. In this study, the authors have attempted to relate how the sediment extraction has been affecting the surrounding socio-environment especially in the lower course of the Balason as villages located adjacent to the river are facing shortage of ground water during dry seasons (especially during March to May). The drying of 65 out of 70 wells during this period in the village named Tarabari in 2016 could be attributed to the river bed incision due to excessive sediment extraction. A questionnaire survey was conducted to understand the local perception with regard to sediment extraction which indicates that since last 5 years the water level in wells has reached to its minimal forcing the residents to use the river water for domestic needs. Similar situations has also been noticed in many local areas located adjacent to the river like the ground water level in Matigara has lowered up to maximum of 8.34 mbgl and 7.17 mbgl in Tumbajote ( CGWB 2016). The river cross sections survey during 2008-2010 has shown the changing river morphological characteristic with an average bed incision of 1.0 m and the village residents considered the continuous sediment extraction inducing such incision responsible for drying of wells. Hence with changing river behavior and uncontrolled human interference will exaggerate the ground water stress in the region which needs immediate intervention.

**Keywords:** Sediment extraction; incision; ground water stress; socio-environment

THEME: S3 : GEOMORPHIC PROCESSES IN COUPLED HUMAN AND NATURAL SYSTEMS

ABSTRACT NUMBER: 72

## EMERGENT PROPERTIES OF FLOOD DISASTERS: TOWARDS THEORY

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There are many concepts and some theories for parts of the coupled socio-hydrologic system that produces flood disasters. But there is nothing that approaches a general theory of the causes and immediate consequences of flood disasters. Such a theory is needed to deepen our understanding, provide input to disaster risk reduction, and enable generalizations to places where case studies are not available. Flood disasters are the result of complex interactions between weather, catchment characteristics, and human perceptions, policies, decisions and actions. It is unlikely that theory can be built from the bottom up. It is more likely that theory can be produced from the fractal emergent properties of flood disasters. This paper will show how multi-fractal distributions of flood damage and deaths emerge from physical phenomena that are also fractal. with human vulnerability reflected in changes to the fractal distributions.

**Keywords:** flood disasters; socio-hydrology; emergent properties; theory



ABSTRACT NUMBER: 247

## CHARACTERISTICS OF THE 2016 FLOOD FOCUSING ON FLUVIAL TOPOGRAPHY AND FLOOD IMPACT ON LOCAL COMMUNITIES IN THE OMOTO RIVER BASIN, NORTHEASTERN JAPAN

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In 2016, the exceptional passage of Typhoon Lionrock through northeastern Japan stimulated heavy rainfall resulting in a flood disaster in the Omoto River Basin (area: 730 km<sup>2</sup>, length: 65 km), leaving 20 dead and 1 missing in Iwaizumi, a town occupying a large part of the basin. Abundant sediment with driftwoods from slope failures and debris flows in the upstream overflowed at knick points from steep to gentle in tributary rivers. Sediment was easily delivered to the main channel and accumulated at topographically weak points where abrupt changes occur in bed slope or channel width or sharp channel bends appear. Such a sediment process with rapid run-off affected by mountainous topography enhanced flood hazards in the downstream. Local communities dotted on valley plains and narrow river terraces were hit by floodwaters widely overflowing the plains and the terraces. The hazardous phenomena disrupted roads, electricity, and other lifelines, and thus isolated the communities. In comparison to continental rivers, those in Japan are considerably short and steep. To mitigate flood risk, most of its large rivers have been artificially altered. However, small-scale rivers, especially those in mountainous regions, have been left behind in this effort because they are often in rural areas with socioeconomic difficulties including decreasing and aging population, a large administrative area, and limited resources. As the case of the Omoto River flood shows, floods in mountainous regions can be intensified by rapid run-off and sediment deposition at topographically weak points, possibly resulting in fatal isolations of local communities. It is therefore essential to identify local vulnerabilities by understanding fluvial behavior from a viewpoint of geomorphology, and the results should be used to promote effective river management, suitable land use and specific disaster prevention measures for local sustainability.

**Keywords:** flood disaster; rivers in mountainous region; river bed evolution; sustainable community

ABSTRACT NUMBER: 397

## CHANGE OR PERSISTENCE? THE IMPACT OF LAND USE CHANGES ON GEOMORPHIC SYSTEM IN DEPOPULATED AREAS (SUDETY MTS. CASE STUDY)

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The Sudety Mts. in SW Poland were subject to substantial depopulation and land use changes within the last 150 years due to various socio-economic and environmental circumstances. They resulted in large scale depopulation (up to 90-100%) and increase in forests and grasslands at the expense of arable lands which declined by more than 50%. The highest dynamics of these processes was observed in the Kłodzko region, therefore it was selected as a case study to investigate the impact of socio-economic processes on geomorphic system. The specific aims of the study were to investigate: 1) the impact of land use changes on soil erosion, and 2) the persistence of anthropogenic landforms in abandoned areas.

Various methodologies were used to answer the research questions. Modelling of past and present soil erosion under varied land use and climate conditions was performed as variant analysis using RUSLE model. Field investigations, including geomorphic mapping and morphometric analysis, supported by the analysis of LiDAR data and historical cartographic sources, allowed to assess the persistence and state of preservation of anthropogenic landforms and objects in areas of past human occupancy. They included remains of former settlements and past economic activities such as agriculture, mining, industry and water management.

The results show that land use changes have highly reduced soil erosion from slopes. Additionally, their impact is much more important than the impact of climate changes, which were also observed in the study area. However, in spite of large scale land use changes and decline of human impact, the geomorphic legacy of past human activities, understood as anthropogenic landforms and objects, is very persistent in the landscape and should be considered as a long-term human impact on geomorphic system.

**Keywords:** land use change; depopulation; soil erosion; anthropogenic landforms; Sudety Mts.

THEME: S3 : GEOMORPHIC PROCESSES IN COUPLED HUMAN AND NATURAL SYSTEMS

ABSTRACT NUMBER: 498

## RIVERBANK EROSION, GEOMORPHOLOGICAL CHANGE, AND MIGRATION EXPERIENCES IN MAJULI, ASSAM: A CASE STUDY

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Ever since the 1950 earthquake of Assam, River Brahmaputra has been eroding land in the island of Majuli at an astonishing rate. In the last 66 years, the area of the island has reduced from 1246 Square Km to 584 Square Km, while during the same time period, the population has increased from 81001 to 167,304 persons. The shrinking of space coupled with an ever expanding population has forced many young Majulians to move out of the island and find work in industrial centers across India. The present paper explores this connection between the loss of land due to riverbank erosion and the resultant outmigration of persons from Majuli. The paper uses long term Remote Sensing images to estimate the loss of land over the last five decades, and Supervised Classification to assess the impact of changing geomorphology on the land and people of Majuli. Finally, with the help of Primary Survey, the paper tries to find out the trend of outmigration from Majuli and the impact of such migration pattern on the demography and the population structure of the island.

**Keywords:** Brahmaputra, Majuli, Ecology, Natural Hazard, Migration

THEME: S3 : GEOMORPHIC PROCESSES IN COUPLED HUMAN AND NATURAL SYSTEMS

ABSTRACT NUMBER: 685

## VULNERABLE OR RESILIENT? LOCAL NARRATIVES OF ADAPTATION IN THE LANDSLIDE-PRONE HILLS OF KURSEONG: A POLITICAL ECOLOGY PERSPECTIVE

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Kurseong, a district subdivision in the eastern Himalayan Mountains, has been subjected to an increasing threat of landslides. A densely forested mountainous region before, Kurseong also underwent massive transformation of land-use and land-cover with the development of tea plantations that started since the 1850s, during the British rule in India. Changing political regimes, market economy and a growing population have shaped human adaptations to the environment and their vulnerability to landslides. This paper explores local narratives of human adaptation to the environment to derive underlying factors that shape vulnerability and resilience. This study takes a political ecology perspective based on the premise that environmental resource management and land-use depend on complex decision-making processes at multiple levels, such as individual, local, and institutional levels that in-turn impact environmental changes. Key-informant interviews were conducted in June 2016 and March – April 2017 with tea plantation managers, government officials, and local inhabitants, who have expert knowledge and/or experience, to derive indicators of vulnerability and resilience in the face of recurring landslides in Kurseong. Field observations indicate that local inhabitants largely depend on land-use and land-based livelihoods for survival. Results show that major landslide areas co-exist with socio-economic vulnerabilities characterized by high unemployment rates, poverty, and poor housing and sanitation. A gap between actual and promised government allocation of funds for environmental protection also has evident implications on environmental vulnerability to landslide disasters. A comparative analysis of relatively resilient areas show more institutional involvement (e.g., in some tea estates) regarding environmental management such as continued afforestation, less deforestation, and better provision of amenities, e.g., roads, housing and sanitation to local land-users compared to areas more frequently affected by landslides.

**Keywords:** adaptation; vulnerability; resilience; landslide; political ecology

ABSTRACT NUMBER: 705

## GEOMORPHOLOGY IN THE ANTHROPOCENE

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The term Anthropocene was introduced in 2002 as a name for a new epoch in Earth's history – an epoch when human activities have become so profound and pervasive that they rival, or exceed the great forces of Nature in influencing the functioning of the Earth System. The term “Anthropocene” has Greek roots (anthropo meaning “human” and –cene meaning “new”). It is a new term for an older concept, and a great deal of argument concerns how it can be differentiated, if at all, in terms of a boundary with the Holocene. It is agreed, however, that the human impact has been increasing in the last few centuries and that humans are now a very potent geological force. It is apparent that in coming centuries a combination of population increases, land cover changes, climatic changes, and new technologies will increase this force still further. One of the great debates surrounding the Anthropocene is when it started and whether it should be regarded as a formal stratigraphic unit with the same rank as the Holocene. Humans will continue to modify their environment in coming decades. New technologies will be developed and applied and increasing human population levels will lead to further changes in land cover and in the exploitation of natural resources. There is a two way relationship between geomorphology and the Anthropocene. This paper illustrates the nature of the changes that have taken place in the Anthropocene and gives examples from many parts of the world. It concludes with a discussion of the question, ‘are we changing the global earth system?’ and discusses the role of geomorphology in earth system science.

ABSTRACT NUMBER: 716

## IMPACTS OF NATURAL AND HUMAN DRIVERS ON THE MORPHOLOGY OF TIDALLY-INFLUENCED DELTAS OVER MULTI-DECADAL TIMESCALES

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River deltas are geomorphological features that provide high value of ecosystem goods and services to hundreds of millions of people. But, currently they face major sustainability challenges due to climate change and the risk of drowning due to rising relative sea-levels. Delta morphology is evolving widely due to multiple and often intensifying drivers. Understanding delta morphology is critical for sustainable management of deltas but our limited observations constrain our understanding of these changes. This research analyses how delta morphology evolves over multi-decadal timescales under multiple drivers of environmental change using a methodology based on a process-based model (using Delft3D software). Focussing on idealised morphodynamics of deltas influenced by tides, a series of model simulations over 100 years explored the influence of three key drivers, both individually and together: (1) varying combinations of water and sediment discharges from the upstream catchment, (2) varying rates of relative sea-level rise (RSLR), and (3) selected human interventions within the delta, comprising polder embankments and cross-dams. The results indicate that tidal asymmetry and the rate of sediment supply together affect residual flows and morphodynamics of delta (represented by sub-aerial delta, progradation and aggradation). The combined influence of drivers on the morphodynamic response is not the same as the sum of their individual effects when combined. When drivers were combined, the natural processes of delta building such as the distribution of sediment flux over the sub-aerial delta, aggradation, and progradation of the delta are prevented by polder embankments or cross-dams and indicated that such interventions can lead to an unsustainable delta building processes and catastrophic flooding events. These idealised findings can inform strategic management choices in real-world tidally influenced deltas such as the Ganges-Brahmaputra delta, while the model-based methodology might provide important insights in other dynamic systems.

THEME: S3 : GEOMORPHIC PROCESSES IN COUPLED HUMAN AND NATURAL SYSTEMS

ABSTRACT NUMBER: 722

## HYBRID APPROACH TO MODELLING CENTURY-SCALE CHANGES IN THE SPATIAL DISTRIBUTION OF STORM SURGE FLOOD RISK

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Rising sea levels will increase the risk of flooding in low-lying coastal areas. This effect is likely to be more complex in estuaries, where tide and surge water levels are influenced not only by oceanographic forcing but also by the morphology of inlet channels and intertidal areas. At timescales of 100+ years, morphological changes - both natural and anthropogenic - can be significant, but are still hard to quantify with any certainty. We present a hybrid approach to this problem that combines models of differing complexity and levels of parameterization into a new Estuary SpaTial LandscapE Evolution Model (ESTEEM). ESTEEM predicts alternative future estuary morphologies based upon combinations of oceanographic forcing (sea-level rise), variability in contemporary processes (especially wind-wave climate), and a set of likely management adaptations (changes in the extent of defended areas). Predicted morphologies can be used in conjunction with a conventional numerical hydrodynamic model to propagate surge events of various return periods.

Simulations for an idealised meso-tidal estuary show that extreme surge water levels can be sensitive to morphological change. Estuaries evolve in response to a close coupling of natural and anthropogenic influences. Although natural changes are rather small, larger step changes in estuary planform result from the removal or realignment of flood defences. Morphology is further modified by the progressive adjustment of the enlarged intertidal area. Inclusion of these effects produces spatial distributions of flood risk that differ subtly, and in some cases significantly, from the imposition of future surge events on the existing estuary morphology. Model parameter and management scenario spaces are large, even before alternative oceanographic forcing scenarios are considered. However, the computational efficiency of the ESTEEM code allows large numbers of simulations to be run in a probabilistic uncertainty framework.

THEME: S3 : GEOMORPHIC PROCESSES IN COUPLED HUMAN AND NATURAL SYSTEMS

ABSTRACT NUMBER: 742

## THE CHALLENGE OF URBAN FLOOD RISK AND THE GEOMORPHOLOGY OF "SPONGE CITIES"

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Flooding is a major risk in many cities in China and Southeast Asia which has been exacerbated by rapid urbanisation. Initiatives such as the Sponge City concept unveiled in China in 2013 aim to enhance urban water management systems which are capable of dealing with increased flood risk and improve capture, storage and purification of rainwater. However, the majority of Sponge City interventions have focused on low impact development strategies often applied at the scale of building plots. These strategies focus on source control, increasing retention of water and reducing peak and total runoff. However, these approaches can be oblivious to the wider functions of the surrounding landscape, the geomorphology of the catchment area and the heavily modified drainage systems. As many Asian cities turn from predominantly grey infrastructures towards blue-green approaches, there is an opportunity to consider how geomorphology can underpin and integrate sustainable urban development.

THEME: S4 : GEOMORPHOLOGICAL RESOURCES

ABSTRACT NUMBER: 404

## A GEOMORPHOLOGICAL APPROACH TO ASSESS LAND SUITABILITY OF KARHA RIVER BASIN USING GIS

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In soil research Geographic Information System (GIS) has recognized itself as a very powerful tool. In the present study an empirical methodology has been used for analyzing and mapping of land suitability using the GIS techniques. Present research paper attempt has been made to study land suitability of Karha drainage basin, a tributary of Bhima river basin, Maharashtra. Land use suitability analysis is a multi-criteria evaluation, which aims to identify the most appropriate spatial pattern for future land uses. Such planning also requires the knowledge of land diversion over a period of the time to judge the priority of the area.

The methodology adopted to land suitability analysis is based on the Analytic Hierarchy Process in which Slope, drainage, physical and Chemical properties of soil and Land use and Land Cover Criteria has been take in to consideration with assigning the weight to each criterion. The weights are defined through the Analytic Hierarchy Process (AHP) module in ArcMap. The purpose of land suitability analysis for agricultural crops is to express the importance or preference of each factor relative to other factor and effects of each factor on crop yield and growth rate of the crops. Overlay analyses of land suitability for agricultural has generated four groups of land suitability namely More suitable 29.26 percent, suitable 49.39 percent, Moderately suitable 14.26 percent and less suitable 6.55 percent.

**Keywords:** Land Suitability; Geographical information system; Analytic Hierarchy Process

*THEME: S4 : GEOMORPHOLOGICAL RESOURCES*

**ABSTRACT NUMBER: 506**

## TALUS CONES AS GEOMORPHOLOGICAL SITES FOR GRAFTING ARTIFICIAL GLACIERS IN THE HINDUKUSH KARAKORAM (PAKISTAN)

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With a glaciation cover of over 18.000 km<sup>2</sup>, the Karakoram Mountains inherit enormous water reservoirs stored in ice, but paradoxically water scarcity was always a pressing issue for farmers in the Upper Indus Basin. At the valley bottoms, where the permanent settlements are located, the annual precipitation ranges with 100–150 mm below the agronomic aridity limit. Sophisticated small-scale channel systems have been developed in a highly geodynamic environment with extreme relief energies to distribute the meltwater from the glaciated tributary valleys to the agricultural fields of the oasis settlements. In order to overcome further water shortages, an indigenous technique has been in operation since centuries, the grafting of “artificial glaciers”. It includes the burying of ice boulders in the soil derived from a special type of natural glacier or the adding of glacier ice and river water to an existing ice core. Special geomorphological and topographical geosites are necessary for a successful ice growth. These are primarily located at the base of talus cones with an internal system of air cooling circulation at altitudes above 4000 m. The procedure is carried out on a community-based level according to strict rules. Field surveys showed that the technique is spread over many valleys of the Hindukush-Karakoram and well preserved in the collective memory of local inhabitants. It is based on a different nature perception, especially of glaciers, than in western cultures. At the same time, knowledge of the microdiversity of mountain topography and climate is used in the same way as in the European Alps. In this project, field studies will be presented of one of the oldest artificial glaciers in the Nagar Valley. In the light of the concern of future water availability in the semi-arid mountains of High Asia, such small-scale indigenous practices should be considered to improve water storage.

*THEME: S4 : GEOMORPHOLOGICAL RESOURCES*

**ABSTRACT NUMBER: 762**

## GEOMORPHOLOGICAL MAPPING OF SANJAI RIVER BASIN, JHARKHAND, INDIA

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Geomorphological mapping represents uniformity and diversity of land forming process and structure. Geomorphology is the science of relief, relief forming materials and changing process. Preparation of geomorphological map is based on certain methodology:

- i) Topographical map playing an important role in guide map making stage
- ii) Satellite imagery and aerial photographs also play a vital role in guide stage
- iii) After completion of guide map field survey is essential.
- iv) With the help of computer aided cartography, remote sensing, GIS technology map should be completed.



Geomorphological maps always depict at large scale i.e micro level land form pattern (river basin). The small scale and large scale coverage of satellite imagery fulfills the actual purpose of detailed study and comparative study of the terrain. Geomorphological mapping should be concerned with complexity of landform as well as complexity of structure and process which acting together on each unique landform. Geomorphological mapping can investigate the complex interactions of geomorphic process and modifying structure of dynamic terrestrial earth.

Sanjai river basin located in Jharkhand state in India covers mainly west Singhbhum and portion of east Singhbhum district of Jharkhand state. In this study the working procedure is based on easily accessible topographical map, field data, and inexpensive remote sensing data. The map legend is suitable for depicting various landform and land use pattern of the basin. Anthropogenic erosion plays a vital role in changing landform and land use pattern of the region. So multi disciplinary approach is very suitable for analysis of this region. 3d visualization of river basin is important for representation of observed phenomena. So Geomorphological mapping acts as a powerful tool for decision making support purpose, water shed management, environmental protection as well as welfare of the society.

**Keywords:** Large and Small scale coverage, GIS technology, Anthropogenic erosion, Multi disciplinary approach

THEME: S5 : VOLCANIC GEOMORPHOLOGY

ABSTRACT NUMBER: 21

## CALDERA KSUDACH (KAMCHATKA): MAIN FEATURES OF THE HYDROGRAPHIC NETWORK DEVELOPMENT

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Ksudach volcano consists of 5 completely or partially nested calderas formed in Late Pleistocene (calderas I and II) and Holocene (III - V) age. The total area of calderas complex is about 64 km<sup>2</sup>. Nowadays, there are 2 lakes and 10 intracalderas river valleys. Our field studies were aimed at solving the problem: how did the Holocene activity of the volcano affect the development of its hydrographic network?

The upper reaches of many valleys were formed on the slopes of calderas I and II. And they are still function as the upper parts of the younger valleys of calderas IV and V. Powerful pyroclastic flows repeatedly filled up valleys and came down along the river Teplaya that drains caldera complex. Subsequent incision of valleys led to formation of erosion terraces there composed by pyroclastic deposits. The growth of the Shtyubel cone within the caldera V had a significant influence on the orientation and morphology of adjacent valleys.

The Late Pleistocene-Holocene history of the caldera polygenic complex is characterized by repeated large fluctuations of its lakes' level. Four levels of terraces can be traced on the shores of the lakes now. The two lower terraces (3-5 and 7-8 m) are correlated with extensive fans and as a rule are accumulative. The third level (12-15 m) is mostly erosional. Formation of these levels occurred after the eruption of the young Shtyubel cone in 1907. Probably, it was caused by partitioning of the source of the Teplaya river that drains calderas by explosive deposits and its subsequent gradual incision. Formation of the terrace level 25-30 m high, which is fixed near edges of the youngest caldera, probably due to the accumulation and subsequent redeposition of pyroclastic after the last caldera eruption 290 AD.

**Keywords:** caldera; river network alteration; geomorphic processes; volcanic relief; level fluctuation

THEME: S5 : VOLCANIC GEOMORPHOLOGY

ABSTRACT NUMBER: 25

## ASSESSING THE VULNERABILITY OF VOLCANIC ERUPTION ON THE JOS AND BIU PLATEAU, NIGERIA: USING GIS

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This study was carried out by scientists from Centre for Geodesy and Geodynamics to map volcanoes in Nigeria using both ground and space techniques. The study identified the volcanic signatures within the Nigerian land –mass, investigate their activity and predict through dating possible re-occurrence in future as well as determining hazard vulnerabilities. Our investigations identified sixteen (16) volcanic cones outcrop in the Jos Plateau and twenty-six (28) of such in the Biu Plateau. The study also developed a Geographical Information System (GIS) database and mapped volcanoes in Nigeria during three field seasons which includes desk

study, compilation of existing data acquired from relevant agencies, meetings and discussions with governmental organizations at Federal and State level. The study affirms that volcanic cones of Jos Plateau are composed essentially of volcanic ash, lappilli, bombs, tuff agglomerates, basalts and scoria. Most of them occur as single cinder cones but rarely as clusters of two or more. The study also affirms that Biu Plateau are constituted by a large volume of volcanic ash and pyroclastic materials (for example, at Gwamy, Tilla Crater Lake, Gadam, Batadeka, Bwatai, Kwatla volcanoes among others) suggesting that there was a tremendous spewing of ash and gases into the atmosphere prior to the violent eruptions and in-between the eruptions. GIS analytical techniques like overlying and buffering showed clearly that the population of people living around these volcanoes totals about 1.5 million people. The study concludes that the occurrence of volcanic eruptions varies over space on both Biu and Jos Plateau. Hence, public awareness of their hazard potentials and encouragement of increased public participation, as well as government and professional intervention in proper management and monitoring of these volcanoes should be encouraged.

**Keywords:** Mapping; Volcano; Vulnerabilities; Nigeria; GIS

THEME: S5 : VOLCANIC GEOMORPHOLOGY

ABSTRACT NUMBER: 316

## DYNAMIC EVOLUTION OF THE 1888 RITTER FLANK COLLAPSE AND ASSOCIATED MASS MOVEMENTS

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The sector collapse of Ritter Island, Papua New Guinea, in 1888 was the largest historically recorded volcanic landslide. On volcanic islands, such events can generate damaging tsunamis, with a global recurrence interval of 100-200 years for events of this type. The 1888 Ritter Island landslide is likely to be representative of the next tsunamigenic volcanic-island collapse in terms of both magnitude and tectonic setting. It is also young enough to be preserved at the seafloor without significant modification.

In this study we use Ritter Island as a test site to better constrain the emplacement dynamics of volcanic landslides. During the 6-week long expedition SO-252 in late 2016, the Ritter Island collapse scar and deposit were mapped using hull-mounted multibeam systems, sub-bottom profiler, and a 2D multi-channel seismic reflection system. We use these data to propose a conceptual model for the development of the Ritter Island flank collapse. The landslide mass initially bifurcated around a remnant block and dispersed within the channel between Umboi and Sakar, where it formed a deposit that is relatively flat at the margins and with irregular channelisation in the central part. Parts of the landslide deposit travelled through a constriction between Umboi and Sakar and incorporated underlying seafloor sediment. Landslide dynamics appear to be strongly affected by minor changes in slope gradient. Taken as a whole, deposition of the landslide entailed a progressive, multi-phase, brittle to plastic failure that mobilised material over a considerable distance, with incorporation of a major proportion of underlying seafloor sediment in the distal deposit. Seismic profiles through the distal deposit indicate that the 1888 landslide was only the latest of a series of large-volume volcanic landslides from the surrounding islands.

**Keywords:** submarine landslide; volcanic island; flank collapse; Ritter Island; Papua New Guinea

THEME: S5 : VOLCANIC GEOMORPHOLOGY

ABSTRACT NUMBER: 562

## RIVER INCISION RATES IN VOLCANIC TERRAINS

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Channel incision in mountainous areas is a common process but still there is a lack of knowledge on the development of river valleys and river longitudinal profile into bedrock. Old river deposits or paleoterraces are suitable for understanding paleoenvironments and rate of formation of modern valleys, but their dating is problematic. However, in volcanic areas, lava flows into river valleys allows, by dating of the basalt cover, the assessment the rate of incision. In the Golan region, episodes of lava flow occurred since 4 My until latest flow about 110 Ky ago.

The aims of the study were: a) to assess the incision rates of the Golan channels. b) to determine the palaeohydrology and sediment transport regime of the mountain streams in the Golan Heights draining into the Rift Valley since the Middle Pleistocene.

In the Hemdal stream the longitudinal profile is characterized by an overall convex shape over the 10.2 km channel length. Channel slope values are between 4% to 9.5% in the mountain area, with an abrupt change to less than 1% in the valley. Several knickpoints are found along the profile, with a series of waterfalls - about 20 m high- and cascades along fault lines which displace the lava flows. The radiometric data of the basalt flows in the Hemdal and Saar rivers indicates an incision rate of 20-40 cm/ka for the last 100 ky. These rates are higher than the average for the last million years: 10-20 cm/ka.

The study conclusions are that there were no major changes in the channel hydraulics, bedload composition and hydrological regime of the Hemdal and Saar rivers since the Upper Pleistocene. Field evidences imply a long term dynamic equilibrium in which channel incision and regional uplift are balanced.

**Keywords:** Incision rates; Basaltic dating; Paleoterrace; Golan Heights

THEME: S5 : VOLCANIC GEOMORPHOLOGY

ABSTRACT NUMBER: 595

## GEOLOGICAL AND GEOMORPHOLOGICAL CHARACTERISTICS OF OBSIDIAN IN BINGÖL VOLCANIC AREA (EASTERN ANATOLIA-TURKEY)

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In the framework of the GeObs scientific project, we propose a systematic and exhaustive study of the geological outcrops and settings of obsidian in Eastern Anatolia, to form the most comprehensive geomorphologic, geologic and geochemical database related to the obsidian sources in this area, also in relationships with obsidian artefacts defined by their

stratigraphic position, cultural identity, and geochemistry. In the study, different factors such as tectonism, volcanism and hydrography which were effective in the geomorphological evolution of the study area were investigated and also radiometric dating methods and Geographical Information Systems were used. Geochemical analyzes have been carried out to determine the origin and characteristics of the volcanic products. Bingöl volcanic area is the one of investigated area in the context of project. In this study field investigations and also the geomorphological and geological setting of obsidian outcrops will be presented. As well as characteristic features of the obsidian determined by geochemical analyzes in the same area will be explained.

**Keywords:** Obsidian, Eastern Anatolia, Bingöl Volcanics

THEME: S6 : KARST GEOMORPHOLOGY

ABSTRACT NUMBER: 49

## DETECTION AND CHARACTERIZATION OF SAGGING SINKHOLES BY TRENCHING IN A SITE SELECTED FOR A CRITICAL INFRASTRUCTURE

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A site selected for the construction of a critical infrastructure was investigated by geomorphological mapping. Aerial photograph interpretation revealed that the site is located within a band underlain by dipping gypsum strata including the following geomorphic anomalies: (1) shallow, vaguely-edged depressions, up to 600 m long with internal or poor drainage, largely obliterated by human activity (levelling for agriculture); (2) drainages interrupted at the flat-bottomed depressions. A total of five trenches with a total length of ca. 400 m were investigated to elucidate the origin of the depressions and obtain information on the potential ground deformation processes involved in their formation. The analysis of the trenches, together with 12 radiocarbon ages, allowed us to infer the following data of relevance to the engineering project: (1) The depressions are bedrock sagging sinkholes developed in poorly lithified gypsiferous facies associated with a contact karst (cartographic contact between argillaceous and gypsum units). The sagging mechanism is recorded by synforms, marginal monoclines and local reversed dips; (2) Presence of recent surface ruptures (collapse-fault scarps and fissures) at the margin of the sinkholes younger than 1.4 ka; (3) The age of some sinkholes has been roughly estimated by dating the organic-rich



sediments of their sedimentary fill (4-12 ka); (4) The minimum subsidence rates estimated on the basis of the sinkhole fill thickness range from 0.1 to 0.7 mm/yr. The actual values could be significantly higher.

THEME: S6 : KARST GEOMORPHOLOGY

ABSTRACT NUMBER: 51

## SUBSIDENCE ACTIVITY IN SINKHOLES INFERRED BY TRENCHING, GPR AND ERI. EVAPORITE KARST OF THE FLUVIA VALLEY, NE SPAIN

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Subsidence behavior is an essential element in the characterization of hazardous sinkholes. This includes important aspects from the applied perspective, such as subsidence mechanism, kinematics (progressive vs. episodic), subsidence rates, or the timing of subsidence episodes, particularly the most recent event (MRE). We analyze the potential of the trenching technique, in combination with electrical resistivity tomography (ERT) and ground penetrating radar (GPR), for subsidence behavioral studies in two sinkholes located in the Fluvia Valley, NE Spain (Anfiteatro sinkhole, Fares sinkhole). These are cover and caprock collapse sinkholes related to the interstratal karstification of a gypsum formation (Beuda Gypsum) overlain by marls (Banyoles Marls). The apparently inactive Anfiteatro sinkhole, 79 m long and 15 m deep, is located in a perched terrace, whereas the active Fares sinkhole, 24 m across, is situated in the floodplain. Subsidence in the Anfiteatro sinkhole was accommodated by dip-slip displacement on a ring fault, with a total throw estimated from the ERT section of ca. 27 m. Radiocarbon ages allow constraining the MRE at 599-777 AD and roughly estimating an age of ca. 6 ka for the sinkhole. Episodic subsidence in the Fares sinkhole is controlled by an annular fault and an internal flexure. This depression has been largely filled by rapid sand accumulation during historical flood events and records an average subsidence rate higher than 6.3 mm/yr. The ERT sections at Fares capture a clear change in the resistivity pattern, although it does not allow to define the geometry of the collapse structure. The performance of GPR, using different antennas (100 and 200 MHz shielded, 40 MHz unshielded) was significantly more satisfactory in the sandy and gravelly deposits of Fares, than in the clayey sediments of the Anfiteatro sinkhole.

**Keywords:** gypsum karst; collapse sinkhole; subsidence rate; hazard assessment; retrodeformation analysis

THEME: S6 : KARST GEOMORPHOLOGY

ABSTRACT NUMBER: 140

## STUDY ON THE EXTRACTION OF TERRAIN ELEMENTS BASED ON DEM IN KARST FENGLIN AND FENGCONG

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Fenglin and Fengcong are the most typical Karst landform in both terrain morphology and geomorphologic characteristic. Because of the limitation of data resolutions and analysis methods, the formal studies only focus on the qualitative description of the individual object. Therefore, with the involvement of GIS as well as the coupling of terrain and geomorphology, qualification and quantization, microscopic and macroscopic, representation and mechanism, there is an urgent for creating a scientific characteristic systems and analysis methods in terrain morphologic from individual – group - and region scale. In this paper, we present a method of automatic extraction of Fenglin and Fengcong in karst landform areas from DEM data. In the karst area, the Fenglin mountains are mostly tower-shaped, the slope is large, the relative elevation is small, the contours are increasing from outside and inside the elevation, there is no saddle, the density of the mountain is small, the space is scattered and the rivers are through the edge. Conversely, the Fengcong hills are mostly cone-shaped, the slope is small, the relative elevation is large, the contour shows the outer low inner high trap structure, there are obvious saddle points, the space distribution shows as cockpit shape, and catchment areas appear along the orientation of Fengcong. According to these morphological features of Fenglin and Fengcong, DEM data is used as the basic data source, the contour analysis model is constructed, the contour model and structure of Fenglin and Fengcong are constructed, and the extraction algorithm of terrain unit is designed. This research is an important attempt to study Karst landforms based on DEM. The proposed new model

and new method of Fenglin and Fengcong extraction is a useful exploration for geomorphometry.

**Keywords:** karst; digital elevation model; terrain feature extraction; Fenglin and Fengcong; topographic feature

THEME: S6 : KARST GEOMORPHOLOGY

ABSTRACT NUMBER: 230

## OBJECT-BASED IMAGE ANALYSIS OF GYPSUM DOLINES USING LiDAR ELEVATION DATA TO REFINE ALPINE LANDSCAPE EVOLUTION IN VORARLBERG, AUSTRIA

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High resolution elevation LiDAR datasets were used for semi-automated detection, delineation and depth classification of gypsum dolines in two test areas, underlain by gypsum-bearing Raibler Formation. In combination with a depth-age relationship the classifications were used to refine the role of gypsum in alpine landscape evolution. The first Gamp Valley site is located in the Rätikon Mountains, the second Lech Mountains site is an elevated plateau area at 2000 m elevation. Composite maps of openness and slope angle, derived from 0.5 m resolution LiDAR-based digital terrain models (DTM) were used as input to extract objects using isodata clustering, filtering techniques and chessboard segmentation using the eCognition9 software. The resulting 1910 individual objects were classified into small (<80m<sup>2</sup>), medium (80-375 m<sup>2</sup>) and large (>375 m<sup>2</sup>) dolines, attributed with depth information, and no dolines using 3 different models in 'R'. Classification accuracies reached varied between 85 and 93%. In addition, existing estimates of surface lowering resulting from known rainfall (~1900 mm/year) and hydro-chemical equilibria were used to obtain an age/depth classification which was prepared in ArcGIS10.4. Results indicate that all dolines in the Gamp Valley are younger than 11.500 years, while the dolines near Lech are of Holocene and Late-Glacial age, while some developed more than 25.000 years ago and thus survived the last Late Glacial Maximum (LGM). We conclude that metrics calculated from high resolution LiDAR elevation data can be successfully used to detect, delineate and calculate depth of gypsum dolines. The age/depth relations fit into the local geomorphological landscape evolution. Using this approach we foresee further advances to advance knowledge of the role of gypsum in for example glaciation/ deglaciation, in the fixation of Pleistocene sediments, in the spatial distribution of collapse features, in the triggering of landslides and in hydrological applications.

**Keywords:** Object-based image analysis; eCognition; landscape evolution; LiDAR; gypsum

THEME: S6 : KARST GEOMORPHOLOGY

ABSTRACT NUMBER: 269

## EPIKARST HYDROLOGY - AN INSIGHT FROM THE CROATIAN CAVE MONITORING

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Understanding of karst hydrology and identifying its influence on speleothem capture of climate and environmental proxies gets an increasing role in paleoclimate research. Recent studies have revealed that karst hydrogeology acquires important part in controlling cave water geochemistry and thus stalagmite chemistry and mineralogy. Here we present the results of parallel 2-year monthly cave monitoring of Nova Grgosova Cave (NG), Lokvarka Cave (LOK) and Modrič Cave (MOD), focused on understanding karst drip water hydrogeology and the relationship between surface climate, drip hydrology and speleothem morphology. Caves are located in parts of Croatia which differ by lithology, morphology, climate settings and altitude. In order to evaluate the influence of parameters such as temperature and rainfall amount on variability of drip rate and stalagmite deposition, surface and cave air temperature and relative humidity and cave water drip rates were measured at high resolution from November 2014 to November 2016. Seven drip loggers were installed at the sites of sampled speleothems. Drip intensity monitoring was performed by an automated acoustic drip counter set to record drips/hour values. All caves recorded low temperature variations and stable cave environments while dripwater intensities displayed different hydrological regimes. MOD drip sites with the seepage flows practically do not react to precipitation events, LOK drip sites show fracture-flow regime with fast response to rain events, while NG drip sites show substantial differences in hydrological response, within only few meters apart. Correlation between the hydrological behaviour and macroscopically observed growth of speleothems pattern is apparent. Drip sites with slow drip rates of low variability, produced the 'candlestick' speleothems with the most homogenous internal structure while speleothems deposited under the fast drip rate are irregular and with large portion of detritus.



THEME: S6 : KARST GEOMORPHOLOGY

ABSTRACT NUMBER: 373

## CORROSION RATES IN THE MIXED ZONE OF UNDERWATER LITTORAL CAVES (MALLORCA, BALEARIC ISLANDS, WESTERN MEDITERRANEAN)

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Despite it is well known that limestone corrosion and coastal cave enlargement is close related to the coastal mixing-zone between meteoric and seawater, there is a lack of quantitative data on corrosion rates in these environments. Recent exploration of Mallorcan coastal caves by means of speleodiving have shown a large number of submerged void characterized by the presence of different haloclines along depth profiles from 0 to 25 m bsl. At Cova de sa Gleda (Mallorca, Balearic Islands, Western Mediterranean), a 10 km in length cave reaching maximum depths of -25 m, we have deployed a three sets of calcarenite and aragonite weight-loss rock tablets (WLRT), 126 tablets, in order to cover a water column profile from 5 to 16 m in depth. The tablets were placed inside individual 63 microns nylon mesh bags. Tablets have been exposed during 749 days around two years. Additionally tables have been explored by means of SEM and XRD analyses. Differences in weight show that calcarenite tablets have lost in average 1.89% of their initial mass, although values range from 0.66 to 4.82%. Whereas aragonite tablets have lost in average the 8.05% being the range 1.21 to 18.51%. There are differences along the depth profile close related to haloclines. The first halocline appears a 5 m in depth, where salinity changes from 10 to 16 psu and where corrosion rates are of 3.10% for calcarenites and 11.08% for aragonite ones. At 10 m in depth salinity changes from 19 to 29 psu and the corrosion increases up to 10.8% in calcarenite and up to 17.93% in aragonite tablets. Finally at 16 m in depth, where the water mass corresponds to sea water (> 35 psu), the corrosion values decrease in both, calcarenite and aragonite tables, being the averaged values of 1.97% and 3.48% respectively.

THEME: S6 : KARST GEOMORPHOLOGY

ABSTRACT NUMBER: 632

## GEOMORPHIC WORK IN KARST LANDSCAPES AND EVOLUTION OF CAVE SYSTEMS IN SOUTHERN INDIA: IMPLICATIONS FOR CLIMATE AND ENVIRONMENTAL STUDIES

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Cave systems are controlled by lithologic, tectonic, topography, base level position and type of recharge. As water flows through the primary fissures in a karst massif, it dissolves the surrounding rock and gradually produces well-organised drainage patterns that evolve in to cave systems.

In the present paper, we discuss the geomorphic features, solution channels, and types and patterns of limestone caves from Chhattisgarh and Andhra Pradesh regions of southern India. The Kutumsar and Kailash caves in Chattisgarh region are located in the vicinity of the Kanger River that flows in NW-SE direction. The geomorphic features Tirathgarh water falls, valleys and hill ridges along the Kanger River surround the Kutumsar and Kailsh caves.

Based on geomorphological, tectonic and hydrological characteristics derived from field observations and satellite data, a conceptual model is proposed to understand the mechanisms of the extensive cave formation in the region. The model describes the role of numerous major and minor strike-slip faults with intense fluvial action resulting in surficial fractures of the carbonates. It is observed that the topographic elevation gradually rises from Kutumsar to Gupteshwar block (in Orissa) indicating the role of tectonic activity.

The evolution and channel patterns, architecture of speleothems of Belum (evolved on plain topography and extended in to sub-surface levels) and Borra (on valley-hills) caves are compared with the caves of the Chhattisgarh area. The Kutumsar, Kailash and Borra caves are influenced by the river hydrological characteristics and varied geomorphic characteristics; whereas Belum cave is influenced by sink holes and horizontal hydrological flow indicating varied climatic and environmental conditions.

**Keywords:** karst topography; limestone caves, solution channels, climate, southern India



THEME: S7 : ANTHROPOCENE GEOMORPHOLOGY

ABSTRACT NUMBER: 118

## HUMAN INTERFERENCES ON FLUVIAL SYSTEM: A STUDY OF RIVER MAHANANDA IN DARJEELING DISTRICT, WEST BENGAL

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Rivers play a significant role in the evolution of any landform. The entire Darjeeling Himalaya and its foothills had continuously modified by the rivers of Tista, Mahananda, Balason, Mechi and its numerous tributaries. But in recent times, the geomorphic process of these fluvial system have seriously disturbed by various human interferences, especially in urban area. The main objective of the paper is to identify the probable causes behind the fluvio-geomorphic change of river Mahananda in Darjeeling District, West Bengal. Extensive deforestation, landslide, bed material extraction activities, increasing impervious layer, faulty embankment construction work, encroachment of active flood plain area, uses of river bed as garbage dumping sites etc. drastically changed the fluvio-geomorphic characteristics of river Mahananda. As a result, the width, depth, wetted perimeter, cross sectional area of the river changes drastically in the last fifty years. Instead that, within these interference, river Mahananda try to adjust to its altered boundary condition and associated flow in the cost of failure of valuable bank protection measures, incidence of embankment breaching, and ultimately flood, which associated with man and properties loss. To find out, the significant fluvio-geomorphic change data derive from SOI topographical maps, satellite images have been used. Extensive field survey with the help of Auto Level, GPS have also incorporated with the previous Spatio-temporal data.

**Keywords:** human interferences; fluvio-geomorphic change; deforestation; landslide; bed material extraction.

THEME: S7 : ANTHROPOCENE GEOMORPHOLOGY

ABSTRACT NUMBER: 205

## HYDRO-GEOMORPHIC PERSPECTIVE OF URBAN RENEWAL: SELECTED EXAMPLES FROM KOLKATA

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The developing countries of the humid tropics, including India, are still experiencing rapid population growth along with their huge base population. It has been observed that the urban renewal is highly related to hydro-geomorphic conditions of the concerned areas. In most of the cases the urban growths are unsystematically expansive to accommodate the influx of population, and as a consequence, there is a continuous change in the urban infrastructure, like buildings, roads, water supply, drainage, waste disposal systems etc. These necessarily alter the hydrological as well as geomorphic conditions of the ambient environment. Very often this becomes a cyclic process to keep balance with the change of one over the other. For example, construction/ renovation of a road may lead to change in local relief to affect many people at household level and/ or neighbourhood level by poor drainage and water logging. Similarly change of sewerage system from surface to underground also adversely affects some localities of the peri-urban areas. Moreover, change in land use from semi-urban residential to urban-commercial results in low infiltration of water and high concentration of run-off effecting urban floods and related problems. A number of such examples have been cited from various parts of the city of Kolkata in this paper. The main objective of this paper is to identify the relationship between urban renewal and hydro-geomorphic conditions of an urban ambient under different scales of interactions. The methodology consists of close observations, some necessary measurements, consultation of various existing maps and published literature for an analytical discussion. The discourse is supported by suitable examples taken from different spatial units.

**Keywords:** Urban Renewal, Water-Logging, Hydro-Geomorphic Conditions

THEME: S7 : ANTHROPOCENE GEOMORPHOLOGY

ABSTRACT NUMBER: 206

## SILENT KILLER : ARSENIC CONTAMINATION IN WEST BENGAL, A CASE STUDY OF

## BARUIPUR BLOCK, SOUTH 24 PARGANAS DISTRICT, WEST BENGAL, INDIA

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Arsenic crisis in India is believed to date back to 1976 when a preliminary survey on arsenic in dug wells, hand pumps and spring water from Chandigarh and villages of Punjab, Haryana and Himachal Pradesh in North India was reported. Arsenic is a chemical element which occurs in many minerals. Groundwater, most often becomes contaminated naturally however contamination may also occur from mining or agriculture. The Pollution Control Board of West Bengal reports that out of the 341 blocks of the State, groundwater in 81 blocks was contaminated with arsenic. Baruipur is one of the arsenic affected community development blocks of South 24 Parganas district, having an arsenic concentration of 2.560 mg/l. This paper takes into account the problem of arsenic contamination in Ramnagar of Baruipur block of South 24 Parganas. Maximum concentration of arsenic was found in Ramnagar II village panchayat of Baruipur Community Development Block which was 3700 µg/L. The Government of West Bengal has proposed 6 schemes covering 25 mouzas for providing arsenic free water. A questionnaire survey was carried out in Ramnagar of Baruipur block. Most of the people have a low income of about 3000 to 10,000 rupees and very few persons who are engaged in service sector have income up to 45,000 rupees a month. Tubewells are the major water source in the area. The tubewells have been tested and these were detected with arsenic nearly 0.05 mg/L. Also, now water is supplied to the area by Public Health Engineering department. The respondents reported that the water appears to be of good quality and to be safe but it should be tested as well. They demand a more frequent service from the PHE. Symptoms of blackfoot disease have been found here and deaths of 14 people from Ramnagar.

THEME: S7 : ANTHROPOCENE GEOMORPHOLOGY

ABSTRACT NUMBER: 271

### ASSESSING THE REHABILITATION POTENTIAL OF FLOODPLAINS: CASE STUDY OF THE LOWER DRAVA PLAIN IN HUNGARY

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Complex human impact on floodplains is manifested in geomorphological (reduced diversity of fluvial landforms), hydrological (disrupted connectivity between river channels and side-arms, dropping groundwater levels) microclimatic (desiccation) and land use changes (conversion to arable land, shrinking riparian forests and wetlands etc.). In recent decades the Drava Plain has also suffered large-scale landscape degradation, which also affected the socio-economic environment. Human impact, first of all, peak-time operated hydroelectric plants on the upper section of the river in Austria, Slovenia and Croatia, resulted in large-scale daily fluctuations of water level. Bed dredging in Croatia also influenced channel processes in Hungary. To counter landscape degradation, a comprehensive landscape rehabilitation government project, the Old Drava Programme, was launched. Its water replenishment scheme focuses on the improvement of water availability through replenishment indirectly from the main river channel, taking advantage of a network of abandoned drainage elements (oxbows, old beds, levee crevasses, backswamps) in the floodplain. On this basis, an ambitious landscape management project is designed which has the long-term objective to significantly improve economic (employment), social (integration of ethnicities) and cultural (preservation of cultural heritage and its utilization for increasing tourism potential). Rehabilitation potential is used as a measure to express the extent to which the scope of ecosystem services/landscape functions can be broadened. Within the frame of our project changes in water availability and the ensuing landscape transformations are monitored with the purpose of assessing the efficiency of the water transfer scheme within the Old Drava Programme.

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THEME: S7 : ANTHROPOCENE GEOMORPHOLOGY

ABSTRACT NUMBER: 344

### IS ANTHROPOCENE GEOMORPHOLOGY DIFFERENT FROM FORMER GEOMORPHOLOGY?

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The current discussion about the pertinence of formally recognizing the Anthropocene as a new geological epoch, has focused mainly on changes affecting climate, biodiversity, atmosphere and hydrosphere chemistry, or the presence of new sedimentary materials and “technofossils” in the geological record. However, possible quantitative and qualitative changes affecting geomorphological processes and landforms have been largely overlooked.

The concepts of human geomorphic pressure and human geomorphic footprint, as well as their consequences on geomorphic processes, will be discussed. A conceptual model to explain the relationship between human drivers and observed changes in geomorphic processes, as well as some predictions formulated from it, will be proposed. Data will be presented to test the predictions. They show that erosion/sedimentation processes as well as frequency of geomorphological disasters increased about one order of magnitude in less than a century, and that this increase has been mainly due to land surface transformation by human activities, not to climate. The increase of both types of processes was particularly sharp after mid-20th century, coinciding with what has been called the Great Acceleration.

Evidence so far available indicates that the present model of geomorphic evolution is qualitatively (mainly human driven) and quantitatively (rates about one order of magnitude greater) different from the former one. This evidence supports the proposal made by the present authors in 2011, in the sense that the Anthropocene is characterized, among other things, by a marked change in geomorphic processes, and that the starting point of this (proposed) new geological epoch should be established after World War II.

**Keywords:** global geomorphic change; human geomorphic footprint; Great Acceleration; geomorphic processes’ rates; geomorphic disasters.

THEME: S7 : ANTHROPOCENE GEOMORPHOLOGY

ABSTRACT NUMBER: 376

## A SPATIAL ANALYSIS OF MASS MOVEMENT EVENTS ON TABLE MOUNTAIN, CAPE TOWN, SOUTH AFRICA

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This study examines the factors - both natural and anthropogenic - that contribute to mass movement activity on the Cape Peninsula, Western Cape. The method employs ground-truthed satellite imagery, based on Google Earth, to develop a series of morphometric and other characteristics of mass movement features that include spatial dimensions, slope angle, underlying geology and land use. We develop a morphological classification of mass movement features based on a dataset of 46 landslides. Predisposing factors are indicated by the fact that most of these features originate on steep topography underlain by Table Mountain Group sandstone with an average slope angle of 32 degrees. Anthropogenic factors are also considered important controlling elements, since more than half (56%) of the landslides are associated with recent wildfires, road or footpath construction and/or alien vegetation clearance. Most of the features were initiated during an unseasonably extreme rainfall event that occurred during the period 15th to 16th November 2013. The results suggest that the extensive wildfires that raged across the Cape Peninsula in the late summer of 2015 predispose the affected areas to future mass movement events and that such areas need to be closely monitored. This paper indicates the potential of free remote sensing products in developing a more complete understanding of extreme events and their geomorphic consequences.

**Keywords:** debris flows; mass movement; geohazard, morphometrics; Google Earth

THEME: S7 : ANTHROPOCENE GEOMORPHOLOGY

ABSTRACT NUMBER: 377

## BUILDING BEYOND LAND: AN OVERVIEW OF COASTAL LAND RECLAMATION IN 15 GLOBAL MEGACITIES

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The increase in global population has been accompanied by rising consumption of natural resources such as clean air, water and land. Demand for land has increased significantly over the past 30 years or so, both inland and at the coast. In coastal regions, reclaiming land from the sea has often been the preferred solution towards meeting the need for more land for urban development. Seaward land reclamation entails the construction of artificial land surfaces extending outwards over the sea using advanced geo-engineering techniques; it is driven by numerous underlying factors and has manifold impacts. Although this pattern of urban development is not new, the nature, scale and magnitude of land extension has changed dramatically for a range of underlying reasons involving both 'natural' geophysical and anthropogenic factors. The overall aim of this paper is to highlight the spatial extent of building beyond the land and to assess the extent of seaward land expansion in fifteen selected coastal megacities. Remote sensing data, spanning the time period mid-1980's to present, were obtained and used to determine the extent of spatial change due to new land construction. Landsat satellite imagery was used to calculate the percentage increase and area reclaimed since the mid-1980s. In addition, a systematic classification was developed on the basis of the types of geomorphic pattern that characterise the process. Among 15 cities analysed in this study, major land reclamation projects have been notable in three Chinese cities, most especially Shanghai which has expanded its coastal area by more than 580 km<sup>2</sup> in the recent past.

**Keywords:** coastal megacities, land reclamation, artificial land, geo-engineering, urban expansion

THEME: S7 : ANTHROPOCENE GEOMORPHOLOGY

ABSTRACT NUMBER: 488

## UNTANGLING THE ANTHROPOCENE IN NEW ZEALAND: ANALYZING A VERY LONG-TERM EXPERIMENT

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As the last major landmass to be settled – towards the end of the 13th century CE, New Zealand provides an excellent experiment for assessing the impact of people on landscapes and their dynamics. This paper presents a meta-analysis of existing data to evaluate this impact, not least because of the excellent series of lake analyses that have been carried out. Untangling the human effect, though, is not straightforward because of the spatial variability of settlement, which is denser in coastal areas compared to inland, and in the North compared to the South Island. Significant changes in past forest cover have been noted, however, well away from these concentrations, for example suggesting that there were significant feedbacks in the ways landscape changes occurred.

We define three levels of potential impact, based on the archaeological record, estimations of human activity around these sites, and the areas of the lake catchments being analyzed. In the near-field, the archaeological site catchments overlap with the lake catchments, while in the mid-field, a further buffer zone is defined based on ethnographic and historic information about Māori land use. Finally, far-field sites are defined as lake catchments beyond this zone. From this division, we demonstrate the differences between impacts in relation to the intensity of past land use, and the importance of spatial feedbacks. We also make comparisons between Polynesian and European settlement impacts.

In broader terms, this analysis enables us to demonstrate further the diachronous nature of the Anthropocene boundary and its implications in probably the best-constrained case. We also consider the importance of connectivity of erosional impacts, and the completeness of palaeorecords, and their implications for studies in regions where the record is less complete.

**Keywords:** Anthropocene, Geoarchaeology, Ecogeomorphology, Sedimentation rates, Methodology

THEME: S7 : ANTHROPOCENE GEOMORPHOLOGY

ABSTRACT NUMBER: 746

## THE CO-EVOLUTION OF GEOMORPHOLOGY AND SOCIETY IN THE ANTHROPOCENE: SEDIMENT FLUX IN A HIGH ALPINE HYDROELECTRIC POWER SYSTEM: RESULTS FROM THE SEDFATE PROJECT

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There is no reason to doubt the importance of human impacts upon geomorphic systems during the Anthropocene. Such impacts may be direct (e.g. river regulation for hydropower) or indirect (e.g. human impacts upon climate, which in turn modify the intensity of geomorphic processes). Comparison of the relative importance of direct and indirect impacts is possible. However, it needs to be undertaken with caution because there may be strong coupling between human experience of geomorphic processes and subsequent adaptation. In this sense, it may be better to talk of the co-evolution of geomorphology and society. In this paper, we present an example of this co-evolution. Geophysical prospection shows that in Lake Geneva, an iconic European freshwater lake, there has been a substantial reduction in fine sedimentation rates in the delta of the Swiss Rhône since the onset of large-scale Alpine hydroelectric power production in the 1950s. The reduction in sedimentation rate is likely to be detectable stratigraphically in the future as an Anthropocene signal. Since the late 1980s, it has been partially countered by an increase in temperature-driven sediment production from glaciated basins. However, both of these changes are complicated by the continual human adaptation to the changing geomorphology of the system, including both gravel extraction and operation of the water intakes associated with the hydropower system. Thus, what is recorded in the stratigraphic record of the Anthropocene in Lake Geneva is a complex combination of the direct and indirect (climate driving) impacts of human activity, as well as positive and negative feedbacks associated with human response to those impacts. It is highly unlikely that, in the Anthropocene, stratigraphic records can be readily linked to climate change and variability, in the ways that they could in earlier geological epochs when human impacts were negligible or less responsive to geomorphic events.

*THEME: S8 : GEOMORPHOLOGICAL OUTREACH*

**ABSTRACT NUMBER: 88**

## **DUNE ECOSYSTEM RESTORATION ON A HIGHLY IMPACTED BEACH: ANALYSING LAND USE/COVER, SPECIES DIVERSITY AND SEDIMENT TRANSPORT AT NORTHWEST BEACH, POINT PEELE NATIONAL PARK, CANADA.**

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Large-scale modifications of the natural landscape in Point Pelee National Park through continuous human interventions resulted in adverse impacts on natural habitats of Carolinian fauna and flora. Conservation and protection of these species through habitat restoration remains a key challenge for managers. This study first examined the spatial/temporal changes in land use and land cover using the Ecological Land Classification System for Point Pelee. Aerial photos for 2015, 2006, 1977 and 1959 were classified into land use land cover (LULC) classes. The ecological land classification system included Shoreline Vegetation, Deciduous Thicket, Sand Barren and Dune type, and Infrastructure for the entire Northwest Beach area. Feature extraction was used to classify each of the photos and then on-screen digitization was performed to visualize dynamic changes of land use and land cover that have occurred in response to impact on the Park. This provided a background of change that impacts an endangered species - Five-lined Skink (*Plestiodon fasciatus*). Sand dune restoration and associated vegetation is critical for Skink habitat restoration. Part two of this study examined habitat restoration through evaluation of sand dune formation and vegetation change. Species diversity and grain size distribution were calculated to determine progress toward dune restoration. Shannon and Simpson's diversity Index for the natural and disturbed areas were calculated. Potential dune building sand supplies were analysed and determined to be unsuitable. Given this result we propose alternate management strategies for dune restoration in Point Pelee.

**Keywords:** outreach; change detection; aerial photo; sand transport; species diversity

*THEME: S8 : GEOMORPHOLOGICAL OUTREACH*

**ABSTRACT NUMBER: 160**

## **MAKING THE MESSAGE SIMPLE : OUTREACH RELATED TO A WORLD HERITAGE SITE NOMINATION FOR A TECTONIC PROCESS SEEN THROUGH A LANDSCAPE**

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Landforms are the surface expression of tectonic processes, interacting with surface processes. They illustrate highly varied tectonic processes. E.g. they may be obvious fault escarpments, lineaments, anticline ridges. They can be small scale outcrop features (e.g. ground cracks, small folds), or huge areas, like rifts or orogenic belts. Tectonics works at a global scale, from the Earth's surface to great depths. For this reason it is not possible often to see the process except through its effects. Though actually this is true for much of geomorphology and geology – so a glacier can be seen, but not so easily the processes behind a drumlin's formation. An example of tectonics is oceanic subduction that can not be seen other than on a global scale view, but can be appreciated through a volcanic arc, or the distribution of earthquakes and surface faulting. Also a hot spot, or melting anomaly may only really be seen in the volcanoes it produces and possibly uplift related features. We provide a description of the outreach we have made to communicate a rift landforms in the Chaîne des Puys - Limagne fault site, part of the Western European Rift. This rift, in contrast to the East African Rift, is related to continental subduction (rather than the supposed hot spots in Africa, or the pull of the final Tethys Ocean subduction). Importantly, the geomorphology of the integrated rift environment provides the elements that can be used in outreach to understand the greater global processes, through a landscape of interlaced faults, volcanoes, inverted relief. This outreach is for the general public, but also is a vital component of UNESCO World Heritage, where the geoscience community needs to communicate sound scientific ideas that can be incorporated in global geoheritage.

**Keywords:** Outreach; Chaîne des Puys Limagne Fault; World Heritage; Rift

*THEME: S8 : GEOMORPHOLOGICAL OUTREACH*

**ABSTRACT NUMBER: 603**

## UNRAVELING GLACIAL LAKE OUTBURST FLOOD GEOMORPHOLOGY: AN EXERCISE ON JOKULHLAUP LANDSCAPE INTERPRETATION IN ICELAND

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Landscape interpretation is a central tenet of geomorphology. This presentation introduces an exercise on glacial lake outburst floods (GLOFs) designed for the laboratory section of an introductory or upper-division undergraduate physical geography, geomorphology, or geology course. It has three principle goals: 1) introduce students to GLOFs and megaflood geomorphology; 2) provide practice at landscape interpretation using a real-world case study in Iceland; and 3) introduce geomorphologic and geochronological field and lab methods. Overall, it gives students a chance to unravel the evolution of enigmatic GLOF landscapes, while inspiring them about the power and complexity of these epic hydrological events. GLOFs pose an increasing hazard in glaciated regions worldwide as climate change triggers rapid glacier retreat and human populations expand in downstream valleys. Meltwater pools in lakes, which can drain in floods when their dams fail or are overtopped. Interdisciplinary researchers map previous flood paths to predict future flood routes and create disaster mitigation plans, such as early warning systems and construction zone restrictions. While most GLOFs result from warming atmospheric temperatures, Iceland presents the unique case of outburst floods generated by volcanic activity. The island sits atop a tectonic spreading center and a mantle hotspot. Geothermal and volcanic activity beneath Iceland's ice caps generates enormous quantities of meltwater, which accumulates in subglacial lakes and frequently drains in GLOFs, known in Icelandic as jokulhlaups. Jokulhlaups have drained from Vatnajökull—Europe's largest ice cap—throughout the Holocene. These catastrophic floods leave behind a suite of erosional and depositional features, which transform existing glacial, fluvial, volcanic, and aeolian landforms. Adding to the complexity of this landscape palimpsest, the whole suite of processes acts again after GLOF events to sculpt a landscape of pitfalls for geomorphologic interpretation. This exercise takes us through these equifinalities to interpret clues of GLOF processes and forms.

**Keywords:** GLOFs; megaflood geomorphology

*THEME: S8 : GEOMORPHOLOGICAL OUTREACH*

**ABSTRACT NUMBER: 625**

## CAUSES FOR THE DEVELOPMENT OF CHAMBAL BADLANDS, INDIA

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The Chambal Badlands are deeply dissected erosional landscape developed in the southern Ganga Plains of India. These are well developed along the Chambal River and cover a vast area. In spite of being a distinct geomorphic feature, the causes of its formation is debated. In this study, we investigate the outcrops along the Chambal River near Dholpur, Rajasthan to understand the reasons for

its development. We evaluate development of the Chambal badlands with tectonic activities in the Himalaya during Late Pleistocene.

The alluvial sequences exposed along the Chambal River shows at least three discontinuity surfaces. The orogenic pulse stage determines the amount of proximal sector subsidence and distal uplift that in turn governs the development of discontinuity surfaces in the forebulge (or peripheral bulge). Southward migration of the Himalayan front should lead to the southward shift of the peripheral bulge leading to deposition in the north (i.e., over the older sequences) and incision in the south (i.e., south of older peripheral bulge axis). On the other hand, uplift in the hinterland would lead to vertical uplift of the peripheral bulge instead of its southward shift, which would lead to the incision of older sequences. The incision and sedimentation pattern in the study area suggests that the vertical uplift in the southern Ganga plains is more than the southward migration of the forebulge; this appears to be the main cause of the badlands formation. Therefore, we suggest that the incision by the cratonic rivers in southern Ganga plains is due to the orogenic pulses in the Himalaya.

**Keywords:** Chambal, Badlands, Forebulge, Himalaya

THEME: S8 : GEOMORPHOLOGICAL OUTREACH

ABSTRACT NUMBER: 645

## TECTONO- GEOMORPHIC EVOLUTION OF RAVINE AND ITS EROSION RATE ESTIMATION IN THE MARGINAL GANGA PLAIN, INDIA

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Yamuna and its cratonic tributaries present in the distal part of Ganga foreland basin show dense ravine with high drainage density and deep dissection and steep slopes ( $> 80^\circ$ ) and have received little attention. Agricultural economies face severe threat due to loss of fertile soil because of expanding gullies and ravine activity. The study area is part of Marginal Ganga plain (MGP) along the ravines of the Yamuna and Dhasan rivers. The study focuses on (i) to quantify the amount of soil eroded from ravine erosion and specific sediment yield (SSY); (ii) is there any role of clay mineralogy that accelerate ravine erosion; (iii) to understand tectonic or climate role in growth of ravines. Two digital elevation model (DEM) were prepared one from Daultapur area situated along Yamuna by RTK survey and another from CARTOSAT-1 stereo images for Jigni area situated along Dhasan river. Erosion rate was calculated by comparing the present day surface to pre-ravined modeled surface. The luminescence dates from several sections from MGP bracketed the section from 100-14 ka. Incision of most of the rivers in the Ganga Plain, Gujarat Plain and Central Peninsular plains took place during the Early Holocene at  $\sim 14-12$  ka. Therefore to calculate the erosion rates and sediment yield from the ravines, we consider the top age to be 14 ka, since then the modern ravines development started taking place. The results indicate that specific sediment yield (SSY) in the Marginal Ganga Plain (MGP) may range between  $800 \pm 100$  t/km<sup>2</sup>/yr to  $1900 \pm 300$  t/km<sup>2</sup>/yr. The correspondence between the orientation of ravine and fractures signifies role of extensional stress regime of foredeep in formation of these ravines. The swelling clay mineral that can initiate cracks and accelerate ravine growth in MGP which may be an added factor for ravine initiation.

THEME: S9 : BIO-GEOMORPHOLOGY

ABSTRACT NUMBER: 30

## WHITE-SAND VEGETATION OF AMAZONIAN LOWLANDS TRIGGERED BY LATE PLEISTOCENE-HOLOCENE GEOMORPHOLOGICAL PROCESSES

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Amazonian wetlands are covered by dense rainforest in sharp contact with a significant proportion of white-sand ecosystems consisting of open-vegetation (grasslands to shrublands) and forest of lower stature, slender trees and simpler canopy structure. White-sand ecosystems have long attracted scientific interest. This is because they show a relatively high proportion of endemic species that have contributed to increase the Amazonian biodiversity, being of unique value for nature conservation, as well as for research on Neotropical forests. Determining how the white-sand ecosystems emerged remains an unanswered question. Geomorphological processes have often been mentioned, but not so much discussed in detail. In this work, we analyze the influence of geomorphological processes on the origin of the Amazonian white-sand vegetation based on the integration of remote sensing and geomorphological field data.

The results revealed the non-random distribution and systematic confinement of this vegetation type to Late Pleistocene-Holocene paleolandforms. These features record Amazonian lowlands having high fluvial dynamics during this time-frame. Such relatively recent dynamics also included the existence of distributary channel networks that formed several triangular-shaped megafan morphologies. Disturbances in the physical environment caused by sedimentary processes determined the morphology of the region. Topographic gradients imposed by these paleomorphologies controlled flood regime, which was a central factor leading to the establishment and development of white-sand substrates and vegetation in the Amazonian lowlands. The megafans record drastic changes in the physical environment, which produced larger sandy deposits with positive relief that constituted the largest patches of white-sand vegetation known from these wetlands. The sandy substrate allied to hydrological contrasts imposed by the morphology of deposits formed in various sedimentary environments produced a substrate suitable for the development of stunted vegetation. It follows that linking biological processes with geomorphological forces will provide a more comprehensive understanding of the Amazonian ecosystem functioning and evolutionary patterns.

THEME: S9 : BIO-GEOMORPHOLOGY

ABSTRACT NUMBER: 57

## RIPARIAN PLANT RESPONSE AND EFFECT TRAITS: A BETTER PREDICTION OF BIOGEOMORPHIC EVOLUTIONARY TRAJECTORIES OF ALLUVIAL BARS?

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Within riparian corridors vegetation establishment is controlled by hydrogeomorphology which in turn is modulated by vegetation, acting as an ecosystem engineer. The potential of different vegetation species to affect geomorphology was poorly considered, especially according to their location on alluvial bars. The comprehension of the variation of morphological and biomechanical response trait attributes of plants is crucial to better understand how riparian plants impact fluvial geomorphology. We investigated the response of vegetation to hydrogeomorphic constraints and its engineering effect at two spatial scales within the dynamic Allier River, France. At the broader reach scale, we studied on sixteen alluvial bars the aptitude of three pioneer riparian Salicaceae species (*Populus nigra* L., *Salix purpurea* L. and *Salix alba* L.) to establish and to act as ecosystem engineers by trapping fine sediment. At the finer bar scale, we quantified the relation between response trait attributes of young (1-2yrs) *P. nigra* plants and their exposure to three different levels of mechanical stress (a highly exposed bar-head, a less exposed bar-tail, a chute channel). Our results show (i) that the capacity of riparian plants to establish and act as ecosystem engineers depends both of species and on their locations and (ii) that *P. nigra* plants develop different response traits depending on their exposure to mechanical stress. From a functional trait perspective our results suggest three main conclusions. First, that functional trait diversity of riparian engineer species plays an important role in plant resilience and in controlling the extent of fluvial landform construction. Second, that the development of different response trait attributes influences the capacity of plants to enhance fluvial landform construction. Third, that different plant response trait attributes may help to better predict biogeomorphic evolutionary trajectories of alluvial bars.

**Keywords:** riparian Salicaceae species; fluvial landforms; ecosystem engineer; response and effect plant traits; multi-scale study

THEME: S9 : BIO-GEOMORPHOLOGY

ABSTRACT NUMBER: 82

## LIFE ENCROACHING ROCKS – DENDROGEOMORPHOLOGICAL EVIDENCE OF BIOMECHANICAL WEATHERING CAUSED BY TREE ROOTS

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Life rules the Critical Zone and through extremely opportunistic behavior impacts its living space and the ecosystems it co-forms. In addition, terrestrial organisms frequently act as a key factor of the landform evolution. The current research project is based on the hypothesis stating that the tree roots are able to penetrate rock joints and fractures, widen them and cause bedrock wedging. Such assumption is frequently made a priori and ought to be thoroughly tested. This type of rock deterioration matches well a recently formulated term and scope of biomechanical weathering which belongs to biological weathering.

Based on dendrogeomorphology and wood anatomy, we tested if tree roots were able to make a mechanical stress on rocks along joints, fractures and openings, and thus contribute to the rock weathering and soil production. We selected a steep rock wall built of rhyolites and occupied by Norway spruce in Suche Mountains, SW Poland. From there we took increment cores of tree trunks and, after the excavation, samples of whole roots. The roots were then cut into pieces and with the use of microtome several microsections were prepared and analyzed applying standard wood anatomy procedures.

Tree roots in favorable conditions of mature soils keep their symmetrical and uniform growth along the main radius of development. However, when growth conditions deteriorate, for instance the roots do not grow directly in soil but in rock fractures, deformations of the roots, their bark and tree rings appear. Following detailed analysis of several microsections we were able to distinguish some key features in wood anatomy which indicate stress growth conditions of Norway spruce roots. These new features have not been previously recognized and they expand our knowledge of dendrogeomorphology of tree roots penetrating fractured bedrock. This project is supported by NCN (UMO-2014/15/D/ST10/04123).

**Keywords:** roots; biomechanical weathering; dendrogeomorphology; tree-ring; Norway spruce.

THEME: S9 : BIO-GEOMORPHOLOGY

ABSTRACT NUMBER: 225

## BIOLOGICAL SOIL CRUSTS MICROMORPHOLOGY ALONG AN ARID ALLUVIAL FAN IN NORTHEASTERN IRAN

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The dominant living forms in drylands involves syntax structure of biocrusts distributed on the arid soils. In Iran with approximately 80% arid and semi-arid environments, biological soil crusts (BSC) play an effective role on dust capturing, soil hydrologic balancing, soil aggregate stability, modifying soil properties, and pedogenesis. This research presents the succession of biocrusts along an arid alluvial fan located in northeastern of Iran. The studied area surfaces are ranged in age from Holocene to Pleistocene. The samples were collected in June 2016 from apex point to base part of the alluvial fan, which included lichens, cyanobacteria, mosses, and algae. Macroscopic features were examined for samples regarding the pedogenic structure and soil aggregation. The micromorphological examination was applied under a field emission scanning electron microscope (FESEM), and an analysis of XRD was used for extracting mineral compositions. The results indicated a significant relationship between soil-sediments development and biocrust succession as we found the cyanobacteria in base part with fewer amounts of soil moisture and debris and also with increasing slope and relief towards apex point, lichen species were the dominant cover. Comparison results of XRD between surfaces with BSC cover and devoid of biocrusts showed that biocrusts surfaces trapped dust and it indicated the stabilized role of BSC. There was a conceptual result that BSC succession can be developed regarding the geological age of surface as Holocene surfaces show mainly cyanobacteria community and older Quaternary layers covered by lichen and mosses species. This research shows a deep relationship between geomorphic structure and biocrust ecology.

**Keywords:** Biological Soil Crust (BSC), alluvial fan, micromorphology, cyanobacteria, Iran

THEME: S9 : BIO-GEOMORPHOLOGY

ABSTRACT NUMBER: 372

## CLOSING THE CIRCLE: SEAGRASS BERM DEPOSITION AND DISMANTLING AND BEACH SHORELINE PROTECTION AT MEDITERRANEAN MICROTIDAL SEMI-EXPOSED BEACHES

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*Posidonia oceanica* (Linnaeus) Delile 1813, is a reef-building seagrass endemic of the Mediterranean Sea that colonizes frequently the

nearshore and rocky bottoms of this Sea. *P. oceanica* loses leaves lately in summer and during autumn; the leaves, directly just after sheeding or indirectly after a temporary stay in the meadow neighbourhood, jointly with leaf epibionts, broken rhizomes, roots and leaf bundles are exported out of the meadow towards the sublittoral reef habitats and deep water, as well as, to the beach, where dead leaves, broken rhizomes and leaf bundles constitute seagrass berms, which can reach thickness of up to 2.5 m. These seagrass berms are thought to play an important role in many coastal processes and there is an intense debate of their contribution to shoreline protection against erosion. By means of coastal videomonitoring at Cala Millor – a 2,5 km in length microtidal semi-exposed beach located at North Eastern Mallorca (Balearic Islands, Western Mediterranean)– we have compiled an extensive database (2011–2016) on shoreline position and the presence-absence of seagrass berms along the shoreline from hourly images. Two different approaches have been developed: firstly a descriptive assessment of the events of seagrass berm accumulation and dismantling; and secondly a supervised automatic mapping and distribution analysis of seagrass berms along the coast. This map product was fronted to the shoreline change rates obtained from videomonitoring shorelines for the same period. Results show that seagrass berms accumulation and dismantling is a complex process mostly related to the last phases of sea storms. In normal conditions, they tend to remain few days on the beachface. We did not find any significant relationship between the presence and absence of seagrass berms along the shoreline and the shoreline change rate. Therefore we cannot conclude that seagrass berms exert an effective role in shoreline protection.

*THEME: S9 : BIO-GEOMORPHOLOGY*

**ABSTRACT NUMBER: 792**

## **LAND SURFACE FEATURES AND DISTRIBUTION OF WILDLIFE – CASE STUDY OF MUSK DEER IN DACHIGAM NATIONAL PARK, KASHMIR (J&K)**

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The association and occurrence of some wildlife with particular earth surface features evidences the role of geomorphology in governing the distribution of wildlife. The roles of geomorphologic factors like aspect, slope, altitude, ground morphology, availability of the plenty of rocky areas and outcrops, hiding cover, etc. and vegetation characteristics have been studied in detail for three years in finding the suitable habitats of Kashmir musk deer in Dachigam National Park (Kashmir, J&K). The geomorphologic features proved important in fairly describing the distribution of musk deer and mapping of the suitable habitats. The aspect (293° Northwest – 68° Northeast) was found highly significant in determining the distribution of musk deer, followed by slope (25° – 40°) and elevation (2100m and above). A dense hiding cover (60–80%) in the 0–50 cm vertical stratum and a less dense hiding cover (30–50%) in the 50–100 cm stratum provided by the landscape features and the vegetation in the suitable musk deer habitats persisted through most of the year. The sighting visibility in the habitats was found limited to between 8 and 20 meters.

**Keywords:** Musk deer, distribution, geomorphology, aspect, slope, elevation, hiding cover

*THEME: S10 : WEATHERING, SOILS AND REGOLITH ON DIFFERENT TIME SCALES*

**ABSTRACT NUMBER: 11**

## **POTENTIAL THRESHOLD RESPONSE IN TAFONI DEVELOPMENT: AN ALTERNATIVE APPROACH TO CAVERNOUS ROCK DECAY**

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Although still considered relatively unconventional in rock decay research, evidence of geomorphologic threshold responses has existed for decades. Generally defined as abrupt responses in a system under gradually changing levels of stress (or energy), thresholds are witnessed in the natural world in occurrences such as dew points, quantum mechanics, mass wasting, and fluvial systems. The purpose of this research was to explore threshold responses in cavernous rock decay and, specifically, tafoni development and evolution. Morphometric data gathered from a datable cultural stone surface exhibit periodic spurts in growth, possibly supporting threshold

modeling for tafoni evolution. Existing tafoni models vary, including linear, non-linear exponential, log-normal, and S-shaped, but none fully incorporate the concepts of thresholds beyond the existence of initiation lag times and heavily rely on the size=age assumption. Research presented here applied threshold response theory to tafoni evolution to create a visual model of growth using empirical data collected from Djinn Block X in Petra, Jordan. While this model is preliminary and non-mathematical, its significance rests in representing a potential new approach to tafoni development research and threshold-based stages of cavernous rock decay.

**Keywords:** Cavernous Rock Decay; Honeycombing; Tafoni; Thresholds; Petra

*THEME: S10 : WEATHERING, SOILS AND REGOLITH ON DIFFERENT TIME SCALES*

**ABSTRACT NUMBER: 44**

## **GEOMORPHIC EVOLUTION OF BHAWAL GARH: A PEDOGENIC APPROACH**

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Pleistocene Madhupur Tract is a large upland situated in the central part of Bangladesh. Northern part of this tract is locally known as Madhupur Garh whereas southern part is termed by Bhwal Garh. Present study area comprises Sreepur and Kapasia Upazila's of Gazipur district belongs to Bhawal Garh of Madhupur Tract. The study area shows geomorphic features such as Madhupur Terrace, Paleochannels, Floodplains, Intermittent Channel, Valley/Abandoned Channel, Gully, Active Channel and its Bar. Soil-geomorphic studies of the Sreepur and Kapasia area have been enabled by the identification of seven soil-geomorphic units. These units are grouped into four soil chronoassociation members i.e., QGBG I-IV (Quaternary Geology Bhawal Garh). Major pedogenic processes are ripening, ferrollysis, acidification, clay eluviation and illuviation. Based on pedality, pedogenic clay content, major oxides and trace element percentage, solum thickness and thickness of B-horizon of soils from different soil-geomorphic units may be ordered according to their maturity Unit G Unit F, E & D Unit C & B Unit A. Landsat TM, SPOT Pan, Rapid Eye and Google Earth Pro Images were used to identify drainage pattern and four lineaments (three longitudinal and one transverse). Distribution of geomorphological features and soils helped to delineate two tectonic blocks bound by these lineaments. Neotectonic movement of these blocks has affected morphogenesis and pedogenesis significantly. Soil development increases from north to south. Climate seems to have become subhumid-semiarid during 20-18 Ka (LGM), leading to sea level regression entrenched the rivers of Bengal Low land and development of terrace formation in the Bhwal Garh area. Between 10-12 Ka, humid monsoon climate leads the deposition of areally extensive soil and parent material of older flood plain soils. Initial phase of soil forming process was observed in channel bars during field check up in the study area.

**Keywords:** Pedogenesis, Lineament, Soil-Chronoassociation

*THEME: S10 : WEATHERING, SOILS AND REGOLITH ON DIFFERENT TIME SCALES*

**ABSTRACT NUMBER: 96**

## **SOIL FORMATION IN THE SOUTHEASTERN TRANSBAIKALIA IN THE HOLOCENE**

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According to the study of the sections, soil formation processes at the northern boundary of Central Asia in the Holocene have been resumed. As a benchmark basin we chose the lake Khara-Nur, located at the boundary with Mongolia. Traces of the first cycle are represented by the residually powerful humus horizon of buried soil in the lake basin. Formation of the lower soil refers to the middle boreal period and dates from  $9210 \pm 190$  calibrated years ago. As a result of a short but strong cooling on the border of the Atlantic and Boreal periods during the short-term regression of the lake, cryogenic wedges have formed in this soil. In the Atlantic period of the Holocene, two powerful regional soils of the chernozem type were formed: about 8 and 6.4 thousand calibrated years ago. In the subboreal period, the relief formation conditions have been changed almost every 500 years. In the sediments of the first terrace of the lake, these changes are represented by a series of alternating lake and eolian interlayers formed from the middle of the Subboreal period ( $3780 \pm 180$ ) calibrated years ago. The time intervals of short-term stabilization of geomorphological processes are recorded by two underdeveloped light chestnut soils. The subatlantic soil has been formed  $1400 \pm 100$  calibrated years ago. This soil developed by the chestnut type. In general, the change in the properties of palaeosoils in the Holocene allows us to outline the paleogeographic evolution

of the region from the damp and warm conditions of the Atlantic period to the cold and dry natural conditions of the subboreal period and further to the sharply continental semi-arid conditions of the sub-Atlantic period.

**Keywords:** Holocene; paleosoils; radiocarbon dates; evolution of landscapes; Transbaikalia

*THEME: S10 : WEATHERING, SOILS AND REGOLITH ON DIFFERENT TIME SCALES*

**ABSTRACT NUMBER: 106**

## GEOMORPHOLOGICAL-PEDOLOGICAL EVOLUTION OF CUESTA ESCARPMENT FOOTHILLS IN SOUTHEASTERN TROPICAL BRAZIL

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The cuesta escarpments, located between the Peripheral Depression of Sao Paulo and the Western Plateau of the State of Sao Paulo (Southeastern Tropical Brazil), are among the most expressive landforms of the Parana Sedimentary Basin, one of the main geotectonic units of South America. According to traditional literature, the landforms of depressed zones lying in front of the scarps have their genesis attributed to erosive processes, whose interpretation is based on the allochthonous or autochthonous nature of the materials and elaboration of erosion surfaces of neogenic age. However, recent studies suggest that on the foothills of the Sao Pedro cuesta's frontslope there are elongated hills where correlative deposits have a restricted presence. Therefore, the objective of this paper was to investigate the genesis and the geomorphological dynamics of these foothills, relating to the evolution of materials (pedological cover, deposits and rocks) of the region. Topomorphological surveys, drillings and trenches were made along a topossequence 830-meter long in a hilly interfluvium, where material samples were collected for physical, chemical, mineralogical and morphological analyses, besides dating by optically stimulated luminescence. Preliminary results show that materials present in the smooth and convex top of the hillslope investigated are homogeneous, mean textured and dark-red colored (2.5YR 3/6); after a convex change of slope, which separates the top from the middle sector of the hillslope, red-yellowish (5YR 4/6) materials occur, with texture varying with depth; in the inferior sector, after a concave change of slope, the material becomes more yellowish (7.5YR 4/4) and clayey, occurring some fragments of basalt, siliceous and ferruginous crusts. The functional association between the relief forms and the existing materials suggest the autochthonous character of the materials in the upper third of the slope and the allochthonous character in the footslope, besides the quaternary elaboration of the landforms and pedological cover.

*THEME: S10 : WEATHERING, SOILS AND REGOLITH ON DIFFERENT TIME SCALES*

**ABSTRACT NUMBER: 123**

## QUANTIFYING CHANGES IN NEAR-SURFACE SOIL MOISTURE AND TEMPERATURE DURING PRESCRIBED FIRE UNDER THREE FUEL LOADS

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Prescribed fires are conducted to reduce accumulated fuel loads and maintain fire-dependent vegetative species and wildlife habitats. Few studies have examined the impacts prescribed fires have on near-surface soil-water dynamics. Fire-induced changes in soil temperature, moisture content, water potential, infiltration capacity, and aggregate stability were measured during experimental fires (fuel loads: 0.5, 2, and 5 T acre<sup>-1</sup>) and a prescribed fire conducted in the field (1.7 T acre<sup>-1</sup>). Burns at fuel loads less than 2 T acre<sup>-1</sup> caused small changes in soil moisture content and water potential, while burns conducted at fuel loads greater than 5 T acre<sup>-1</sup> may reduce soil moisture content and prolong increased temperature in near-surface soil. Burns aimed to remove invasive vegetation should be conducted at fuel loads greater than 4.2 T acre<sup>-1</sup> to achieve the 60°C threshold for root mortality; however, land management may need to plan for erosion control in these burn situations.

**Keywords:** prescribed fire; soil moisture; matric potential; aggregate stability

THEME: S10 : WEATHERING, SOILS AND REGOLITH ON DIFFERENT TIME SCALES

ABSTRACT NUMBER: 164

## FERRICRETE GENESIS IN THE NORTHWEST OF PARANÁ STATE (BRAZIL)

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In the Northwest of Paraná (Brazil) there are records of the occurrence of preserved ferruginous materials in the form of duricrusts, positioned at the top of hillock and knolls. The ferricretes investigations in this area were focused on the identification and mapping of their distribution. However, there is no research concerning about the genesis and relationship with landforms. Therefore, this study aims to analyse the genesis of these ferricretes, using the mineralogical characterization (XRD) and micromorphology of soil profiles with ferruginous concentrations. By the micromorphological analysis and mineralogy from the base (mottled horizon) to the top of soil profile (ferricrete) it was observed that both the micromorphological and mineralogical properties change. The initial S-Matrix consists of quartz enveloped by fine material gradate to ferricrete, which is cemented by ferruginous material, producing a diversity of crystalline pedofeatures. We identified 7 phases of pedogenetic development in the profiles formation with ferricrete. The first and second are related to rock weathering and regolith formation (including mottling); the third one is the ferruginization; fourth to sixth are characterized by the S-Matrix cracking and precipitation of pure iron oxide in fractures, and the seventh and the present phase, profiles dismantlement. This phase is also attributed to soil erosion, mobilization and deposition of ferricretes in the form of stonelines, witnessing phases of quaternary planation. Evidences suggests that ferricretes are testimonies of geomorphological stability (ferruginization), with recent disturbance of the system (dismantling), and can be used as an indicator proxy data of landform evolution in the northwest of Paraná.

THEME: S10 : WEATHERING, SOILS AND REGOLITH ON DIFFERENT TIME SCALES

ABSTRACT NUMBER: 306

## AEOLIAN PEDOGENIC CHARACTERISTICS OF TERTIARY LIMESTONE NEAR PORT CAMPBELL, VICTORIA AUSTRALIA — MARINE OR PEDOGENIC?

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The stratum of coastal cliffs near Port Campbell in Victoria, Australia is generally considered to be deposited in a moderate to high-energy continental shelf environment during the Miocene Period, known as Port Campbell Limestone. However, aeolian pedogenic features are observed from this sequence. In order to understand the origin of the Limestone, one section from the Twelve Apostles was sampled. Grain size, morphology of quartz grains, rare earth elements (REE) and rock magnetic parameters are measured. The particles size of the whole section shows uniform fine feature and smaller than 100  $\mu$ m, very similar to those of loess and palaeosols according to Sahu's empirical judgement equation (the Y-values of aeolian deposits using the equation should be smaller than  $-2.7411$ ). Scanning Electron Microscopy (SEM) analysis demonstrations that most of the quartz grains from Port Campbell Limestone have irregular and angular shapes and many are characterized by sharp edges and conchiform fractures of wind-blown. The REE patterns of Port Campbell Limestone show extreme homogeneity, similar to those of Chinese loess-palaeosol. These samples enriched LREE and fairly flat HREE profiles, are also the REE properties of the upper continental crust, suggesting that the sediments of Port Campbell Limestone were all derived from well-mixed sedimentary, very likely to be aeolian, other than marine deposits. In addition, the outcrop of the Port Campbell Limestone shows well bedding of pedogenic  $\text{CaCO}_3$  nodules, features of secondary origin of  $\text{CaCO}_3$ , continental topography and plant root fossils, the "Port Campbell Limestone" was thus suspected to be developed in continent as topsoil environment mainly rather than environment of continental shelf. This hypothesis is effectively supported by a report of palaeosol/sand dune sequence from the coastline of Port Lincoln, South Australia.

**Keywords:** Port Campbell Limestone; Victoria Australia; Continental shelf deposition; Aeolian palaeosol origin; Sedimentary Environment

THEME: S10 : WEATHERING, SOILS AND REGOLITH ON DIFFERENT TIME SCALES



ABSTRACT NUMBER: 307

## STUDY ON THE ORIGIN OF THICK LATERITE ON DECCAN PLATEAU, INDIA

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Deccan Plateau in India is formed by number layers of basalt eruption before the end of Cretaceous. During eruption intermittent periods, top basalt was subjected long time weathering, Deccan plateau is therefore actually composed of multilayer basalt and weathering red soils. Its thickness is more than kilometers. Across southern Deccan Plateau there is a 25 m thick laterite capping on the basalt, this laterite is conventionally hypothesized to derive from in situ weathering from underlying basalt. The red soil underlying the laterite (but above basalt) is speculated to be of similar origin. However, homogeneity in vertical weathering and absence of any relic features of parent rocks (i.e. underlying basalt) in so thick laterite, while the weathered basalt red soils developed during eruption intervals show clear difference of weathering from top to bottom within 3-5m thickness, these phenomenon does not support the hypothesis above. Mode of relief inversion is implausible for origin of the red soil and homogeneity in vertical weathering. It is noted that dust storms are recently reported every years; and modern aeolian deposits are observed from root parts of surface grass to top of tablelands on Deccan Plateau. Based on the occurrence of modern aeolian sediments on Deccan Plateau and laterite characteristics in weathering, it is proposed that formation of the thick laterite and the red soil is probably related to aeolian accumulation. Aeolian deposits are likely altered so much in tropical climate that they were not previously identified. It is hypothesized that dust has sustainably accumulate since 65 Ma ago to offer adequate iron source for the thick laterite. Dust accumulation is contemporaneous to chemical weathering. The homogeneity in vertical weathering might attribute to paleoclimatic stability during laterite formation.

**Keywords:** Indian laterite; Basalt in Deccan Plateau; Laterite origin; Basalt weathering; Aeolian deposit and pedogenesis

THEME: S10 : WEATHERING, SOILS AND REGOLITH ON DIFFERENT TIME SCALES

ABSTRACT NUMBER: 366

## CAVES IN CAVES: EVOLUTION OF POST-DEPOSITIONAL MACROHOLES IN STALAGMITES

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Using CT and direct observations, we have examined twenty-six stalagmites from a variety of settings and shown that almost all have a variety of microscopic to macroscopic pores. These individual holes can be divided according to their position axial holes and off-axis holes. Axial holes form along and parallel to the stalagmite axis, are usually elongated, ranging in length from 0.5 to 4 cm. A significant feature of the axial holes is the downward bending of the surrounding growth layers towards the holes; Off axis holes (OAHs) are developed away from the stalagmite axis. They cut discordantly through growth layers, and rarely terminate at a current growth surface. OAHs are usually more rounded and smaller than the axial holes, ranging from 1 mm to 2 cm; their axis vary from parallel to the stalagmite axis to parallel to the crystal growth axis or completely irregular.

Possible origins of OAHs in stalagmites include (1) corrosion of micro gours at surface, enhanced by further dissolution beneath the stalagmite surface whilst calcite precipitation during stalagmite growth has subsequently sealed these cavities off from the outside environment under new calcite layers; (2) a post-depositional shift in the chemical equilibrium to  $\Omega_{ct} < 0$  at specific loci inside the stalagmite, i.e. diagenetic porosity. The process could be enhanced or even triggered by the action of bacteria living inside the stalagmites. By lowering pH conditions necessary for corrosion of the host calcite. The known permeability of stalagmites would permit entry of the bacterial spores and continued supply of nutrient in the form of dissolved organic species derived either from the soil or from excretions of resident spelean fauna. We have shown bacteria inside off axis macroholes, and on the surface of an active growing stalagmite from a cave in Israel.

**Keywords:** Stalagmites; Diagenesis; Bacteria; CT; Weathering

ABSTRACT NUMBER: 367

## POST-FIRE GEOMORPHIC RESPONSE IN MEDITERRANEAN CARBONATES HILLSLOPES

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The role of wildfires as a major geomorphic agent has shaped the Mediterranean landscape for millennia. Every year >50 000 fires burn an estimated average of 600 000–800 000 ha, equivalent to 1.3–1.7% of the total forest area. Short-term increases in runoff and erosion are prevalent in the burnt areas, however, integration of these processes into landscape evolution models or estimations of denudation rates are less common. The study suggests a conceptual model to address the long-term effects over the landscape.

Following the wildfire in 2010, massive destruction of carbonate rocks was observed on the slopes of Mt. Carmel (Israel). The bedrock surfaces exhibited extensive exfoliation into flakes covering up to 100% of the exposed rocks. The fire affected six carbonate units composed of chalk, limestone, and dolomite. The most severe response was found in the chalk formations which are mostly covered by calcrete. These rocks reacted by extreme exfoliation, at an average depth of 7.7 to 9.6 cm and a maximum depth of 20 cm.

Field survey conducted seven years after the fire revealed that the upper layers of the burned rocks were removed, the flakes that disintegrated and detached have fallen, and a new, fresh rock face has been exposed to weathering processes. The abundant flakes, so prevalent during the first year after the fire, were either removed by gravity and runoff, covered or incorporated into the topsoil.

It is difficult to estimate the frequency of high-intensity fires in the Carmel region over the past 2-3 million years. It is even harder to assess the fires frequency over a single outcrop. Our findings show that wildfires can be responsible for a high percentage of the total denudation rate and therefore, may serve as extremely important factors in landscape evolution.

**Keywords:** Mediterranean Wildfires; Denudation; Soil erosion; Weathering; Fire regime

ABSTRACT NUMBER: 436

## WEATHERING OF BEDROCKS, FORMATION OF HARDPAN CALCRETES IN THE THAR DESERT, WESTERN RAJASTHAN: STRAIGRAPHIC MARKER HORIZONS

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Hardpan calcretes (greater than 400 ka) are formed over the Precambrian substrate occurs as duricrust horizons in the Thar desert Desert, Western Rajasthan. These hardpan calcretes have formed by the weathering of bedrock of the Precambrian hornblende gneiss, schists, rhyolite and carbonaceous phyllites forming a distinct cover over which the late Quaternary sand dunes are deposited. The bulk chemistry of calcic nodules and the hardpan calcretes show little variation in CaO, SiO<sub>2</sub>, Al<sub>2</sub>O<sub>3</sub> and Fe<sub>2</sub>O<sub>3</sub> content. The trend of trace metal content in calcic nodules and in the hardpan calcrete is Mn > Zn > Ni > Cr > Pb > Co > Cu and Zn > Mn > Ni > Co > Pb > Cu > Cr respectively. PAAS-normalised REE data of the calcretes (calcic nodules and the hardpan) demonstrate a positive Eu anomaly. The Eu anomaly is attributed to the occurrence of feldspar, apatite mineral alteration and soil diagenetic processes, and differential weathering leaving behind plagioclase phenocrysts which are enriched in Eu. The stable isotope values of the hardpan calcretes vary from (δ<sup>18</sup>O –2.91 to –12.98‰) and δ<sup>13</sup>C (–0.05 to –7.4‰). The palaeoenvironment during the formation of the calcretes nodules was dominated by the C<sub>4</sub> plants with sparse vegetation cover and that the parent material/bedrock supported a thin veneer of soil column as present day. The hardpan calcretes has been formed because of differential weathering and chemical histories within. These hardpan calcrete can be applied as straigraphic marker horizons to correlate and understand late Quaternary straigraphy of western Rajasthan, Thar desert, India.

**Keywords:** Weathering, Bedrock, Hardpan Calcretes, Late Quaternary straigraphy, Marker horizons

ABSTRACT NUMBER: 509

## GEOMORPHOLOGICAL AND REGOLITH MAPPING IN PARTS OF WAJRAKARUR KIMBERLITE FIELD, ANANTAPUR DISTRICT, SOUTHERN INDIA

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Regolith mapping has many applications in terrain mapping, mineral exploration, natural resource management, environmental planning etc. In the western world, regolith mapping gained vital importance in the reconnaissance mineral exploration whilst in India it is not so popular. Especially in exploration of diamond, gold, rare earths etc., it is proved to be useful in defining the exploration targets. Kimberlites and lamproites rarely carry diamonds from the mantle to the surface. Firstly, it is important to find kimberlites/lamproites and their diamond potentiality is ascertained in course of exploration. Understanding geomorphic evolution and regolith distribution is an important aspect in diamond exploration. As kimberlites/lamproites occur as small outcrops, satellite image studies may not detect these rocks on the surface. Hence a close-space geological mapping is inevitable during reconnaissance and helps in locating surface expressions like calcrete that guide the explorationist towards a kimberlite discovery. In this paper, high resolution geomorphological and regolith map, interpreted from satellite data, has been presented with reference to known kimberlites at Lattavaram of the Wajrakarur Kimberlite Field (WKF) where four diamondiferous kimberlites were reported earlier. The lithology constitutes granitoid and gneissic terrain intruded with dolerite dykes trending in NW-SE, ENE-WSW, NNW-SSE directions. Geomorphologically the area comprises fluvial erosional and depositional landforms such as residual hills, linear ridges, rocky knobs, pediplain and valley fills. The NW part of the study area comprises 1-2 meter thick black soil cover. The area mostly possesses brown residual granitic soil. Pedogenic calcrete originated from different rock types is a common feature. The kimberlitic calcrete possesses relict textures and kimberlitic mineral grains whereas the granitic calcretes display cherty character with weathered or fresh feldspar. The soils over kimberlites show a conspicuous variation in tone and texture when compared to the granitoid country. This work highlights the importance of geomorphological/regolith mapping in kimberlitic terrains.

**Keywords:** Regolith, Geomorphology, Mapping, Kimberlite Field, Wajrakarur, Diamond Exploration

ABSTRACT NUMBER: 573

## LITHOLOGICAL AND CLIMATIC CONTROLS ON CHEMICAL DENUDATION IN SMALL WATERSHEDS OF THE WESTERN INDIA

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Small watersheds of three different geographical locations in Western India, Mount Abu, Western Udaipur and Saputara, having distinct climatic and geologic settings are sampled to assess the chemical weathering and its controlling factors. Mount Abu and western Udaipur are located in semi-arid region, having granitic-gneissic and phyllitic-schist lithology respectively whereas Saputara lies totally in Deccan basalt exposure with high rainfall conditions. Average total dissolved solids (TDS) in west Banas (Mount Abu) and Berach (Udaipur) rivers are  $257 \pm 161$  and  $352 \pm 139$  mgL<sup>-1</sup> respectively. In Saputara, Ambika and Girna rivers have averaged TDS  $333 \pm 109$  mgL<sup>-1</sup>. Ternary plots among Ca, Na+K, Mg apices and Si, HCO<sub>3</sub> and SO<sub>4</sub>+Cl apices indicate dominance of silicate weathering during monsoon in Mount Abu compared to Udaipur. Saputara region indicates dominance of basalt weathering as samples cluster towards Ca+Mg and HCO<sub>3</sub> apices. The total annual chemical denudation rates (CDR) are also calculated based on TDS, weighted over monsoon (85%) and non-monsoon seasons (15%). Average CDRs at sampling locations in the basin are  $53 \pm 18$ ,  $60 \pm 15$ ,  $224 \pm 74$  t km<sup>2</sup>y<sup>-1</sup> respectively for Mount Abu, Udaipur and Saputara regions. At the outflows of the basins, the CDRs are 77, 71, 327 and 294 t km<sup>2</sup>y<sup>-1</sup> for West Banas, Berach, Girna and Ambika rivers successively. Mount Abu and Udaipur regions have significantly lower CDR than Saputara, indicating the high weatherability of Basaltic rocks in Saputara region intensified by heavy rainfall. This observation needs to be verified as Saputara region is sampled during non-monsoon only. Mount Abu and Udaipur regions display similar CDRs with dominance of silicate weathering in former due to the presence of primary silicate minerals in its basin (K-feldspar rich in Granites) compared to sedimentary rocks in later (schist, phyllites). This study clearly indicates the significant impact of lithology and climate in controlling the chemical weathering.

**Keywords:** Dissolved major ions; Chemical Denudation; Ternary plots

ABSTRACT NUMBER: 657

## UNSCIENTIFIC INTERFERENCE WITH PEDO-GEOMORPHIC PRINCIPLES AND ITS IMPACT ON CROP PRODUCTION IN BARDDHAMAN OF WEST BENGAL, INDIA

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Selection of crops and its productivity are integrally related with soil texture. Because the vital pedological components of agriculture like moisture retention, cation exchange capacity, pH, soil organic carbon content, nutrient holding and buffer capacity are determined by soil texture. But, based on rampant use of irrigation facilities (canal and or submersible) as well as chemical fertilizers, the farmers of Bardhaman District cultivate mono crop (aman and boro) ignoring all sorts of pedo-geomorphic principles what incurs huge loss in the agro-economic livelihood.

Eight C.D.blocks of the district have been studied to reveal the impact of unscientific interference with pedo-geomorphic principles in the cropping system. In one hand, higher organic carbon pool, SOC concentration and nitrogen content are found in fine texture than coarse texture soil. On the other, replenishment of sediment maintains the neutral pH of the soil in Ketugram-II (6.51) and Purbasthali-II C.D. Block (7.38) than older alluvium in Galsi-II Block (5.706). Again, soil organic carbon concentration and pool in sandy loam texture is relatively lower in Galsi II (3.997 g /kg and 8.112 Mg/ ha) than Ketugram II (5.66 g /kg and 11.954 Mg/ ha) which is 30% lower than new alluvium. Interruption of riverine ecosystem through embankment and decline in sediment yield can significantly alter the soil ecosystem where intensive subsistence farming is practiced. Consequently, productivity of paddy is higher in fine texture than coarse one in spite of using more chemical fertilizer in rice cultivation in coarse texture soil. In this circumstance, to maintain productivity of crops and sustainability of economy, selection of crops must be done according to the texture of the soil.

**Keywords:** Pedo-geomorphic Principles, Soil Texture, Moisture Retention, Cation Exchange Capacity and Soil Organic Carbon

ABSTRACT NUMBER: 670

## THE RELATION OF FERRICRETE AND PEDOLOGICAL SYSTEMS WITH THE LANDSCAPE EVOLUTION IN MARACAÍ – SP (BRAZIL)

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The ferricretes were formed through pedological processes and contribute to understanding landscape evolution. Presently, there's still little material correlating soil and landscape evolution over the space and time. We present the role of the ferricrete in the landforms in the southwest of São Paulo State, Brazil. We worked with a multiscale analysis, from a regional to a soil scale. Firstly, we analysed the geological, geomorphological and pedological contexts (map scales: 1: 100,000 and 1: 50,000), which led to the landscape compartmentation, and then, we selected the flattest compartment with lakes. Next, we did a morphological map combining aerial photographs in the scale 1: 25,000 with the soil data collected in the field. Finally, we analysed in detail two soil toposequences in the same closed depression, using a three-dimensional analysis of the pedological cover. Our results show that the ferricrete outcrops occur in the same elevation throughout the entire compartment. In the areas where they cannot be observed on the surface, we were able to find them within the latosol profiles and the landscape is flatter. There are two different pedological systems: a red soil system, in which the water level is below of the ferricrete, and a yellowish-red sandy soil system, in which the water level is above the ferricrete; the first transforms into the latter as we move towards the center of the compartment. The current climate conditions transformed the ferricretes and the latosols associated with them. The ferricretes disappear due to the hydromorphic processes, changing soil profiles, such as the formation of the Bt horizon, the depressions and the drainage channels that follow the geological structural lines. Concluding, this approach allowed understanding how small forms acted transforming the older and larger forms in the landscape, making possible to perceive their evolution in space and time.

**Keywords:** Soil, Laterite

THEME: S10 : WEATHERING, SOILS AND REGOLITH ON DIFFERENT TIME SCALES

ABSTRACT NUMBER: 765

## LANDSCAPE EVOLUTION MODEL ON ANCIENT RELIEF IN TROPICAL AREA

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This research aims to understand how the evolution of the relief affects other elements of the environment on stable ancient landscapes located in the tropics, where they are associated with deep weathered mantles and a predominance of low relief. The study was carried out on granite-gneiss domains with moderately undulating relief covered by the Cerrado biome, which is the second largest in the country, in the Espinhaço mountain range, in Southeast Brazil. Besides geomorphological mapping, slope characterization and vegetation sampling, physical, chemical and 14C OMS analyses of the rock and soil were conducted at different laboratories. Results show that soils accompany slow geomorphological changes leading to adaptations as valleys deepen and slope declivity increases, bringing fresher rocks near the surfaces, enabling better chemical conditions for plants to grow. Also, accumulation of organic matter on the lower slopes creates better potential for the installation of richer more diversified vegetation cover and the accumulation of sediment, which favors, together with higher humidity, the development of riparian vegetation. Concentrated erosion plays an important role in stripping away the old depleted erosive surface, enabling positive succession to take place. The results supported the proposition of a model for long term evolution of the area, where climate apparently did not change sufficiently, in terms of duration or intensity, to promote alterations in the evolution pattern along geological time.

**Keywords:** role of relief; ancient stable landscape; tropical area; granite-gneiss domains; geomorphological evolution model

THEME: S10 : WEATHERING, SOILS AND REGOLITH ON DIFFERENT TIME SCALES

ABSTRACT NUMBER: 766

## SLOPE AND WATER TABLE DYNAMIC AT SEMI ARID AREA - BRAZIL

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Water table exfiltration is responsible for the formation of rivers in semi-arid areas of Northern Minas Gerais in Southeast Brazil, which are characterized by specific ecosystems called veredas belonging to the Cerrado biome, which is the second biggest in the country. One of these rivers was studied because it is drying out, threatening this ecosystem. It runs through gently undulating relief developed on very weathered sandstone from Cretaceous deposition. The main objective of this research is to understand the mechanisms involved in the water table dynamics and the capacity to provide water flow to the river. Slope characterization, physical and chemical analyses of the regolith, as well as soil micro-morphology and Ground Penetrating Radar data were obtained. They indicated the presence of a possible water level maintenance mechanism, controlled by lateral migration of clay due to throughflow, as the valley incision takes place. Soil micro-morphology and field observations also show that water table fluctuations have influenced reordination of minerals inside the weathered mantle giving them a layer-like internal arrangement.

**Keywords:** perched water table; mechanism of formation; semiarid area; lateral clay migration; mantle reordination of minerals

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS



ABSTRACT NUMBER: 109

## ANALYSIS OF HYDROGEOMORPHOLOGICAL CHARACTERISTICS AND NATURAL DISASTER PREVENTION: DEBRIS FLOW IN PALMITAL RIVER, APIAÍ MUNICIPALITY, SÃO PAULO / BRAZIL, 2014.

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Debris flow are a type of mass movement of essentially hydrodynamic character that stand out due to the high potential of material



transport, its speed and its radius of reach. The disaster that took place in the Gurutuba River and Guarda Mão river basins in the municipality of Itaóca (São Paulo / Brazil) on January 13, 2014, caused twenty five deaths and left two people missing. Although widely referenced in the literature, no study specifically contemplated the contribution of detrital material carried from the Palmital River, upstream of the above-mentioned basins, whose slopes have a large distribution of sliding scars in an area belonging to the municipality of Apiaí, as may be verified from satellite images in the period. When the mapping was carried out in May 2014, a team from the Geological Survey of Brazil observed that the area was subject to high energy flow composed of mud, remnants of vegetation uprooted from the slopes as well as enormous amount of blocks. It was verified the need to deepen the regional knowledge as a subsidy to obtain the characteristics and parameters that define similar areas with strong potential predisposing to the occurrence of new debris flow events. This work includes, as an initial proposition, data acquisition and parameterization of hydrogeomorphological characteristics including the areas surrounding the 2014 event. The methodology for data collection uses geoprocessing tools from the SRTM (Shuttle Radar Topographic Mission) with resolution of thirty meters worked in a Geographic Information System (GIS). The following parameters were considered: altimetric range of the basin, relief ratio, slope, drainage density, circularity index, roughness index and slope shape. As a result a preliminary map of areas potentially subject to debris flow was obtained. A second step to be undertaken is fieldwork for benchmarking and validation of the methodology.



THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 116

## COASTAL CLIFFS, GIANT ROCKSLIDES AND LATE QUATERNARY TRANSGRESSIONS OF THE BLACK SEA ALONG THE SOUTHERN CRIMEA

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Chronological constraints of rock-slope failures along global coastlines remains poorly documented. Here we focus on the geomorphic and chronological implications of giant rockslides affecting the Crimean Mountains along the Black Sea coast. Geomorphic evidence suggests, that high (>100 m) limestone cliffs flanking southern slopes of the Crimean Mountains are scarps of rockslides nested within larger deep-seated gravitational slope deformations (DSGSDs). Such pervasive slope failures originated in an unstable slope conditions as lateral-spreads consisting of intensively faulted blocks of Late Jurassic carbonates moving on weak/plastic Late Triassic flysch and tuff layers. By introducing the novel dating strategy relying on U-Th series dating of unroofed speleothems covering landslide scarps combined with Cl-36 exposure dating, we are able to approximate time interval between the origin of incipient crevices and the final catastrophic collapse of limestone blocks exposing cliff faces. As for the three representative large-scale rockslides between the Foros and Yalta towns, initiation of DSGSDs evidenced by widening of crevices and the onset of speleotheme accumulation started >300 ka BP, but recent cliff morphology of the coast is a result of Late Pleistocene/Holocene failures spanning between ~19 – 1.0 ka BP. Exposure of rockslide scarps took place mostly in two time intervals ~19 – 15 ka and ~9 – 4.5 ka, temporally coinciding with the last major Black Sea transgressions. Our study suggests that before the ultimate catastrophic slope failure, relaxation of rock massifs connected with crack opening, karstification and incipient sliding lasted in the orders of  $10^4$ – $10^5$  years. Rapid Late Glacial/Holocene transgressions of the Black Sea likely represented the last impulse for the collapse of limestone blocks and origin of giant rockslides, contemporary affecting majority of SW coast of the Crimean Peninsula.

**Keywords:** Rockslides; DSGSDs; U-Th dating; Cl-36 dating; coastal cliffs; Crimean Mountains; Black Sea

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 173

## GEOSPATIAL REVIEW AND VALIDATION OF VARIOUS PREDICTION MODELS FOR THE LANDSLIDE SUSCEPTIBILITY MAPPING IN DARJEELING HIMALAYA

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Landslide susceptibility mapping provides the relative likelihood of future landsliding events based solely on the intrinsic properties of a locale or site. Each unit area is ranked into category in terms of magnitude of susceptibility. Various models are applied to get such unit area wise probability of future landslide occurrences on the basis of weightage assigned to individual dependent variable

influencing the event. This study was conducted on a part of Darjeeling Himalaya within West Bengal, India, where, effort was made to run a comparative analysis among the output susceptible zones generated by few well known models like Analytical Hierarchical Process (AHP), Information value method etc. For the purpose, elevation, slope, aspect, geology, land use, lineament density and some topographic indices were taken as factors influencing the hazard. Digital elevation model, Landsat-8 OLI satellite image, and other secondary data sources were utilized to generate the thematic rasters for these dependent variables. By means of weightage calculation and integration, areas with the highest probability to slide were detected individually in each model used. Thus, the magnitude of applicability of individual method was assessed through validation with reference to the existing landslide occurrences. Such a comparative analysis to choose a suitable model for the landslide susceptibility mapping will help to mitigate or even to avoid the unwanted circumstances resulted from hill slope mass movement as well as to guide effective land use planning and management.

**Keywords:** Landslide susceptibility mapping; dependent variable; AHP; Information value; validation

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 231

## ESCARPMENT RETREAT IN TABLELANDS – DOES IT ALWAYS REQUIRE CATASTROPHIC MASS MOVEMENTS? NEW FACTS AND ALTERNATIVE SCENARIO FROM THE STOŁOWE MOUNTAINS TABLELAND, SW POLAND

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Rock slope failures have long been considered a dominant pathway of escarpment retreat in sandstone tablelands. Our goal was to verify whether this scenario applies to the realities of the Stołowe Mountains – a typical multi-storey tableland, with weaker sedimentary formations capped by sandstones. Here, no rock fall events have been recorded in historical times, apart from one minor fall in 1921. To solve the problem we have focused on the usually neglected lower escarpment slopes. Field mapping and run-out distance simulations have revealed that the actual extent of sandstone boulders is up to three times bigger than predicted by modelling exercise. Such results correspond with Schmidt hammer determinations which showed a systematic decrease in intact rock strength of boulders with an increasing distance from rock faces. These two independent lines of evidence suggest that boulders are of diachronic nature and record long-term escarpment backwearing rather than episodic rock falls. The scenario is supported by additional observations from nearly level footslope zones where sandstone slabs in excess of 10 m commonly occur. Field mapping revealed the presence of sandy cones at the outlets of fissures in rock walls, which store c. 1000 m<sup>3</sup> of removed detritus. Further redistribution of material resulted in the formation of thick sandy covers within the lower slopes, as demonstrated by electrical resistivity tomography. All these findings taken together have led us to suggest an alternative scenario of escarpment retreat. The model of in situ disintegration assumes that marginal parts of cliffed escarpments separate into joint-bounded compartments as a result of underground erosion and sand removal. As the slope surface is lowered, remnant boulders occupy increasingly further position from the cliff lines. However, a contributing factor may have been shallow landslides in the middle and lower slopes, which passively transport caprock boulders to very distant positions.

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 250

## INTERACTION OF EXOGENOUS PROCESSES IN GULLY FORMATION, DEVELOPMENT AND FILLING IN THE SIBERIA (RUSSIA)

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Interaction of exogenous processes at different stages of the development of relief forms, including ravines, is given insufficient attention. Leading exogenous processes in drainage basins create structures that are transformed during climate change and economic activity. Gully erosion is one of the leading exogenous processes. Gullies in their development pass several stages (incision, expansion, filling).

Leading exogenous processes (piping, karst, thermokarst, cryogenic cracking, earthflow, landsliding, etc.): 1. form a variety of negative forms of relief on the surface of the earth, underground cavities, which under favorable conditions can turn into gullies; 2. karst-

erosion, erosion-landslide, tunnel erosion-erosion regional complexes of ravines are formed; 3. Partial and complete filling of gullies and/or transition to another category of erosion forms (dells, draws).

Exogenous processes in terms of their participation in the development of ravines are divided into three groups: directly or indirectly involved in the formation and development of the gullies), accompanying (existing before the ravine, not directly involved in its formation) and due to its occurrence. The first (piping, tunnel erosion, cryogenic cracking, etc.) predetermines the location of the ravine, creating negative forms of relief of various sizes and genesis. The second group of exogenous processes (creep, sheet wash, deflation, etc.) exists in the catchment area irrespective of the gully. The third (sidewall processes) is manifested only after the formation of the ravine.

In the northern regions of Siberia gully erosion closely interacts with cryogenic, in the taiga zone with piping and landslide, in forest-steppe and steppe landscapes with piping and aeolian processes. The manifestation of the leading exogenous processes determines morphological features, specificity of development and filling of gullies in natural zones and geomorphological regions of Siberia.

**Keywords:** leading exogenous processes, gully erosion, Siberia

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 253

## INTERRELATIONSHIP OF TECTONICS, PRECIPITATION AND LANDSLIDES, NORTHWEST HIMALAYA, INDIA

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The Satluj and Yamuna River valleys in the Northwest Himalaya comprise huge debris slides and rockfall, mostly in the Higher Himalaya and relatively less in the Lesser Himalaya. The present study reveals an interrelationship of tectonics and precipitation regime with the spatial and dimensional distribution of landslides in both the river valleys.

In order to infer tectonics in both the valleys, concavity index ( $C$ ), steepness index ( $ks$ ) and the ratio of valley floor width to valley height ( $Vf$ ) were calculated at an interval of 300 m along the main stream, using CartoSat-1 digital elevation model. Due to scarcity of rain-gauges in the area, Tropical Rainfall Measuring Mission precipitation data was used in the study. Field observation and high resolution Google Earth imagery were utilized to locate and map the dimension of landslides.

Results show that Satluj River channel exhibits a concavity index of 0.5 while that of Yamuna is 0.6. In both the valleys, steepness index profile at these concavity indices show highest values at the contact of Higher-Lesser Himalaya. Further, rockfalls are mainly associated with high  $ks$  (500-1000 in the Satluj; 13000-17000 in the Yamuna valley) and low  $Vf$  (0.2-0.4 in the Satluj; 0.2-0.5 in the Yamuna valley) whereas debris slides are dominantly associated with low  $ks$  (100-300 in the Satluj; 5000-9000 in the Yamuna valley) and high  $Vf$  (0.4-1.0 in the Satluj; 0.4-1.5 in the Yamuna valley). The contact of Higher-Lesser Himalaya is also found to be associated with the high precipitation (average annual rainfall of 250 mm in the Satluj and 1900 mm in the Yamuna valley) which is an indicative of relatively enhanced hillslope erosion. Further, the spatial coexistence of huge landslides (0.2-0.5 km<sup>2</sup> area), high  $ks$  and enhanced precipitation strengthen the proposed interrelationship in both the river valleys.

**Keywords:** Landslides; Tectonics; Precipitation

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 277

## ANALYSIS AND MONITORING OF SUPERFICIAL EROSIVE PROCESS IN DIFFERENT VEGETATION COVER IN AMAZONIAN ENVIRONMENT - ACRE - BRAZIL

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The research aims to analyze the surface erosion by runoff in two parcels (20m<sup>2</sup> each), one planted with sugarcane and another with pasture, using experimental pins from 11/2013 to 03/2014 in the municipality of Capixaba in the State of Acre southwest Amazonia, Brazil. The plots were installed in the middle slopes with an average inclination of 4.5°. Slope angle, soil infiltration, compaction and also rain precipitation were measured. In one of the parcels 44 sugarcane seedlings were planted in pits 30cm deep, and equidistance of 50x90 cm from each other. A total of 70 pins were installed and monitored weekly in each plot. The Pearson correlation ( $r$ ) and the



T-Student tests were applied to the data and the results of the T-test showed differences in the relation between the two plots (p-value <0.05) except for the 10th and 19th week. This may be linked to the intensity of rain. Higher values for erosion were obtained in the pasture area (4.95 cm / m<sup>2</sup> and 4.99 cm / m<sup>2</sup>) in front and behind the pin, respectively, while in the sugarcane plot the values were 2.46 cm / m<sup>2</sup>, at the back of the pins and 2.73 cm / m<sup>2</sup> at the front. The results of superficial erosion were lower possibly due to the retention of sediments in the tufts of sugarcane, causing, in turn, higher dispersion than flow of water.

**Keywords:** Amazonian region; superficial erosion; sediment loss; different land uses; slope dynamics

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 333

## PRESENTING LOGISTIC REGRESSION-BASED LANDSLIDE SUSCEPTIBILITY RESULTS

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A new work-flow is proposed to summarize landslide susceptibility results obtained from Logistic Regression analyses.

Although Logistic Regression models and methods have been widely used in the geomorphology community for several decades, no standards for presenting results in a consistent way have been adopted; most papers report parameters with different units and interpretations, therefore limiting potential meta-analytic applications. The North-easternmost sector of Sicily (Italy) is chosen as a straightforward example with well exposed debris flows induced by extreme rainfall. We initially introduce a powerful approach used in statistics for simultaneous estimation and variable selection in generalized linear models, namely the Least Absolute Shrinkage Selection Operator (LASSO), and discuss its advantages with respect to the unanimously accepted Stepwise Selection method. In this framework we present a list of actions to be taken to unify the way the community shares Logistic Regression results for landslide susceptibility purposes.

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 351

## ANTHROPOGENIC AND CLIMATOGENETIC IMPACT ON THE LANDSLIDES IN LESSER HIMALAYAN BELT OF J&K: DISTRIBUTION, CHARACTERISTICS AND MANAGEMENT

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Landslides are recognized as the third type of natural disaster in terms of worldwide importance. It is the one of the largest geological hazard that causes multiple human and economic losses. As per EM-DAT landslides cause approximately 1000 deaths in a year worldwide with a property damage of about US \$ 4 billion (Pardeshi S.D 2013). NH 1A is the only road, which connects the whole state with rest of the country and is considered as the lifeline of J&K state. It gets closed almost during every monsoon period due to landslide events. The mountainous tract of the area is composed of alternate beds of shales, mudstones, siltstones and sandstones. These porous and fragile rocks along with moderate to steep slopes are assumed to be the major slide prone areas which are triggered by heavy and concentrated rainfall during monsoon period.

Landslides are the major problems that effect development of J&K state. It mainly hamper the activities around the NH. The economy of J&K is dependent on tourism. But due to militancy in the state, the economy was badly hit. Therefore to attract the tourists, other areas were developed as tourists resort centers. To create new tourist spots, hotels and huts were constructed in the vicinity of the dense forest. Due to this, increasing demand of timber and fuel wood led to massive scale deforestation. Moreover, unscientific cutting of hill slopes for the construction of roads, buildings, bridges etc., as well as unscientific and unplanned usage of land together appear to be the aggravating factors for such menace. Hence, there exists a crying need to delineate stable and unstable areas in a realistic manner to arrest such hazardous phenomena. This can only be attempted through identifying the characteristics and impact of this menace and also suggesting proper management for it.

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 386

## LITHOLOGY AND GEOMORPHIC CONTROL ON SLOPE STABILITY IN KONKAN AREAS OF MAHARASHTRA, INDIA

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Landslides are common along Western slopes of Sahyadri ranges and isolated hills of coastal plains in Konkan region of Maharashtra. Numerous landslides with low magnitude is an important characteristic of slope failures in this region. Though the magnitude of landslides in this region is low, they result in huge losses in terms of property damage and even loss of lives especially those occur along major communication routes. Present paper deals with the spatial distribution of landslides in Raigad District of Konkan region of Maharashtra State in India based on the historical landslide records and field investigations. The landslide occurrence and its relationship with the rainfall have been assessed to determine the role of rainfall in slope failures. The results of the study revealed that the concentration of landslides in Raigad district is observed in the South and South Eastern hilly tracts of the District. Magacryst basaltic flows at the elevation up to 350 m are susceptible to debris slides in the foot slope areas of Western Ghats escarpment whereas rock fall and wedge failures are caused by numerous joints and fractures on slope faces covered by simple to compound flows above the elevation of 450 m from mean sea level. Besides, weathering of the upper mantle of the road cut slopes often cause slope failures at places on the western slopes of Western Ghats. It is observed that the landslide process in this area is also influenced by geo-environmental factors such as slope, aspect, structure, drainage, roads etc. Most of the slope failure sites are situated on the slope range between 25 to 35 . Proximity to drainage and structurally weak zones also play important role in the initiation of slope failures in this area.

**Keywords:** Landslide Inventory, Landslide Geometry, Rainfall intensity, Landslide frequency

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 389

## LANDSLIDE SUSCEPTIBILITY MAPPING ON MACRO SCALE- A CASE STUDY FROM IDUKKI DISTRICT OF KERALA, INDIA.

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Landslide is the most recurring natural hazard in the highlands of Kerala, a southern state of India. Idukki is the most affected district with 233 notable landslides mapped till 2014. Landslide susceptibility mapping is the primary activity towards management of landslide disaster. Hence, landslide susceptibility mapping along the arterial road corridors of Idukki district had been carried out for about 414 L. km. including National Highways, State Highways and main district road stretches. The landslide susceptibility evaluation has been done taking 30 m x 30 m pixel as basic unit. A total of seven parameters viz., slope gradient, slope aspect, slope curvature, relative relief, soil type, soil thickness and land use have been assessed pixel wise and maps were prepared accordingly. GIS based integration of the selected and weighted geofactor maps using the knowledge driven technique known as Weighted Multiclass Index Overlay (WMIO) method was applied to prepare a quantified predictive model of landslide susceptibility. The landslide susceptibility map was prepared by integrating the various thematic maps. About 19% of the area is categorized as highly susceptible, 41% is under moderately susceptible and 40% falls under low susceptible categories. Interestingly, most vulnerable road sectors identified through the present work coincides with all the major landslide incidences of past two decades of Idukki district. Based on this study, it is surmised that toe removal due to extensive cutting for aligning the road corridor played a major role in bringing the slope into the critical condition and the pore pressure increment due to heavy rainfall is assessed to be the triggering factor.

**Keywords:** Landslide susceptibility; Road corridors; Idukki; Kerala; Weighted Multiclass Index Overlay (WMIO)

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 402

## ANALYSIS OF THE GEOMORPHIC EFFECTS OF AN EXTREME PRECIPITATION EVENT ON A

## SMALL ALPINE MEADOW CATCHMENT, SOUTHERN SIERRA NEVADA, CALIFORNIA USA

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Studies have shown that extreme events can have a disproportionate impact on erosion and sediment transport. However, in mountainous environments analysis of these events is rare with few captured with detailed monitoring. Hurricane Dolores, a 2015 Eastern Pacific cyclone, pulled tropical moisture northwestward into the southwestern United States, producing torrential rainfall in mid-July 2015. The storm passage resulted in significant flood and debris flow events within and along the periphery of the Sierra Nevada Mountains, California and inundated a high-altitude site at Horseshoe Meadow on July 21st. Meteorological stations along the storm track recorded precipitation rates for the July 21st event exceeding 8.8 cm/hr. with total rainfall of 11.2 cm in < 2 hours. A network of temperature sensors at Horseshoe Meadow and an automated meteorological station ~2.5 km to the north also recorded the event.

The July 21st event produced significant overland flow and localized channel runoff from catchments as well as sediment transport to fans fringing Horseshoe Meadow. Transverse ripples, comprised primarily of coarse to very coarse sand with wavelengths between 20-24 cm and amplitudes of 1-2 cm, were visible 10 days after the event. These ripples were present on most non-vegetated surfaces above the meadow to nearly the top of the drainage divide. Areas with tree burial up to 10 cm occurred along fans above the meadow. Based on analysis of long-term erosion at sites in the southern Sierra Nevada, these rare high-intensity precipitation events, with resultant non-channelized overland flow, are likely the primary agents in the erosion and transport of sediment from small low slope catchments. However, lack of sediment deposition within the meadow suggests that even exceptionally rare extreme events are not capable of transporting sediment to the main channel under current climatic conditions.

**Keywords:** Extreme events; erosion rate; overland flow; deposition; Sierra Nevada

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 430

## POSTGLACIAL FAN EVOLUTION IN THE UPPER RHONE VALLEY, SWITZERLAND – GRADUAL OR CATASTROPHIC?

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What dominates geomorphic process effectiveness: high-frequency or high-magnitude? Especially in the European Alps, where slopes adjust to postglacial conditions, this question has important implications for natural hazard assessment and for understanding postglacial landscape development. In the Upper Rhone Valley, Switzerland, three very large fan systems (footprint area ~1 km<sup>2</sup> each) are fed by catchments of just about similar size.

Grounding on three different methods, geomorphometric analysis of high-resolution digital topography, ground penetrating radar surveys, and surface exposure dating using cosmogenic radionuclides, we seek to analyze 1) the morphology of the fans and its feeder basins, 2) the sedimentary facies and architecture of the deposits, and 3) the chronology of the events that lead to the formation of the fans.

The sediment source regions for the three fans, all coming down from the northern valley flank, are well defined consisting mainly of gneissic lithologies. Based on morphometric analysis, we estimate the volume eroded from the feeder catchments to range between 50 and 62 x 10<sup>6</sup> m<sup>3</sup>, translating to minimum uniform denudation rates of ~5-6 mm/yr averaged over 15 kyr (when deglaciation exposed the valley), outranging 10Be-derived denudation rates from adjacent catchments by factor 2 to 15. Ground penetrating radar surveys (>10 km length), taken out with 40 and 200 MHz antennas, reveal a predominance of large boulders in the subsurface and clearly identifies levees and channels, pointing towards high-magnitude events as the dominant generation process. This finding is supported by drillings on the margin of one of the fans, as well as a series of m-sized angular to subangular boulders covering parts of the fans. Using cosmogenic nuclide abundances, the exposure age of these large boulders as well as the exposure ages of bedrock outcrops within the feeder catchment will be determined to establish a chronology of fan generation.

ABSTRACT NUMBER: 496

## RAPID REWORKING AND REACTIVATION OF MASS MOVEMENTS BY GULLY EROSION IN THE MANGAEHU CATCHMENT, EAST COAST REGION, NORTH ISLAND, NEW ZEALAND

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Mass movement and gully erosion are widespread processes on slopes in the East Coast Region, North Island, New Zealand. Gullies, which initiate mass movements by undercutting their sidewalls, were named “gully complexes”. However, the opposite sequence of mass movements eroded by gullies have not yet been sufficiently addressed. This study focusses on reworking and reactivation of such mass movements in the 4.2 km<sup>2</sup> large Mangaehu catchment, located on the North Island, New Zealand, by interpreting aerial photography taken in 06.1939, 04.1957, 09.1971, 06.1988, 05.2005, and 01.2012 to map the distribution of mass movements and gullies and by analysing erosion pattern using differential digital elevation models.

The largest part of the study area was affected by deep-seated slumps and earth flows in 1939. Incipient gullies eroding along mass movement deposits reworked these deposits in a first stage by retreat of gully sidewalls followed by reworking of the deposits by flowage with lengths up to 810m. Gully channels were overwhelmed with sediment supplied by successive failures, leading to a relocation of channels of up to 55 m towards the opposing side causing in turn undercutting and failures. Gullies eroding into the main body were modified by shallow slumps. Where gullies eroded up to the main scar, mass movement bodies were reactivated at the rupture surface. One gullies eroded through the deposits into the head scarp and up to the catchment divide.

These findings indicate that a.) gully erosion causes rapid reworking and reactivation of mass movements on decadal scale, b.) the importance of gully erosion for reworking and reactivation might be masked when phases of infilling and re-incision of gullies cannot be reflected, and c.) to prevent export of stored mass movement deposits into the fluvial system, incipient gullies on unstable slopes need to be prioritized for erosion control measures.

ABSTRACT NUMBER: 504

## CAN LOW-MAGNITUDE EARTHQUAKES ACT AS A TRIGGERING FACTOR FOR LANDSLIDE ACTIVITY? EXAMPLES FROM THE WESTERN CARPATHIAN MTS, POLAND

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There are numerous examples of the impact of strong earthquakes on landslide activity. There is however very little information about the ability of low-magnitude earthquakes ( $M < 5.0$ ) to affect the stability of pre-existing landslide slopes. Two landslides were studied (Hołowiec and Kamień, Western Carpathians, Poland). These are located 20-30 km from seismoactive zones where earthquakes of  $M \leq 4.4$  occur. We have used tree rings to date past landslide movements possibly caused by earthquakes. We have dated events of tree tilting by landslide activity, after which the trees developed eccentric rings and reaction wood, in a sample of 40 Norway spruce (Hołowiec) and 51 European silver fir (Kamień). The results of dendrochronological dating were compared with the occurrence of earthquakes in the study area (magnitudes, epicentral distance, etc.). We have also analysed precipitation data to help to disentangle the impact of rainfall and earthquakes as triggering factors. We were able to distinguish: earthquake-triggered landsliding with no impact of precipitation, precipitation-triggered landsliding with no seismic impact and landsliding triggered by the overlapping impact of precipitation and earthquakes. The results show that the combination of both triggering factors has the most significant influence on the stability of landslides under study. The study demonstrates the ability of low-magnitude ( $M < 5.0$ ) earthquakes to trigger landslide activity, even at distances larger than appears from limiting curves published for co-seismic landslides. The results also suggest that the activity of the Kamień landslide can possibly be influenced by the long-distance (over 500 km) influence of strong earthquakes ( $M 6.8-7.4$ ) from outside of the study area. The study demonstrates that the seismic factor, both local, low-magnitude earthquakes and distant, strong earthquakes, can be an important trigger of landslide activity. Their role may be underestimated in the study area and other areas considered as seismically non-active or of low seismic activity.

ABSTRACT NUMBER: 538

## THE IMPORTANCE OF RAINFALL AND GROUNDWATER DATA FOR LANDSLIDE HAZARD ASSESSMENTS DEMONSTRATED BY NEW ANALYSES OF THE VAIONT LANDSLIDE USING A REALISTIC FAILURE SURFACE GEOMETRY

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The Vaiont landslide of 1963 is probably the best-known example of a human-induced hazard with a catastrophic impact. The hazard was identified before the Vaiont dam was completed, and the possible impacts of a landslide moving into the planned reservoir were investigated by the dam's Project Director. Unfortunately, the size of the displacement wave in the reservoir was entirely unforeseen because the velocity of the landslide was underestimated. Furthermore, the cause of the landslide has always been attributed to the filling of the Vaiont reservoir, i.e. it has always been regarded as a disaster caused by human intervention.

The velocity of the landslide was underestimated because of an incomplete and incorrect understanding of the landslide, specifically the geometry of the failure surface. This single factor had prevented the derivation of an explanation for both the occurrence and behaviour of the landslide. Stability analyses using a new 3D model of the failure surface derived by Bistacchi et al. (2013) can now fully explain the landslide. The results show that the filling of the reservoir was largely incidental. It now seems that the failure was initiated by exceptional rainfall, and that its subsequent progressive development was also driven by unusually high rainfall though perhaps exacerbated by the presence of the reservoir.

The development of landslide science in recent decades by geomorphologists, geologists and geotechnical engineers means that most relevant possibilities should now be identified and investigated accordingly. However, the Vaiont case now demonstrates the need to (i) take explicit account of realistic rainfall scenarios, particularly arising from climate change predictions, and (ii) consider all realistic groundwater responses to hypothetical extreme rainfall. Furthermore, for future reservoir projects in mountainous terrain, it is essential to obtain adequate data for realistic displacement scenarios to be developed.

**Keywords:** landslide, Vaiont, rainfall trigger, reservoir effects

ABSTRACT NUMBER: 604

## MORPHOLOGICAL ASSESSMENT OF SHALLOW LANDSLIDES IN GURUTUBA BASIN, SÃO PAULO STATE, BRAZIL

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Itaóca municipality, located in southern São Paulo State, was affected in 2014 by many mass movements triggered during an extreme rainfall event, exceeding 200mm in two hours. The Gurutuba basin has an area of 4,5 km<sup>2</sup>, which about 4% was affected by shallow landslides. In this paper, we evaluate the landslides by means of: (a) an inventory, that results in 336 scars, based on Google Earth imagery; (b) a Digital Elevation Model (DEM) with 10 meters resolution, elaborated upon topographic map with 1: 10.000 scale; (c) a frequency (F) and a scar concentration (SC) indexes for the scar area, which is the ratio between the number of cells with scars, in each class; (d) extraction from the DEM, of the morphological parameters (aspect, curvature, slope and elevation), producing F and SC indexes for each of one of them. Our results show that the average area of the scars is 429,5 m<sup>2</sup>, with a median of 177 m<sup>2</sup>. Most scars have less than 300m<sup>2</sup>, concentrating on the class that ranges from 100 to 150m<sup>2</sup>. Also, the scars are situated on the low and medium portion of the watershed. Assessment of morphological parameters indexes reveals that the scars occurred mostly on slopes with convex curvature (F=33,3%; SC=35,2%), angle between 25° and 35° (F=44,8%; SC=49,7%), aspect towards E-SE (F=39%; SC=66,6%) and elevations from 850m to 950m (F=21,7%; SC=22,4%). In general, the analyses demonstrated the magnitude of the 2014 event and may indicate susceptible areas for shallow landslides.

**Keywords:** Mass Movements; Inventory; Digital Elevation Model (DEM); Vale do Ribeira

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 605

## LITHOLOGICAL SUSCEPTIBILITY ASSESSMENT OF MASS MOVEMENTS IN THE SERRA DO MAR, SÃO PAULO STATE, BRAZIL

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The Serra do Mar is a mountain range that extends for about 1500km along the southeast coast of Brazil and has been affected by shallow landslides, as well debris flows, especially during intense summer rainstorms. It has different lithologic types that associated with intense rainfall can generate instability areas. In this way, the aim of this work was to evaluate the relationship between lithology and mass movements in a critical sector of the Serra do Mar located in the crystalline complex of the Paraitinga/Paraibuna and Bocaina plateaus. In this paper, 171 mass movements were analyzed in an area of 2000 km<sup>2</sup>. The geological map (1:100,000 scale) and scars inventory were used to evaluate the Landslide Potential (LP), which is the ratio between the number of cells with scars, in each class of lithology, and the total number of cells of that same class. The results indicated the following distributions of lithologic types: sedimentary deposits (2%), micashist (3%), migmatites (52%) and granitoid rocks (43%). Regarding the landslide potential (LP), it was proved that the most susceptible typologies were agmatitic migmatites (15%) followed by granitoid rocks (9%). The other types of migmatites also had a high LP values, around 8%. The next steps of this research will evaluate the influences of morphological parameters in the distribution of mass movements, such as slope angle, and aspect.

**Keywords:** Mass movement; Lithology; Susceptibility; Serra do Mar

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 607

## PHYSIOGRAPHIC MODELING WITH 3D SIMULATION SOFTWARE AS A SUBSIDY TO RETRO-ANALYSIS STUDIES OF MASS MOVEMENTS: APPLICATION IN MOUNTAIN AREA OF STATE OF SÃO PAULO, BRAZIL

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The aim of this work is to present and discuss the results obtained by simulation in 3D simulation software (RAMMS - Rapid Mass MovementS) as a subsidy to studies of mass-movements retro-analysis in the São Sebastião and Caraguatatuba coastal and mountains areas (São Paulo State, Brazil), places susceptible to these types of processes. The retro-analysis studies help to understand the mass movements through the historical retrieval of the variables that influenced its occurrence, in order to analyze and identify the main conditions that led to the incidence of these processes in any place. So, the use of 3D simulation software allows and helps in the identification of these factors, since it combines all the variables and simulates the conditions that have caused in landslides and debris flows, for example. In 1967 the Caraguatatuba region was affected by rains of great rainfall magnitude, the consequence of which was the unleashing of landslides and debris flows generalized. The retro-analysis showed that the areas most affected in 1967 by mass movements were the watershed of the Santo Antônio River and the Canivetal River, in Caraguatatuba (São Paulo State, Brazil). The main factors that led to the occurrence of the large processes in 1967 were mainly the large pluviometric volumes and the physiographic conditions of the watershed (mainly the shape and angle of the slopes, the circular form of the watershed and the existence of numerous first order channels). Concomitant statistical analyzes revealed that Geology was not a determining factor for the occurrence of mass movements. The results obtained will be used as tools to elaborate mitigating measures for the occurrence of future processes and to evaluate their possible range and destructive potential, since mass movements are recurrent in the study area.

**Keywords:** RAMMS, Mass Movements, Retro-analysis and physiographic modeling

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 687

## DEBRIS FLOWS AND LONG-TERM DENUDATION RATES IN THE SERRA DO MAR/SP, BRAZIL

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The continental margin of the southern and southeastern coast of Brazil constitutes a landscape whose geological-geomorphological evolution has been studied in the light of various timescales and techniques. Dating methods such as thermochronology (fission traces and (U-Th)/He) and the cosmogenic nuclide <sup>10</sup>Be were used to reconstruct the denudational history of this passive margin escarpment. On the other hand, in the short-term, studies about the dynamics of the most active geomorphological processes, such as shallow landslides and debris flows (DF), predominate to provide data for the prediction of areas susceptible to these processes. Therefore, the aim of this research was to verify the relationships between DF magnitude, basin morphometry and long-term denudation rates in a steep landscape of passive margin in humid tropical environment, such as Serra do Mar, Brazil. The procedures adopted were: (i) sampling fluvial sediments in 10 drainage basins; (ii) mapping DF deposits; (iii) application of morphometric indices; and (iv) <sup>10</sup>Be concentration analysis. The identification of the superficial DF deposits and the size of the blocks subsidized the classification of five basins as being of greater magnitude and five with smaller magnitude. The denudation rates varied between 10.9 m My<sup>-1</sup> and 35.2 m My<sup>-1</sup>, with an average of 25 m My<sup>-1</sup>. We observed that the lithological variety and the structural lines explained better the distribution of the rates. Dating by <sup>14</sup>C of past DF deposits has shown that, every 1,300 years approximately, there is a major event in the study area. Considering the volume of material mobilized by DF that reached the area in 1967, it was possible to estimate the denudation rate of this event. These rates, the long-term rates measured by <sup>10</sup>Be and the recurrence interval allowed us to verify that the processes of episodic nature are essential for landscape evolution of the Serra do Mar.

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 768

## THE OCCURRENCE AND SUSCEPTIBILITY TO MASS MOVEMENT IN THE WESTERN SAN JUAN MOUNTAINS, COLORADO: A 3-D MAPPING APPROACH

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Mass movement contributes to the evolution of hillslope morphology characterized by the downward displacement of rock, vegetation and/or debris, which poses a potential hazard to human activity in mountainous terrain. Hence, identification and quantification of risk from mass movement are vital to saving lives, protecting infrastructure and implementing best possible land use practices. The complex-geologic setting combined with rugged topography of San Juan Mountains have facilitated propagation of mass movement in the area. Climate change and increased human activities are altering equilibrium conditions of remnant ice-contact slope deposits, which potentially can lead to greater frequencies of mass movement in the area. As a result of more people expected in the San Juan Mountains as permanent residents or tourists, a comprehensive contemporary mass movement susceptibility study, addressing risks is needed.

The study area encompasses ~ 1,615 km<sup>2</sup> as mapped on the Ridgway, Dallas, Mount Sneffels, Ouray, Telluride, Ironton, Silverton and Ophir USGS quadrangles. We have developed a GIS-based virtual 3-D model, which highlights the susceptibility of mass movement in the area. We applied a weighted-overlay method integrating six terrain variables of slope angle, slope length, aspect, geology, vegetation, and soil drainage. The weighted-overlay technique was two phased, including a heuristic and Principal Component Analysis based application of said parameters. Our findings suggest that roads in areas highly susceptible to mass movement may experience, damage, closure and destruction. Susceptibility analysis of the 3-D model indicates that aspect, slope angle, and geology have the greatest extent of relative influence on slope failure. We have implemented a combination of emerging geospatial and visualization techniques to improve landslide prediction in mountain regions. The 3-D model is beneficial in helping layperson to visualize spatial location and the extent of potential mass movement in the area.

**Keywords:** Landslide Susceptibility; Geographic Information Systems; Weighted-Overlay; Aspect; 3- Dimensional Visualization

ABSTRACT NUMBER: 102

ARE ALLUVIAL FAN SEDIMENTATION AND EROSION PATTERNS CONTROLLED BY AFRICAN HUMID PERIOD CLIMATE DYNAMICS (CAPE VERDE ISLANDS, OFFSHORE WEST AFRICA)?

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We report new findings from ongoing Quaternary fluvial landscape development investigations on the tectonically inactive Cape Verde volcanic archipelago, an offshore climatic extension of the Sahara Desert. On Santo Antao Island large (6km long) coalescent coastal alluvial fans have developed along the SW volcanic edifice flank margin. These fans display an expansive relict surface incised by up to 120m. Fan incision reveals an up to 100m thick sequence of coarse grained cobble-boulder dominated fluvial sediments interbedded with a spatially extensive basaltic lava flow (undated) and tephra unit (Argon dated = 193 +/-23ka). We have characterised the fan surface morphology using 10m resolution TanDEM-X data, alongside targeted field survey and drone mapping along cross-fan transects (distal, mid and proximal fan locations). The fan surface comprises a network of fluvial bars and channels with a spatially variable relief in distal (<3m), mid (<5m) and proximal (<3.5m) surface regions. The age of the fan surface has been determined using <sup>3</sup>He cosmogenic exposure dating targeting basalt boulders sampled from high relief fluvial barforms in distal, mid and proximal fan surface locations. Preliminary results suggest the fan surface is a composite long-lived feature that has persisted for at least 150ka but has been incised and abandoned since 10-20ka. The age distributions show an older fan surface area (>50ka) in the central distal fan and a younger fan surface area (<20ka) in central-eastern parts of the mid-proximal fan. This configuration suggests the fan surface has been built by avulsion-related fan lobe switching. We hypothesise that avulsions are related to abrupt and short duration African Humid Period hydrological events that occur every 20ka in low latitude Africa and that the longer term fan surface abandonment is base-level driven, related to global eustatic changes over a 100ka glacial-interglacial climate cycle.

**Keywords:** Alluvial Fans; Climate; Eustacy; Palaeohydrology; Fluvial Archives

ABSTRACT NUMBER: 132

READING PALAEOHYDROLOGICAL INFORMATION FROM MODERN AND ANCIENT ALLUVIAL FAN ARCHIVES IN ARID SETTINGS: THE ATACAMA DESERT, NORTHERN CHILE

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The large alluvial fans of the Central Depression in the hyper-arid Atacama Desert in Northern Chile provide unique opportunity to examine the geomorphology and sedimentology of flood flows generated from their Precordillera catchments over geological time-scales. The hyper-aridity preserves geomorphic features within the landscape over long time periods and in unusual detail. Catchment areas range from 100-2000km<sup>2</sup> in size with reliefs of up to 3km, whilst modern rainfall typically ranges from <1mm pa in the alluvial fan depositional areas to ~50 mm pa in the flood generating catchment areas. Evidence from packrat middens suggests that even the wettest periods of the Quaternary were no more than 2 times wetter, thus maintaining a likely arid – hyperarid climate for the life-span of the landforms generated. Modern rainfall distribution is most commonly associated with the ‘Bolivian Winter’ when thermal air currents from Bolivia bring moisture to the Pre-Cordillera in the southern hemisphere summer months.

We will examine field evidence from the older Pleistocene record of extensive debris flow events associated with relatively more humid periods and how these events can be subsequently modified on the fan surface by later processes to form concentrated boulder fields. We will then consider how we recognize these features and the data that can be extracted from them using a combination of geomorphic mapping using UAV, CRN geochronology, flow sedimentology and palaeohydrological modeling. We will also examine how this compares to the more arid phases of flood deposits which are dominated by extensive mud-flows which show remarkable affinity with features observed on other arid planetary bodies such as Mars, using a combination of sedimentology and drone video footage and observations from a recent active flow (January 2017) witnessed by the research team.

**Keywords:** palaeohydrology, alluvial fan, Atacama, climate change, mars



ABSTRACT NUMBER: 146

## STORM-GENERATED HOLOCENE AND HISTORICAL PALAEOFLOODS IN NEW ZEALAND

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This paper reports the first reconstruction of storm-generated Holocene and historical palaeofloods in New Zealand. We compare and date fluvial sedimentary archives within representative river environments in New Zealand's North Island, and assess their suitability for palaeoflood reconstruction. These environments are: 1. bedrock-confined gorges; 2. confined and unconfined single thread meandering channels; and 3. partly-confined wandering-semi braided rivers. Slackwater deposits were investigated within a bedrock reach of the Whanganui Gorge, located on a volcanoclastic bench c.20 m above river level. The sedimentary infills of 20 palaeochannels were studied in the lower alluvial reaches of the Manawatu, Whanganui, and Hutt Rivers. Holocene and historical floods in these palaeochannels were recorded as a series of sand- or gravel-rich units, set within finer-grained channel fills. Flood chronologies were constrained using a combination of radiocarbon and cosmogenic dating, documentary sources and palynology. Flood unit sedimentology was characterised using high resolution ITRAX-XRF core scanning and grain-size analysis. Holocene palaeoflood records differ significantly between river environments in both length and nature. Highest resolution and longest palaeoflood records extend over 2,000 years in palaeochannel deposits within the single-thread unconfined Manawatu River. The resolution and length of the Manawatu record reflect accommodation space, channel dynamics and mobility, and sediment supply. In the Hutt valley high rates of valley-floor reworking by laterally active semi-braided channels limited the thickness of fine-grained channel fills, precluding identification and dating of palaeofloods. Flood records preserved in the Whanganui Gorge contained reworked charcoal from the 1.8 ka Taupo volcanic mass flows and OSL dating was hindered by incomplete bleaching of quartz minerals. Floods in the Manawatu during the mid-1800s coincident with European land clearance, and in the first decade of the twentieth century, would appear to be the largest recorded in the last 2,000 years.

**Keywords:** fluvial sedimentary archives; palaeoflood reconstruction; core scanning

ABSTRACT NUMBER: 175

## RUN-UP SEDIMENTS AS (PALAEO-)HYDRAULIC INDICATOR

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Run-up sediments can be found in river channels and floodplains in front of local obstacles like trees trunks, bridge piers or bedrock cliffs. Upstream of the obstacle, the flow velocity of the current decreases resulting in a locally elevated water surface due to the transfer of energy from kinetic to potential energy. Transported suspension load might be deposited at a higher level in front of the obstacle or mark the higher water level to one side or either side of the obstacle.

Run-up effects as special feature of flood debris lines were first mentioned by Costa in the context of debris flows, but were not investigated in detail. Along the pathway of the Pleistocene ice-dammed lake outburst floods in the Altai-Mountains, Siberia, run-up sediments are located at numerous valley obstructions in front of local bedrock ridges. The clue of the interpretation is not their sedimentological structure or texture, but the configuration of their deposition and especially their elevation in relation to undisturbed flood stage indicators upstream of the obstruction. Typically, they generate a relatively thin layer of deposited suspension load in front of the obstruction.

They indicate the amount of energy transfer and can be used to conclude on the mean flow velocity of the current upstream of the obstruction. According to the energy equation by Bernoulli, energy can only be transferred from kinetic to potential energy as pressure energy is negligible for open channel flow. Hence, once a current is blocked its kinetic is transferred into potential energy indicated by a risen water level. As the amount of the water level differences upstream and in front of the obstruction can be measured in the field – or surveyed of suspension load marks and deposits for palaeofloods – flow velocity can be estimated.

**Keywords:** Palaeohydrology; palaeoflood; hydraulic; sedimentology; Altai

THEME: S12 : PALAEOHYDROLOGY AND FLUVIAL ARCHIVES -  
HYDROLOGICAL EXTREME AND CRITICAL EVENTS (HEX)

ABSTRACT NUMBER: 360

## PALAEO- HYDROLOGICAL EXTREME EVENTS FROM THE INDUS AND ZANSKAR RIVER SYSTEM, LADAKH HIMALAYA

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Indus River flow northwestwards, nearly along the strike of Indus Suture Zone in the Ladakh Himalaya and is bounded by Ladakh batholith in the Northeast and by highly folded and thrust Zaskar ranges in the Southwest. Zaskar River is major tributary of the Indus River in terms of discharge and sediment flux, which confluence with the trunk channel at Nimu. As the region lies between the Indian summer monsoon fed Higher Himalaya in the south and westerly dominated Tibetan plateau in the north, the hydrology of the region is mainly controlled by two rainfall systems viz. SW Indian Monsoon that brings moisture from the Arabian Sea and the Westerlies that rising from Mediterranean region. The phases of stronger SW monsoon results into floods and massive landslides in the region. However, there exists a debate on the moisture source of these floods and therefore it is important to reconstruct past flood history vis-à-vis climate of the region.

Quaternary landforms are well preserved in this dry hinterland of Himalaya, and provide very good examples for studying interplay of climate and tectonics. The slack water deposits (SWDs) are identified as a sand-silt couplets and used as a strong proxy for reconstruction of paleoflood history of Indus and Zaskar basin. In the present study, 9 sections of SWDs along the Indus River from Hymia to Saspol and along Zaskar River are studied. Chronology based on luminescence and <sup>14</sup>C AMS dating indicates four major flood clusters from ~ 4 to 16 ka that are correlatable with the phases of strengthened SW monsoon. The presence of hearth (burnt layer of sediments) at different layers of SWDs indicate anthropogenic activity and possibly post-LGM route of human migration in the upper Indus and Zaskar valley.

**Keywords:** Slack water deposits; Indian summer monsoon; Westerlies; chronology; paleoclimate

THEME: S12 : PALAEOHYDROLOGY AND FLUVIAL ARCHIVES - HYDROLOGICAL EXTREME AND CRITICAL  
EVENTS (HEX)

ABSTRACT NUMBER: 393

## RECONSTRUCTION OF PALEO-DROUGHT CONDITIONS ASSOCIATED WITH MONSOON SYSTEM IN MAKRAN, IRAN

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In order to reconstruct paleo-drought conditions in south east of Iran, the past temperature and precipitation data were reconstructed by Macro-physical Climate Model (MCM) during Holocene. Model verification by statistical methods showed that the moving average model with the lowest statistical error represents a reasonable estimation of the temperature and precipitation in the study area.

Reconstruction of past climatic variables have done by using monthly observed data as recorded in south east of Iran during period from 1901 to 2011. Then the paleo-drought conditions were investigated by calculating SPEI index method by using observation data during last century. The results showed that the evaporation intensity has increased during last century in Makran region. We can conclude that the correlation between SPEI index in Jazmourian wetland and Chabahar as representative points of Makran region is associated with monsoon system.

ABSTRACT NUMBER: 415

## SENSITIVITY AND RESPONSES OF THE CHER RIVER (RÉGION CENTRE, FRANCE) TO CLIMATE VARIABILITY AND HUMAN PRESSURE

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This presentation examines a case of human impacts on the Cher River located in the South of the "Bassin de Paris". Preliminary investigations conducted in two study areas (DEM LiDAR analyses, geophysical approach and boreholes) show the high potential of fluvial archives to reconstruct past hydrological dynamics. Indeed, several generations of palaeochannels were identified. Moreover, many archaeological sites (Neolithic, Roman and Medieval eras) were recognized within the floodplain and the riverbed. This work aims to identify the respective part played by climate changes and humans pressures on fluvial morphologies and associated processes. High resolution sampling of sediments from cores collected in former channels provide palaeoenvironmental and palaeohydrological data about post-cutoff evolutions. These analyses involve interdisciplinary approaches (grain size distribution, X-ray fluorescence analyses, Total Organic Carbon, palynology). Radiocarbon dating allows the cutoffs of palaeochannels to be dated and then the chronological frame to be reconstructed. Most ancient fluvial landforms studied correspond to mounds slightly higher than the floodplain level, incised by wide and straight palaeochannels. These channels were abandoned during Bølling/Allerød and progressively filled during Younger Dryas, Preboreal and Boreal. A second fluvial pattern is characterized by palaeomeanders active during the Late Atlantic and Subboreal. These inherited landforms show a readjustment to climate variability through a fluvial metamorphosis occurring between the Last Glacial Maximum and the Holocene. The more recent generation of palaeochannels correspond to historical large-sized meanders whose cutoffs are dated from 5th to 12th century. It shows a high lateral mobility during the Late Antiquity. These dynamics contrast with the behavior of current meanders characterized by low migration rates. Our investigations show that a tipping point is reached during the Medieval era. Human settlements probably start to exert a great pressure on the fluvial environment from the 12th century through numerous hydraulic structures impacting planform mobility.

ABSTRACT NUMBER: 422

## ESTIMATION OF FLOOD DISCHARGE TO REJUVENATE THE EARLIER CHANNELS- A STUDY ON LOWER DAMODAR BASIN, WEST BENGAL, INDIA

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Damodar fan delta has lost flood water dispense capacity for the insufficient drainage network as the major distributaries like Kana Damodar, Kana Nadi, Gangur and Behula are permanently disconnected from the main channel at Selimabad and Palla in the district of Burdwan due to construction of embankment. This study attempts to estimate the minimum requirement of flood discharge in the main channel to link the earlier channels in aim to analyse the feasibility of flood water diversion through the earlier channels. Study has been done at Jamalpur, Selimabad and Palla for estimating discharge at different stages. Rating curve has been prepared for three sites and extended by Logarithmic Method according to necessary. Difference of bed level between Damoar and the earlier channels has been measured through levelling. Frequency analysis has been worked out for the annual peak discharge of Jamalpur site. The result shows that more than about 1925 cumec and 1300 cumec discharge in the main channel are required to reconnect the Kana Damodar and Gangur respectively as these are presently at higher elevation than the level of the main stream. The frequency analysis shows that the return period for the discharge of more than 1925 cumec and 1300 cumec is 1.45 years and 1.14 years respectively and the probability to exceed these minimum discharge in a particular year is .69 and .88 which indicate that flood water can flow almost

every year through these channels.

**Keywords:** Damodar River; Levelling; Rating Curve; Frequency Analysis

*THEME: S12 : PALAEOHYDROLOGY AND FLUVIAL ARCHIVES - HYDROLOGICAL EXTREME AND CRITICAL EVENTS (HEX)*

**ABSTRACT NUMBER: 478**

## **DIRECT CATCHMENT RESPONSE TO THE LAST QUATERNARY CLIMATE TRANSITION: DRIVERS AND RATES OF SURFACE PROCESSES IN INTRAMONTANE BASINS OF THE SOUTHERN PYRENEES, SW EUROPE.**

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Intramontane basins function as (temporary) sediment traps and their archives provide important insights into erosion and sediment dynamics in mountain ranges. Aiming at establishing the timing and drivers of late-stage erosion cycles in the Pyrenees, adjacent 10–100 km<sup>2</sup> drainage basins were investigated regarding their morphogenetic development.

The Valle de la Fueva is a highly erodible drainage basin that comprises a number of catchments in the southern Pyrenean thrust belt. Field observations revealed high-lying talus slopes, extensive residual erosion surfaces (i.e. low-angle pediments and glacis) and "cut-in-fill"-type alluvial terraces that are situated in the ravines. Morphogenetic mapping points at three common recent catchment development stages: i) extensive surface levelling by denudation and sheet flooding, ii) intense basin excavation and fluvial dissection accompanied by large-scale sediment routing, and iii) minor late-stage incision and terrace formation.

New OSL-data and 10Be exposure ages for the glacis and talus slopes cluster between 20 and 50 ka (MIS 3–MIS 2), testifying to a lasting cold-climate genesis of extensive denudation plains (i) and the present talus surface levels. The lower, undulated surfaces (ii; ca 8–12 ka) denote an Early Holocene termination of intense catchment erosion followed by relative quiescence and late-stage terrace formation (iii).

Our catchment evolution model indicates only a few thousand years of intense erosion during the last major climate transition and much lower surface process rates during stable glacial and interglacial conditions. This is crucial, because modern (e.g. basin scale) erosion rates are affected by systematic averaging bias and often fail to reflect actual surface process rates and amplitudes.

Findings also suggest that confined, non-glaciated mountain catchments have high preservation potential for (at least) the latest landscape rejuvenation cycle. Hence, they could play a key role in assessing the direct impact of environmental (e.g. climatic) changes and quantifying real-world erosion processes and sediment fluxes.

*THEME: S12 : PALAEOHYDROLOGY AND FLUVIAL ARCHIVES - HYDROLOGICAL EXTREME AND CRITICAL EVENTS (HEX)*

**ABSTRACT NUMBER: 526**

## **FLOOD PHASES DURING THE LAST 5500 BP (CA 4350 CAL. BC) - THE COURSE AND CORRELATION IN THE EASTERN CARPATHIAN FORELAND**

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In the mountain foreland, the Dniester and Seret Rivers form a system of the Holocene terraces, which were a matter of the detailed geomorphological-sedimentological studies and radiocarbon datings.

The objective of the study was an answer the questions, whether in the river valleys of the Eastern Carpathian Foreland the flood phases are of the similar ages, and whether the occurrence of these phases were synchronic along the whole Carpathian arch.

The humid climatic phase at the end of the Atlantic Phase caused an increase of fluvial activity ca 4300 cal. BC. However, the water table rise in the peat-bogs of the Dniester River valley 3300-2900 is not recorded as the individual flood phase (3100-2600 cal. BC), which is documented in the Vistula River valley.

The flood phase 500-400 cal. BC is marked only in the Strvyaž River valley. The phase 50 cal. BC–350 cal. AD is commonly recorded both in the Dniester and Bystrica River valleys, where overbank sands were deposited above the peat sediments bearing cereal pollen from the Roman Period. The younger insert is represented by channel alluvia bearing tree trunks dated at 5-6th centuries AD and overbank sediments deposited in 10-12th centuries AD.

In the Stryj alluvial fan the floods fall into 350–650 cal. AD, 800–1150 cal. AD and ca.1400–1450 cal. AD.

The gravel floodplains in the Upper Dniester and Seret Rivers was formed during the Early Middle Ages. In the tributaries of Seret river, the channel alluvia bearing tree trunks were deposited in 13-14th centuries and at the beginning of the 16th century.

The flood phases occur in the valleys of the Eastern Carpathian Foreland are synchronous with the phases of increased fluvial activity in the Upper Vistula River basin and reflect the pulse of climatic fluctuations and colonisation phases.

**Keywords:** Flood phases; Neoholocene; Dniester river

*THEME: S12 : PALAEOHYDROLOGY AND FLUVIAL ARCHIVES - HYDROLOGICAL  
EXTREME AND CRITICAL EVENTS (HEX)*

**ABSTRACT NUMBER: 542**

## **ALLUVIAL MEGAFANS OF EUROPE: MORPHOLOGIES, ARCHITECTURES AND FORMATION PHASES**

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Alluvial megafans are not very common in Europe and the use of this term is not diffuse in the continent because of the persistent habit of describing as "fans" even the huge divergent alluvial landforms (>1000 km<sup>2</sup>). Considering the megafans that are currently still recognizable in the topography, they can be found only in some of the alluvial areas facing the Alps and the Carpathian chain.

Along the southern Alps, megafans are present from Milan (central Po Plain) to the whole Venetian-Friulian Plain. The major landforms are the ones formed by Adda, Olona, Oglio, Adige, Brenta, Piave and Tagliamento rivers. All these systems experienced a strong depositional phase in the LGM (29-17.5 ka BP), when the Alpine glaciers stationed at the mouth of their valleys and the rivers played as glacial outwashes. Sedimentary starvation characterized all the megafans of northern Italy since Late Glacial. Thus, the Alpine megafans can be mainly considered as relict products of the last glaciation, mainly controlled by the climate forcings.

Megafans are documented also in the Little Hungarian Plain (Danube River near Bratislava and Rába River megafans; mainly fed by the Alps) and in the Great Hungarian Plain (e.g. megafans of Maros, Szamos and Timis rivers). The largest megafan is the one formed by the Maros River, which consists of two lobes covering an overall area of at least 7000 km<sup>2</sup>. The dated traces of braided and meandering channel belts testify a continuative activity until late Holocene. Compared to the Alpine ones, the megafans of the Great Hungarian Plain are fed by larger catchments, but these were not severely glaciated during LGM and sustained important depositional phases also in Late Glacial and after. In the Carpathian Basin the megafan evolution was strongly influenced by differential subsidence.

**Keywords:** Northern Italy; Carpathian Basin; LGM; Holocene

*THEME: S12 : PALAEOHYDROLOGY AND FLUVIAL ARCHIVES - HYDROLOGICAL  
EXTREME AND CRITICAL EVENTS (HEX)*

**ABSTRACT NUMBER: 647**

## **LUMINESCENCE DATES FROM LOWER GANGETIC PLAIN, INDIA AND ITS IMPLICATIONS FOR QUATERNARY EVOLUTION OF THE WESTERN BENGAL BASIN-FILL**

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We present here for the first time, quartz optically stimulated luminescence (OSL) ages from the lower Gangetic plain (LGP) deposits

and discuss its implications on the evolution of fluvial landscape. The study area is located on the stable shelf zone of western Bengal Basin and the drainage comprises eastward flowing parallel monsoon-fed cratonic rivers that debouch into the Bhagirathi-Hooghly River (a tributary of Ganga). Ten OSL dates reported here are from the valley-fill and associated deposits. Luminescence ages are obtained by sampling the trenched section of Damodar (Barjora) and cliff section of the Ajay (Nelegarh) including drill core samples from some parts of the Ajay (Panduk) valleys. This has been supplemented by detailed field surveys, topographical analysis, geomorphometry data and shallow subsurface stratigraphic studies. Comparison with more than twenty published OSL or 14C dates from Bengal Basin and Ganga-Brahmaputra Delta (GBD) plain shows that the sedimentary records in this area are significantly older. In the western LGP sediments 10 m below surface, yield an age varying between 10 and 29 ka whereas those occurring at a depth of 15-20 m are mostly 69 to 86 ka old. The data also reveals that during 90-82 ka (end of MIS-5), the LGP and associated deltaic plain experienced aggradational fluvial activities due to higher sea level and frequent climatic fluctuations and continued till 74-64 ka. In addition, decreasing precipitation and sea-level lowering (>100 m) during Last Glacial Maximum (24-14 ka) is reported in the western Ganga-Brahmaputra Delta (GBD). It has been postulated that these result in a relatively stable landscape and pedogenesis, and that in turn has prompted the formation of a pedocal soil and caliches nodules in the strata (<29 ka) of terraced alluvial surface in LGP.

**Keywords:** Lower Gangetic plain; fluvial deposits; OSL dating; stratigraphic studies; Quaternary climate change

THEME: S12 : PALAEOHYDROLOGY AND FLUVIAL ARCHIVES - HYDROLOGICAL  
EXTREME AND CRITICAL EVENTS (HEX)

ABSTRACT NUMBER: 788

### QUATERNARY ENVIRONMENTAL CHANGES IN THE EAST GOBI DESERT: PALEOHYDROLOGICAL EVIDENCE

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Reconstruction environmental changes in the desert driven by fluctuated climate is of great significance to understand its response to the warming climate. Water flow is an important process moulding desert landscape. And paleohydrology is one of few archives could be used in the desert paleoenvironmental studies. There has been a debate about the climatic and hydrological conditions of the Gobi Desert during the late Quaternary. Here we use the digital elevation model, remote sensing, combining with field investigation and geochronology to reconstruct the paleohydrology in the southeast part of Gobi Desert. Many shoreline features has been identified around the margins of the paleo-lakes. Uranium series dating of the mollusk shells, which are cross-checked by the radiocarbon and optically stimulated luminescence dating methods provide the chronological control for the paleo-lakes. Based on the geomorphological and chronological results, the paleo-lakes during late Quaternary are constructed. It is shown that mega-lake with an area of 14,000 km<sup>2</sup> developed during MIS 5 with the lake level 20-40 m higher than that of mid-Holocene (ca, 6.5 ka BP), indicating an enhanced summer monsoon. There has not been MIS 3 shoreline found in this area yet. The mollusk *Corbicula* sp. prevailed during MIS 5, implying a fresh-brackish water lake and much milder winter. We speculate the mean January temperature would be ca. 10 °C higher than the present, indicating a weak winter monsoon during MIS 5. And the annual precipitation would have been ca. 100% more than that of the present. The geometry of the paleo meander connected two lake basins suggests a much higher runoff, which implying there could have been other lakes in the arid west part of the desert to hold the water overflow through this meander.

**Keywords:** Gobi Desert; Quaternary; climate changes; geomorphology; paleohydrology

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 42

### DEGENERATING DISTRIBUTARIES IN THE UPPER GANGA DELTA, INDIA: EVIDENCES FROM MEANDER CUT-OFFS

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Most of the distributaries and palaeodistributaries of the Upper Ganga Delta, India, are characterised by intense meandering and cut-off development, resulting into formation of numerous oxbow lakes. Most of these lakes exist as stagnant water bodies, while the others



are clogged by sediments brought by floods and/or agricultural activities. The dimensions of these water bodies vary significantly as compared to the present channels. The ancient cut-offs and associated oxbows highlight the ancient flow regimes of the distributary channels.

The cut-offs in the study area were identified by using historical maps and satellite images. These included Rennell's Bengal Atlas (1764-77), Atlas of India sheets (1849-55), Survey of India toposheets (1916-28, 1949-51) and images from Corona (1967), IRS (2001-2013) and Landsat (1972-2014) missions. Distances of the oxbow lakes were measured from the present channels and their curvatures were quantified by using tortuosity index. Cross section surveys were carried out across selected oxbow lakes and present river courses. Discharge of the ancient channels were estimated by using the cross-sectional dimensions and compared with the presently active channels.

In the Upper Ganga Delta, only 24% of the cut-offs were completed in the last 160 years, two-third of which occurred along the Bhagirathi-Hugli, resuscitated in 1975 by the Farakka Barrage Project (FBP). A number of presently degenerated distributary courses were quite active in the past, as revealed by the larger dimensions of their oxbow lakes. About 29% of the oxbow lakes are highly tortuous, pointing toward extremely winding and sluggish distributary segments in the past. Abetted by the FBP, the Bhagirathi-Hugli River continues to flow actively and its present channel dimension, in most instances, is greater than the nearby oxbow lakes.

**Keywords:** delta, distributary, meander, oxbow lake, discharge

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 86

## CHANGING PATTERN OF CHANNEL MORPHOLOGY OF ALAKNANDA RIVER AND ITS IMPACT ON LOCAL ENVIRONMENT IN SRINAGAR VALLEY (GARHWAL HIMALAYA)

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River morphology is the field of science dealing with changes of river form, rapid change in shape and flow pattern mainly due to sedimentation and erosion processes.

In this paper we study the changing pattern of channel morphology of the Alaknanda River in Srinagar valley. Alaknanda River is a most significant tributary of the Ganga and form 11km long and 2.5 km wide valley locally known as the Srinagar valley.

In this study we high light the recent landform changes in the Alaknanda channel course after Kedarnath disaster 2013. Cartosat 1 data with reference to Google earth data is used to detect changes, along with, GPS and field observation techniques. The results indicate a 8.79% area reduction, 39.49% area increment of sand and boulder bed and 26.39% area directly affected by flood during 2013 disaster. The river changed its course at Srikot, SSB and Sriyantra Tapu. The lower terraces were silted by sands at Ranihat, SSB, Bhaktiyana and Sriyantra Tapu. A new point bar terrace was also formed opposite to Sriyantra Tapu. About 2-5 m silt was deposited on the lower terrace at SSB, NIT and ITI. At Srikot, the river bed bar was upgraded to 4.60m during 2013 flood. New lateral channel bars, braided channels, back swamp, rapids, pools and river souls are identified in the channel course of the river. The continued shifting of channel course at Chauras is a very serious problem to the Garhwal University Campus. The river undercuts the terrace scarp which is still in process. This study concludes that 2013 flood was the biggest disaster in the study area after 1894 and 1970 which damaged the inhabited area, agricultural land and accelerated the river bank erosion in the low lying area.

**Keywords:** Morphology, disaster, erosion, discharge, terrace

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 103

## INSIGHTS INTO QUATERNARY FLUVIAL LANDSCAPE DEVELOPMENT IN NW AFRICA USING RIVER TERRACES

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This study documents river terraces from upstream reaches of the Dadès River, a major fluvial system draining the south-central High



Atlas Mountains of Morocco in NW Africa. Terraces occur as straths with bedrock bases positioned at 10 m altitudinal intervals up to 40 m (T1-T5) above the valley floor, becoming less common between 50-140 m. The rock strength, stratigraphy and structure of the mountain belt strongly influences terrace distribution. Terraces are absent in river gorges of structurally thickened resistant limestone; whilst well-developed, laterally continuous terraces (T1-T4) form along wide valleys occupying syncline structures dominated by weaker interbedded limestone-mudstone. Terrace staircases develop in confined canyons but associated with weaker lithologies and influence from structural dip and stratigraphic configuration.

Terraces comprise a bedrock erosion surface overlain by coarse-grained fluvial conglomerates, rare overbank sands and gravel colluvium. This sequence, its morphological expression and with some OSL age control, suggests terrace formation over a 100 ka climate cycle with valley floor aggradation during full glacials and incision during glacial-interglacial transitions. This integrates with other archives (e.g. lakes, glaciers, dunes), appearing typical of landscape development along the NW Saharan margin south of the High Atlas, and similar to patterns in the western-southern Mediterranean. The 100 ka climate cycle relationship suggests that the terrace sequence documents Late-Middle Pleistocene landscape development. Consistent altitudinal spacing of terraces and their distribution throughout the orogen suggests sustained base-level lowering linked to uplift-exhumation of the High Atlas. Low incision rates (<0.2 mm a<sup>-1</sup>) and a general absence of terrace deformation suggests that active tectonic processes (e.g. faulting / folding) are low implying that isostatic base-level lowering is important with relief initiation being Early Pleistocene or older.

**Keywords:** River Terraces; Fluvial Landforms; Climate; Tectonics; Sahara Desert

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 119

## MORPHOLOGIC EVOLUTION AND SEDIMENT DYNAMICS IN A LOW-ENERGY RIVER IN A CONTEXT OF DAM REMOVAL: THE YERRES RIVER IN THE SEINE CATCHMENT

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Since 2000, the implementation of the Water Framework Directive (WFD) aims at improving ecological and geomorphological state of European rivers through dam removal. Countless studies have been led to evaluate its consequences on hydromorphological behavior of the river system and on sediment transport processes. They generally focus on large rivers or high-energy streams where post-removal processes are well-documented. As only few studies deal with low-energy rivers, evaluating dam removal consequences for these systems constitute major scientific issues.

This study aims at evaluating the hydromorphological disturbance of a small mobile dam that should be removed with the WFD application. It is led on the Yerres River (1000km<sup>2</sup>, s=0,009%), a Seine River tributary located 20km upstream of Paris.

An intensive field work has been carried out and two methods have been applied. A high-precision bathymetric survey has been led at different dates over a 2-year period with a Total Station Theodolite in order to (i) establish channel initial state and thus determine dam-related perturbations, (ii) assess channel post-removal morphological adjustments capacity, (iii) monitor channel evolution regarding hydrology and run-of-the-river dam maneuvers and (iv) quantify channel dynamic both bed and banks.

Meanwhile, a high-density sediment-size analysis of bed-material has been performed at different dates depending on flood occurrence. It allows (i) characterizing and mapping bed-material size spatial variability, (ii) determining post-flood and/or dam-operating sediment-size evolution and (iii) linking morphological changes to bed-material characteristics.

Results show hydromorphological and sediment features in accordance with the over 30-year long dam presence, with 3000m<sup>3</sup> of sediment trapped in the upstream reach. Despite a low mean specific power (<5W/m<sup>2</sup>), bed adjustments and sediment dynamic occur during flood season and dam opening, but changes remain moderate (vertical evolution of the decimeter order) even after June 2016 100-year flood.

**Keywords:** dam removal; morphological adjustment; low-energy River; sediment transport; Seine Basin

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 125

## UNDERSTANDING THE GENESIS OF 2008 KOSI FLOODS: COULD KOSI BED MORPHODYNAMICS BE ITS PROBABLE CAUSE?

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River Kosi is notorious for its vagrant behaviour. Spatially extensive flooding caused by its waters and, in its wake, the large scale destruction and socio-economic disruption is common in North Bihar. The flood of 8th August, 2008 is arguably amongst the severest in the history of Bihar floods. Many investigators attribute this catastrophic event to a breach in the eastern embankment of Kosi near Kusaha, 12 km upstream of Kosi barrage. Following it, the river is said to have 'avulsed' back into one of its old historical courses.

This study suggests an alternate understanding that Kosi's locally dynamic river bed morphology may indeed have been a likely trigger for the aforementioned catastrophic event of 2008. Study suggests that changes in bed morphology may be attributable to development of critical sediment deposition patterns due to the natural interplay between fluvial dynamics and the hydrodynamic influence of Kosi Barrage. The phenomenological causality for this 2008 event has been established based on inferences from 2-D hydrodynamic simulation of flood flow propagation in Kosi for pre and post-barrage bed morphological scenarios.

The modelling approach has enabled simulation of the velocity field, and the capture of its acute convexity in the vicinity of the site of interest is demonstrably notable. As a result, the erosive potential of the flow is likely to have been greatly enhanced by the bed form induced flow channelization and a transverse water surface slope that caused the flow to bank towards the eastern embankment.

**Keywords:** Kosi; Kusaha floods; bed morphology; avulsion; fluvial

*THEME: S13 : FLUVIAL PROCESS AND LANDFORMS*

**ABSTRACT NUMBER: 141**

## **FLOOD HYDROLOGY OF THE MAHI RIVER: WESTERN INDIA**

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The Mahi River in western India is regarded as one of the most intense flood regimes in the seasonal tropics. The gauged Annual Maximum Series data were collected from the CWC for six sites on the Mahi River and its tributaries for 17 to 30 years. The data have been used to evaluate floods and their frequencies. The data are used to understand interannual variations, characteristics of floods, and to estimate different return periods and the recurrence interval of discharges. The data plots reflect considerable interannual variability. It is also indicated by high the values of coefficient of variation and the flash flood magnitude index. The maximum annual peak discharges are 2 to 7 times higher than the mean annual maximum discharges. High unit discharges in the upper reaches and on the tributaries indicate the high potential of floods. The magnitude-frequency analysis indicates that the mean annual peak floods have a recurrence interval of 2.33 years, whilst the return period of large floods is 6.93 years. The recurrence interval of maximum discharges is between 21 and 396 years. The discharge-area envelope curve of the Mahi Basin shows that drainages in the area produce relatively smaller flood peaks than some of the drainage basins with comparable basin area in the other part of the world. The study of hydrographs reveals that large flows occur for several tens of hours. Two general conclusions emerge from the investigation. First, the Mahi River displays all the hydrologic characteristics of a flood-dominated river and large floods are relatively common. Second, the high-magnitude events are long-lasting and the discharges remain high for a considerable period of time.

*THEME: S13 : FLUVIAL PROCESS AND LANDFORMS*

**ABSTRACT NUMBER: 142**

## **ESTIMATION OF THE ROCK RESISTIVITY OF THE PAR RIVER USING SCHMIDT HAMMER REBOUND VALUES**

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The morphology of channel is largely controlled by the compromise between fluvial forces applied and bedrock resistance offered. The rock resistance to flow dynamics noticeably varies with respect to lithological considerations. In order to study the control of lithology on the channel, rock mass strength (RMS) of the Par River has been estimated. For above purpose, 371 Schmidt hammer rebound

values (N) for 14 cross-sectional sites comprised of basalt were obtained. Besides, 44 N values of dykes have been obtained to find out control of dykes on the river. The N values were converted into standard-averages of RMS (N/mm<sup>2</sup>) by calculating statistical power-law relationship. Statistical parameters of RMS were derived. Rock erodibility between basalt and dykes have been analysed semi-quantitatively and comparison between them has been shown by using box-whisker plots. The average RMS of dykes is 92.72 N/mm<sup>2</sup>. It is greater than basalt rock in the river (78.03 N/mm<sup>2</sup>) due to hardness of dykes. The analyses further suggest that the basalt rock is comparatively weaker than dykes. The RMS values can be surpassed only at long interval during infrequent large magnitude floods. It is assumed that Schmidt hammer numbers are proportional to the tensile strength. Higher N values indicate less erodible bedrock. The results of analyses reveal the hypothesis that the differences in rock erodibilities are present. It is further proved by control of dykes on the channel of the Par River at few locations.

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 158

## RIVER BANK EROSION AND MEANDER MIGRATION IN LOWER DISANG RIVER, ASSAM

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The present study aims at assessing the rate of bank erosion, accretion and meander migration of the Lower Disang River, Assam. It uses evidence of six years (1916, 1970, 1990, 2000, 2005 and 2016) of SOI toposheets (1: 63360 of 1916 and 1:50,000 of 1970) and satellite images combined with field investigation in order to examine the morphological changes of the river over ~100 year period. This allows insight into the spatial and temporal variability of bank line movement. Bank lines were mapped for approximately 200 km reach and the digitized courses compared in ArcGIS to estimate erosional and depositional areas and rates. Meander migration prediction is done using GIS based measurement and extrapolation techniques. Quantitative assessment shows that the total area of bank erosion during the given period of time is 15.223 sq. km, out of which 7.177 sq. km was along the left bank and 8.046 sq. km along the right bank. The total area of bank accretion from 1916 to 2016 is 16.69 sq. km, out of which 8.045 sq. km was along the left bank and 8.645 sq. km along the right bank. From the above estimations it is found that the quantum of accretion is more than erosion over 100 year time period. During the study period, the average lateral migration of the channel was 1.11 m per year, which varies along the reaches. This has resulted in the loss of agricultural land and property along the river banks.

**Keywords:** River bank erosion; accretion; meander migration; Lower Disang River

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 174

## HYDROLOGICAL DIS-CONNECTIVITY IN A SEMI-ARID LOESS COVERED AREA

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Spatial hydrological relationships represent a basic concern in our understanding of geomorphic processes and their effects on the structure and functioning of ecosystems. The aim of the present study is to present a peculiar hydrological regime that prevails in a semi-arid loess covered area. The area is characterized by a very high frequency of storm channel flow in ephemeral streams (4-9 flows in a year); extremely low peak discharges at very high and very low rain intensities (below 5 mm/hr-1). The explanation proposed is that runoff is limited to the channel area, with no contribution from the adjoining hillslopes. The study was based on two complementary approaches: 1) The analysis of the pedological properties along a hillslope 350 m long and 2) properties of the upper part of the alluvial sediment. Pedological data obtained show no differences in the chemical composition of the soil, down to 100 m; no differences in the particle size distribution and no differences in the depth of water penetration and soil moisture content. These results are regarded as indicative of negligible runoff generation over the hillslopes. The properties of the alluvial sediment covered the following aspects: particle size composition, mineralogical composition of the clay fraction and porosity of the depositional layers. Data obtained fully support the research hypothesis that runoff generation is limited to the channel area. Smectite, a highly dispersive clay, is the dominant clay in the alluvial sediment. Total clay content is much higher than on the hillslope soils, and the porosity of the thin layers in the alluvial sediments is very low, with limited connectivity between the small voids. The above properties are ideal for clay dispersion, drastically limiting infiltration depth.

**Keywords:** hydrological connectivity; semi-arid loess covered areas; partial area runoff contribution; hydrological disconnection at hillslope- channel interface; clay dispersion.

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 210

## BANK EROSION IN AN ANDEAN PÁRAMO ECOSYSTEM: ASSESSING THE POTENTIAL FOR FLUVIAL EXPORT OF ORGANIC CARBON

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The recent assertion that global terrestrial carbon export to the oceans is controlled by fluvial erosion has prompted the need for higher resolution studies of erosion in carbon-rich environments. The páramo ecosystems of the tropical Andes are known for their Andesitic soils that contain large amounts of organic carbon, and as such have become part of the discourse on carbon-related ecosystem services in the neo-tropics. However, little is known about the hydro-geomorphic characteristics that control fluvial erosion in streams draining páramo, and thus rates of erosion remain unknown. This research combines geomorphic surveys, erosion pin analysis, geographic information systems analysis, and bank soil analysis to characterize bank erosion along the Ningar River, Cañar Province, Ecuador, and assess the potential for fluvial export of soil organic carbon (SOC) from the páramo. Visual classification of bank conditions showed that 39% of bank length along the páramo section of the Ningar River is in a state of active erosion. Erosion rates from nine eroding banks representing a range of erosion types ranged from 3mm/yr to > 390mm/yr. Field descriptions of bank soils closely matched previously published descriptions of valley bottom soils in the Ningar River watershed that reported average bulk densities of ~1.0 g/cm<sup>3</sup> and an average SOC content of 118 g/kg. Soil organic carbon flux was then estimated as the product of eroding bank length, erosion rate, SOC content, and soil bulk density. Soil organic carbon flux from bank erosion along the 2.5 kilometers of the Ningar River páramo was conservatively estimated to be 77 tons annually. These results suggest that SOC flux from fluvial erosion could be a significant component of páramo carbon cycles, as well as global-scale terrestrial to marine carbon flux, and that páramo river systems may export a disproportionate amount of SOC per unit area than other ecosystems.

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 280

## SOIL EROSION, SUSPENDED SEDIMENT INFLOW/OUTFLOW AND CHANNEL DEGRADATION/AGGRADATION IN THE MORA DHANSIRI RIVER BASIN, ASSAM, INDIA

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This study attempts to estimate rate of soil erosion, magnitude of sediment inflow/outflow and rate channel degradation/aggradation in the Mora Dhansiri River basin, India. Rate of soil erosion is estimated following RUSLE model for the period 2009-15. Magnitude of suspended sediment inflow/outflow is measured and estimated adopting field based conventional methods for the period 2009-15 and channel degradation/aggradation is estimated using this data. Rate of soil erosion is estimated to be 2.12, 5.28, 5.09, 5.11, 5.10, 5.32, and 5.46 tha-1y-1 respectively in the years 2009-2015. The thickness of soil layer eroded from the catchment is 0.004 cmy-1. An amount of 0.773 x 10<sup>4</sup> m<sup>3</sup> of sediment was removed from the river during 2009-15. As against to this 0.283 x 10<sup>4</sup> m<sup>3</sup> of sediment was accumulated in the channel during 2009-15. As a whole, the bed of the 76 km long channel is investigated to be degrading channel with an average rate of 0.07 cmy-1. River bed of roughly upstream half of the channel evident to be degrading while the downstream half slowly aggrading. The rate of bed degradation/scoring in the upstream half is 0.079 cmy-1 while aggradation/filling in the downstream half of the channel is 0.032 cmy-1. On account of degrading status of the channel, fluvial processes viz. flood, bank erosion are not much evident except occasionally in lower section. However, the river bed started aggrading at a rate 0.032 cmy-1, naturally from the lower reach to the upper ones, which will cause fluvial hazards in near future. Thus, measures of fluvial hazard mitigation such as bank protection, river training including dredging are required to be taken-up at the earliest for minimizing loss of cultivated lands and crop protection which are recurring problem in the state of Assam.

**Keywords:** Mora Dhansiri River basin; Soil erosion; sediment inflow/outflow; bed aggradation/degradation

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 285

## A MULTIDISCIPLINARY APPROACH TO RECONSTRUCTING HOLSTEINIAN OXBOW ON THE PIEDMONT FAN AT KRZCZONÓW, SUDETIC FORELAND, SE POLAND

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Paleogeographical reconstructions in the piedmont fan formed during the Middle Pleistocene interglacial (Holsteinian) are difficult. Alluvial and lacustrine environments, are key areas with both high geomorphological and palaeoecological potential. However, the often deep stratification of sites and complex sedimentological variations hamper a detailed reconstruction of Holsteinian oxbow filling the Bystrzyca river valley within the piedmont fan on the front of the Sudety Mts. Combining different methods can offer detailed insight into such landscapes. Using various methods allows for a collection of continuous information on large-scale palaeolandscapes variability.

Here we present a combined approach to Holsteinian river system with a palaeolake in SE Poland. Basing on lithological, structural (7 units), textural (3-4 units), palaeobotanical (2 units), palaeozoological (1 unit), geochemical (geochemistry - 5 units and isotopes - 3 units) and magnetic (1 unit) analysis we can attempt to reconstruct the filling of oxbow by different deposits. Tills levels enabled dating of the evolving river system to the transition between Late Elsterian and Early Saalian. This river system could be traced further through the palaeolake area.

A multiproxy analysis allows to distinguish three main phases: 1. Origin of the oxbow within the valley with peats, organic and minerogenic silts deposition. 2. Closed, fairly deep late Holsteinian lake continued to exist under relatively warm conditions with mainly mineral depositions from slopes. The lake became shallower and wider, and then more open and better oxygenated (with through-flow). 3. The lake was completely filled by organic sediments under interglacial conditions. Absence of diatom, molluscan and ostracod communities indicates an acid lacustrine environment at that time.

Obtained results allowed for the delineation of palaeochannels in the area and enabled modelling depth of the lake of 8-10 m in the survey area, providing insight into flow vectors from NE to E.

**Keywords:** Holsteinian; palaeolake; multiproxy studies; Sudetic Foreland

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 332

## INFERRING MORPHOLOGICAL CHANGES IN THE ADIGE/ETSCH RIVER DURING THE LAST TWO MILLENNIA: INTEGRATING GEOMORPHIC, GEOARCHEOLOGICAL AND GEOPHYSICAL APPROACHES

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The Adige River is the second longest river in Italy and drains 12,100 km<sup>2</sup> of the Eastern Italian Alps. As many other rivers in Europe, it suffered remarkable modifications related to climate changes and human impact, specifically a massive channelization that was implemented from the first decades of 19th century.

The study aims to reconstruct the evolution of the Adige valley over the last 2000 years, assessing the relationships between channel modifications, human disturbances and climate changes, along a 115 km long river segment.

A multidisciplinary approach was adopted, including the analysis of: archaeological deposits, covering the time period from the 1st century bc to the XIX 19th AD; geological cores; geophysics data; and historical maps (ten sets of maps and orthophotos from 1750 to 2006).

Channel morphodynamics relevantly increased during the “Late Antiquity” (350-600 AD)” and during the Little Ice Age (1500-1850) as proven by the increase of floods frequency and by the increase of coarse sediments. Soils development and alluvial fans stability were instead prevailing during the Roman Warm Period (ca. 300 bc – 550 AD) e the Medieval Climate Anomaly (ca. 950-1250 AD).

Concerning the last 200 years results show that the Adige suffered the most intense alteration from 1847 to 1855, because of the channelization. Adjustments consisted in narrowing from 14% to 70%, straightening, and strong reduction of the secondary channels, bars and islands.

The study shows that climate change had strong influence on fluvial dynamics in the past millennia but, starting from the 19th century, human disturbance has largely overcome climate constraints of the Adige’s dynamics and morphology. Results also offer a strong basis for comparison with predictive river morphodynamic models over long time scales.

**Keywords:** Climate changes, Late Holocene, Little Ice Age, Human impact, channelization, fluvial morphology

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 349

## LONG-TERM IMPACTS OF HYDRAULIC MINING SEDIMENT IN THE SIERRA NEVADA, CALIFORNIA: A MASSIVE ANTHROPOGENIC SEDIMENTATION EVENT REVISITED

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More than a billion cubic meters of hydraulic mining sediment (HMS) were produced in the mountains of northern California between 1853 and 1884 (Gilbert, 1917). Previous studies have emphasized the volumes and characteristics of HMS that were transported into the Sacramento Valley and beyond. This study re-examines the anthropogenic HMS that remain in the mountains in selected watersheds using a geomorphometric analysis of 2010 LiDAR data. Gilbert’s (1917) early sediment budget is reevaluated by volumetric analysis of hydraulic mine pits and HMS storage in channels, terraces, and tailings fans. Locations and volumes of HMS storage are mapped and compared with (1) patterns of energy expended on sediment transport, and (2) sediment production measured from volumes of hydraulic mine pits. Energy expended was measured as unit stream power above a threshold integrated over time. Unit power was computed as the product of discharge and local valley bottom slope, where discharge is a function of drainage area from a flow accumulation model and channel slope was derived from the LiDAR DEM using channel-segment end-point elevations.

At broad spatial scales, storage potential was strongly related to stream power with little storage in large, steep gorges of main channels and much storage in low-gradient tributaries. In tributaries, long-term storage occurred primarily where high rates of sediment production deeply buried valley bottoms. This resulted in high terrace scarps and tailings fans isolated above and away from incised channels, and self-armoring of the incised channels. Following large episodic sedimentation events that cause deep aggradation, sediment may have much longer residence times than moderate events that generate deposits within the range of frequently occurring discharges.

**Keywords:** Fluvial sedimentation; Anthropogenic change; Sediment storage potential; Hydraulic mining

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 357

## SEDIMENT TRANSPORT, RIVER CHANNEL CHANGE AND RIVER REGIME IN THE LOWER YELLOW RIVER: A RATIONAL ANALYSIS

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Abstract: The Yellow River is famous for its high suspended sediment load and frequent river channel change. Varying sediment load

carried by large flood generally results in significant river channel scour or deposition. Because of the easily movable river channel boundary, it is difficult to achieve a rational solution for river regime. In this study, we proposed a rational analytical procedure using suspended sediment transport formula and an empirical model for river channel change. We revised the empirical model for river channel change into a width-depth ration dependent river regime model. Our revised model represents the interrelationship between river morphology, sediment transport and river channel change. Based on the principle of maximum sediment transport efficiency, we obtained the final solution of the river regime model. The solution implies the river channel in the Yellow River has the optimal river channel morphology for sediment transport with no or least channel scour or deposition. The results from the validation of this model with the available data of the lower Yellow River show that the large alluvial rivers would have the similar channel morphology to gravel bed rivers if they achieve a regime state. We hope this kind of rational analysis for river regime of large alluvial rivers would contribute to river regulation and management in the lower Yellow River.

**Keywords:** Sediment transport; River channel change; River channel morphology; River regime; Rational analysis; the Lower Yellow River

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 361

## MORPHOLOGICAL CHARACTERISTICS OF A RIVER CONFLUENCE: A CASE STUDY OF RIVER PRAVARA IN MAHARASHTRA

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Channel confluences are critical zones where large scale changes in physical process occur. These changes affect both at the confluence and downstream characteristics of the flow and form variables with respect to standard variables of the confluences explained by Best (1987).

The changing form of channel confluences is play important role in fluvial network. In this paper researcher has tried to find out the morphological characteristics of the middle reach of river Pravara with regards to standard confluences. Six tributaries of the river Pravara have taken for the study. River Pravara is a major right bank tributary of river Godavari, originates in Ratangarh hill at the height of 1479 m.

The main aim of this research to study the confluence zone morphology of river Pravara and correlate it with standard characteristics of confluence characteristics described by best and et al. The primary data is collected in the field survey at six confluences. Cross sections have been taken at this sites and rainfall runoff is also carried out last ten years data. A channel confluence represents points of significant changes which are characterized by scour and deposition zones. Morphology is controlled by confluence angle, discharge ratio and other flow and form variables.

It is found in all the confluences that deep central scour zones are present except the tributary Mahalungi. In case of Mahalungi confluence it is affected by anthropogenic interference bars within separation corner are formed at all the sites but location differs at every junction. It shows that increasing the junction angle also increases separation zone dimensions.

It can be said that confluence angle and discharge ratio between main stream and tributary are the predominant variable which control the morphology of the confluence zones.

**Keywords:** Channel Morphology and Junction Angle

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 398

## ESTIMATING BEDLOAD TRANSPORT IN A LARGE GRAVEL-BED RIVER USING THE VIRTUAL VELOCITY APPROACH

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In large gravel-bed rivers, bedload transport estimation is a challenging task because it is difficult to collect direct samples during

floods, and theoretical formulas often fail to predict actual bedload fluxes. A viable alternative is the virtual velocity approach, which is based on empirical relations, derived from field data, between the water flow (specifically shear stress) and the velocity of sediments and thickness of the active layer. This research aims to improve the virtual velocity approach, and to assess its reliability by comparing it with the morphological method. The study was carried out in a reach of the Parma River (north-Apennine, Italy). Painted sediments, particles marked with passive transmitters (PITs), and scour chains have been deployed in four monitored cross-sections. Over the period January 2016 - May 2017, six flood events were monitored, collecting data on water level, transport processes, particle travel distance and active layers thickness. The derived site-specific relations allowed us to calculate bedload transport for each flood event. For one of the sections, bedload transport ranges from  $142 \pm 54 \text{ m}^3$  to  $962 \pm 237 \text{ m}^3$  for the lowest (RI < 1 year) and highest flood (RI = 2.1 year), respectively. Partial transport contribution to the overall transport volume ranges from 42% to 13%. Bedload volumes tend to increase downstream and, except for the lowest magnitude events, they are considerably lower than those provided by traditional formulas. The outcomes highlight the applicability and reliability of the virtual velocity approach and give new insights about variable relevance of partial transport contribution in function of flood magnitude.

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 424

## SHORT-TERM CHANNEL ADJUSTMENTS OF THE SELE RIVER (SOUTHERN ITALY)

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The Sele River is the second most important river in southern Italy from the mean annual flow discharge standpoint (about 69 mc/sec at the river mouth), notwithstanding a moderate length (70 km). The basin is 3,250 km<sup>2</sup>-wide and shaped into calcareous rocks and terrigenous deposits, unconformably covered by Quaternary continental sediments. The climate is mainly of Mediterranean type. Land-use is dominated by forests (52% of the basin area) and agricultural lands (43%).

In this work, the morphological changes experienced by Sele R. in the last 150 years were investigated by introducing into a GIS topographic maps from 1870, 1909 and 1955 at 1:50,000 and 1:25,000 scale and aerial orthophotos from 1998, 2004, 2008, 2011 and 2014, at 1:10,000 and 1:5,000 scale. The upper part of the river, which was too narrow to be correctly reported on the topographic maps and/or hidden by arboreal riparian vegetation on orthophotos, was not analyzed. Land-use changes analysis at the basin scale between 1960 and 2012 was also carried out. The results were checked in the field.

From 1870 to 2008, the Sele R. experienced a remarkable narrowing, as mean width decreased from 173 to 48 meters (-72.3%). Between 2008 and 2011, a slight widening by 25% (from 48 to 60 m) occurred, followed by substantial stability in channel width. Sinuosity increased from 1.2 to 1.4 between 1870 and 1955, then remained almost unchanged. Between 1870 and 1909, sinuous channel morphology was dominant over sinuous with alternate bars, wandering and braided morphologies; these latter became strongly dominant in 1955, while between 1955 and 2014, sinuous morphology became the most widespread one, suggesting a decrease in sediment supply which is coherent with the afforestation of abandoned farmlands highlighted by land-use analysis. Human disturbances along the river were limited.

**Keywords:** channel adjustments; fluvial geomorphology; Sele River; Italy

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 426

## SEDIMENT DYNAMICS IN EPHEMERAL CHANNELS

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Sediment dynamics of channels have major practical and geomorphological impacts. Sediment fluxes in ephemeral channels are highly episodic and have distinctive characteristics from events in perennial channels. Increased understanding of conditions for sediment transport, flux magnitude, mechanisms, sources and connectivity in ephemeral fluvial systems is still needed, especially for large events. The dynamics of sediment flux in different type of channel are examined from evidence of channels of contrasting morphology and lithology in different regions and for a range of event magnitudes and characteristics. The influence of sediment calibre and supply on distribution, transport processes and deposits is analysed. Sources of sediment are identified and the relative importance of hillslope and channel sources in different settings is discussed, together with the impacts on and feedback effects of connectivity. Measurements

in a gravel channel with high sediment supply of the impacts of a large flood event with very rapid hydrograph rise and fall provide evidence of the amount of flux, competence, mechanisms and dynamics that can occur. The flood produced massive aggradation in the form of large flat bars. Evidence from very large transported blocks indicates very high competence and deposits in a tank indicate particles of up to 100 mm size were being carried in suspension. The adequacy of sediment transport relations to model and predict such characteristics and their applicability to ephemeral channels is discussed. The results have implications for channel management and for paleohydrological interpretation of deposits in dryland environments.

**Keywords:** channel; semi-arid; sediment flux; flood; deposits

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 439

## IMPLICATIONS OF MORPHOLOGICAL CHARACTERISTICS AND LITHOLOGY ON GULLY DEVELOPMENT: A CASE STUDY OF GARHBETA BADLANDS, WEST BENGAL, INDIA.

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Land degradation due to gully erosion is a severe erosional hazard within the humid tropics. Gully formation is a threshold-dependant process controlled by topographical, hydrological, morphological and lithological factors. Gully morphology includes physical properties of gullies such as, gully width, depth, length, cross-section area etc. and can be measured from gully cross-sections. The present study provides a comprehensive analysis of changes in morphological characteristics of gullies from head to mouth in relation to lithological properties of the underlying strata to highlight the mechanism of gully development. For this purpose cross-sectional profiles are surveyed along gullies at regular intervals using Total Station and GPS in the Garhbeta Badlands of Paschim Medinipur district, West Bengal. The twenty-six morphological parameters are categorised into Dimension parameters (gully width, depth and area); Asymmetry parameters (left width, right width, area of left side, area of right side); Erosion degree (erosiveness, concavity and shape index); and Erosional pattern difference (width-depth ratio). The average gully length varies from 330-350 m. The gully width and depth increases respectively from 9-12 m and 2-3 m near gully head to 30-35 m and 4-6 m near gully mouth, reaching a maximum of 45-50 m and 7-8 m in the gully middle. The pattern and rate of gully network development as well as morphology of individual gullies are related to the host material. The formation of duricrust in this lateritic area generates runoff and concentrates flow downslope, making the area prone to severe gully erosion. V-shaped cross-sections are found near gully head-cuts, while U-shaped cross-sections are seen in the gully mid-portion due to undercutting and mass instability along the sidewalls. The comprehensive analysis of gully shape and its response to the lithological properties of soil is thus crucial to the understanding of the gully development processes.

**Keywords:** Gully; cross-section; morphology; lithology; Garhbeta

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 463

## RIVER LONG PROFILE AND STREAM POWER ANALYSIS TO MAP SPATIAL VARIABILITY IN GEOMORPHIC PROCESSES ALONG MAJOR RIVERS OF PENINSULAR INDIA

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Geomorphic processes are governed by the catchment scale distribution of stream power (SP). Downstream variability in SP distribution pattern is controlled by the shape of long profile, an outcome of geological evolutionary processes and lithology. Here, we analyse long profile (LP) shape and its effect on geomorphic process diversity for the major bedrock rivers of Peninsular India. Peninsular India is characterized by rivers flowing within the Precambrian metamorphic terrains with Cretaceous Deccan Basalt in the North Western part. LP of the peninsular rivers show major convexities as they exit the plateau region and enter the plains. SP was estimated by taking the product of ten year return period discharge and channel slope along the LP. We used ten year return period discharge, considering that bedrock channels of Peninsular India attain bankfull conditions during these flood values and maximum change occurs during these events. LP slope was estimated by taking the derivative of second order exponential functions fitted to DEM (SRTM 90m resolution) derived long profiles. The Tapi and Narmada rivers show peak SP (50000 to 100000 W/m) at 250 km from origin. SP maxima (30000 to 60000 W/m) is estimated at mid-stream reaches around 400 - 600 km from origin for Cauvery, Krishna and



Godavari rivers. The geomorphic characteristic of river reaches shows an incoherent relationship with SP estimates. Godavari River is characterized by extensive channel bars in spite of high SP. However, reaches with high SP values for Narmada, Tapi and Cauvery rivers are characterized by absence of sand bars indicating no sediment storage and those with low SP values shows extensively developed point bars and longitudinal bars.

**Keywords:** Long Profile; Stream Power; Bedrock Channel; Peninsular India

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 497

## ISO AND META-CHRONICAL TERRACES AND THEIR EXPRESSION ON THE FORMATION OF THE MIDDLE REACH OF THE YELLOW RIVER

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As the fifth longest river in the world, the Yellow River is a unique one for the big river study of long geomorphic history because in most cases its terraces are covered and preserved by thick and dated Quaternary loess and late Neogene red clay. However, there are still debates on the age, origin and process of the formation even though its over 100 year research, e.g., N<sub>2</sub>, Qp<sub>1</sub> and late Qp<sub>2</sub> to Qp<sub>3</sub> in origin age. Previous research considered that same terrace was of the same age that could be correlated to paleosol and so as to interglacial period. By very detailed field investigation and comprehensive datings along the middle reach of up- to downstream Hetao Basin-Jinshan Gorge-Fenwei Basin-Sanmen Gorge-flood plain, we identify: 1) The terraces caused by abruptly uplift faulting usually at gorge mouth such as Jinshan and Sammen Gorges, were carving upstream graded to individual knickpoints, resulting meta-chronological terraces, which are covered by increasing younger red clay-paleosol-loess sequences upstream but in most chance by paleosol in Quaternary because of faster and stronger carving during interglacial period. 2) The terraces formed by draining and Fenwei Basin base level lowering communicating with the Sanmen Gorge, appear all rivers that fed into the Basin. 3) Terraces created by downcutting because of connection of upstream Hetao Basin are only distributed along the main course. Terrace ages in case 2 and 3 are iso-chronological covered by about 200ka and 100ka paleosols, respectively. The gorges are characterized by broad valley with meta-chronological terraces since N<sub>2</sub>, then V-shape valley incised in Qp<sub>1</sub>, and last narrow gorges with iso-chronological terraces because of much stronger downcutting induced by connection of the Fenwei Basin with Sanmen Gorge about 200ka and by connection of the Hetao Basin with Jinshan Gorge about 100ka.

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 502

## POST-FLOOD PERIOD SERIAL GEOMORPHIC ANALYSIS (POPSEGA) AND RECENT CHANNEL PLANFORM EVOLUTION OF A BRAIDED-WANDERING RIVER

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The post-flood period serial geomorphic analysis (POPSEGA) approach coupled with GIS analysis was used to identify morphological changes that occurred during particular flood periods of the braided-wandering river Belá in Slovak Carpathians. The study focused on assessing how six flood periods (FP) with differing flood characteristics have influenced the evolutionary trend of the river. Seven sets of aerial photos (1949, 1961, 1973, 1986, 1992, 2003, 2009) provided data about channel landform changes in 227 river segments of 100-m length. The multitemporal data analyses of channel parameters (river active zone width, channel number, island number and mid-channel bar number) for identification of the recent channel planform (single, braided or wandering) evolution were used. The largest proportion of the braided planform was identified in 1949. The first FP (1949–1961), with a very high-magnitude flood in 1958 (RI50), was characterized by increasing total channel length, island number/area, and the number/density of confluence–diffuence pairs (nodes), and by decreasing bar area. The following FP (1962–1973) with four 5- to 10-year floods exhibited the inverse pattern of changes in channel form parameters, although the core frequency of channel dynamics and Shannon's diversity index were high. The stabilization of in-channel landforms and channel narrowing between years 1973 and 1992 (third FP, fourth FP) reflect the prevailing of wandering channel planform. An increase in all analysed channel parameters, especially bar area and pattern metrics values (channel segments with braided channel planform), occurred in the years 1993–2002 (fifth FP) as a consequence of two floods in 1997 (RI7)

and 2001 (RI3.5). The mid-channel bar stabilization and its transformation into islands significantly decreased the braided channel planform and support its transition to wandering one during the last FP (2002–2008).

**Keywords:** POPSEGA, planform evolution, flood, braided-wandering, river response

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 568

## INCISIONAL RIVER AVULSIONS: PROGRESS IN UNDERSTANDING THEIR DISTRIBUTION, LENGTH, AND FREQUENCY.

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Global mapping demonstrates that river avulsions, far from being unusual geomorphic events, are in fact globally ubiquitous. Wherever a river valley is wide enough to accommodate a meander belt, it will avulse. This accelerates rates of valley widening. River avulsions can develop by both incision and progradation. We demonstrate that the length of incisional avulsions increases downstream, and this is strongly controlled by some local hydraulics driven by valley slope. This paper also explores how often avulsions occur, identifying, for the first time, how long each phase of the avulsion life-cycle lasts.

**Keywords:** avulsion, avulsions, incisional, fluvial, river

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 612

## LATE QUATERNARY AGGRADATION AND INCISION OF INDUS RIVER: ROLE OF CLIMATE AND TECTONICS

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The upper Indus River flowing NW in a longitudinal valley along SW edge of Tibet, Karakoram fault zone, Indus Tsangpo Suture Zone, Ladakh Batholith, and Zaskar ranges, represents a first order geomorphological feature of Ladakh Himalaya. The Indus River arises from Mount Kailas and sink into Arabian Sea via plains of Punjab (Pakistan), has a very large (1×106 km<sup>2</sup>) catchment area. A ~ 350 km stretch of upper Indus River from village Nyoma to Dah was examined for longitudinal river profile, stream length gradient index, and river/strath terraces, which divided the studied area into four segments. The valley fill river terraces are abundant and strath terraces occur in the lower reaches where the Indus River cuts through deformed Indus Molasse. The valley filling based on optically stimulated luminescence dating indicate that the valley aggradation occurred in three pulses, at ~ 52, ~ 28 and ~16 ka, and are broadly coincide with stronger SW Indian summer monsoon phases. Downstream to the Leh, presence of strath terraces indicate two paleo profiles of the Indus. These paleo-river profiles provide an upper limit on the bedrock incision rates ranging from 1.0 ± 0.3 to 2.2 ± 0.9 mm/a, which suggested a rapid uplift of the western syntaxes aided by uplift along the local faults led to the formation of strath terraces and increased fluvial incision rates in this stretch of the river.

**Keywords:** Indus River; Luminescence dating; Aggradation – incision; NW Ladakh Himalaya

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 614

## ASSESSMENT OF FLOW VELOCITY AND BANK EROSION OF THE PUTHIMARI RIVER OF ASSAM, INDIA

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The Puthimari River is one of the north bank tributaries of the Brahmaputra River in the Assam Valley characterized by bank erosion leading to channel changes and bank line migration. This study is aimed at quantifying the actual bank erosion along the Puthimari River within the alluvial track and measuring the flow velocity. The study has been carried out for a period of four years from 2011 to 2014. The straight reach of Tarai Zone and acute meander bend of Bhangar Zone have been taken for flow velocity measurement. The velocity has changed even within the channel from one bank to another of a particular reach. The study clearly indicates that the high velocity has migrated from right to left bank and vice versa for several times within the study period of four years and erosion has taken place in the bank with higher flow velocities. The near bank flow velocity has exerted pressure on bank material and eroded away by hydraulic actions.

Bank erosion rate has been plotted against near bank velocity in a scatter diagram to find out their relationship. The scatter plot of these two variables reveals the strong positive relationship established between flow velocity and bank erosion. Most of the cases the near bank flow velocity and bank erosion shows a strong positive relationship. It determines that near bank flow velocity is one of the most important causes of bank erosion. The results show that the rate of erosion varies from bank to bank and one reach to another over the time.

**Keywords:** Bank Erosion; Flow Velocity; Puthimari River

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 620

## WHAT CONTROLS CHANNEL WIDTH IN AN INTERMONTANE VALLEY ALONG THE NW HIMALAYA?

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Intermontane valleys (Duns) present in the sub-Himalaya act as sediment buffer zones and play a vital role in controlling sediment flux to the foreland basin. Rivers flowing in Duns connect sediments stored in these valleys with the foreland. Processes like erosion, sediment transportation, deposition and remobilisation operating along the rivers in different time scales control the channel geometry. A study of channel geometry can help in understanding various processes acting along the channels. Channel width—an important parameter of channel geometry—can be easily measured from satellite images. In this study, we have documented channel width variation along 20 rivers flowing in Dehra Dun, an intermontane valley in the NW Himalaya, using Google Earth images. The rivers flowing in the Dun originate from the Lesser Himalaya (the Mussoorie Range; average elevation-2200m) in north and the Siwalik hills (the Mohand Range; average elevation-800m) in south; they form 2 major drainage networks—the Song and the Asan rivers—that feed the Ganga and the Yamuna rivers respectively. In general, the channel width varies between 5 to 30m in the mountains and 50 to 400m in the Dun. These channels show widening after crossing the Main Boundary Thrust (MBT), the Santaugarh Thrust (ST), and the Bhauwala Thrust (BT). We observe that the development of braid bars and increment of fines along the banks influence channel width variation. A correlation of the channel width with channel gradient, SL index, mean boundary shear stress, structures, tributary confluences and field data indicate that the factors controlling channel width are unique to different reaches of the rivers. Our study reveals that structures and lithology, sediment concentration and channel bed armoring, and bank stability and anthropogenic activities are the major factors that influence channel width in the upstream, middle, and downstream reaches respectively.

**Keywords:** Sub-Himalaya; Intermontane Valley; Dehra Dun; Channel Width

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 631

## DIFFERENCES BETWEEN WANDERING AND BRAIDING RIVERS

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Wandering rivers occur in many places of China, with the upper reach of the Lower Yellow River as a typical case. However, controversy remains about classification of this type of rivers. While they have been widely regarded as a special type of rivers in China, they are categorized as braiding rivers largely in international geomorphological community. In this study, we take the wandering reach of the Lower Yellow River as a typical example and present a detailed evaluation of the self-adjusting characteristics of channel morphology, focusing on the factors impacting the channel morphological changes. In a consequence, a comparison is made between braiding and wandering rivers, including their definitions, morphological features, sediment characteristics, forming processes and energy expenditure mechanisms. It is shown clearly that wandering rivers develop mainly in environments where the energy slope of rivers is much lower than that required for transporting sediment load without causing erosion or aggradation in river channels. In contrast, braiding rivers form in environments where the energy-slope of rivers can be high or low, characterized with stable or unstable river channel morphologies.

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 633

## MODELLING FLUVIAL GEOMORPHIC RESPONSES TO HUMAN PERTURBATIONS

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A method to investigate geomorphic changes in rivers are landscape evolution models (LEMs) that simulate the movement of water and sediment. Although much progress has been made in the development of LEMs, few have been tested in rivers subject to human perturbations and extreme forcings. As such, it remains uncertain if LEMs are useful and stable in extreme situations that include large movements of sediment and water. To shed light on this topic we use a LEM (CAESAR-Lisflood), historic maps and documents to develop a detailed reach scale model (10 m spatial resolution) of the Kander River (Switzerland) starting in the year 1714. We use this model to simulate the extreme geomorphic events that followed engineering works that deviated the Kander River into a lake and resulted in a large decrease in base level. Our model simulates decades of channel change as impacts of the river deviation cascaded upstream. We test our model by replicating observed long term effects to the river that include 1) rates of incision within the deviation, 2) knickpoint migration, and 3) delta formation in the lake. In doing this we build confidence in the LEM and gain understanding of how the river system responded to anthropogenic perturbations.

**Keywords:** landscape evolution model; knickpoint migration; channel change; fluvial geomorphology

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 638

## THE LOWER LOIRE RIVER FLOODPLAIN FORMATION: A MULTI-SCALED APPROACH TO CHARACTERIZE LANDFORMS, PROCESSES AND DRIVERS EVOLUTION ON THE LONG-TERM

## (LAST 10 MILLENNIUMS) (VAL D'AUTHION, FRANCE).

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In the current context of global change, the knowledge of floodplain formation in response to past climate and societal changes is a solution for a better perception of the current and future dynamics. This research deals with floodplains formation, particularly with fluvial landforms, processes and drivers evolution on the long-term, during the Holocene. The case study is the Lower Loire River floodplain, a major hydrosystem of mid latitudes Western Europe, where current flood risks issues are significant and where the river embankment began during the Middle Ages [Research program: AGES (Ancient Geomorphological Evolutions)]. Fluvial landforms and sedimentary records studied are archived in this wide floodplain (section width 10Km, length 70Km). Hydrosedimentary flows come from a watershed (> 100 000Km<sup>2</sup>) extending partly on Hercynian massifs (Massif Central and Massif Armoricaïn) and a meso-cenozoic sedimentary basin (Bassin de Paris). Past fluvial dynamics, processes and temporalities of floodplain formation were reconstructed through an integrated approach [geomatics (LiDAR DEM), morpho-stratigraphy (core-drillings), sedimentology, geophysics (resistivity methods), geochronology and archaeology]. Within the Lower Loire River floodplain, Holocene fluvial landforms and alluvial deposits are nested in Weichselian formations and vertically stacked. During the last 10 millenniums, many Weichselian inheritances and the relatively low specific stream power of the river explain the low lateral mobility of the active channel. The Loire River built a significant natural levee and induced a vertical aggradation of the distal plain. Fluvial dynamics and sedimentary environments of the Lower Loire River evolved according to multi-millennium and multi-centennial scales. Responses of the river to external factors (climate, anthropogenic impacts, eustatism) and autocyclic evolution are discussed. Several episodes of the floodplain formation are characterized and are correlated with Holocene drivers evolution. Current fluvial dynamics inherit this floodplain formation on the long-term.

**Keywords:** Floodplain formation, Multi-scaled integrated approach, Lower Loire River

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 678

## SPATIO-TEMPORAL ASSESSMENT OF FLUVIAL CHANGES AND THEIR IMPACTS: A CASE STUDY OF SANGAM, ALLAHABAD CITY, INDIA

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Sangam (Triveni), confluence of rivers Ganga, Yamuna and invisible Saraswati, is spiritually and geomorphologically significant location at Allahabad. Maha Kumbh (every 12th year), Ardh Kumbh (every 6th year), Magh Mela (each year) and every day rituals are the most important events that recognize and distinguishes the Sangam worldwide. These socio-cultural events attract thousands of millions of spiritually and religiously motivated people at the bank of river Ganga besides lacs of permanent residents of Allahabad in the vicinity of Ganga and Yamuna. On the other hand Sangam, which is part of middle-Ganga-Plain, is also geomorphologically very dynamic in the context of spatio-temporal fluvial changes taking place in the environs of this riverine ecosystem. While the Yamuna is deep, tranquil, and greenish in colour; the Ganga is shallow, vigorous, muddy and pale in colour. While the Ganga is only 4 feet deep, the Yamuna is about 40 feet deep near the point of their confluence. During the monsoon, when rivers are vigorous and the confluence is seen clearly due to the force of water; having a holy dip (snan) at the confluence is very difficult. Whereas during lean seasons, water is so scarce and polluted that it makes a holy dip again difficult at Sangam. Moreover, the fluvial changes in the vicinity of Sangam have endangered the socio-cultural and economic activities. Present paper endeavor to assess the fluvial changes in order to facilitate and optimize the socio-cultural and economic activities that are indispensably taking place in the environs of Sangam. The study identified shifting courses, inadequate river flow and insufficient water level, increased sedimentation, enormous formation of amplified lateral and mid-channel bars and increased bank erosion as the most important fluvial aspects that need immediate attention in the vicinity of Sangam.

**Keywords:** Sangam; Socio-cultural, Shifting courses; Channel bars; Spatio-temporal fluvial changes.

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 682

## GEOMORPHOMETRY AND STAGES OF LANDFORM DEVELOPMENT IN A CENTRAL HIMALAYAN DRAINAGE BASIN

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The drainage network and basin morphology are the measures of fluvial process operation in the basin. In geomorphology it is applied to numerical examination of landform, which may be more properly termed geomorphometry. The present attempt endeavors to find out the stages in the geomorphic development of the study area, with the help of different morphometric attributes taking the micro-watersheds from the middle valley of a Kumaun Lesser Himalayan river i.e. Western Ramganga as a study unit.

The various types of morphometric data has been utilized mainly to understand geomorphic processes and the evolution of landforms as conditioned by these factors in the characteristic geographic background of the study area. The geomorphic changes have been revealed by using analyses of satellite imagery, Survey of India toposheet, and extensive field surveys in the micro-watersheds of the study area. The knowledge based semi-automated method has been found very effective to define geomorphological units and mapping of major geomorphic features in the form of landforms and their analysis in conjunction with structures.

Based on the concept of chronological approach the relief morphometry of the study area reveals that the landforms undergo progressive changes starting from initial forms to ultimate forms, with the result the hilltops and interfluvies are gradually lowered, weathering, rain-wash and creep leading to decline in the steepness of slope angles therefore, it may be correlated with stages of landforms development. Low bifurcation ratio with very high stream frequency is suggestive of early mature to youthful stage of drainage network vis-à-vis topography of the area. Analysis of various other morphometric attributes also reveals that the micro-basins are undergoing a stage of transition from late youth to early maturity.

**Keywords:** Central Himalaya; Geomorphometry; Landform Development

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 713

## IMPACT OF CHANNEL MORPHOLOGY ON JHELM RIVER FLOODING IN KASHMIR VALLEY, NW HIMALAYAS, INDIA

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Geomorphological analysis of river channel provides important information in the identification of critical river reaches that impact the river behaviour during flooding. In the present study geomorphic aspects of river Jhelum are used to illustrate its response to 2014 Kashmir flooding. The Srinagar reach (42 km) of Jhelum is characterized by complex meandering and variable width ranging from 61 m to 116 m with river depth ranging locally from 2.5 ft to 19.5 ft in the city stretch. In response to the high-magnitude hydrological event a large number of landslides and river breaches occurred along the Jhelum due to bank erosion. We used various parameters and indices including river profiling, bathymetric profiling, lateral entrenchment ratio, stream power, sinuosity index, supported by GPS and laser based detailed field measurements to establish a relationship between the river morphology and flooding. Results suggest that the sudden deflection of river course, formations of braid bars and convexities in the river channel, varying bathymetry and channel sinuosity are controlled by a set of neo-tectonic faults/lineaments, some of which cross the river Jhelum in the Srinagar reach. A dramatic decrease in channel gradient in the Srinagar reach favours the deposition of sediment load contributed by adjacent high gradient tributaries which mostly drain through the unconsolidated Karewa sediments. Based on this study, it is suggested that river meandering, sudden shift in river course, river perturbations, high gradient of tributary rivers, siltation and flat topography of the Srinagar reach of the Jhelum along with extreme rainfall are the causative factors for extreme flooding in Srinagar city during 2014.

**Keywords:** River morphology; River breach; River flooding; Flood mapping; Srinagar city

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 715

## GEOMORPHIC ASSESSMENT AND SPATIAL DISTRIBUTION OF SEDIMENT AND MINING METAL STORAGE IN CHANNEL AND FLOODPLAIN DEPOSITS IN BIG RIVER, OLD LEAD BELT, SOUTHEAST MISSOURI (USA)

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The Old Lead Belt in southeast Missouri was a global leader in lead ore production for more than a century (1869-1972) and discharged large quantities mine wastes contaminated with lead (Pb) and zinc (Zn) into Big River (2,500 km<sup>2</sup>). While mining sites have been remediated, remobilization of contaminated sediment from alluvial storages continues to be a major source of contamination along 171 km of the river below mining areas. This study assessed the magnitude and spatial distribution of mining-contaminated sediment stored in channel and floodplain deposits of Big River within the Ozark Highlands in the Midwest, USA. The most heavily contaminated floodplain cores extended 40-50 km downstream of mine sources, typically ranged in depth from 1.5-3.5 m, and averaged >2000 mg kg<sup>-1</sup> Pb and >1000 mg kg<sup>-1</sup> Zn. Channel sediments were most heavily contaminated within 20-30 km of the mines where average site concentrations were >1400 mg kg<sup>-1</sup> Pb and >1000 mg kg<sup>-1</sup> Zn. A total of 157 million Mg of contaminated sediment is stored along the Big River, with 92% within floodplain deposits. These contaminated sediments store a total of 188,500 Mg Pb and 34,300 Mg Zn. Interestingly, fine gravel-sized tailings account for 13-20% of the total mass storage of contaminated channel sediment, contain concentrations of >4000 mg kg<sup>-1</sup> Pb and >1000 mg kg<sup>-1</sup> Zn, and contribute to 60% of the Pb stored in channel deposits within 25 km of the mines. The magnitude and basin wide distribution of Pb and Zn storage in legacy floodplain deposits ensures that remobilization by bank erosion will be a continuing problem for water quality far into the future. Furthermore, the abrasion and weathering of coarse tailings particles in the channel may represent an important source of metal contamination in the future.

**Keywords:** Legacy sediment; floodplains; mining contamination; fluvial storage; Ozark Highlands

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 745

## RIVERS UNDER TEMPERATE VALLEY GLACIERS

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Both geophysical measurements (ground penetrating radar) and hydrological inference has shown that subglacial drainage networks under temperate valley glaciers are dendritic and comprise subglacial channels, or conduits. They are typically form each summer due to the combined effect of hydraulic pressure driven ice melt (which opens them) and ice overburden pressure (which closes them). They may close partially or fully in winter when there is no ice melt. This model has now dominated modern glaciology for over 50 years. However, geomorphological reasoning questions this domination. Temperate valley glaciers, when they retreat, commonly reveal beds comprised partially or fully of soft sediments. Glacier bore hole imagery as well as caving has confirmed that the channels have potentially erodible beds. As such they might better be viewed as rivers under ice rather than channels eroded into ice, and that the dominant mode of subglacial hydrological network formation may need to be revisited. Here, we do this with data from the Upper Arolla Glacier in Switzerland. First, river discharge measurements confirm that there is the development of a progressively more efficient subglacial drainage system from spring through summer, supporting the development of more channelized flow. Second, ground penetrating radar measurements in late melt season suggest that these channels are eroded into the glacier bed more than they are eroded into the ice above them. Third, continuous bedload and suspended load measurements in the glacier outlet stream suggest that sediment transport is discontinuous, implying overnight deposition (when melt ends and discharge falls) and daytime erosion (when melt starts and discharge rises). Taken together, the field data suggest that it is quite possible that the development of subglacial drainage channels during summer months is due to the headward expansion of an under-glacier network of rivers rather than due to the pressure-melt related erosion of ice.

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 757

## MEANDER GEOMETRY IN THE INTERFLUVES AREA BETWEEN BURHI DIHING AND NOA DIHING RIVER, ASSAM, INDIA

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Rivers are the most intriguing domain of study in Geomorphology, due to its infinite permutation and combinations of various parameters viz. width, depth, slope, flow velocity and plan shape, sediment load, sediment types, valley slope, flow resistance, bed load, bank competence, meander equations and many more. Meander geometry is an important element in the study of fluvial geomorphology as well as their applications for bank erosion, channel migration besides its stability; i.e. use of old floodplain areas for other purposes like agriculture, settlement etc. The area taken for study of meander geometrical properties is between two tributaries Burhi Dihing and Noa Dihing of mighty Brahmapura River. Thirty nine meander sections have been analysed for meander radius, amplitude, wavelength, entry point, pool, riffle sequence and valley length. It is found that there is a strong positive relationship, significant at 0.01 level, among all these parameters. This clearly indicates the meander geometry are uniformly controlled by the fluvial regime (HSI: 82.35 percent) of the area as the area is almost flat without topographic control (TSI: 17.65 percent). As the rivers have a large catchment area, the river discharge fluctuates highly along with the rainfall in the region. This has resulted in this area being one of the most volatile and unstable meander system in the world. The whole area is having wide spread presence of oxbow lakes, abandoned channels. This instability poses as a challenge for people of the area and planners as well for a long term plan and development.

**Keywords:** Meander Geometry; meander stability; Bharhmaputra River; topographic and hydrological control.

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 771

## ASSESSMENT OF CONTROL FACTORS AND SENSITIVITY OF A RIVER CHANNEL TO CHANGES BASED ON A COMBINATION OF HISTORICAL AND FIELD DATA, DORDOGNE RIVER (SW FRANCE).

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Retrospective analysis is an important issue in geomorphology to explore causal factors controlling channel changes. One of the scientific challenges is to separate and potentially hierarch the role of each factors for assessing respective responsibilities of the different actors concerned, understanding the present channel capacity to adjust and proposing adapted solutions using a quantitative approach. Using innovative techniques and data, we explore this question on the middle Dordogne River (southwest of France). During the twentieth century, the Dordogne River has recorded in its middle reach (160 km long), several morphological changes, due to different human pressures. To evaluate and quantify the unit and cumulative effects of these pressures, historical data and in situ measurements had been collected and analysed. Historical data (old maps, aerial photographs, longitudinal bed profiles, cross-sections, LiDAR, flow series) show a decrease of potentially critical discharges, a general trend towards incision of the riverbed and a significant active channel narrowing after the construction of reservoir dams in the upstream part of the basin and along major tributaries (1950). Incision and narrowing were amplified by in-channel gravel mining (1960-70) and riverbank protections (1980). Field data provide additional information for interpreting river and floodplain morphological adjustment. They were collected all along the middle reach : (1) at the bar head for grain size analysis, (2) in the side channels and floodplains to assess fine sedimentation dynamics, (3) in the channel itself to quantify bedload transport (critical shear stress, transport distances, active layer thickness and bedload volume) using RFID. Historical data and field data are also combined to establish a sediment budget and better understand the capacity of the river to adjust.

**Keywords:** anthropogenic effects; bedload transport; channel adjustments; cumulative impact; floodplain connectivity; middle Dordogne.





THEME: S14 : LARGE RIVERS

ABSTRACT NUMBER: 78

## DRYLAND FLUVIAL SEDIMENTOLOGY FROM THE MODERN LUNI RIVER, THAR DESERT, WESTERN INDIA

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The Luni River is the largest river in the Thar desert, and one of the important dryland fluvial systems worldwide. Although several studies exist on the Quaternary deposits of the Luni River basin, details of the sedimentological characteristics of the modern channel are sparse. Monsoon-related peak discharges in the Luni River can reach nearly 14,000 m<sup>3</sup>s<sup>-1</sup>, carrying high sediment loads, scouring the bed and leaving substantial deposits, yet the bed is dry most years. A 700 m long and 5 m deep section across the channel was opened. This paper presents the results of the detailed sedimentary architecture of the Luni river that bring new insights into sedimentary processes in dryland rivers.

GPS positioning and mm-resolution survey levels of marker strata record cross-section stratigraphy using field logs and photomosaics. Nine OSL results indicate that the whole section is 'young' < 5000 years and usually 100's of years old. These dates reflect considerable deep scour and reworking to depth and rapid alluviation during recent times which is somewhat surprising given the rarity of large floods.

Fine sand is abundant at all depths and quite independent of sedimentary structure types (possibly due to available material reworked from aeolian deposits). Planar USPB lamination is more abundant than dune stratification. No clear fining-upward trend in dune set thickness is observed, as large dune sets (> 50cm thick) are not frequent but were observed in the deepest trench. Sand-to gravel-size, sub-rounded mud clasts are strikingly abundant; these are often found at the base of planar laminated layers, at some places near their source layer but also within stratification of plane beds or dune sets at any elevation. Gravel-sized clasts other than mud-clasts are rare. Only one 1-cm thick continuous clay-mud layer was found topping a typical decreasing-flow deposit.



THEME: S14 : LARGE RIVERS

ABSTRACT NUMBER: 97

## SUSTAINABLE MANAGEMENT OF LARGE RIVERS USING A GEOMORPHIC TEMPLATE: A CASE STUDY OF THE GANGA RIVER, INDIA

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A geomorphic framework defines the mutual linkages between the river forms and the processes within a specific zone in the river. It can therefore provide attributes at different scales that can create a platform to distinguish different geomorphic classes of rivers. In large river systems, the characterization of geomorphic diversity and assessment of geomorphic processes in each geomorphic class should therefore be the pre-requisite for the sustainable rehabilitation of river systems and for assessment of river health. The Ganga River system in India is a large, complex system with two distinct hinterlands – the Himalaya to the north and the cratons to the south. During its >2500 km long journey, the Ganga traverses through a diverse climatic regime across the alluvial plains with precipitation ranging from 600 mm/year near Delhi to 1200 mm/year in the eastern plains. Through complex interactions of climate, topography and hinterland characteristics of various tributaries which meet the river at various points, a diverse assemblage of channel forms characterize this river. Using systematic mapping from satellite images and field observations at strategic points, we have recognized a total of 10 different river classes for the trunk river from Gangotri (source) to Farakka (upstream of its confluence with the Brahmaputra) based on a) landscape setting, b) in-channel and active floodplain characteristics, and c) channel planform parameters. We also note that several reaches of the river have been significantly modified due to human impacts. We demonstrate that the geomorphic diversity of such large rivers can be useful for developing a sustainable river management programme in particular for assessment of habitat suitability, environmental flows and flood risk.



THEME: S14 : LARGE RIVERS

ABSTRACT NUMBER: 171

## HOW CAN WE BETTER UNDERSTAND THE WATER TRANSFER PROJECT OF THE CHANGJIANG RIVER? AN ESTUARINE PERSPECTIVE

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The densely-populated mega-city of Shanghai relies increasingly on freshwater from the Changjiang estuary (70% now). However, this strategy is facing potential threats due to extensive water diversion in the basin and future sea-level rise. The present study evaluates the ability of Shanghai to source its water from the estuary, especially in the dry season. Flow  $<15,000 \text{ m}^3 \text{ s}^{-1}$  ca. 50% for dry seasons, represents the threshold for salinity 0.45 psu (chloride 250 mg/L) above which the estuary is unusable for freshwater. Correlating discharge and salinity, maximum salinity and related time duration, and taking the future water diversions and sea-level rise into consideration, we extrapolated salinity events into the future at intervals of 10 years until 2040. We estimate that water diversions of  $56.2 \times 10^9 \text{ m}^3$  ( $1800 \text{ m}^3 \text{ s}^{-1}$ ),  $59.2 \times 10^9 \text{ m}^3$  ( $1900 \text{ m}^3 \text{ s}^{-1}$ ) and  $61.3 \times 10^9 \text{ m}^3$  ( $2000 \text{ m}^3 \text{ s}^{-1}$ ) will occur in 2020, 2030 and 2040, and a rise of sea level of 0.12 m by 2040 (from 2010), equivalent  $506 \text{ m}^3 \text{ s}^{-1}$ , ca. 19.4% of the total reducing discharge of 2040 into the estuary (ca. 28% projected to the worst case of February of 2040). Based on scenario building, the pattern of salinity distribution would remain  $>0.45$  for 20-65, 75-90 and 120-128 days (in 2020, 2030, and 2040, respectively), for extreme low-flow conditions. These periods exceed the present 68-day maximum freshwater storage in Qingcaosha reservoir, which is meant to secure freshwater for Shanghai in the future.

**Keywords:** Water transfer; Changjiang River estuary; Saltwater intrusion; Freshwater sources; Sea level rise

THEME: S14 : LARGE RIVERS

ABSTRACT NUMBER: 242

## IMPACT OF RECENT CHANNEL DYNAMISM ON LAND USES IN THE INTER-FLUVIAL ZONES IN MIDDLE GANGA PLAIN

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The Land use pattern of any area is a reflection not only of the immediate requirements of the community but rather the cumulative needs or the pressure exerted on the space over time. The physical variability like, channel dynamism adds to this dimension. Channel dynamism is one of the most conspicuous forms of geomorphological change. In an inter-fluvial alluvial tract the channel dynamism leads to change in land configuration with potential influences on the spatial variation in land uses.

This fact is applied on three districts of the state of Bihar in the inter-fluvial alluvial tracts of four important rivers, i.e. the district of Saran coinciding to the inter-fluvial area of Ghaghara and Gandak rivers joining Ganga from north, and districts of Buxar and Bhojpur in the inter-fluvial area of Karamnasa and Son rivers joining Ganga from south, wherein the channel migration of the rivers due to physical variability is evident.

The recent channel dynamics is understood through integration of thematic information on spatial configuration of the river channel using inputs from topographical sheets and remotely sensed data. The dynamic character of the river channel is substantiated through limited field evidences. In the month of September to November, flood occurs in the low lying area along the rivers that affect the kharif crops and sometime also the rabi crops. Soil erosion is high due to the steep slope and the shifting characteristics of major rivers in the region. The Ganga channel have made significant shifts, transgressing more leading to definite channel widening at certain stretches. The cumulative impact of various other socio-economic needs of the growing population has also exerted pressure on the limited space and is reflected on the pattern of land uses.

**Keywords:** Recent Channel Dynamism; Land use; Inter-fluvial area; Physical variability; Middle Ganga plain

THEME: S14 : LARGE RIVERS

ABSTRACT NUMBER: 248

## DIFFERENT DYNAMIC PROCESS OF FLUID MUD DURING NEAP AND SPRING TIDE OF THE DRY SEASON IN THE CHANGJIANG ESTUARY TURBIDITY ZONE

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Fluid mud in estuarine turbidity maximum zones (TMZ) can pose considerable navigation risks due to potentially substantial reductions in nautical depth. Despite many pro-efforts, but, our insight about the spatial and temporal dynamics of fluid mud is still not sufficient. This study, the combined use of a dual frequency echo-sounder, GPS, ADCP, OBS and Lisst has detected the dynamic process of fluid mud at neap and spring tidal stages in the South Passage of the Changjiang estuary. It was found that maximum fluid mud is highly occurred at the slack stage of neap tide, and however, it is highly occurred at the max-ebb stage of spring tide. The formation of fluid mud is largely restricted to channel sediment flocculation process in the neap tide, and but restricted to shoal sediment transport process in the spring tide and storm tide. Furthermore, the velocity of up layer of fluid mud is less than 15cm/s during the normal neap and spring tide, however, it will reach to 27 cm/s during the storm tide.

THEME: S14 : LARGE RIVERS

ABSTRACT NUMBER: 260

## MORPHODYNAMIC STUDY OF THE FLUVIAL ISLANDS IN LARGE ANABRANCHING RIVERS

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Many large rivers adopt an anabranching pattern including large forested (or vegetated) islands. The islands have been relatively neglected by the scientific literature. To better understand the fluvial island dynamics, i) we analyzed the pluri-decadal planform changes on the basis of aerial photographs and satellite images and ii) we conducted field surveys to measure erosion and sedimentation during different hydrologic events. The study is based on three rivers that develop islands in different climatic and hydrologic environments: the Rio Napo (Peru), the Lena River (Siberia) and the Loire River (France).

First, the mobility of islands is demonstrated. Second, different types are identified with regards to age and morphological parameters. Four types are identified: i) young islands occupy less than 10% of the channel width. Under a size threshold they can be eroded. If not they evolve into ii) elongated islands (low width/length ratio) which migrate downstream rapidly. iii) Large round islands are less mobile and migrate laterally and iv) very large islands are more stable and can be merged to the channel bank. The different types can be associated with the dominant sediment load. Field surveys help document the sedimentary construction at a finer spatial scale. Sediment deposits were sampled along cross-sections after different floods and deposition processes were determined. The sedimentation on the young islands mainly occurs on the central part and depends on the density of the pioneer vegetation (with a height lower than 2m). Older and larger islands traps more sediment on the banks. So, the vertical accretion is the dominant process on young and elongated islands, whereas large islands are mainly constructed by lateral accretion. The part played by the different vegetation sequences is also examined. Finally, the study shows the part that represent the islands in the sediment transfer of the fluvial system.

THEME: S14 : LARGE RIVERS

ABSTRACT NUMBER: 276

## RIVER'S QUICK RESPONSE TO SEA LEVEL CHANGES FROM ONE THOUSAND KILOMETERS AWAY

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Large magnitude of sea level changes occurred periodically during the Quaternary. For example, the sea level of the East China Sea was probably below -120 m during the Last Glacial Maximum (LGM). As the ultimate base level, tremendous changes of the sea level would undoubtedly exert impact on river systems. However, the rate and amplitude of river's response are still under debate. In this study, we employed the optically stimulated luminescence (OSL) dating method to investigate the late Quaternary sediment in the Jiangnan Basin, the first major sedimentary basin in the middle reaches of the Yangtze River. A total of 37 OSL ages were obtained from the upper 50-m part of two cores. According to the age-depth relationship, there are three distinct intervals of sedimentation rate: relatively low before the LGM (>20 ka), extremely high in deglaciation (20-8 ka) and relatively low after 8 ka. Considering the sea level changes since the last glaciation, the variations of sedimentation rate in the Jiangnan Basin reflect a quick response of the middle reaches of the Yangtze River, which is about 1000 km away from the river mouth, to the sea level changes of the East China Sea. In the glacial period, low sea level led to strong erosive ability, resulting a deep-cutting landscape from the delta to the Jiangnan Basin. When the sea level began to rise after the LGM, incised valleys were filled within a short period (~10 ka). When the sea level became stable after 8 ka, sedimentation rate from the delta to the Jiangnan Basin returned to a low value again. Though details of this mechanism awaits further study, river's response to sea level changes is likely to be far more widespread and quicker than we thought.

**Keywords:** sea level changes; Yangtze River; Jiangnan Basin; OSL; river evolution

THEME: S14 : LARGE RIVERS

ABSTRACT NUMBER: 330

## HYDRODYNAMIC AND MORPHOLOGICAL UNDERSTANDING OF THE BRAHMAPUTRA RIVER, INDIA: CHALLENGES AND EXPERIENCES

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The Brahmaputra River, one of the largest and dynamic braided-river-system in world carries enormous discharge and sediment load during monsoon-season. The river basin experiences high intensity long duration rainfall generating flood peaks of long duration along with regular monsoon flood waves. These events trigger landslides, soil erosion and other soil erodible sources producing, large sediment waves passing through river. The water and sediment-waves cause large scale floods and bank erosion, and in response the river changes its braided planform for making efficient energy dissipation system. The understanding on braided-morphology of river has become one of the challenging task for researchers because of limited in-situ hydrologic, hydraulic and morphological dataset. The limited data collection is due to its large-width (1.2km-18km), highly-variable-discharge (3,000-40,000cumecs) and multiple-channels during low-flow season. A number of field-surveys conducted with ADCP, echo-sounder, suspended-sediment-analyzer showed very interesting flow and sediment characteristics in critical zones. The satellite-imagery analysis revealed significant morphological changes in planform and also unique lateral sediment transport in river. The river increased its braided-belt width from 5km-18km in long-term response to 1950 earthquake. The river-training-works like porcupines, land-spurs, bandalling are in practice along the river to protect from erosion and for providing navigability. Mathematical modeling (CCHE2D and CCHE3D) framework helped us to understand and predict complex fluvial response of the river to these river training works. The effectiveness of hybrid-river-training-works (combination of porcupine-screens and geo-bags) in terms of length of sediment deposition zones and velocity reduction is studied using CCHE3D. CCHE2D is also simulated for different river-training-layouts and effective layout is proposed to stabilize one of the critical-zone of river. A lot more to be learnt from this large fluvial river to develop appropriate river-training-works, short and long-term mitigation for flood and bank-erosion issue, and also to provide stable river navigation.

**Keywords:** The Brahmaputra River, braided-river-system, river-training-works

THEME: S14 : LARGE RIVERS

ABSTRACT NUMBER: 337

## AMAZONIAN WHITE WATER RIVERS SPATIAL PATTERNS OF SUSPENDED SEDIMENT TRANSPORT

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Suspended sediment yield and transport are important active geomorphological processes of the Amazonian fluvial systems, particularly in the so called white water rivers (WWR). The focus of the research summarized here is on the representation and understanding of the spatial differences of sediment transport of those rivers. This research used a new data series of suspended sediment concentration, estimated by means of Landsat 5/TM satellite images, to extend and to fill the in situ collected data sets. By using that data compilation, were generated temporal series of suspended sediment transport for nine WWR stations. Currently, great rivers (like: Amazon, Solimões and Madeira) have high frequency suspended sediment transport series of approximately 30 years. Analysis was performed about the following topics: i) regional differences of sediment transport and yield; ii) intrannual and interannual variability of sediment yield. The obtained results allowed the following conclusions in relation to the spatial patterns and determinants relationships: i) toward downstream, larger the drainage basin area and larger the sediment transport, which are described by a logarithmic relationship; ii) taking into account the whole basin, the smaller sediment yield values occur in the period from august to October, and the larger values occur in the period from January to March; iii) along a typical year, the greatest sediment yield follows the ITCZ (Intertropical Convergence Zone). As the Amazon basin encompass areas in the two Hemispheres, the southern tributaries (Madeira, Purus and Juruá rivers) have a large sediment contribution in the period between December to April. By the other side, the northern tributaries (Içá and Japurá rivers) have a maximum from June to September.

THEME: S14 : LARGE RIVERS

ABSTRACT NUMBER: 434

## BEDROCK RIVER INCISION AND LOESS DEPOSITION RESPONSE TO BASIN CONNECTION OF THE SANMEN GORGE, THE YELLOW RIVER, NORTH CHINA.

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Basin connection drives the critical transition of fluvial system, and thereby induces rapid incision within the river course and changes the compositions of the associated deposit. However, absence of continuous sediment record in most large fluvial system make it difficult to reconstruct the long-term process of basin connection and its subsequently response. Here we present the longitudinal profile of the Sanmen Gorge, the Yellow River, where extensive fluvial terraces are in well preserved by diverse loess-paleosol sequence with previous dating, which shows the connection of upstream basin via the knick-point retreat within the gorge induced rapid incision along the downstream river course since late mid-Pleistocene. We apply the trace elements and major elements composition for comparisons among the loess deposit in the floodplain area downstream the gorge (the MS loess), the terrace sediment along the gorge and the typical loess in China Loess Plateau (the LC loess), which suggests the excessive deposit compensation on the floodplain due to the great upstream sediment flux after basin connection became an extra supply for the MS loess since late mid-Pleistocene, substantially increased the thickness, the accumulation rate and grain-size comparing with the LC loess. We also present heavy mineral indexes comparison of terrace sediment, which show proximal source before but distal supply after the basin connection. These observations provide rare continued sediment record for the long-term fluvial evolution of large river, suggesting that critical transition of fluvial system positively correlated with upstream basin connection and subsequently great change on drainage area and discharge.

Keyword: fluvial terrace; loess; the Yellow River; rapid incision; late mid-Pleistocene

THEME: S14 : LARGE RIVERS

ABSTRACT NUMBER: 477

## LARGE MONSOONAL RIVERS: A NEW PERSPECTIVE FROM THE SEDIMENTARY SINK

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Strictly monsoonal rivers deliver most of their flow and sediment load during several months of summer and remain near baseflow for the rest of the year. In contrast monsoon-influenced rivers draining the Himalayas and Tibet have their hydrographs less skewed due to substantial contributions from melting ice and snow. Is this fundamental difference in hydrology reflected by the mechanics and morphology of the source to sink system?

Here I examine the effects of monsoon seasonality on basinwide erosion, sediment transport as well as coastal and continental margin deposition for peninsular rivers such as Godavari, Krishna, and Mahanadi rivers vs. Himalayan rivers such as Irrawaddy and the Indus. As a result I propose a new interpretational framework for the Holocene morphodynamics of monsoonal vs. monsoon-influenced deltas and its effects on continental margin architecture. The distinctive evolution experienced by monsoonal fluvial systems progressed since Neolithic in close interaction with humans by either boosting or attenuating natural and/or social trends.

THEME: S14 : LARGE RIVERS

ABSTRACT NUMBER: 482

## COSMOGENIC BURIAL AGES OF THE EARLY PHASE EVOLUTION OF THE JINSHAAN YELLOW RIVER, CHINA

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The Jinshaan Gorge of the Yellow River connects the Hetao and Fenwei Basins with about 700km apart, becoming one of the key areas to understand the fluvial evolution of the large river. Different opinions to the uppermost gravel layers lead to different interpretations about origin and evolution of the river.

Based on detailed field survey, two different types of gravel layers are identified. The first one distributes along the west piedmont of the NS Luliang Mountain with poor roundness and sorting of the pluvial origin. The second one with good roundness and sorting of alluvial origin only distributes along the Jinshaan Gorge west to the pluvial gravel but much wider than the gorge, implying that there had been a broad valley stage before the downcutting by the V shape valley. Three gravel profiles across the broad valley in upper, middle and lower reaches of the gorge were selected for cosmogenic burial and magnetostratigraphic datings. The results show that the gravel layers in middle and lower reaches own the cosmogenic burial ages of 2.56Ma and 2.90Ma, respectively. Together with the magnetostratigraphic ages it can be found that the second type gravel ages are increasing younger downstream along the broad valley. It is very apparent that terraces of this gravel are non-synchronous, correlating knickpoint slowly migration upstream from south to north combing with lateral shifting of the river in the gentle tectonic uplift in the Late Pliocene. Because of vertical incision and lateral erosion, the older terraces were preserved farther and the younger closer to the gorge, leading increasing younger age downstream when sampling along the gorge.

**Keywords:** cosmogenic burial age; terrace; broad valley; Yellow River

## COMBINED CONTRIBUTION OF ACTIVE RFID TECHNOLOGY, TIME LAPSE CAMERA AND DTM FOR THE MONITORING OF THE HAUT-DRAC RIVER RESTORATION (SOUTHERN ALPS, FRANCE)

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The Drac River in the Champsaur valley drains a 544 km<sup>2</sup> catchment. In the recent past, this braided river was largely impacted by intensive gravel mining. In the section near Saint-Bonnet-en-Champsaur, a dramatic channel incision occurs, with important consequences on bank stability. The embankment protecting a leisure centre artificial water body has been threatened by channel incision, and therefore, the local water management authority (CLEDA) decided to restore the river in 2014 in order to stop incision and to recover the braided morphology.

The aim of this study is to design a specific methodology for monitoring the restored site. In fact, most of the sediment supply is actually controlled by the "Chabottes plain". This plain is a large active braided section located 3 km upstream of the restored site. For understanding the recovery of the restored site, it is important to evaluate the sediment connectivity between the upstream braided plain and the restored reach.

One hundred artificial pebbles have been equipped with active RFID tracers and deployed in the downstream part of the Chabottes plain in order to characterize distances of transport of bedload particles. Moreover, 100 active RFID transponders have been inserted in erosion columns in order to evaluate scour-and-fill depths along the intermediate section. This equipment is completed by sequential high-resolution DTMs (from airborne LiDAR data and from SfM photogrammetry) and by time lapse cameras in order to quantify and characterize channel adjustments.

## HYDROMORPHOLOGICAL MONITORING OF A SEDIMENT REPLENISHMENT OPERATION: THE CASE OF THE SAINT-SAUVEUR DAM IN THE BUËCH RIVER (SOUTHERN ALPS, FRANCE)

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The Buëch River is a right bank tributary to the Durance, a braided river that drains a 1478 km<sup>2</sup> catchment. The Saint-Sauveur dam was built in 1992 in the middle section of the catchment. Downstream from the dam, a pluri-metric channel incision is observed. In order to restore channel incision, around 44 000 m<sup>3</sup> of gravels were excavated in the proximal part of the reservoir and reinjected downstream from the dam in September 2016 by EDF (the power plant company in charge of the dam). Only three weeks after the restoration works, a ten-year flood occurred, allowing for the remobilization of the sediment recharge.

The aim of this study is to understand the evolution of sediments reinjected after a Q10 flood in order to measure (i) the efficiency of the restoration works and (ii) gains for aquatic habitats.

The monitoring of the sediment replenishment impact on channel morphology and aquatic habitats is based on a combination of (i) change detection using sequential high-resolution DTMs (from airborne LiDAR data and from SfM photogrammetry), (ii) bedload tracing using active RFID technology, and (iii) complementary field surveys of channel grain-size distribution and morphology for bedload transport computation.

Preliminary results of the monitoring show that the morphology of the restored site has rapidly changed and that reinjected coarse sediments have dispersed along a 3-km reach. These results allowed us to (i) characterize the morphological change, (ii) quantify the sedimentary balance of the flood, and (iii) analyze dam management impact's during the flood on the sedimentary balance.

Perspectives of this study consist in continuing the monitoring of the restoration works to understand the evolution of the sedimentary deposits associated to the reinjected materials. This operation will be replaced in a larger spatiotemporal scale to propose to the dam manager a sustainable management.

THEME: S15 : INTEGRATED RIVER MANAGEMENT

ABSTRACT NUMBER: 65

## INTEGRATING ECOLOGICAL RESPONSE TO FINE BED SEDIMENT INTO ENVIRONMENTAL FLOW ASSESSMENTS

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Fluvial geomorphology has become an important consideration in the assessment of environmental flows in South Africa, from providing an overview of river processes at the catchment scale to predicting the affect of changed flows on bed sediment and habitat quality for aquatic organisms. How sediment deposition on the channel bed responds to variable flow and the significance of this for stream biota has been an unresolved question that frustrates the development of effective flow assessment methods. Two studies in contrasting South Africa rivers have contributed to our better understanding of this problem, the one in a small groundwater-fed stream in the semi-arid karoo, the other in the larger, perennial Tsitsa river in the more humid Drakensberg foothills. Both studies monitored bed condition and benthic macroinvertebrates through one year. Quadrat surveys were undertaken to monitor both the bed condition and the invertebrate assemblage at intervals through the year. Conditions were related to flow levels that were monitored continuously through study period. Both rivers experienced small floods but neither experienced large floods during the monitoring period. The results point to complex relationships between the variables measured; there is a lack of a linear relationship between sediment deposition and antecedent flows but in both rivers there was a tendency for sediment to accumulate during periods of lower flows. Macroinvertebrate assemblages were related to the extent of sedimentation, with more sensitive species being absent from embedded sites. In conclusion it can be stated that in both rivers macroinvertebrates respond to fine sediment deposition and fine bed sediment has clear ecological significance. However, further research is needed to better understand the relationship between sediment deposition and flow rates before we can be confident in recommending geomorphologically effective flows for maintaining habitat quality.

**Keywords:** bed sediment, macroinvertebrates, habitat, environmental flows

THEME: S15 : INTEGRATED RIVER MANAGEMENT

ABSTRACT NUMBER: 145

## INTEGRATING GEOMORPHOLOGY AND ECOLOGY FOR RESILIENT RIVER ENGINEERING

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Flood protection schemes typically involve channel straightening and a reduction in geomorphic complexity. Engineered rivers are also usually fixed in place to reduce channel migration. These engineered rivers are expensive to maintain. Disconnection with adjacent floodplains limits replenishment of bedload calibre sediment leading to bed degradation, which undermines costly hard-rock bank protection. These rivers are highly vulnerable to catastrophic failure when floods occur that exceed their design limits. Furthermore, in a narrowed, deepened, simplified form, these rivers lack the diversity of habitat to sustain healthy river ecosystems.

This paper reports on an approach that integrates geomorphology and ecology to encourage river engineering that is more resilient to catastrophic failure, and provides a diversity of habitat for aquatic life. We achieve this objective at a number of levels. Firstly, by using archive material to assess pre-engineered channels, we identify natural equilibrium river forms. This state of the river is then compared with the current river condition, and a river habitat quality index (HQI) quantified to identify the scale of change from pre- to post-engineered channel assemblage. The HQI can then be used to recommend changes for future river engineering to improve resilience and habitat quality. Secondly, a similar pre-and post-engineering assessment can then be executed to establish the nature and extent of changes effected by engineering intervention.

We illustrate the integration of geomorphology and ecology to derive a habitat quality index at different temporal and spatial scales using case studies from New Zealand, including the Hutt, Otaki, Waikanae and Motueka Rivers.

**Keywords:** Flood protection schemes; habitat quality index; river resilience



**RAINWATER MANAGEMENT FOR CAPACITY BUILDING FOR THE ENVIRONMENTALLY VULNERABLE LOCAL COMMUNITIES OF POLDER-LIKE SUNDARBAN ISLANDS IN INDIA-  
SELECTED CASE STUDIES**

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The Indian Sundarban Delta (ISD) region is an intriguingly complex geo-hydrological setup. The islands lying in the south-eastern tidal part of West Bengal and supporting about 4.5 million population faces acute fresh water scarcity. Although the total rainfall in the region is about 1700 mm, mostly concentrated during June to September, the average ground water recharge in this period is only around 233 mm. The sweet groundwater in these islands occurs in a zone of pervious granular sediments at 250m depth and it lies under a thick sticky clay blanket of 100-200 m. The soils being formed entirely of fine silt impede rapid infiltration. Therefore, a large amount of rainwater is either converted into runoff or gets evaporated. With salinization and effluent contamination in the rivulets, this water is unavailable for agricultural purposes which in turn restricts food production, thereby impacts the economy adversely. Thus, in the contemporary climate change scenario, fresh-water harnessing techniques are essentially useful. This paper aims at quantifying the demand and availability of fresh water for water budgeting in two selected islands of the ISD region. The average monthly rainfall, mean potential evapotranspiration, potential infiltration, storage capacities of the enclosed water bodies, and average seasonal runoff have been calculated to analyse the fresh water management. Irrigation, aquaculture, and domestic needs of fresh water of the local communities are estimated through target group questionnaire surveys. These water bodies are capable of supplying drinking water in the normal monsoons, but due to poor maintenance, siltation, eutrophication, etc. the quality of potable water remains a major concern. To overcome the problem 'moisture storage pits' technology can be an effective alternative. The seasonal demand supply gap and competence of storage technologies are assessed to management fresh water resource in these environmentally vulnerable islands.

**Keywords:** Sundarban, Rain-water harvesting, Water budget

**ANTHROPOGENIC TRANSFORMATIONS OF LOW ENERGY RIVERS IN NORMANDY;  
GEOMORPHOLOGICAL LEGACY OF AN HISTORICAL MANAGEMENT OF THE SEULLES RIVER.**

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In Lower Normandy, knowledge of the hydrosedimentary dynamics of river before and during the installation of the numerous hydraulic installations since the Middle Ages is very fragmentary. Little is known about the rates of erosion and sedimentation that have occurred in Lower Normandy rivers over the last two millennia and what anthropogenic and climatic forces have influenced these processes. The challenge today is to understand and measure the share of inheritances in the current functioning of Lower Normandy rivers in order to help with their contemporary management. To provide answers, geomorphological and geoarchaeological research has been carried out in the middle valley of the Seulles. The study centered on the valley of the Seulles makes it possible to highlight the weight of the hydraulic installations and in particular the developments related to the mills in the setting up of this alluvial plain. Indeed, the complete structuring of the watercourse since the central Middle Ages completely artificialized the course of the channel, the slope of the water line and partitioned the minor bed favoring lateral stability and overflow sedimentation in the plain Alluvial. The installation of the mills is accompanied locally by a simplification of the layout of the Seulles as on the site of Heuzé where a large part of the current course is artificial. This structure and the acceleration of silt sedimentation for 600 years are at the origin of the establishment of a dynamic equilibrium and the hydrosedimentary forms of the present Seulles which are largely inherited. The abandonment of the management of the hydraulic structures and their destruction during the last fifty years comes to question this balance.

**Keywords :** Fluvial system; sedimentation; floodplain; watermill; Normandy

ABSTRACT NUMBER: 778

## ASSESSING THE IMPACT OF LANDUSE/LANDCOVER CHANGE ON STREAMFLOW AND SEDIMENT YIELD USING A DISTRIBUTED HYDROLOGIC MODEL

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A fully distributed physically based hydrologic model, SHETRAN was used in this to assess the hydrologic response as well as the effect on sediment yield due to landuse/landcover change within the Netravathi basin located in Southern part of India. A model grid of 1 X 1 Km was chosen to represent spatial variations in soil, and land use within the basin.

Landsat imageries corresponding to the years 1979, 1991 and 2012 were utilized to derive the proportional changes in five classes of land use within the watershed. These imageries displayed that the forest area decreased (21%) and the agricultural land as well as urban land increased by 30% and 25% respectively between 1979 and 2012. Daily streamflow and sediment load is calibrated for the period from 1988-1993 and validated for the period 1994-1997. Various Statistical indices revealed the capability of the SHETRAN model to predict streamflow and sediment load. Further, the calibrated SHETRAN model was fed with landuse datasets depicting the changes within the watershed to quantify its impact on hydrology and sediment yield. Four scenarios were developed to show the effect of landuse and climate change separately.

The results indicate that the streamflow increased by 38.4 mmyr<sup>-1</sup> due to landuse change whereas the actual evapotranspiration (AET) showed a decrease by 38.2mmyr<sup>-1</sup>. This can be attributed to the decrease in % of forest and wasteland area. The streamflow is found to decrease by 275.8 mmyr<sup>-1</sup> due to climate change effect whereas AET shows an increase by 24.2 mmyr<sup>-1</sup>. The combined effect of both landuse and climate change showed both streamflow and AET to decrease. Overall, the effect of climate change is more pronounced than landuse change. Sediment yield also showed a significant increase owing to the deforestation and urbanization within the region.

**Keywords:** SHETRAN; landuse/landcover change; Streamflow; sediment yield

ABSTRACT NUMBER: 779

## COMPARISON OF CONCEPTUAL RAINFALL-RUNOFF MODELS FOR WATER RESOURCES ASSESSMENT IN A RIVER BASIN

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Rainfall-runoff (RR) models are the simplified conceptual representation of rainfall-runoff processes in the real system and they are important tools for catchment-based water resource assessment. Among the different RR models, conceptual models are gaining much attention due to its simple structure and satisfactory performance. 'Source' is an integrated water resource management tool developed by eWater Limited, Australia for catchment and river modelling. Source catchment mode includes a conceptual RR modelling framework for estimating catchment water yield and runoff characteristics. The framework provides an option to choose from ten conceptual RR models.

In the present study, we are comparing the performance of two models, 'GR4J' and 'Sacramento', in Mula catchment of upper Godavari Region, Maharashtra. When compared to four parameter GR4J model, Sacramento is a complex model having sixteen parameters to optimize. Gap-filled rainfall data and pan evaporation data from same or adjacent catchments are the two major inputs for these models. These models are calibrated from 2000 to 2009 and validated for next four years. A combined Shuffle Complex Evolution (SCE) and Rosenbrock optimization is used to calibrate each model at daily and monthly scale. Nash-Sutcliffe Efficiency (NSE) of streamflow with bias penalty is used as the objective function for calibration. Performance of each models are evaluated using the statistical measures such as NSE and correlation coefficient (R2) of streamflow. From the results obtained, GR4J is recommended for Mula catchment due to its superior performance and simple structure compared to Sacramento. Also, an inter comparison of models will be presented in the paper with various advantages and limitations of the models.

**Keywords:** Rainfall-runoff, Conceptual models, GR4J, Sacramento, Water Resource Assessment



THEME: S15 : INTEGRATED RIVER MANAGEMENT

ABSTRACT NUMBER: 780

## ASSESSING LAND USE/LAND COVER CHANGE ON STREAMFLOW AND SEDIMENT YIELD IN A WESTERN GHAT RIVER BASIN IN INDIA

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The land use/land cover (LULC) changes have considerable impacts on the annual water balance of a local basin and sub-basins influencing various parameters such as streamflow, sediment yield, evapotranspiration (ET) etc. In this study, we used a Soil and Water Assessment Tool (SWAT) hydrologic model to study the change in LULC impacts on streamflow and sediment yield at sub-basin scale for three time periods (1988, 2000, and 2013) of Kadalundi river basin in Western Ghats of India. The hydrologic model was calibrated for the period from 1990 to 2000 and validated from 2001 to 2010 using observed monthly river streamflow and sediment yield data. The sensitivity analysis, model calibration, and validation indicated that the SWAT model could reasonably simulate streamflow and sediment yield in the river basin. The results show that the spatial extent of the LULC classes of urban (5.02% to 7.56%), agriculture (16.15% to 26.75%), and plantation (12.48% to 17.66%) increased, whereas that of forest (40.14% to 32.63%) and grassland (24.12% to 13.46%) decreased but water bodies shows no significant change from 1988 to 2013. We found that in general, streamflow and sediment yield increasing in all time periods of land use change. Further, the results indicate that the streamflow and sediment yield would be higher in 2000 to 2013 land use in comparison to 1988 to 2000 land use. In addition, streamflow and sediment yield increases higher during late winter and early spring; while the summer period largely demonstrates a reverse trend. This approach could be applied to other river basins for which temporal digital LULC maps are available.

**Keywords:** Land use/land cover; river basin; streamflow; sediment yield; modelling

THEME: S16 : COASTAL GEOMORPHOLOGY AND MANAGEMENT

ABSTRACT NUMBER: 22

## INTEGRATED GEOINFORMATICS APPROACH TO COASTAL HABITAT VULNERABILITY MAPPING ALONG THE SOUTHWEST COAST OF KANYAKUMARI, INDIA

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The Habitat Vulnerability Index (HVI) model is used to define the vulnerability zones detrimental to marine and coastal habitats, human settlements and infrastructures. Analysis of multiple parameters using HVI model demarcates site-specific zones indicating measure of vulnerability to human settlements and ecosystems in varied eco-morphological regimes such as beaches, estuaries, and shallow marshes. The HVI values estimated for the area range from 08 to 52 and the mean vulnerability index value is around 30. Among the coastal area, nearly 09 % of area belongs to very high vulnerability zone category. It is dispensed in the active shelter for numerous species of coastal and marine habitats in estuaries and associated landforms. Moreover, 18 % of the area is falling under high vulnerable type wherein the HVI score is estimated within the range of 36 – 48. Increasing of salinity in the backwater and other surface water bodies usually affects growth and productivity of many species in marine and fluvio-marine ecosystems. Unregulated placer mining leads to harmful impacts on diversity of marine and coastal ecosystem in the near-shore environment. Removal of sands due to mining activities affects nutrient supply to the diverse flora and fauna of coastal ecosystems existing in the marine and coastal habitats. The coastal areas having HVI values of 24 – 36 are identified as moderately vulnerable. Population growth and industrial developments severely affect the productivity and spatial distribution of coastal and marine habitats due to obliterating dunes vegetative cover, shallow marshes and water bodies. It is observed that habitats in the marine and fluvio-marine landscapes undergo alteration in terms of distribution and productivity being sensitive to changes in hydrodynamic forcing by natural and anthropogenic activities.

**Keywords:** Coastal Habitat Vulnerability, HVI model, GIS and Remote sensing, South west coast, Kanyakumari



ABSTRACT NUMBER: 35

## RECONSTRUCTION OF PALEO-TOPOGRAPHY OF THE EASTERN PART OF LOMBOK ISLAND (INDONESIA) BEFORE THE AD 1257 ERUPTION OF SAMALAS VOLCANO

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The eastern part of Lombok Island is a highly dynamic environment with many physical processes as well as very complex landuse. In addition to anthropogenic origin, sedimentation in this area also occurs due to natural origin such as volcanic eruptions. One of the most powerful eruptions of the Holocene took place in Lombok Island in AD 1257, known as the Samalas eruption. The entire island almost covered by volcanic materials due to this eruption. Heretofore there has been no study of the geomorphological evolution of the eastern part of Lombok Island during the past millennium. Therefore, this research focuses on the reconstruction of paleo-topography of the eastern part of Lombok Island before the AD 1257 Samalas eruption. The documentations of more than 1.300 point were obtained from the cliffs and outcrops along the shore and the main rivers, man-made outcrops on the quarries, the wells spread in the research area, as well as geophysical measurement with a resistivity meter. These data were collected to gain a stratigraphic information and thickness data on the eastern part of Lombok Island. A Digital Elevation Model (DEM) which is extracted from TerraSAR-X data is used as present-day topography that will be utilized to deduce the pre-AD 1257 topography of the eastern part of Lombok. In general, the research result shows that the topography of the eastern part of Lombok is changed dramatically since the AD 1257 eruption. For example in Korleko sub-district (3 km from the present-day shoreline), the predicted pre-AD 1257 topography is approximately 20 m deeper than present-day topography. Moreover, the predicted pre-AD 1257 Korleko coast lies below the present-day sea level.

**Keywords:** paleo-topography; geophysics; DEM; Samalas; Lombok

ABSTRACT NUMBER: 66

## REVIEW OF DELTA GEOMORPHOLOGICAL CHANGES CONSIDERING CHANGES IN GEOCHEMISTRY OF SEDIMENTARY FACIES (CASE STUDY: ARVANDRUD DELTA, SOUTHWEST OF IRAN)

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Arvandrud delta is located in southwest of Iran and northwest of Persian Gulf. The Holocene sequence of this area has been investigated in the context of coastal geomorphology and sedimentary environment evolution. Considering literature review, tectonic movements have not influenced on the plain. Moreover recent investigations revealed that the study area has been more affected by eustatic sea level changes and deltaic progradations. The main aim of this study is to reconstruct coastal geomorphology and sedimentary environment evolutions by using Holocene sedimentary succession. For this purpose, 7 undisturbed hand-operated cores (continuous cores by depth of 6–10 m below the surface) along to 3 shallow outcrops were surveyed. Coring sites selected by regarding coverage and considering changes from delta proximal to distal environments. Sedimentary facies are unidentified based on lithology, sedimentary structures, macrofossils and preliminary facies identification. Furthermore, geochemical investigations coupled with granulometry data were helpful to make sure about what happened in sequence alternation during Holocene. 47 samples were selected for laboratory analyses by considering of significant changes in color, texture or lithology were observed at the field. Half of the 47 samples transported to geochemistry laboratory for XRD and ICP-OES analysis, and the rest considered for granulometry analysis. Consequently, five sedimentary environments named ‘mainstream, crevasse plain, flood plain, intertidal and intertidal channels’ recognized. Spatial and vertical distribution of the observed sedimentary environments has been recognized, then it appeared that they have changed by respect to sea level fluctuations during the 5000 year time period. It is also showed that sequences normally changes from terrestrial to marine at the depth of about 3 to 4 m. This claim also proved by preview research in Khuzestan plain which considered the area as a tidal flat from 8000 up to 450 years ago.

**Keywords:** Costal Geomorphology; Deltaic changes; Geochemistry; Arvandrud; Persian Gulf

THEME: S16 : COASTAL GEOMORPHOLOGY AND MANAGEMENT

ABSTRACT NUMBER: 74

## THE DICHOTOMY BETWEEN VULNERABILITY AND PROTECTION MEASURES: A FRAMEWORK FOR DEVELOPING CROSS-CUTTING PERSPECTIVES OF COASTAL DUNE MANAGEMENT

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Vulnerability assessment of coastal sand dunes is necessary to evaluate the conservation status as well as to find out the most relevant disturbance events along the shoreline. In the present study, the usefulness of the DVC (Dune Vulnerability Checklist) has been critically verified along the Odisha coast, Bay of Bengal, with an aim to classify the dune shoreline into vulnerable segments, to analyse the system responses to environmental perturbations and to prescribe suitable management strategies for dune conservation. The methodology of the coastal dune vulnerability index (DVI) comprises three major steps: a) segmentation of the studied shoreline, b) setting parameters for the DVC and c) field surveys and mapping. Shoreline segmentation was performed using the linear referencing tool embedded in a GIS environment. Out of 124 km studied shoreline, a total of 111 numbers of dynamic segments was identified and linked to the DVC. Proposed checklist, comprises 71 variables, grouped into four vulnerability (VI) e.g. dune morphology, marine influence, Seaward surface character, anthropogenic influence and one protection measure (PM) indices. Each index graded between 0 and 1, with the later being most vulnerable. Summation of four VIs provides the total DVI. The DVI/PM ratio allows classification of the segment as an 'out of equilibrium system', either positive or negative, system either requires maintenance or protection and an 'in an equilibrium system' indicating the dune stability. Results indicate that a total of 35 km stretch of shoreline has been classified as stable, maintaining the equilibrium, whereas, 23.195 km of shoreline requires proper maintenance and seasonal investigations to maintain inherent resilience against the degradation factors. A total of 52.67 km long dune segment shows the actual sign of degradation requiring complete protection with the installation of strict legislations at the Government level.

**Keywords:** Coastal dune; Shoreline segment; DVC; DVI; Odisha

THEME: S16 : COASTAL GEOMORPHOLOGY AND MANAGEMENT

ABSTRACT NUMBER: 91

## CONCEPTUAL MODELS FOR NATURAL MECHANISMS OF SEDIMENT BYPASSING AT THE TIDAL INLETS ALONG THE KONKAN COAST OF MAHARASHTRA, INDIA

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Inlet sediment bypassing is the process by which sediment moves from the up drift to the down drift side of the inlet, involving the inlet channel and ebb tidal delta. Sediment movement onshore typically takes place in the form of large landward migrating swash bars which may vary in size. Part of the sediment moving along the down drift beach may be recirculated back towards the inlet or even get transferred further down the bar. In either case sediment movement will be totally determined by the morphology of ebb tidal delta and the wave approach. These general patterns of sand transport result in sediment bypassing at the inlet.

This paper attempts at demonstrating mechanisms by which sand is transferred to the down ward shoreline at the tidal inlet along the Konkan coast. Four conceptual models are presented based on the pioneering work of Brunn and Gerritsen (1959), Brunn (1966) and FitzGerald (1982 & 1988). In all the models only natural, unstructured inlets are considered. The first model proposes the mechanism of spit elongation, ebb channel extension & elongation and natural reclamation of the bay area. The attributing factors being sea level regression and excessive sedimentation based on past processes. The second model tries to stress mechanism behind the spit extension and inlet migration in the near past. The third model is related to the ongoing processes and proposes the mechanism of ebb tidal delta breaching and ebb channel shifts. The last model relates to flood delta formation and bay filling.

**Keywords:** Inlet; sediment bypassing; ebb tidal delta

ABSTRACT NUMBER: 203

## APPLICATION OF DIFFERENT BEACH MANAGEMENT TOOLS FOR THE PROMOTION OF TOURISM DEVELOPMENT AND CONSERVATION OF COASTAL RESOURCES OF SOUTH ANDAMAN

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Andaman and Nicobar Islands are very popular with tourists for its landscape and scenic beauty. Limited scope in industrial activities makes the tourism as most important sector for economic development, revenue collection and employment generation in these Islands. As it has negative socio-cultural and environmental impacts, tourism operations in such fragile coastal environment need to be carefully planned, managed and monitored to ensure long-term sustainability and conservation of resources. In the present study, three beach management tools; Coastal Scenery Assessment (CSA), Tourism Carrying Capacity (TCC) and Functional Analysis (FA), were applied on 14 beaches of South Andaman. CSA were obtained consulting the coastal users and experts in the field with checklist of 26 parameters that can provide the Coastal Scenic Evaluation Index (D) determined by evaluating individual site strength and weaknesses and finally classified the beaches into three classes e.g. Extremely attractive natural site, Attractive natural site and Natural sites. TCC estimated the optimum number of tourists that should be allowed in an area without hampering surrounding ecological, socio-cultural environments over a particular time. Results confirmed that the current magnitude of tourism activities are in lower level with respect to the Island's actual carrying capacity. Implementation of better infrastructure and services will help the beaches to reach their optimum TCC by promoting tourism in the near future. The FA provides the normalized scores for beach conservation and socio-economic components and their subsequent location in the conservation/development matrix, which helps in assessing the comparison between the beaches. Results showed that five beaches will be benefitted from conservation plans, two from development and seven from either conservation or development plans. Database, thus generated will be very useful to research and developments, policy making, resource management and environmental protection of the islands.

**Keywords:** Beach management; Tourism carrying capacity; Scenery assessment; Functional analysis; Andaman

ABSTRACT NUMBER: 208

## PALEOGEOMORPHOLOGY OF THE URMIA LAKE (NORTH WEST OF IRAN) IN QUATERNARY

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The lake terraces are the best evidence to reconstruct the paleogeomorphological conditions in coastal environment and occurrences of these terraces related to climate change and tectonic phases. The Urmia Lake basin covers a wide area of Azarbayejan Provinces mainland in the northwestern of Iran. The Urmia Lake is a hyper-saline lake in northwestern Iran. We don't have comprehensive investigation about paleogeomorphology of this lake especially during quaternary. Lake terraces one of the best indicator to detect paleogeomorphology of this lake especially during quaternary. Hence, we study these terraces in coastal area of the Urmia Lake. Using remote sensing, field study and laboratories research (sedimentology and paleontology), we could found and investigate about 24 lake terraces in different elevation in coastal area of this lake. The Highest lake terrace is located above 100 meter above present the Urmia water level. According to elevation of this lake terraces extend of this lake where identified during quaternary. According to this information extent of the Urmia lake in Quaternary was more than 10000 Km<sup>2</sup> (Current extent of The Urmia Lake is 2500 Km<sup>2</sup>). Most of Current peninsula likes as Golmankhaneh, Zانبildaghi and Eslami was island during water level rise. Erosional evidence this lake level rise where identified as erosional terraces, Sand dune deposit, Using Sedimentological study we can detect cycle of transgression and regression the Urmia Lake During this time. Microscopic research on shell fragment shows, palaeohydrology and paleo ecology of the Urmia Lake was totally different from present condition (Hyper saline water). Some microfossils species in lake terraces sediments shows, chemical condition of water the Urmia Lake change to fresh and brackish environments when lake level raised.

**Keyword:** Paleogeomorphology; The Urmia Lake; Coastal erosion

ABSTRACT NUMBER: 216

THE CONCEPTION OF THE DEVELOPMENT OF THE COASTAL ZONE OF THE SUBARCTIC SEAS IN THE TRANSITION OF AVERAGE DAILY TEMPERATURES TO THE FREEZING VALUES

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Conceptual principles of the development of the coasts of subarctic seas and the seas of the boreal zone in the cold period are considered in the presented work.

There are three dynamic phases of the development of the coast.

The freezing of the beach, the formation of flattened ice and the strengthening of the erosion of the coastal ledge due to the weakening of wave-breaking properties of the beach characterize the first morpholithodynamic phase of the coast development during the cold period. Observations and calculations showed that if for sand - pebble beach with the average statistical parameters, the height of the calculated uprush is 2.21 m, so for an ice slope of the same morphometric parameters this value is 5.67 m.

Reformation of the above-water part of the coastal zone ceases after the formation of stable marginal coastal ice and fast ice. This happens in a few weeks after the beginning of the freezing of the beach deposits. Ice formations of the initial period are usually destroyed. In the next 2-3 weeks, several ice ridges are formed. Moreover, each newly formed ice body is on lower hypsometric position. During the tidal phase, the wave splashing and the beach sediments deposited on the ice increase the morphometric parameters of ice body. With the formation of the ice cover, tidal currents under the fast ice continue to reform the underwater coastal slope. Values of deformations can reach 1.5-2.0 m.

A period of maximum danger of destruction of the coastal ledge, beginning with the freezing of the beach and ending with the formation of ice body was determined. Its duration on different shores is visualized by a map.

**Keywords:** beach, freezing, uprush, bluff erosion.

ABSTRACT NUMBER: 237

RESILIENCE DEVELOPMENT FOLLOWING STORM-INDUCED CHANGE TO A PREVIOUSLY MANAGED UK COASTAL GRAVEL-BARRIER

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Coastal gravel-dominated barriers in the UK, are often anthropogenically forced into non-sustainable coastal flood defence structures (FDS). Barriers that experienced quasi-stabilization through re-profiling and re-nourishment (to act as FDS) operate as non-sustainable and non-functioning geomorphic barriers. To return to natural coastal barriers is a potential major ICZM policy change in 21st Century UK. To move to sustainable barrier management involves knowledge of coastal barrier resilience (R). R is an oft-cited component of geomorphic systems, but how it works and over what time and spatial-scales it is experienced, is open to debate. R is essentially negative feedback loops, which come into play, as a system is stressed at exceptional forcing levels (e.g. extreme events). R is regarded as a system capacity to re-set the system after change into a working state characteristic of the initial system. Barrier R becomes a strategic issue when forcing increases (i.e. sea-level change and/or storm intensity change), while anthropogenic intervention (re-profiling) is halted. Under these forcing changes, barrier R is measured by the rate of re-establishment of a geomorphic-functioning coastal barrier. There is uncertainty about switching to a non-intervention policy, given the limited experience of letting barriers change naturally. Cley barrier in Norfolk, UK (10km long) was held near stationary for over 60 years, following the North Sea Flood of 1953, when the barrier was rolled onshore and lowered. Restructuring of the barrier profile as a FDS then dominated management practice, until intervention was abandoned in 2006 as annual costs was deemed too expensive. Between 2000 and 2015 Cley was subject to 10 LiDAR surveys, allowing measurement of the barrier evolution following 4 major storm surges that overwashed the barrier. LiDAR analyses allowed measurement of the re-establishment a geomorphic-functioning barrier indicative of the Resilience process.

**Keywords:** coastal gravel barrier; forcing change; resilience; LiDAR; geomorphic functioning

ABSTRACT NUMBER: 318

## THE DEPOSITION OF RED SAND DUNES AT FUJIAN COASTAL, CHINA ON RESPONSE OF THE LAST INTERGLACIAL EAST ASIAN MONSOON CHANGES

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The red sand dunes distributed in the coastal zone of Fujian in the southern China are Quaternary dunes. They deposited on various types of coastal landforms, with color of brown-red and light brown-red, content of fine sand of Quartz and feldspar and Multi-cycle sedimentary formations. Previous studies more focus on its sediment features, less focus on its paleoclimatic significances. However, later studies have found that the red sand deposition response of the Asian monsoon changes during last interglacial.

Our study is about the section at Qingfen, Pingtan Island, Fujian Province. The section contain 4 formations red sand with thickness 5.1m, 1.8m, 2.6m and 1.9m from bottom to top. The ages dated by optically stimulated luminescence are 122.5KaBP, 97.7KaBP, 83.1KaBP, and 61.9KaBP for each formation response to ages of last interglacial MIS5e, MIS5c, MIS5a and MIS4. The grain size curve for the samples from the section is a logarithmic normal distribution with a granularity peaks respectively locate in 300 $\mu$ m. Both aeolian sand samples of winter and summer in the gulf near Qinfeng were also collected to measure their grain sizes. The peaks for winter sand and summer sand are of 400 $\mu$ m and 260  $\mu$ m. Summer sand and winter sand mixed in the ratio of 7:3 can simulate the grain size distribution of the red sand that indicate the intensity of the summer monsoon are stronger during red sand deposition. These characteristics can compare with that of East Asian monsoon changes during the last interglacial. The study shows that the red sand dunes deposited at Pingtan, Fujian record the east Asian monsoon cycle during the last interglacial and warmer climate made sands red.

Keywords: red sand dunes; coastal zone; last interglacial

ABSTRACT NUMBER: 322

## EFFECT FACTORS AND CLASSIFICATIONS OF PLANFORM GEOMETRY OF ARC-SHAPED BEACHES

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Abstract: Using the principal component analysis, hierarchical cluster analysis and non-metric multidimensional scaling analysis, 10 factors about coastal plain shape and hydrodynamics of 47 arc-shaped beaches in South China were analyzed, aiming to study the influencing factors and classification spectrum of arc-shaped beach configurations. The results show that: (1) the planform geometry of South China arc-shaped coast is mainly controlled by antecedent geologic conditions (with exception of bay orientation), hydrodynamic conditions (wave and tidal range) and sediment supply; (2) the arc-shaped beaches in South China can be divided into 4 groups, with each group having several sub-classifications. The first group is meso- and macrotidal coasts; the second group is wave dominated beaches; the third group is geological structure controlled large arc-shaped beaches; and the the fourth, consisting of Yangpu Bay and Puqian Bay, represent a unique type of arc-shaped beach; (3) non-metric multidimensional scaling analysis reveals the effects of morphodynamic factors on the coastal shape and the types, which shows the categories are objective. These conclusions will be helpful to the arc-shaped coasts processes research and engineering constructions.

**Keywords:** arc-shaped beaches; coasts processes; principal component analysis; hierarchical cluster analysis; non-metric multidimensional scaling analysis



ABSTRACT NUMBER: 342

**INFLUENCE OF SYSTEM CONTROLS ON THE HOLOCENE GEOMORPHIC EVOLUTION  
OF A RAPIDLY-INFILLED INCISED-VALLEY SYSTEM: THE LOWER MANAWATU  
VALLEY, NORTH ISLAND NEW ZEALAND**

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The Holocene geomorphic evolution of the Manawatu incised-valley estuary was reconstructed using water well logs and vibracores. The valley was flooded during the Holocene marine transgression, and rapidly infilled between 7,100-4,500 cal. yr BP. The valley preserves a complete record of Holocene estuary evolution, making it an excellent site to investigate the influence of the systems controls of sea-level change, sediment flux, and accommodation space on the extremely short infilling history of the palaeo-estuary. Sediment flux into the palaeo-estuary was greatest during the marine transgression between 12,000-8,000 years BP. This transgressive sediment formed a large tidal delta that subsequently evolved to form a subaerial barrier in the mid-Holocene. Sediment delivery during the transgression was sufficiently high that by the time sea-levels stabilised c. 7,500 cal. yr BP, the palaeo-estuary had been substantively infilled. Limited accommodation space in the valley resulted in rapid infilling of the central basin within 2,700 years. The Manawatu valley fill consequently lacks the mud facies characteristic of less-rapidly-evolved estuaries. The fluvial bay-head delta facies that marks the transition from estuarine to fluvial conditions is missing completely from some parts of the valley, while in most locations it is present only as a very thin deposit, indicative of this rapid environmental transition. Infilling of the central basin resulted in sediment bypass of the system, and a consequent decrease in the sedimentation rate in the later Holocene. Sediments deposited in the estuary during the Holocene have undergone consolidation, with an observed fall in RSL in the valley corresponding with calculations of the volume of valley fill lost due to sediment compaction. The unique features of the Manawatu estuary's geomorphic evolution are interpreted to primarily reflect the rapid infilling of the palaeo-estuary driven by the high rates of sediment supplied to the valley from both marine and fluvial sources.

ABSTRACT NUMBER: 356

**PAN-EUROPEAN MAPPING OF COASTAL EROSION AND ACCRETION:  
DEVELOPING EMODNET COASTAL RESILIENCE DATA**

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EMODnet is developing tools to connect national data and information resources to make them easily available and interoperable to provide European and transnational decision makers with harmonised geological background information. Building on the results of EUROSION, an EU-project completed some ten years ago, EMODnet-Geology has been compiling coastal migration data and information for all European shorelines. Coverage is being expanded, and data and information are being updated. Significant challenges are posed by a) differences between parameters used as indicators of shoreline migration, b) restricted access to third-party data, and c) data gaps. There are many indicators of coastal behaviour, with inherent incompatibilities and variations between low-lying sediment and cliffed rock shorelines. Regionally, low data availability and limited access result in poor coverage. With Sentinel data expected to become increasingly available, it is time to invest in automated methods to derive coastal-erosion data from satellite monitoring. Even so, consistency of data and derived information on coastal erosion and accretion does not necessarily translate into usability in pan-European coastal-zone management. Indicators of shoreline change need to be assessed and weighted regionally in light of other parameters in order to be of value in assessing coastal resilience or vulnerability. There is no single way to portray coastal vulnerability for all of Europe in a meaningful way. A common legend, however attractive intuitively, results in data products that work well for one region but show insufficient or excessive detail elsewhere. For decision making, uniform products are often not very helpful. The ability to zoom in on different spatial levels is not a solution either. It is better to compile and visualise vulnerability studies with different legends, and to provide each map with a confidence assessment and other relevant metadata.

**Keywords:** EMODnet-Geology, vulnerability index, cliffs, bluffs, soft-sediment coasts

ABSTRACT NUMBER: 405

## COASTAL VULNERABILITY AND MANAGING STRATEGIES: A CASE STUDY ON PARTS OF COASTAL DISTRICTS OF SOUTH ANDAMAN ISLAND, INDIA

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Coastal hazards and related vulnerability is a global issue and indeed India is not an exception. Vulnerability of coastal zone depends upon the risk arising from the various natural hazards like cyclonic storms, tsunamis, etc. and the characteristics of the exposed area. Assessing this vulnerability becomes an emerging challenge for the coastal districts of South Andaman especially for the Port Blair as the area was massively destructed due to the earthquake and tsunami waves in December 2004. The present study exclusively addresses the coastal vulnerability of South Andaman Islands to tsunami hazard and also applied the environmental zoning concept as a functional management tool. Two different measures have been computed for assessing the vulnerability, one is the “coastal insularity” and the other is “coarse vulnerability” for four subdivisions of Port Blair: Urban Port Blair, Rural part of Port Blair, Havelock Island and Neil Island respectively. Coastal insularity is a measure of the openness of the coast, whereas demographic profile includes the number of population which is exposed to the coastline. The physical attributes and demographic profile of the coastal districts were extensively surveyed and documented during the field works carried out in different areas of the studied Island. Necessary mapping tasks for the estimation of final vulnerability index for all the coastal districts were performed combining the insularity index data and population density data. Results indicate that the Port Blair town shows highest vulnerability index thus high risk of tsunami hazard, while rural part of Port Blair shows the lowest index value. Finally, seven environmental zones have been demarcated on the basis of their functional values to restore the environmental balance as well as to promote sustainable management for the entire Island community.

**Keywords:** Hazards, Vulnerability, coastal insularity, coarse vulnerability, Andaman

ABSTRACT NUMBER: 452

## USING COMMERCIAL DRONE FOR MAPPING ECOLOGICAL PHASE SHIFTS ON THE CORAL REEFS OF SOUTHERN FAAFU ATOLL, REPUBLIC OF THE MALDIVES

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The Republic of the Maldives is a Small Island Developing States with a unique geographic configuration: an archipelago composed of more than 1100 islands surrounded by coral reefs, in the Indian Ocean. Maldivian islands are carbonate landforms, totally composed of biogenic sediments produced by the surrounding coral reef. Healthy coral reefs are thus essential for the survival of the Maldivian islands due to their capacity to keep-up with the rising sea-level. Nevertheless, the Maldivian coral reefs are threatened by anthropic and climatic issues and during April and May 2016 they faced a massive coral bleaching.

In our study, we collected high resolution images using a commercial drone (DJI Phantom 4) along different sector of reefs surrounding inhabited, uninhabited and resort islands of the Southern Faafu Atoll. The acquired data were processed in order to map the extension and the composition of shallow lagoons habitat, from the beach to the reef crest. Comparing these new results with habitat maps realized using satellite images databases from 2011 to 2016 (RapidEye, Sentinel 2 and LandSat8) and field data (snorkelling and diving transects), we were able to realize habitat change maps and correlate these changes to environmental disturbances. In addition, high resolution images (1,5 cm/pixel) were collected in situ, at selected locations, in order to realize a 3D model of shallow reef communities using structure from motion photogrammetry technologies. These 3D optical models will be used as the first step of a 3 years monitoring campaign addressed to observe the 3D structural complexity changes of the reef after the 2016 bleaching event.

The whole study will focus on the integration of multi-scale maps to investigate, on a multi-temporal scale, ecological and geomorphological shifts in the study area and to figure out relationships with human activities and pressures related to global climate changes.

ABSTRACT NUMBER: 453

## PALAEOENVIRONMENTAL 3D RECONSTRUCTION OF THE LATE HOLOCENE EVOLUTION OF THE NATURAL RESERVE AND MARINE PROTECTED AREA OF TORRE GUACETO (BRINDISI, ITALY)

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The Area of Torre Guaceto stretches along the Adriatic side of Apulia. During the Middle Pleistocene, thin coastal deposits accumulated and abrasion surfaces were cut whereas, to the south, marine sediments were deposited. During the last interglacial period, two thin transgressive beach deposits formed along with a dune belt and backdune deposits. As consequence of the Holocene transgression, sea motion scraped part of the Late Pleistocene dune belt inducing the shaping of an archipelago and of swamp areas limited by dune belts that are together the main geomorphological feature of the Marine Reserve. In its perimeter, remains of a long human occupation are preserved; during the Bronze Age (2nd millennium BC) the entire coastal area was characterised by the presence on the cemented dune belt of two fortified settlements. They supplied evidence of structures destroyed by fire events dating back to the beginning of the Middle Bronze Age (17th century BC). The whole territory seems to have played a minor role during the following Messapic-Greek Age. It was re-occupied during the Roman time, as evidenced by the well known amphora kiln at Apani, as well as by the remains of a lighthouse on a small island that limits the inlet and that defines a sheltered area able to offer fresh water during coastal sailing. The rich archaeological dataset has been implemented by a detailed geological and core survey. Cores were drilled up to the local basement at about 2.5 m b.m.s.l.; they were analyzed to identify paleontological association useful in the reconstruction of the paleoenvironment and of the sea level changes. AMS age have been performed. The entire data set are at the base of the 3D reconstruction of the evolution of the studied coastal area.

**Keywords:** sea level change; coastal environment; Torre Guaceto, Puglia, Italy

ABSTRACT NUMBER: 454

## MODELLING THE SEA FLOOD SCENARIO FOR FOUR ITALIAN COASTAL PLAINS FOR 2100 ACCORDING TO THE START PROJECT

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Projections of sea-level change for the year 2100 by adding isostatic and vertical tectonic components to the IPCC 2013 and Rahmstorf scenarios have been elaborated for four key areas of the Italian peninsula. We focus on the subsiding North Adriatic coast, including Venice lagoon, the tectonically stable Oristano and Cagliari coastal Plains (Sardinia) and the slightly uplifting area of the innermost part of Gulf of Taranto ( Apulia). To depict a multitemporal flooding scenario up to 2100, we used high-resolution DTMs based on Lidar data.

Geomorphological and geoarchaeological data from sea level change indicators for the Holocene, are compared with the predicted sea-level curves providing estimates of the vertical tectonic contribution to the relative sea-level change. Results are based on the most recent model and discussed against available GPS observations for present day vertical land motion and sea level trend from tide gauge data. On the basis of eustatic, tectonic and isostatic components to sea-level change, flooding scenarios are given for those coastal

plains currently placed at elevations close to present-day sea level. Results shows that the expected sea level rise in the investigated areas will flood 4.7-5.4 sqkm with the subsequent loss of land and impact on local infrastructures. Moreover, for these provisional scenarios, the hydrodynamic model developed in the framework of the project START permitted the assessment of the maximum possible flooding due to impacting sea storms.

**Keywords:** Relative sea-level rise; climate change; marine flooding; sea storm flooding; Project START.

THEME: S16 : COASTAL GEOMORPHOLOGY AND MANAGEMENT

ABSTRACT NUMBER: 523

## HYDRODYNAMIC BEHAVIOR OF TIDAL INLET SYSTEMS: A COMPARATIVE STUDY OF JALDHA AND PICHABONI INLET, PURBA MEDINIPUR, WEST BENGAL

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The hydraulic geometry parameters of tidal inlets, such as, cross-sectional area, wetted perimeter and hydraulic gradient is controlled by the dynamics of tides and wave-induced littoral drift along coastline. The littoral drift brings materials that may be pushed in the inlet during flood tide and flushed out during ebb tide. The flow velocity within an inlet varies as a function of its cross-sectional area. An inlet which can maintain its hydraulic stability has its velocity so adjusted that it is able to flush all the material pushed into the inlet.

The continuity of the Purba Medinipur coast of West Bengal is interrupted by four inlets, namely, Talsari, Ramnagar, Jaldha and Pichaboni. These inlets divide the coastline into four sectors. In this study, we have considered only Jaldha and Pichaboni to examine their hydrodynamic stability.

Tide monitoring was done in spring tidal condition for around 10 hours and water samples were collected at every 30 minutes interval for determining the variation in suspended sediment concentration at three monitoring stations for each inlet. Several cross-sections were measured by total station and echo-sounder at almost equal interval to compute the longitudinal profiles and inlet bathymetry.

In both cases the inlet mouths are very dynamic in nature. The changing position of the mouths may be influenced by the relative dominance of littoral drift and the flushing capacity of the inlet. From the study, it is observed that the throat cross-sectional areas of both inlets are equal or slightly larger than the computed equilibrium cross-sectional area, indicating that the throat cross-sections in both the cases are in a stable condition. If the throat cross-section experiences any reduction in area due to sand deposition, the system will increase the maximum flow velocity and scouring capacity accordingly.

**Keywords:** Throat cross-section; equilibrium cross-section; inlet stability; scouring capacity

THEME: S16 : COASTAL GEOMORPHOLOGY AND MANAGEMENT

ABSTRACT NUMBER: 665

## GROWTH PATTERNS AND MORPHODYNAMIC FEEDBACKS RECORDED IN DANUBE DELTA EVOLUTION

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Deltas are large-scale coastal accumulation features continuously evolving to adapt to natural and anthropogenic-induced environmental changes, and commonly evincing a large diversity of landscapes. The Danube delta is a world heritage natural reserve, famous worldwide for the numerous pristine fluvial, marine and coastal landscapes. Here, the concurrent controlling factors sort out locally into the prevalence of different morphodynamic processes which lead to the coexistence of divergent morphological patterns and related features such as wave- and river-influenced lobes, asymmetrical lobes, erosive and accumulative coasts, subsiding and stable areas.

This work presents the latest progresses made on Danube Delta evolution based on new cores, sedimentological and morphological analyses which together with the newly obtained absolute ages (AMS 14C and OSL) shed a new light upon the delta formation and its evolutionary phases (chronology). For the first time, it is proven that the early stage of delta plain formation preceded with more than a millennium the relative stabilization of the sea level, whilst the fluvial delta morphology is reinterpreted showing that most of the present landscape is the recent result of fluvial aggradations which followed after the initial topography (former delta plain) was

drowned through the concurrent action of subsidence and sea level rise.

With regard to the maritime delta, we highlight the evolutionary patterns which governed the evolution of each of the six open-coast lobes emphasizing “the common denominator”, respectively the specific processes which succeeded to replicate a common lobe morphology and stratigraphy into all deltaic lobes. Specific discussion are dedicated for different features of the assymmetric lobes – beach ridge plains, barrier-marsh plains, barrier islands and spits, river mouth bars - in relation with Danube flow changes and their chronology, progradation rates or spatial extension.

**Keywords:** delta evolution, large scale coastal behavior, assymmetric lobes, strandplains, barrier islands

THEME: S16 : COASTAL GEOMORPHOLOGY AND MANAGEMENT

ABSTRACT NUMBER: 755

## THE ROLE OF RAPID DEGLACIATION AND PARAGLACIAL SEDIMENT FLUXES IN CONTROLLING THE POST-LITTLE ICE AGE EVOLUTION OF HIGH ARCTIC COASTAL SYSTEMS

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The coastal zone is a key interface where environmental changes impact directly on Arctic communities. Recent rapid warming of the Arctic atmosphere has intensified the operation of the geomorphic processes that control coastal evolution, causing increased degradation of permafrost, enhanced sediment supply from deglaciated catchments and prolonged periods of open-water conditions and wave activity. Despite the potential significance of these climate-driven processes, relatively little is known of the physical processes that control past, present and future Arctic coastal geomorphology.

In this paper, we summarize the results of several coastal studies carried out along paraglacial coast of Svalbard during the last decade.

We reconstruct the post-Little Ice Age evolution of coasts in western, central and southern Spitsbergen to illustrate the highly variable coastal zone responses to both paraglacial and periglacial landscape transformation associated with deglaciation and intensification of extreme geomorphological processes.

Our results emphasise the role of climate changes in controlling sediment fluxes from deglaciated valleys to the coastal zone. Under intervals characterized by a warming climate, retreating local ice masses, a shortened sea-ice seasons and melting permafrost most of studied coastal systems rapidly responded to excess of freshly released sediments and experienced significant geomorphological changes leading to development of new coastal landforms (e.g. spits) and progradation of existing forms (e.g. beach-ridge plains).

Our research was based on a combination of methods including aerial photogrammetric and GIS analyses, sedimentological tests of coastal deposits, isotopic dating, rock surface tests, geophysical surveying and field-based geomorphological mapping in central and southern Svalbard.

The study highlights the need for a greater understanding of the controls on High Arctic coastal systems, especially given the potential for future accelerated climate warming, decay of sea-ice, storminess, sea-level rise and rapidly growing human impact on Arctic resources and strategic locations.

**Keywords:** coastal evolution; paraglaciation; LIA; glacier retreat; Svalbard, Arctic

THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 29

## PROVENANCE, TRANSPORT AND MIXING OF TAKLAMAKAN DESERT SAND

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Identifying provenance, transport and mixing of aeolian sediments in the Taklamakan Desert is overwhelming significant for understanding physical geologic large cycle, formation and changes of earth surface processes. While many earlier studies focused on

the palaeoenvironment on the basis aeolian and inter-dune fluvial-lacustrine sediments, few on provenance, transport and mixing of the desert sand. In this paper, we put new geochemical data, grain size data, sand drift potential (DP) and elevation together to provide a more comprehensive insight to desert provenance, transport and mixing of aeolian sand in the Taklamakan Desert, northwestern China, an important dust source on the earth. We sampled aeolian and fluvial sand from south to north of the Taklamakan desert, and measured their grain size distribution and major elements composition in bulk samples, finer (<63µm) and coarser (>63µm) fractions. Our results show that bulk and coarser fractions of Taklamakan desert sand are most similar in composition to fluvial sand which river is originating in the southern mountains (Kunlun and Altun), and finer fraction sand has some similarity in composition to fluvial sand which rivers both originating in the southern and northern mountains, indicating different provenance and transport between coarser and finer fractions. We conclude that: (1) sand is transported by rivers originating in the southern rivers to the desert mostly because of the favorable topography; (2) finer fraction sand is transport by wind from the north side of the Tarim River because of enough higher DP, and then mixed with sand in situ; (3) sediment availability change because of hydrological fluctuations is more important to controlling formation and change of dune fields than wind transport capacity in the desert.

THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 81

## CYCLIC CHANGES OF LANDFORM UNDER THE IMPACT OF FLUVIAL-AEOLIAN INTERACTION

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To explore the influence of fluvial-aeolian interaction on geomorphology over long timescale in a large spatial scale, a cellular landscape evolution model CASEAR-lisfood was combined with a dune model to simulate the landscape change in a fluvial-aeolian interacting field. Generic simulations have been carried out with a minimum of alteration from any external causes to achieve the minimal conditions which can be completely dominated by the system self-organized driving factors.

The simulation results presented various interaction behaviours between river channels and aeolian sand dunes, which resulted in distinct landform characteristics. In addition, a surprisingly cyclic behaviour of landscape change was observed. This periodic change of whole channel location without external forces could indicate that the sudden landscape changes may be inherent in the normal development of the fluvial-aeolian interacting field and that a change in an external variable is not always required for a significant geomorphic event to occur. In addition, this may indicates that there is the potential for self-organized criticality in the evolution of the fluvial-aeolian interacting field thus a geomorphic threshold might be existed. If this geomorphic threshold condition can be identified, not only will different explanations for some landform or hydrologic, sedimentologic and stratigraphic anomalies emerge but also the ability to identify unstable landforms and to predict their change.

**Keywords:** fluvial-aeolian interaction; rivers; dunes; geomorphology; numerical modelling

THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 258

## AEOLIAN-ACCUMULATIVE COMPLEX SARYKUM AS A UNIQUE GEOMORPHIC OBJECT OF RUSSIA: STRUCTURE, ORIGIN AND AGE OF ITS SANDS

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The aeolian-accumulative complex Sarykum (or Sarykoom) is the largest (over 2,000 ha) in Russia and one of the highest isolated (i.e., formed away from the deserts) sandy landforms in Eurasia, located within the Terek-Sulak (Caspian) lowland plain at the north-eastern foothill of the Caucasus Mountains (Russia). This is a whole system of dunes, ridgy and hilly sands. By the Shura-Ozen' River valley the complex is divided into two unequal parts: left-bank Great (Western) Sarykum and right-bank Small (Eastern) Sarykum. The maximum height above sea level of the Great (Western) Sarykum is 245.8 m (43°00'30.76"N, 47°14'27.39"E), according to our latest measurement in August 19th, 2016; its relative height is about 160–170 m.

On the base of granulometric and mineralogical composition analysis of the sands, as well as alluvial deposits within the Shura-Ozen' River valley including their radiocarbon dating, the complicated layered structure of the sandy complex was determined, reflecting the climatic change stages in the western part of the Caspian Sea basin in the Late Quaternary. It is proved that sandy materials of the

complex, which served as a basis for its subsequent aeolian transformation, was supplied to the outer foothills of the Mountainous Dagestan and accumulated there by the Shura-Ozen' River in the form of mainly deltaic deposits not earlier than 17–18 ka BP. The granulometric spectra analysis of the Shura-Ozen' River alluvial deposits made it also possible to draw an important, albeit cautious, conclusion that the most active forming phase of the Great Sarykum's aeolian landforms took place in an epoch preceding the forming of the highest terraces of the Shura-Ozen' River valley, i.e. after the forming of the sands as (proluvial-) deltaic formations, but before the valley origin.

**Keywords:** dune, sand, aeolian landform, delta, Sarykum (Sarykoom), Shura-Ozen' River, Caucasus, Russia

THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 273

## REVISING AND EXTENDING LATE QUATERNARY DUNE ACCUMULATION HISTORIES IN THE THAR DESERT, INDIA.

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The Thar Desert in north-west India lies at the limit of the region receiving precipitation from the Indian monsoon. It is generally accepted that insolation driven changes in monsoon intensity have affected desert contraction and expansion during the late Quaternary, impacting on the construction and accumulation of aeolian landforms. Observation of dune alignment using remotely sensed imagery has shown that regionally, dunes are closely aligned with the prevailing wind direction of the southwest monsoon system. Previous studies have suggested that aeolian accumulation occurs within limited time windows, when an optimal balance between wind and vegetation is reached and maintained. Therefore, the Thar dune systems potentially provide a rich archive of past climatic and geomorphological change. To investigate this, systematic sampling of dune fields, including some not previously dated, was carried out in different parts of the desert. Field sites were selected considering their locations along the mean rainfall gradient and their relation to the sediment depositional styles for an optimum understanding of the resolution and duration of the aridity record. Optically stimulated luminescence dating was carried out on samples from full dune profiles with an aim to infer the sensitivities of dunes to the changes in environment in the past, and different time scales over which they register and preserve the palaeoenvironmental record. It is anticipated that with records from new areas, full dune profiles and improved luminescence methodologies, analysis of the full dune age dataset will potentially change the interpretation of dune accumulation histories and permit the assessment of the roles of changing sediment supply and/or monsoon intensity in the late Quaternary development of the Thar Desert.

**Keywords:** Thar; luminescence dating; late Quaternary; geomorphological change; palaeoclimate

THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 284

## FORMATIVE TRIGGERS IN ALLUVIAL PLAINS OF THE BORBOREMA HIGHLANDS, NORTHEASTERN BRAZIL

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The origins of formative geomorphological triggers in alluvial plains within the elevated compartments of the Borborema Highlands, semi-arid northeastern Brazil, remain poorly understood. Located in an area where sediment transfer along the landscape is related to high magnitude precipitation events, little is known about the overall climatic control over such events, neither whether they are related to variations in global temperatures or in the surface of tropical neighboring oceans. In this regard, the present work aims at analyzing the chronology and stratigraphy of alluvial deposits in the Bruscas creek, that drains the higher elevations of Serra da Baixa Verde syenitic massif in the Northeast of Brazil. Sedimentological and chronological analyses of alluvial deposits were carried out. Sediments were dated by Optically Stimulated Luminescence (OSL). Results point to the occurrence of recent aggradation events in the alluvial plain, separated in three episodes of landscape hysteresis throughout the Upper Holocene. The first episode, dated from 1.300±240 BP was related to Bond Event 01, during the lowering of tropical North Atlantic sea-surface temperature, which might have shifted the position of the subtropical high towards the equator, thus pushing the ITCZ to more southerly latitudes, increasing rainfall totals in the study area. The second episode, from 415±65 BP, is related to the deposition of fine-grained sediments, indicating a period of moister

local environmental conditions. The trigger mechanisms associated to this event are related to the effects of ENSO in the area. The last episode of sediment transfer rendered an age of  $385 \pm 65$  BP, and also exhibits ENSO controlled characteristics, this time related to enhanced semi-arid conditions. Results point to a strong link between sea-surface temperature variations in the tropical North Atlantic and Equatorial Pacific oceans and sediment transfer to the floodplain in the study area.

**Keywords:** geomorphological triggers, ENSO, Borborema Highlands, Northeastern Brazil

THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 290

## EOLIAN LANDSCAPE EVOLUTION CONTROLLED BY SEDIMENT AVAILABILITY SINCE LGM IN THE HULUNBUIR SANDY LAND, NORTHEAST CHINA

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Eolian landscape evolution under different climates are key to understanding how the eolian records respond to the external forces such as climate change. On the basis of well vetted sedimentary facies and stratigraphic features, palaeoenvironmental proxies, geochemical analysis and optically stimulated luminescence chronology, especially taking the sediment supply, availability and mobility into account, the eolian landscape evolution history in the Hulunbuir Sandy Land was reconstructed. We conclude that there were few sand dunes developed prior to ~15 ka due to sediment availability limited by frozen ground. Instead, a cold climate sand sheet landscape developed under the high wind energy but low sand availability condition. We ascribe the coexistence of enhanced eolian accumulations and soil formation processes between 14.5 ka and 9 ka to the increasing sediment availability released by thawing ground and vegetation growth under the warmer climate. Widespread palaeosols and few eolian records between 9 ka and 3.5 ka indicate that the dune fields of Hulunbuir had been totally stabilized during middle Holocene. The eolian sand alternated with dark soil during the last 3.5 ka with high frequency of OSL ages of eolian sand, particularly during the last 1.5 ka, implying that the landscape status of Hulunbuir during the last 3.5 ka is more complex and human activities may play an important role. The evidence from geomorphology, stratigraphy, sedimentology and the perspective of sediment availability collectively support that the extent of dune fields in the study area during LGM did not change largely compared with the present, much smaller than pervious claimed.

**Keywords:** Eolian records; OSL ages; Sand sheets; Sediment availability

THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 336

## CATCHMENT CONNECTION CONTROLS MEGA-LAKE EVOLUTION ON THE CENTRAL TIBETAN PLATEAU

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The Tibetan Plateau and its surrounding mountains with a mean elevation of more than 4000 m above sea level, are known as Asia's water tower and the Third Pole and sensitive to natural climate change, because they have more than 1200 lakes ( $>1 \text{ km}^2$ ) and an extensive distribution of glaciers out of polar regions and inconsecutive permafrost and unique geomorphological conditions. Paleoshoreline are among the best straightforward indicators of lake dynamics and hence past climate change. Here we reconstruct lake level variations of Selin Co and Nam Co, the largest lakes in the Tibetan Plateau, since the deglaciation based on chronological data from paleoshorelines in the central Tibetan Plateau. Detailed OSL chronology reveals that a Selin Co-centric mega-lake, many times larger than its modern area, occurred since the last deglaciation with the feed from glacial meltwater, and had existed for ca. 10 ka until the beginning of arid late Holocene. However, the lake level of Nam Co was relevant stable from deglaciation to the beginning of late Holocene, when the lake was exorheic. We estimated meltwater from mountain glaciers and permafrost contributed the highstands, and more high-altitude lakes outflowed into mega-lake during the deglaciation and early Holocene, while due to the limited meltwater thus less water supplies from high-altitude lakes, monsoonal precipitation substantially controlled lake dynamics since the mid-Holocene. We therefore



conclude that lake expansion and shrinkage were directly controlled by catchment unicom and separation. These observations indicate that catchment connection system could provide insights into the mechanism of hydrogeological processes under climate changes and the modern lake level raising trend will not last long and keep relative stable in the future.

**Keywords:** mega-lake; catchment; meltwater; OSL chronology; paleoshoreline; Tibetan Plateau

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THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 374

## A SELF-ORGANIZING MAPS APPROACH TO MERGE EXPERT BASED KNOWLEDGE AND SPATIAL DATA ANALYSIS TO PREDICT SOIL AND LANDFORM PROPERTIES IN DESERT ENVIRONMENTS

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One of the challenges in geomorphology is to map landscape features and their properties when field measurements are limited in number, clustered or even impracticable to collect. To cope with potential problems, we propose a new approach, based on the self-organizing map (SOM) technique, to model soil properties relating them to landform categories. This approach exploits underlying nonlinear relation of the steady-state geomorphic features and minerals spectral signatures to spatially limited soil textural data. The topographic and spectral features are extracted and enhanced through spatial modeling and band ratios from the Advanced Spaceborne Thermal Emission and Reflectance Radiometer sensor; whereas soil texture (clay, silt, and sand) and potential dust emission were collected (0 to 6 inches depth) in 90 sites across an extensive area in the Mojave Desert. A categorical geomorphic map was produce based on expert knowledge, fieldwork and imagery interpretation for Silver and Soda lake region. In contrast to parametric multivariate analysis approaches, such as principal component analysis, the SOM identifies nonlinear relations among soil texture, spectral and relief features. Stochastic cross-validation indicates that the SOM is unbiased and provides a way to measure the magnitude of prediction uncertainty for all variables. Pearson's correlation index and SOM cross-component plots of the soil texture and landforms reveals positive correlation between fine particle contents with playa margin and washes. The sand ratio is positive correlated to distal fans and dunes; and negative correlated with desert pavement. Silt has a trend similar to clay and both present a correlation salt and silt playas. The proposed approach, estimated soil physical properties merging collected field data to continuous surfaces of explanatory variables and quantifying correlations between categorical maps and image band ratios to enhance mineralogic features provides a robust alternative approach to map soil properties in arid environments with limited soil data collection.

THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 379

## GEOMORPHOLOGICAL IMPLICATIONS DUE TO CLIMATE-TECTONIC IMPACTS IN THE FRAGILE COLD ARID DESERT OF LADAKH, TRANS-HIMALAYA, INDIA DURING THE LATE QUATERNARY

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Morphometric analyses aided by GIS, remote sensing and a ground check was carried out along the Indus Suture Zone (ISZ) and Karakorum Fault to understand the role of climate and neotectonics in the evolution, shaping and reshaping of this dynamically active part of the Trans-Himalaya in short timescales like the Late Quaternary. The study was based on the sediment distribution and the reconstruction of the palaeo-environment and changing geomorphology. The major river valleys viz the Indus, and its tributaries, Shyok, Nubra and Tangtse were studied to address landscape development in terms of Quaternary sedimentation and neotectonics. The palaeolake and associated fluvio-glacial sediments have been mapped and dated (OSL and AMS) to reconstruct the past environments and how they have changed in short time scales in this westerly dominated high altitude cold desert. Geomorphic indices of active tectonics such as gradient index, steepness index, asymmetry factor, hypsometry integral, elongation ratio and valley width-height ratio to quantify the recent tectonic activity along with the study of seismites recorded in sediments was done. Seismic activity around 27 ka, 23 ka, 17-19 ka, 11-10 ka and 6 ka along the Karakorum Fault and ISZ. Based on morphometric parameters the area region

is divided into three morphotectonic segments one comprising of erosion dominated asymmetric basins in the Leh region, while higher elevations in the lower reaches of the Indus valley lower two segments suggest a still continuing uplift. Blockage of River Indus by Lamayuru dam burst during the deglaciation, after LGM and subsequent increase in water level led to the formation of a ~55 km Saspol-Khalsi palaeolake having a surface area of 370 km<sup>2</sup> and a 40 km Spituk palaeolake of 104 km<sup>2</sup> upstream. These palaeolakes record a depositional and climatic history from LGM to 1500 cal yrs BP.

THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 429

## RECONSTRUCTING THE QUATERNARY SEDIMENTATIONS OF TSAGAAN SUVARGA FORMATION IN SOUTHERN MONGOLIA

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Quaternary sedimentation has been reconstructed in Tsagaan Suvarga formation at the most northern border of Govi region in southern Mongolia. In the Tsagaan Suvarga formation area fluvial and aeolian are the dominant geomorphological processes during the late Quaternary. The Tsagaan Suvarga formation consists of fluvial gravels which have been deposited during the mid to early Pleistocene at the top and a mixture of silty and sandy sediments at the bottom. The thermoluminescence (TL) dating allows us to know its minimum age higher-less than ~ 80.9±7.3 ka BP. Erosional and highly weathered characteristics of the gravels on the elevated position show that the site area would be expected as older than MIS 4-5. The mineralogical composition of the sediments contains abundant clay minerals, K-feldspar and carbonate. The K<sub>2</sub>O/Al<sub>2</sub>O<sub>3</sub> and SiO<sub>2</sub>/Al<sub>2</sub>O<sub>3</sub> ratios indicate that the clay mineral is composed of smectite. Si, Al, Ti, K, Na and Fe reside in clay minerals, while Ca, Mg and Mn are mostly associated with carbonates (e.g., calcite and dolomite) and phosphorous is present as apatite. Paleoclimatic index (C-value) varies between 0.5 and 8.29 reflecting a generally semiarid to humid conditions. Rb/Sr (~0.49) and Sr/Cu (~7.55) ratios support the idea that warm and humid conditions prevailed during deposition of the Tsagaan Suvarga formation. Sr/Ba ratio (0.13–0.17) suggests the less salinized paleoenvironment. The co-variation among this factor and paleoclimatic indicator suggests that climatic conditions exert a primary control in the salinity. The substantially low C-value, Rb/Sr ratio and significantly high ratios of Sr/Cu and Sr/Ba show that these sediments were deposited during the warm and humid periods and that the paleoclimate controlled the terrigenous sediment flux. Chemical index of alteration (CIA), A-CN-K ternary diagram and high Th/U ratios indicate that the parent rocks of the sediment experienced moderate chemical weathering.

THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 447

## PATTERNED VEGETATION OF THE AUSTRALIAN DRYLANDS: WHAT DO WE KNOW AND WHAT KNOWLEDGE GAPS REMAIN?

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Various forms of patterned vegetation occur widely across the Australian drylands. They occur in grasslands, shrublands, and woodlands. Similar patterned plant communities occur in other global drylands, and these ecosystems have attracted considerable attention, especially as regards their origin and functional significance. The description of these landscapes has included documentation of the soil properties that result in compartmentalised runoff-runon systems with associated soil surface microtopography. Less well known is how the development and operation of patterned vegetation relates to the rainfall climate, and in particular to the temporal patterns that occur in drylands rainfall. Likewise, there remains uncertainty about whether the vegetation patterns are stable in the landscape or exhibit upslope migration. Finally, there also remains uncertainty about how climate variability such as that related to ENSO in Australia, affects patterned vegetation. This paper will present data that demonstrate how convective drylands rainfall may be important to patterned vegetation and how soil changes related to ENSO may likewise be influential. Much of the study of patterned vegetation has been based on theoretical model development, and lacks a solid basis of empirical data. This paper will highlight areas where the assumptions frequently made in model development conflict with field evidence, and in so doing will highlight the significant challenges that remain in understanding these widespread features of the global drylands.

**Keywords:** patterned vegetation; Australian drylands

THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 450

## ESTIMATING BLOWN SAND ENTERING INTO THE NINGXIA-INNER MONGOLIA YELLOW RIVER DURING 1981-2014

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The Ningxia-Inner Mongolia Yellow River (NMYR) flows through 4 deserts, Tengger, Mu Us, Ulan Buh and Kubuki. It is a difficulty to predict blown sand into the river because of complex surface and lack of calibrated data. In this article, an integrated method was presented to estimate the quantity of sand blown into both the main stream and tributaries of the NMYR during 1981~2014 and the results were calibrated partly by observation data in the field and particulate matter data from local Environmental Protection Agency (EPA). Surface classification, vegetation coverage, wind speed and wind direction, and the location of dikes were integrated into a GIS platform. An integrated step-by-step model on the sand transport rate formula was built to estimate the sand blown into the river by retrieving data in the GIS platform. The estimations showed a highly positive correlation with the concentration of PM10 in atmosphere caused by wind erosion observed by local EPA, and an agreement at large with a field observation on the reach over Ulan Buh Desert. The results showed that, during 1981~2014, the annual average quantity of sediment blown into NMYR was 7.31 million tons, and that the quantity into the tributaries was 13.19 million tons. The annual quantity of both the main stream and the tributaries declined significantly during 1981~2014, respectively, with the specific values of -0.388 and -0.727 million tons per year on average. The vegetation coverage increasing, the wind weakening and the dike building cooperatively resulted in the decline of blown sand entering into the river.

**Keywords:** Ningxia-Inner Mongolia Yellow River; blown sand; model; calibration

THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 566

## GEOCHEMICAL CHARACTERISTICS OF A LOESS PROFILE IN NORTHWEST CHINA

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Beiyuan loess profile, located at north of Linxia City, Guansu, Northwest China, is situated on the second terrace of Daxiahe River, a tributary of the Yellow River. The profile is 40 m thick covering last 150 Kyr. Geochemical analysis of 72 samples taken from the profile show that the main chemical components of loess are similar to those in other places of Loess Plateau. Studies for chemical element migrating capability present such a sequence as: Ca<sup>2+</sup> > Mg<sup>2+</sup> > Fe<sup>3+</sup> > K<sup>+</sup> > Na<sup>+</sup> > Si<sup>4+</sup> > Fe<sup>2+</sup> > Al<sup>3+</sup>. Ca with its chemical compound CaCO<sub>3</sub> is the most active composition in loess sediment. It can be taken as a representative of geochemical characteristics of loess deposits. Its distribution is related to the filter dissolving process in the loess, so it can be used to indicate the humidity of paleo-climatology. The ratios of oxides in loess that show weathering pedogenic degrees are correlated with bio-climatic changes. CaO+MgO/Al<sub>2</sub>O<sub>3</sub> is more sensitive than other index to indicate the environmental changes.

THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 569

## LATE HOLOCENE GEOMORPHIC EVOLUTION BY MINERAL COMPOSITION AT A DRIED LAKE PLAYA

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We reconstructed late Holocene geomorphological conditions at Sabzevar playa, an arid and dried lake playa in northeastern Iran. The

methodology used in this research arose by an approach that mineral compositions save major environmental changes considering Holocene climatic oscillations. Sediment sample cores along playa geomorphologic facies with 1m depth and 5cm diameter applied for sampling and ultimately 30 sediment samples were gathered. For mineralogy analysis, an x-ray powder diffraction (XRD) and an x-ray fluorescence (XRF) were used. Soil characteristic regarding EC, SAR, particle size, and pH were measured at the laboratory of Natural Resources and Environment college. The mineral compositions indicated that geomorphology of salty pans is significantly affected by evaporation ratio and soil capillary power. The major minerals in the sediments are Quartz, Muscovite, Gypsum, Calcite, and Halite in records of evaporite. The deposition pattern of evaporate minerals in the region shows a “bull’s eye” pattern regarding capillary fractionation with the composition of carbonates, sulfates, and chloride from Eastern part to the Western part of the playa. Wind deposits on the playa surfaces and mineral compositions indicated that the current playa environment is changing with a high percentage of carbonate minerals (calcite), and deep sediments of playa demonstrated the higher water level as well in the past. Meanwhile, evaporite minerals regarding gypsum and halite salts on the surface of playa indicated a falling process in water level of Sabzevar playa during the time that can be a record for existing a wet- lake playa in the past and now was dried.

THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 675

### CONNECTING THE DOTS: THE POSSIBLE LONG DISTANCE IMPACTS OF KALAHARI DUNE MOBILIZATION

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The Southern Hemisphere shows relatively low levels of atmospheric dust concentrations because most sources of atmospheric dust on Earth are located in the Northern Hemisphere. The lower dust emissions in the Southern Hemisphere in part limit the supply of micronutrients (primarily soluble iron) to the Southern Ocean, thereby constraining its productivity. Climate and land use change can alter the current distribution of dust source regions on Earth through the activation of new dust sources as a result of drought and land use intensification. In particular, dust concentrations could increase as a result of losses of vegetation cover in the southern Kalahari. There is some evidence of an ongoing remobilization of stabilized dunefields in the southern Kalahari where dune crests with sparse vegetation cover are reactivated during dry and windy periods, a phenomenon that is predicted to intensify with increased land degradation, overgrazing, and droughts. Despite the potentially important implications of dust emissions from the Kalahari, it is still unclear whether the predicted remobilization of the Kalahari dunes could be associated with increased dust emissions from this region. Here, we report the results of an aeolian sediment sampling campaign over a variety of land covers in the southern Kalahari. We use these results to quantify the potential rate of dust emissions and its dependence on vegetation cover and to make an estimate of dust fluxes from a portion of the southern Kalahari. The results show that the loss of vegetation could lead to substantial increases in dust emission and nutrient loss. We also evaluate the soluble iron content of Kalahari dust and the dust generation potential of Kalahari sands and other sediment deposits in the region. We then map the regions of the Southern Ocean that are prone to the deposition of dust from Southern Africa.

THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 694

### INITIAL FORMATION OF SAND SEAS IN NORTHERN CHINA: FROM GEOMORPHOLOGICAL PERSPECTIVE

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Climatic aridity is often considered by palaeoclimatologists as the sole factor for determining the desert landscapes in northern China and elsewhere. Thus the Miocene loess in the downwind sites was interpreted as evidence of the occurrence of sand seas in northern China and potential changes of the landscape since then are often ignored. In the community of aeolian geomorphology, it is, however, well-accepted that at least three aspects, i.e., sand supplies, erodibility of the land surface and wind power, are collectively responsible for the forming of the dune landscape. The sediment sequences reported from the desert regions in northern China and their chronologies mostly indicate a much young age for the sand seas. For the case of the Hunshandake Sandy Land in the eastern portion of Asian mid-latitude's desert belt, the earlier stratigraphical correlation suggested early Tertiary as the initial formation of this desert. The abundant outcrops of lacustrine sequences in this desert and their OSL chronologies indicated, however, large lakes and wetlands occurred in the

region about 5000 years ago. There might be aeolian landforms prior to the occurrence of these lakes. But could we ignore the large-scale occurrence and long duration of the different landscapes other than aeolian dunes in defining the initial timing of the current sand seas? And for a full understanding of the sand seas in the drylands of Asian middle latitudes it is imperative to give consideration to all factors contributing to the formation of the sand seas, not just the initial climatic aridity.

THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 733

## DESERTIFICATION AS EVIDENCED FROM CHANGING PASTURE LANDS ECOLOGY- A CASE STUDY IN INDIAN DESERT

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Man has been one of the most important and active agents of biotic interference particularly in an arid ecosystem. Overuse of marginal lands, uncontrolled grazing, over exploitation of water, reducing pasture lands, shrinking forests, sparsely distributed pasture lands and eroded agricultural fields directly indicates weakening of an arid ecosystem. Grasslands and pastures are valuable resources and mainly provide fodder and forage in the desert ecosystem. Droughts in Indian desert not only influence the food and fodder production, but also result in lowering of groundwater. Drought occurrence leads to marginalization, overgrazing and other environmental instabilities. This situation renders harsh and unfavorable periodical environmental strains on human and livestock population and on vegetation fraction cover. Biomass variability coincides with the areas mostly receiving deficiency of rainfall. The present study has been attempted as a case study in Indian desert. Remote Sensing derived data have been used in order to make a spatial enquiry on stress on limited pasture lands. Grazing pressure, grazing Intensity and fodder requirement have also been analysed in order to assess the risk of spatial vulnerabilities in desert ecosystem. The analysis has been done in G.I.S. environment. It has been observed that there is risk of forage deficit due to stress of livestock population and mismanagement in planning of desert development measures.

**Keywords:** Marginalization; pastureland; forage; vulnerabilities; Intensity

THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 751

## RECONSTRUCTING DESERT DUNEFIELD ACCUMULATION HISTORIES: A NEW APPROACH USING CHRONOMETRIC DATA

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Desert dunefields are both a function of contemporary aeolian processes and the legacy of Quaternary conditions that favoured sand transport. The application of luminescence dating, pioneered in the Thar Desert in the 1980's (Singhvi et al. 1982) provided the potential to establish the timing of past accumulation events, and to test hypotheses of the response of dunefields to major global climate changes. Since then, luminescence dating has generated many hundreds of dune sediment ages. Environmental and climatic interpretations of these records have however proved enigmatic and sometimes controversial, and it remains challenging to test hypotheses of the systematic response of dunefields to changes in external forcing in the past and to make predictions of the future.

A new method of handling and modelling age data at the dunefield scale, provides an approach that addresses many of the issues associated with past age interpretations (Thomas and Bailey 2017). This takes account of key factors including sediment preservation, sampling bias, and dating errors that can complicate the interpretation of past accumulation records (Bailey and Thomas 2014). The Accumulation Intensity method quantifies dune sediment accumulation from age datasets, rather than simply using the ages themselves as proxies of change. This allows periods of dune accumulation, over 102-105 years, to be identified from compilations of dated sand sea stratigraphic sequences. This approach is applied to several compiled dunefield age datasets (Lancaster et al. 2016) from some of the world's major sand seas including in Arabia, Australia and Africa, allowing hypotheses of the drivers of dune system accumulation through time to be tested.

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Singhvi AK, Sharma YP, Agrawal DP. 1982. Nature 295, 313-315.

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THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 789

## DUNEFIELDS OF PATAGONIA

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Patagonia (40°-60° S) is the only continental territory exposed to the southern westerlies. The velocity and frequency of the westerly winds generate a landscape strongly influenced by aeolian processes. The winds coming from the Pacific Ocean ascend on reaching the Andes, while cooling adiabatically and generating high precipitation on the western slopes, whereas the eastern side of the Andes is in the rain shadow, which generates true desert conditions. Pans, tablelands, closed basins and ephemeral streams are dominant in the landscape due to the climatic conditions. Dunefields mainly consist of transverse dunes, barchans, sand shadows and sand sheets and they move predominantly in a west-east direction. Yardangs, desert pavements, exhumed roots and decapitated soils were recognized in interdune areas. Longitudinal sand ridges, parallel to the prevailing wind direction, often remain preserved after the dunefields have passed. This allows to recognize the path of the dunes in the past. The barchans and barchanoid transverse dunes have a height between 3.5 and 14 m. The average speed movement measured in the dunes located at the east of Lake Colhué Huapi is 45 m/year. The sand sheets are 0.4 - 1.2 m thick and they are located at the eastern end of the dunefields as sandy tongues shaped in top view. Their shifting speeds are the highest in the region and often exceed 100 m/year. Dunes with similar morphology show large textural differences associated with the sediment supply environment. The main sediment supply to dunefields development is lakebed of pans and west facing beaches of lakes and gulfs. Also, they feed by erosion of top soil horizons of interdune areas. The climatic variations control the development and stabilization of all the dunefields studied.

**Keywords:** dunefields; barchans; transverse dunes; Westerlies; Patagonia

THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 793

## BLOWING IN THE WIND: EVENTFUL HISTORY OF A THAR DESERT DUNE, RAJASTHAN

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The Thar Desert of northwestern India and eastern Pakistan is a continuation of the great tropical deserts that extend from the Sahara across Arabia, Iraq, Iran and Afghanistan through over 8,000 km and 110 degrees of longitude. The Thar Desert has an area of 320,000 square kilometres. Annual rainfall is less than 100 mm in the west and more than 450 mm in the east. Dunes are active today where the annual rainfall is less than 250 mm; fixed dunes extend east into areas now in receipt of 450 mm of rain or more. The eastern desert is well vegetated and has many Saharan floral elements. The now vegetated and stable dunes in the east were once as active as those in the west, prompting us to ask how old is the Thar Desert and whether it is a result of human activities that caused land degradation and desertification, as some workers have claimed.

A trench 18.3 m deep and dug by hand near Didwana in the north-east of the desert revealed a sequence of twelve cycles of dune sand accretion, calcareous dust accretion, soil formation, and calcrete development spanning the last 190,000 years. Each cycle lasted about 20,000 years, consistent with a precessional influence over the waxing and waning of the summer monsoon. The polygenic dune contained a stratified sequence of prehistoric stone artefacts ranging from Lower Palaeolithic through Middle and Upper Palaeolithic to Mesolithic in age. Analyses of carbon isotopes on organic matter within the sand profiles suggest initial soil formation during a climatic phase in which grassland was giving way to woodland. Although it is unwise to extrapolate too far in space and time, we can safely rule out human impact as the cause of the Thar Desert.

**Keywords:** Thar Desert, Dunes, Dust, Calcrete, Prehistory

THEME: S18 : TROPICAL GEOMORPHOLOGY

ABSTRACT NUMBER: 36

## GRAIN SIZE CHARACTERISTICS OF INTRA-FORMATIONAL CONGLOMERATE EXPOSED

## A LONG TYRSAD AND WEILOI AREA OF MEGHALAYA, INDIA

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The intra-formational conglomerate of the intracratonic Proterozoic Shillong basin of Shillong plateau are exposed along the road section of Tyrsad and Weilo area of East Khasi Hills, Meghalaya. The outcrops are characterized by the presence of rounded clasts with cementing material indicating the fluvial deposition. The conglomerate have variable well rounded and sorted clasts with sand, silt, clay, mud as cementing material. It may be inferred from the composition and distribution of matrix and cementing material that they are contemporaneous and have originated from the same environment of deposition. Grain size is one of the factors for deciphering the energy level of the environment of deposition. In the present study, 96 samples are evaluated for its grain size characterization and textural parameters analysis using the standard techniques. The results show that clasts size varies from medium sand to gravel which helps in understanding the depositional environment better. The grains size are mostly very coarse skewed, very well sorted and extremely leptokurtic suggesting that the rocks were deposited from a far source in a high energy fluvial depositional environment.

**Keywords:** Grain Size; Intra-formational conglomerate; Tyrsad; Weilo; Meghalaya

THEME: S18 : TROPICAL GEOMORPHOLOGY

ABSTRACT NUMBER: 39

## AN INTRODUCTION OF MORPHOLOGY AND PEDOLOGY OF TILLA-LUNGA TOPOGRAPHY, INDIA

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Tilla is the upland whereas lunga is the dried up channel which are connected with each other. Tilla-lunga topography is a regional rare phenomenon noticed in the Tripura State in India. The present paper investigated morphology and pedology of tilla-lunga topography that is unique, interesting but still undocumented. The morphology has been revealed from Satellite images (ETM+ and SRTM DEM), topographical map and litho-morphic section analysis. The pedological process has been revealed from testing and analysis of physical (texture and grain geometry) and chemical property (soil moisture, pH, Electrical Conductivity, Organic Carbon, available N and trace mineral) of around 105 soil sample collected from upper portion of tilla, slope and lunga. The grain geometry has been assessed from the flurocene image. The dendritic network of lunga forms a dried up drainage basin. The lungas are connected with present river course. Tilla is rib structure act as water divides among river basin. The whole topography belongs to the Pleistocene period. Correlation matrix between pH, EC and iron content indicates significant relation between pH and EC in lunga; OC and iron content in tilla slope. The leaching process of soil horizon formation in tilla is also hindered by the hard conglomerate layer in the upper portion of soil. The soil structures are not prominent in the tilla due to the younger soil formation.

**Keywords:** Morphology; Tilla; Lunga; Electrical Conductivity

THEME: S18 : TROPICAL GEOMORPHOLOGY

ABSTRACT NUMBER: 334

## PEDO-GEOMORPHOLOGY OF THE HILL REGION OF PURULIA DISTRICT, WEST BENGAL, INDIA AND ITS INFLUENCE ON LULC

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Soil and land forming process are unique and general environmental factors perform their role concomitantly. The factors are integral and play an important role in soil geomorphic evaluation of any landscape, as in this case the residual hill region of Purulia district, West Bengal, India. Soil is strongly linked to the landform upon which they develop. The dominant hill slope processes impact upon soil development in Ajothya and Garpanchakot hill regions of the district. Physical and chemical properties of the concerned soils change according to the elevation and slope of the region.

Application of geo-informatics is of great significance for identification of pedo-geomorphic characteristics of this region. The study has been done through review of published literatures, analysis of topographical maps, analysis of climatic data, soil sample analysis and analysis of SRTM and ASTER data through ArcGIS for surface analysis. Image transformation techniques have been applied for better interpretation of satellite data of this region. Another objective of this study is to identify and characterize the type, amount and condition of the present vegetation cover. The soil samples have been taken randomly with the change of elevation as well as slope from the top to the foothill of the region. It is found that even a minor change of elevation and slope has significant impact on pedo-geomorphic character of the region to produce different micro-geomorphic units.

**Keywords:** Pedogeomorphology, Geoinformatics, Hill slope, Purulia

THEME: S18 : TROPICAL GEOMORPHOLOGY

ABSTRACT NUMBER: 492

## SOIL-GEOMORPHOLOGY RELATIONSHIP IN ETCHPLAIN OF BRAZILIAN CENTRAL PLATEAU

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The Jardim River Basin is located in the Brazilian Central Plateau, an etchplain formed by residual reliefs, mainly tableforms supported by lateritic curauisses and quartzite rocks. The basin presents asymmetrical hillsides, evidencing a smooth slope on the right margin and steep slope on the left margin. Soil samples were collected on the right margin of the Jardim River in different geomorphological contexts. This area presents denudated relief with partially dissected headslope and depositional ramps. In addition, the soil depth varies according to position of the lateritic curauisses, kaolinitic saprolite or water table level. The objective of this work was to analyse the soil-geomorphology relationship of Jardim River Basin. Four toposequences were chosen with dissection and deposition reliefs. The soil interval (60-80 cm) was analysed with the following procedures: soil color, iron extracted with dithionite-citrate-bicarbonate (Fed) for the determination of crystalline iron, iron extracted with ammonium oxalate (Feo) for determination of amorphous iron and thermogravimetric analysis for quantification of gibbsite and kaolinite. In the dissected relief, the results presented the lowest value of Feo-Fed ratios, but the soil tended to be more yellowish, highlighting the iron washing. Moreover, the kaolinite-gibbsite ratio was the lowest value in this relief, indicating a higher proportion of gibbsite. The depositional ramps were more kaolinitic and had a higher proportion of Feo than the Fed, indicating that the ramps tended to have a greater subsurface water flow, altering the iron structure. These results showed that the dissected relief still has a mineralogical characteristic of the ancient tableform. Probably, the depositional ramps are an advanced stage denudation where the weathered top soil was removed. Besides that, the water table oscillations are more effected although the soil is more reddish.

**Keywords:** weathering; minerology; denudated relief; iron forms; kaolinite-gibbsite ratio

THEME: S18 : TROPICAL GEOMORPHOLOGY

ABSTRACT NUMBER: 688

## USING COSMOGENIC NUCLIDE <sup>10</sup>Be METHOD IN SANDSTONE KARST AREA IN THE SOUTHEASTERN OF AMAZONIAN REGION (BRAZIL): LIMITS AND POSSIBILITIES

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This research aims to investigate the morphogenesis of a tableland landscape with sandstones and paleokarst geofoms located in a humid tropical area within the Southeastern part of the Amazonian (State of Maranhão, Brazil). For that purpose, denudation rates affecting twenty-two catchments located in this flat-topped area at the water divide of four major river basins: Itapecuru, Mearim, Tocantins and Parnaíba, were determined using the in situ-produced cosmogenic nuclide <sup>10</sup>Be method. The deduced denudation rates ranging from 5.06 to 151.3m/Ma are much higher than those otherwise measured in similar contexts (tablelands) and all those ever measured in Brazil. Their correlation with morphometric parameters, lithological substrate, structure, tectonic and climate are weak and ineffective to explain the observed denudation rate variations. These significant denudation rate variations may be explained considering that the morphogenesis of the landscape are remaining evidences of a sandstone karstic system that was active in a recent



past. The deduced denudation rates thus registered the interference of sediments exhumed at a fast pace in a karstic landscape and do not reflect the actual denudation rates of the area. The denudation rates deduced from the in situ-produced cosmogenic nuclide <sup>10</sup>Be method should therefore be interpreted with caution in sandstone areas which present some evidences of karstic or paleokarstic geofoms.

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 18

## HIGH-FREQUENCY HOLOCENE GLACIAL CHRONOSTRATIGRAPHIES IN THE HIMALAYAN-TIBETAN OROGEN OFFER INSIGHT INTO PAST SHIFTS OF EARTH'S THERMAL EQUATOR AND COEVAL CHANGES IN THE SOURCES OF MOISTURE

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Despite the preservation of abundant young moraines across the Himalaya, a comprehensive spatiotemporal assessment of Holocene glacial advances remains enigmatic. Likewise, interhemispheric past changes in intensity of major atmospheric belts associated with the shifts in Earth's thermal equator and coeval changes in the sources of moisture have also been poorly addressed. To gain insight into recent Himalayan glacial advances, high-frequency Holocene glacial chronostratigraphies are reconstructed in six glaciated valleys of the Himalaya: Bhagirathi, Hamtah, Kulti, Karzok, Lato, and Stok. Glacial geomorphological assemblages in respective valleys are mapped in the field using handheld GPS and are additionally aided by Google Earth satellite imageries. Holocene local chronostratigraphies are developed using cosmogenic Be-10 surface exposure dating of 76 moraine boulders. These new and 424 published Holocene Be-10 ages are compiled to reconstruct regional Holocene glacial chronostratigraphies across the orogen. In addition, to gain insight of spatial pattern of Holocene glacial advances, glaciated valleys with similar present climate are clustered together into six broad groups utilizing the CRU CL 2.0 and TRMM climate data and using Cluster Analysis and Principal component analysis. Reconstructed regional Holocene glacial stages indicate several short-lived glacial advances across the orogen: at ~12.9, ~11.5, ~10.2, ~9.2, ~7.8, ~4.1-5.6, ~3.3, ~2.8, ~2.5, ~1.9, ~1.3, ~0.97, ~0.67, and ~0.33 ka. More extensive glacier advances and larger change in equilibrium-line altitudes have occurred during the early Holocene whereas progressively restricted advances have been observed in the later part. Overall, regionally uniform extensive early Holocene glacial advances correspond to northerly shifts of ITCZ and enhanced summer monsoon, whereas cooler late Holocene glacial advances are likely synchronous with changes in the north Atlantic. Identical pattern of Holocene glacial advances is also reported in New Zealand and in low Latitudinal regions and is likely attributed to shifts in major atmospheric belts and North-South linkages.

**Keywords:** Holocene;TCN;Himalaya;ITCZ;Paleoclimate

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 24

## AN ATTEMPT TO IMPROVE DATING OF PERIGLACIAL LANDFORMS IN HIGH MOUNTAIN ENVIRONMENTS USING SCHMIDT-HAMMER EXPOSURE-AGE DATING

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Rock glaciers and patterned ground are among the periglacial landforms characteristic for the alpine periglacial zone in high mountain environments worldwide. They may provide valuable palaeoclimatic information due to their inherent climate forcing. One common challenge constitutes the precise dating of many of those features as applications of many conventional numerical dating methods prove difficult or impossible.

The Schmidt-hammer exposure-age dating method (SHD) utilising numerical TCND(Terrestrial Cosmogenic Nuclide Dating)-ages as fixed points to calculate a calibration curve for R(Rebound)-value data. Given homogenous local or regional lithology, the sample sites for TCND do not necessarily have been located on the investigated periglacial landforms but monochronous surfaces like moraines or even bedrock. The resulting local or regional calibration curves can eventually be applied to many features avoiding common problems of representative sampling.

Two case studies will be presented to show the potential of SHD for the dating of periglacial landforms. Rock glaciers in the Ben Ohau Range, Southern Alps, New Zealand, have been investigated by sampling transects along their flow lines. They reveal continuous trends of decreasing Schmidt-hammer R-values (indicating more intense weathering and longer exposure) from their apex towards their lowermost ridges. The rock glaciers must have experienced uninterrupted activity during long periods of the Holocene. Their ages support the hypothesis of rock glacier initiation around Termination 1 contrasting with conventional views of slowly but continuously retreating glaciers during the Holocene.

The second case study demonstrates the application of SHD to achieve age constraints of patterned ground on Juyflya, Jotunheimen, Norway. The results reveal that stabilisation of stone rings commenced much earlier than anticipated in early Holocene. Surprisingly it does not show any relationship to fluctuation of the regional permafrost limit during the Holocene. Therefore, other factors must be taken into consideration for explaining the timing of their maximum activity.

*THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY*

**ABSTRACT NUMBER: 71**

## **THE VARIABILITY AND UNIQUENESS OF CIRQUES IN THE SCHLADMINGER TAUERN (EASTERN ALPS, AUSTRIA): A MORPHOMETRIC ANALYSIS**

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Geomorphologists celebrate the mountain group of the Schladminger Tauern for its superb landforms of glacial erosion. Hikers celebrate it for its scenic quality. The cirques of this non-glacierized mountain group straddling the main divide of the Eastern Alps are of unusual density, frequently arranged in cirque stairways and every second one has a lake.

The data base for analysing morphometry, allometry and cirque aspect distribution included all 76 cirques of the mountain group, regardless of their development stages. Morphometric variables and measurement procedures were defined in order to achieve optimal comparability with existing morphometric cirque studies.

Three prominent results are noted: (i) cirques of the study area are larger than elsewhere, but most conspicuous is their relatively deep incision; (ii) there has been an above average rate of glacial downcutting; and (iii) analysis of aspects indicated an almost symmetrical cirque development.

The superb cirque landscape of the study area may be explained by a combination of two factors. Firstly, by the delimitation of the study area, embracing the most famous cirque landscape of the Eastern Alps. Extension of the survey to adjacent mountain groups with softer rock types would probably lower mean values. Secondly, as cirque enlargement is thought to primarily occur during periods of restricted glaciation, when glaciers are largely constrained to their cirques, the intermediate altitude of the study area on the main divide of the Eastern Alps was important. During glacial maxima the coalescent alpine net of ice streams extended to this region. But far longer times of the glacial periods were characterized by local glaciation with separate cirque glaciers.

**Keywords:** Cirque; Glacial erosion; Morphometry; Allometry

*THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY*

**ABSTRACT NUMBER: 136**

## **DRAINAGE RE-ORGANIZATION AT THE SE MARGIN OF THE SCANDINAVIAN ICE SHEET, NW RUSSIA**

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There has been a long debate on flow re-routing in North-Western Russia during the LGM. Kvasov (1975) proposed large-scale re-organization of drainage both during the LGM and in postglacial time compared to that before the last glaciation. He assumed the existence of significant glacier-dammed water overflows from the then-existing Lake Komi (Rivers Pechora and Vychegda) and upper

reaches of Rivers Volga and Dnieper into the middle Volga basin and further into the Caspian Sea, which caused, according to Kvasov, the Pleistocene highest sea level stage – the Early Khvalynian transgression. Also, Kvasov suggested that before the LGM, the upper parts of Dnieper and Volga fluvial systems partly drained into the Baltic Sea, partly were not existing at all, and present-day drainage patterns are of very young, postglacial age. This concept was supported by a number of recent workers (Lavrov, Potapenko, 2005; Larsen et al., 2006, 2013; Lysa et al., 2011, 2014). However, there is strong geological and geomorphological evidence that the magnitude of glacier-induced flow re-routing during MIS 2 was much less than has been assumed. Here, we focus on three case studies from the so-called Kel'tma and Ugra spillways, to show that they did not operate in MIS 2, and from the upper Volga River spillways at Plios and Tutaev to illustrate the still unclear mechanism and age of their formation.

This study contributes to the Russian Science Foundation (RSF) Project No. 17-17-01289.

**Keywords:** glacial dammed lakes, spillway, flow rerouting, MIS 2

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 196

## GLACIAL GEOMORPHOLOGY AND GLACIER EVOLUTION OF MOUNT ARARAT/AĞRI DAĞI (EASTERN ANATOLIA, TURKEY)

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This work presents the results of a novel survey of geomorphological features and glaciers' evolution of Mount Ararat/Ağri Dağı in Eastern Anatolia (Turkey) a volcanic complex covered by the unique ice cap of the Near East. The massif is the result of multiple volcanic phases, and present day landforms are the results of subsequent and overlapping glacial, periglacial, and slope processes.

The geomorphological mapping of this area was firstly performed on the basis of desktop studies, by applying remote sensing investigations on high-resolution satellite imagery (PLEIADES and SPOT) and a preliminary draft of the map was crosschecked in the field. Collected data suggest that the Ararat glaciation played a crucial role in the evolution of the massif landscape. The Ararat glaciation is characterized by a wide ice cap with four ice bodies flowing downward from the summit plateau. For the first time, we assess that three of these glaciers are characterized by a thick debris cover (> 20 cm) that strongly influences surface melting. Coupling remote-sensing investigations with the field survey we estimated a glacier coverage of ca.  $7.28 \pm 0.03$  km<sup>2</sup>, including  $1.82 \pm 0.01$  km<sup>2</sup> of debris-covered ice surface. The analysis of multi-temporal satellite images (Corona, Landsat, SPOT, and Pleiades) allowed reconstructing the evolution of the Ararat glacier. From 1976 to 2015, we observed a glacier surface retreat of ca. 30%; this rate is comparable to the extent of the recent glacier shrinkage in the Alps, whereas it is higher to the rate reported for other Asian glaciers. Moreover, high-resolution satellite imagery highlighted the occurrence of a debris-covered body of dead-ice in the Ahora Gorge (NE flank of the volcano). The morphological characteristics and the historical sources reporting on a wide landslide suggest that an abrupt glacial surge occurred in 1840, possibly as a consequence of a phreatic explosion.

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 310

## GLACIER DYNAMICS IN THE CHANGME KHANGPU BASIN, SIKKIM HIMALAYA (INDIA) SINCE 1974 TO 2016

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Glaciers being physically complex and dynamic in nature are more sensitive to change of climate. Therefore, the present burning issue of climate shift necessitates attention on an accurate analysis of glacier dynamics of the Changme Khangpu Basin of Sikkim Himalaya. The objective of this study is twofold: (1) to generate a glacier inventory map for the Changme Khangpu Basin; and (2) to investigate spatial patterns of glacier area changes from 1974 (Corona KH9) to 2016. The glacier inventory map has been generated according to GLIMS Classification, based on an updated 2014 Landsat 8 (OLI), Sentinel-2A satellite image (2016) and Shuttle Radar Topography

Mission (SRTM) along with Google Earth Imageries. The Landsat satellite images (1988, 2001 and 2014) were atmospherically rectified by converting DN value into TOA reflectance values and have been further used for calculating the different indices (NDSI and NDWI), elimination of impurities (e.g. shadow, fresh snow etc.) and PAN Sharpening of multispectral bands. The high resolution declassified image Corona KH9 (1974) was rectified using the Sentinel-2A image with 100 to 190 GCPs.

The Changme Khangpu basin consists of 60 glaciers (including rock glaciers) covering an area of  $77.94 \pm 1.93$  km<sup>2</sup> in 2016. The rock glacier has been excluded for the change detection of glacier in this study. The loss of glacier area was  $-20.30 \pm 2.43$  km<sup>2</sup> ( $95.93 \pm 1.64$  km<sup>2</sup> in 1974 to  $75.62 \pm 1.8$  km<sup>2</sup> in 2016) along with decreasing total number from 56 to 48. It has been identified that glacier size, debris coverage, flowing direction are some determinant factors for reducing the glacier area in Changme Khangpu Basin.

**Keywords:** Glacier extent, Climate change, NDSI, NDWI, Sikkim

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 327

## GLACIER ADVANCES AND SURGES IN THE HINDU KUSH-KARAKORAM MOUNTAINS (PAKISTAN): GEOMORPHOLOGICAL EVIDENCES FROM THE LATEROGLACIAL SEDIMENT ENVIRONMENT

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The peculiar mass balance and dynamics of the Karakoram glaciers became a major focus in the discussion on the present status and future evolution of the glaciation in the Himalaya Region. Despite the global trend of glacier ice loss, the Karakoram glaciers showed in the last decades partly positive mass balances or even rapid glacier advances. The paper presented here uses the lateroglacial sediment environments as geomorphological archives for the reconstruction of the glacial history and behavior. The Karakoram Range possesses the longest valley glaciers outside the Polar Regions. Thus they are accompanied over several tens of kilometers by sediment accumulations at their lateral margins and contain ample evidence of locally distinct glacier changes. The results are based on a long-term empirical field study carried out during 12 expeditions in between the years 1992-2013 to the Karakoram. Based on a glacial landsystem approach, relative dating of glacial landforms and 14C-sampling of organic material preserved in the lateral moraines were undertaken to reveal the glacial changes. Multi-temporal comparison of photos and satellite images and reports from early travelers were examined. Interviews with local inhabitants, using the lateroglacial environments as pasture grounds, gave valuable information on the most recent glacier dynamics. Glacier surges with extreme vertical changes of the glacier surfaces in very short time periods could be documented. The recent glacier changes have even destroyed the geomorphological traces of the older Neoglacial glacier extent. Specific landform associations of the lateroglacial sediment system will be presented in selected case studies. Overall, the present study provides a contribution to the only scarcely available empirical field data of these remote mountain areas for a better understanding of the glacier dynamics.

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 339

## THERMAL EROSION IN THE PRO GLACIAL OF THE GEPATSCHFERNER GLACIER, EASTERN EUROPEAN ALPS

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Thermal erosion describes the surface volume loss due to thawing of ice in a sediment matrix and the drainage of the water eroding finer sediments. This process has been described in pro glacial areas of mainly northern regions and it was hypnotized that it might have even greater significance in the Alps, since the glacier retreat rate, and therefore the exposure of unconsolidated sediments to erosion, is greater compared to Norway, Svalbard, or Iceland. Thermal erosion in lateral moraines affects the local slope stability and water budget,

as well as the quantification of sediment flux via imaging methods, such as LIDAR, TLS, and SfM.

For the detection of thermal erosion, springs welling from the lateral moraines were analyzed monthly for temperature, electrical conductivity,  $\delta^2\text{H}$ , and  $\delta^{18}\text{O}$ . Results show that the measured parameters can differentiate between “ICE” and “NOICE” springs. Using a long-lived anthropogenic nuclide  $^{129}\text{I}$  the relative dating of the waters were possible, giving information on the existence of permafrost or recent ice. Electric resistivity measurements support the hydro-chemical results and suggest the existence of ice lenses in the subsurface. Ice ablation and discharge measurements allowed first rough estimates of the thermal erosion volume caused by the melt out and drainage of ice from the matrix.

**Keywords:** Dead ice, stable isotopes, radio nuclides, hydro-chemical detection

*THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY*

**ABSTRACT NUMBER: 409**

## **RECESSION PATTERN AND GEOMORPHOLOGICAL CHANGES OF MENTHOSA GLACIER, LAHAUL HIMALAYA (INDIA)**

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Recession pattern of Menthosa glacier has been documented using satellite images between 1975 and 2016, in addition to the in-situ measurements since 2006. This is a valley type glacier of the Miyar basin, consisting of 76 glaciers, located in the NW-Himalaya. Much of the precipitation receives from the Westerlies yet the SW Monsoons also brings in considerable moisture and precipitation to this valley. ASTER DEM V2 has been judiciously applied to compare elevation difference in the frontal zone, in addition to the repeated hypsometric measurements on the yearly basis. Snout area of the glacier was further mapped using Trimble R6 fully robotic Total Station and Trimble R5 RTK differential global positioning system. Similar to many other glaciers across the Himalayan Range, this glacier has also recorded varied recession between satellite image years; 1975, 1990, 2005, 2015 and 2016. However, it is interesting to note that the rate of recession has greatly reduced from  $\sim 10$  m/y in the last decades of previous Century to less than half in a similar temporal scale of this century. Observable changes is obvious at the frontal zone (4.26 m per year), with regular switching of snout and thinning at the left margin. Contemporary ablation area of this glacier stands at 37.3% of the total, encased in two defined pairs of high lateral moraine. Low frequency ground penetrating radar was used to determine the ice-depth of the glacier at the accumulation and ablation regions of this glacier. Thickness of ice at the terminal area is measured at 44.5 meters and 79-81 meters in the accumulation area, respectively. These geophysical techniques have been employed to calculate the total mass of present ice of this glacier, which can be extrapolated for estimation to calculate approximate fresh water reserve in most of the glaciers in the Himalaya.

*THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY*

**ABSTRACT NUMBER: 445**

## **DEBRIS COVER EVOLUTION AS A FACTOR OF MORPHOLOGICAL CHANGES OF THE DJANKUAT GLACIER, CAUCASUS**

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Three consequent debris thickness surveys, undertaken in 1983, 1994 and 2010 all over the surface of the Djankuat Glacier in the Caucasus, the best explored in Russia, revealed that superficial moraine became thicker by 70 cm near the terminus during 1983–2010 whereas total lithogenic matter volume experienced 141% increment. Currently ongoing deglaciation due to protracted rise of ablation season air temperature (almost 10C since 1968), coupled with concomitant freezing-thaw shattering, provokes intensive and frequent rockfalls (particularly tremendous in 2001-2003). They promote hereby colluvium delivery onto the glacier snout - mainly at the expense of belts with the least ice thickness, i.e. on the steep slopes of rocky framework over the firn basin which are highly unstable due to stress relaxation. Covering only 2% of the entire glacier area in 1968, debris share grew up to 13% by 2010, resulting thereby in 6.5-fold enlargement during 42 years. This process influenced mass balance values and distorted its spatial pattern. In general, debris cover renders a screening effect upon melt-rate, and thereby glacier-derived liquid bulk run-off turns out to be reduced annually by ca. 20% on average. Debris surface differs from clean ice by its thermo-physical properties - it is characterized by its peculiar heat

balance structure. After studying influence of debris cover on ablation and considering its anticipated evolution, glacier topography by 2025 was predicted based on HadCM3 climate model (A2 scenario). Downscaling air temperature and precipitation led to a forecast of Djanguat mass balance patterns and glacier morphometry for every year till 2025. Debris-covered parts would experience lowering 7-15 meters less than clean ice, and lowering rate would be 42-45% smaller. Hence, at the current stage debris cover evolution seems to have significance for glacier behaviour comparative with that of climate change factor.

**Keywords:** glacier, debris, deglaciation, mass balance, forecast

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 461

## CRYO-CONDITIONING OF LANDSCAPE EVOLUTION REVISITED

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While cold regions for a long time have been regarded geomorphic hot-spots, both due to the effects of glacial erosion and frost weathering, the effects of these processes have also been questioned in the context of long-term landscape development. Along the passive margins of the North-Atlantic, the general landscape relief has traditionally been attributed to tectonically uplifted ancient peneplains. Outside areas of selective linear erosion, the Quaternary ice sheets were considered to preserve older landscapes beneath cold-based ice. Mainly, glaciers and periglacial processes were treated as distinctly different scientific domains and interactions between glaciers and permafrost less investigated. We claimed in 2011 that cryotic ground conditions have a significant influence on landscape development, both as a driver for individual processes but also by controlling interactions between surface processes, and developed the concept cryo-conditioning of landscape evolution. Researchers had started exploring climatic controls on summit heights using the terms glacial buzzsaw and, somewhat later, periglacial buzzsaw. Accordingly, the origin and altitude of high elevation low relief surfaces (HELRS) such as along the Norwegian passive margin, were reinterpreted as surfaces created by late Neogene and Quaternary cold-climate processes, lifted due to isostatic rebound.

In this presentation, we will revisit the cryo-conditioning concept in the light of new developments within landscape evolution modelling. Modelling of long-term landscape development from the periglacial buzzsaw and glacial erosion heavily relies on using temperature changes in time (Quaternary climatic cycles) and space (especially effects of altitude) as model input. This is a basic point in cryo-conditioning, as it assumes temperature as the main driver for the relevant geomorphic processes and process interactions.

**Keywords:** cryo-conditioning; landscape evolution modelling; process interaction; permafrost; glacial erosion

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 462

## SAFEGUARDING AND SUSTAINING LONG RECORDS OF SURFACE DISPLACEMENT MEASUREMENTS ON PERIGLACIAL SORTED CIRCLES

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Modelling of the Earth System response to climate change benefits from records documenting sub-system response across climatic perturbations. For many of the processes that today are incorporated within an ESM, we do not have this advantage. One example is cryoturbation, the overturning of soil in permafrost areas, suggested highly relevant for the carbon budget. Within ESMs cryoturbation is treated as a diffusive process, but there are no physical or empirical models available that can predict the response of cryoturbation (in terms of increasing or decreasing soil overturning) as a function of changing atmospheric temperatures. In order to develop such models, geomorphic records documenting the system response to a changing climate would be advantageous. The process itself leaves no proxy records, except a mixture of soil organic carbon of variable age beneath the ground surface, so recorded values of soil surface displacements through time is needed for this purpose.

During the 1980'ies, before the onset of accelerated climate warming in the Arctic, Bernard Hallet initiated measurements on the stone circles on Kvadehuksletta, Svalbard. The stone circles are a remarkable example of the effects of large-scale cryoturbation. Although

these measurements are not continuous, the installations are partly still in place. They were re-measured in 2010, 2015, 2016 and again in September 2017. The purpose of this presentation is to document our work on safeguarding the remains of these installations, and to transform the methodology using Structure-from-Motion from ground-based images, to enable continuing these measurements into the future. Our goal is to document how ground surface movements and cryoturbation have responded to the amplified effects of global warming at high latitudes, and to understand this response.

**Keywords:** cryoturbation, global warming, earth system modelling, SfM, sorted circles, long measurement series

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 485

## MORPHODYNAMICS OF GLACIAL AND PERIGLACIAL ENVIRONMENTS AND RELATED HAZARDS: CASE STUDIES IN THE MOUNTAINS OF NORTHERN ITALY AND WESTERN CANADA

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The analysis of glacial and periglacial morphodynamics and the study of past climate changes are important tasks for scientific and management purposes within recently deglaciated areas. Climate changes and related effects occurring in the last decades cause uncertainties on the survival of glaciers and affect stability of mountains.

A systematic study of natural hazards related to glacial and periglacial morphodynamics of the Western Alps in Italy and the Coast Mountain and the Cordillera in Canada started only in the early 1990s. Since then, several instability phenomena of these glacial and periglacial environments have been analyzed, as well as their relationship with the climatic and environmental changes taking place since the end of the Little Ice Age. From the beginning of the 2000s, it became clear that environmental changes related to global warming were accelerating so quickly in high elevation and glaciated mountains.

Within this perspective, we started an international effort to collect data and compare geomorphic processes occurring in the high mountains of two distant geographic areas, but with similar physiographic characteristics. Aims was to provide scientists and local administrations with the most advanced knowledge and tools to deal with climate-related instability events occurred in glacial and periglacial areas of the Italian Alps and of Western Canada, such as landslides, debris flows, glacial lake outburst floods, ice avalanches. We identified the types of instability mainly conditioned by climate change and discussed hazard scenarios. Methodological approaches used in Italy and Canada for studying the impacts of degrading permafrost and glacier ice loss on mountain environments were compared, and strategies for communication and dissemination of results were addressed. Studies have shown differences and similarities among the two areas, which highlight the effects of regional/local physiography and climate and, at the same time, confirm the global scale of the changes underway.

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 540

## THE POSSIBLE GEOMORPHOLOGICAL EVIDENCES OF PALAEO-SURGES

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A geomorphological activity of surge glaciers is one of the problems of the glacial geomorphology. The system of reliable geomorphological evidences of surge glaciers would allow reconstructing the glacial surges of the past (or "palaeo-surges").

There was the attempt by D.J.A. Evans and B.R. Rea to reveal indicator landforms (push moraines, crevasse-fill ridges, concertina eskers, flutings, hummocky moraine) in the marginal zones of glaciers that would indicate the surge nature of the glacier advances. A significant part of the assumed landform indicators is also can be found in the marginal zones of non-surge glaciers.

The Spitsbergen archipelago is one of the regions of modern glaciation, where surge glaciers are widespread. There are reliable data on the surges of 145 glaciers (about 13% of large glaciers) of Spitsbergen. However, according to some researchers, from 57% of the total area of glaciation up to 90% of all glaciers in Spitsbergen can be classified as surge glaciers.

As a result of the geomorphological mapping of the marginal zones of two non-surge glaciers in Spitsbergen (Aldegonda and Gronfjodenbreen) the analysis of the spatial distribution and configuration of the landforms bearing information on the maximum limits of ice advance, ice movement directions and steps of ice degradation, and correlation it with the conception of the surge glacier behavior in its various dynamic phases (active and quiescent) was proposed in addition to the evidences of the landform indicators.

This idea was tested on some modern surge glaciers of Spitsbergen (for example Comfortlessbreen).

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**Keywords:** glacial geomorphology; palaeo-surges; landforms; marginal zones; dynamic phases.

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 567

## POST-GLACIAL ROCK-SLOPE FAILURES IN ICELAND: SPATIAL DISTRIBUTION, TEMPORAL PATTERN AND TRIGGERING FACTORS

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At the scale of Iceland, rock-slope failures are numerous, especially in the Tertiary basaltic formations in the northern, eastern and north-western regions of the island. At a regional scale, the spatial distribution of rock-slope failures depends on several factors, such as the timing of the deglaciation and its consequences (e.g. post-glacial rebound, ...). At a local scale, the spatial distribution of rock-slope failures is also correlated with deep-seated gravitational slope deformation (DSGSD).

The temporal pattern of rock-slope failures is fundamental for the understanding of post-glacial events. In the Skagafjörður district, central northern Iceland, seventeen rock-slope failures have been investigated to determine their dating. A geomorphic survey was carried out to identify and characterize landform units, both on the deposits and in their immediate vicinity. In this coastal area, we used landform assemblages including the relationship between rock-slope failures and raised beaches formed by glacial isostatic rebounds; the chronology of the latter has been established by earlier works. We also carried out profiles within the depressions upon the rock-slope failures; this stratigraphic approach provided results from two dating techniques: radiocarbon dating from wood remnants and tephrochronology, both of which were complemented by age-depth model calibration. The results confirm that all rock-slope failures potentially occurred before the Boreal (8 ka), while 94% occurred before the Preboreal (10 ka). They all potentially occurred shortly after the glacial retreat following the maximal ice extent and the Preboreal. This study shows the relationship between the deglaciation and destabilization of slopes during the paraglacial phase (debuttrekking, decompression, glacial isostatic rebound, seismic activity, etc.), which are also controlling factors favourable to landsliding but difficult to identify for each individual rock-slope failure specifically.

**Keywords:** Landslide; Deglaciation; Holocene; Paraglacial geomorphology; Iceland

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 570

## SURFACE MORPHOLOGY, INTERNAL STRUCTURE AND WATER STORAGE CAPACITIES OF ROCK GLACIERS IN THE DRY CENTRAL ANDES OF ARGENTINA (30-33°S)

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The extensive periglacial belt in the semiarid to arid Andes hosts one of the highest rock glaciers concentrations in the world. Here, rock glaciers develop impressive forms up to several kilometers in length covering large areas up to 3 km<sup>2</sup> considering a single landform. The surface morphology of intact rock glaciers with ridges and furrows indicates ice-rich material compositions that allow creep deformations. Due to their size and abundance, massive ground ice and ice-rich permafrost bodies in rock glaciers potentially constitute significant water reservoirs and sources for this part of the Andes – and particularly the foreland. The seasonally thawing active layer is an important melt water aquifer contributing to runoff during summer time. The overall water storage capacities in these landforms and the amount of runoff contributions, however, are largely unknown.

Ice contents are quantified at the talus-derived rock glacier “Dos Lenguas” (30°S) and the giant debris rock glacier system “Morenas Coloradas” (32.5°S). The sites are located at the northern and southern edges of the regional study area. It should be highlighted that the total surface area of intact rock glaciers (309 km<sup>2</sup>) is significantly larger than those of ice glaciers (240 km<sup>2</sup>) and debris-covered glaciers (104 km<sup>2</sup>), respectively. The material composition of both rock glaciers is quantified by geophysical four-phase modeling, which is based on multiple electrical resistivity and refraction seismic tomographies (survey lines > 3 km). First results of the geophysical long and cross sections indicate heterogeneous ice content distributions that are closely related to surface characteristics of the rock glaciers. High resolution DEMs of both rock glaciers are derived by structure-from-motion techniques using images taken from unmanned aerial vehicles (UAV). The interrelation of surface morphology and material composition will be finally used for sophisticated quantification of water storage capacities of both rock glaciers.

*THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY*

**ABSTRACT NUMBER: 648**

### **SORTED PATTERNED GROUND IN SLOVENIAN KARST CAVES**

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Periglacial landscapes are characteristic for high latitudes or high elevations. One of the most distinctive periglacial landscape landforms is patterned ground. Karst caves can be affected by cold air and ground temperature anomalies and can host periglacial conditions in milder climates. Patterned ground has been reported from several karst caves in Slovenian Dinaric Mountains and Alps. The aim of our study is to identify environmental conditions responsible for patterned ground formation in karst caves using two karst caves as an example.

In cave Ledena jama pod Hrušico, thirteen 20-50 cm wide stripes of coarse limestone debris developed on fine cave sediment on an inclined slope of side passage. The grain size of the fine sediment is predominantly silty (80 %) and susceptible to frost heaving. A geoelectrical survey and drilling revealed one metre sediment thickness. Several freeze-thaw cycles occur at the sediment ground surface in winter due to cave temperature fluctuations. Cave air temperature measurements show that surface air enters the cave only when its temperature drops below the cave air temperature, which results in preferentially cold and oscillating winter temperatures and the formation of a cool air pool in the summer. Similar climatic conditions are present in the Barka Cave where around 20 distinctive sorted circles with diameters ranging from 30 to 70 cm developed in a small side passage.

Karst caves can contain significant amounts of silty sediments that accumulated during flood events when the caves were situated in the floodwater zone or as an insoluble limestone residue. Frost shattering of parent bedrock is a potential source for coarse debris. The cold climatic conditions that result from cave morphology sustain low ground temperatures in summer and cause freeze-thaw cycles in winter, which result in frost heaving that causes sediment sorting.

*THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY*

**ABSTRACT NUMBER: 680**

### **THE POSSIBLE GEOMORPHOLOGICAL EVIDENCES OF THE GLACIAL PALAEO-SURGES**

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A geomorphological activity of surge glaciers is one of the problems of the glacial geomorphology. The system of reliable geomorphological evidences of surge glaciers would allow reconstructing the glacial surges of the past (or "palaeo-surges").

There was the attempt by D.J.A. Evans and B.R. Rea to reveal indicator landforms (push moraines, crevasse-fill ridges, concertina eskers, flutings, hummocky moraine) in the marginal zones of glaciers that would indicate the surge nature of the glacier advances. A significant part of the assumed landform indicators is also can be found in the marginal zones of non-surge glaciers.

The Spitsbergen archipelago is one of the regions of modern glaciation, where surge glaciers are widespread. There are reliable data on the surges of 145 glaciers (about 13% of large glaciers) of Spitsbergen. However, according to some researchers, from 57% of the total area of glaciation up to 90% of all glaciers in Spitsbergen can be classified as surge glaciers.

As a result of the geomorphological mapping of the marginal zones of two non-surge glaciers in Spitsbergen (Aldegonda and Gronfjodenbreen) the analysis of the spatial distribution and configuration of the landforms bearing information on the maximum limits of ice advance, ice movement directions and steps of ice degradation, and correlation it with the conception of the surge glacier behavior in its various dynamic phases (active and quiescent) was proposed in addition to the evidences of the landform indicators.

This idea was tested on some modern surge glaciers of Spitsbergen (for example Comfortlessbreen). The reported study was funded by RFBR according to the research project No. 16-35-00274 мол\_а.

**Keywords:** glacial geomorphology; palaeo-surges; landforms; marginal zones; dynamic phases.

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 693

## SURGE GLACIERS IN THE KARAKORAM: DISTRIBUTION AND CHARACTERISTICS

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The irregular behavior of Karakoram glaciers has generated some controversy, and how they differ from or are out of phase with other Himalaya ranges. Inconsistent behavior among the region's own glaciers was long and widely observed. The paper investigates this as a problem of response to climate change where there is an exceptional concentration of surge-type glaciers. A comprehensive overview is presented of known, newly discovered and suspected examples. Evidence comes from historical archives and recent satellite coverage, documenting surface displacements and elevation changes in successive images and DEMs. Higher numbers and greater diversity of surge events are reported, including 'Alaskan' and 'Svalbard' surge types, mini-surges, and kinematic waves. The notion of surge-modified developments introduces a variety of indirect effects of surge activity on other ice streams. The greatest disturbances occur in active surges, but surge-related impacts extend to much more of the total ice cover and hitherto neglected roles of the longer 'quiescent' phases. These phenomena are shown to intervene in, and may be decisive for, anomalous climate relations. In surge-type and surge-modified ice, mass balance profiles and changes, and sediment delivery, depart from typical findings elsewhere. Surging means that mass balance budgets are unique to each glacier, and out-of-phase with climate, with major consequences for interpreting ice fluctuations as well as geomorphic signatures of recent changes. The concentration of surge-type glaciers proves critical for understanding the depositional record of Quaternary glaciations, as well as tracking how global climate change affects the region now.

**Keywords:** Surge glaciers; Karakoram; Surface Displacements; Elevation Changes; DEMs

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 721

## STRESS PATTERN IN THE GLACIERS AND ITS RELATIONSHIP WITH THE ICE THICKNESS AND BEDROCK SLOPE – A CASE STUDY FROM SVALBARD ARCTIC

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Glacier movement depends upon various factors, especially its thickness, surface slope and the bedrock slope. Stress is developed in the glaciers due to its movement and remains unequal throughout the glacier body and is responsible for the formation of crevasses. The continuous change in the stress pattern in the glacier body forces the crevasses to change their shape and intensity. Svalbard archipelago located within the Arctic Circle is highly glacierised and at present about 60% of the land is covered by the glacier and perennial snow.

The Vestre Broggerbreen (VB) glacier system in the Ny-Alesund area of this region is separated into southern VB-I and the northern VB-II glaciers by a medial moraine with overall extension towards ENE. Ground Penetrating Radar (GPR) studies were carried out in this glacier system to estimate the ice thickness and the bedrock slope. Accordingly, the stress is calculated to be in the order of 20 to 60 kPa. In the VB-I glacier the highest stress of 60 kPa and the least stress of 20 kPa is concentrated near the equilibrium line of altitude (ELA) and the glacier snout respectively. In the lower part of the ablation zone of this glacier, the glacier stress pattern shows two longitudinally similar patterns. In the VB-II glacier, the highest stress of 58-60 kPa is observed in a very small area within the accumulation zone. There are two distinct least stress zones observed near ELA and the ablation zone in VB-II glacier whereas, the majority area in the upper ablation zone experiences 40-50 kPa. This study shows that the stress pattern in this glacier system is more dependent upon the bedrock slope than the surface slope, though the later one is responsible for the formation and modification of the crevasses.

**Keywords:** Stress Pattern; Glacier; GPR; Svalbard; Arctic

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 743

## LANDSCAPE ANALYSIS AND GEOMORPHOLOGICAL MAPPING FOR INVESTIGATING THE INTERACTION OF CLIMATE CHANGES AND CRUSTAL THERMO-MECHANIC VARIATIONS IN DRIVING EAST ANTARCTIC GLACIAL HISTORY SINCE LATE CENOZOIC

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Geomorphic processes acting under glacial environments leave and have left geological signatures recognizable in landform assemblages documenting the close relationship between climate changes and glacial response. On the other hand, the glacial system is highly sensitive to any other external event that may affect energy balance. Our aim is to understand how, and to what extent, the thermo-mechanic evolution of the lithosphere in the northern Victoria Land (NVL), during the Late Cenozoic, interacted with global climate changes in driving the behaviour of the East Antarctic glacial system that, in turn, induced ice volume variations and consequent sea level changes.

We conducted a regional landscape analysis in Victoria Land for investigating glacial history in order to assess the relationship between the East Antarctic Ice Sheet (EAIS) and the other component of the complex Antarctic glacial system.

Geomorphological survey allows to recognize older volcanic and intrusive rocks with well-developed alpine topography (sculptured by wet-based glaciers) and younger volcanic cones lacking these features. The alpine topography postdates the fluvial origin of the valley network and was sculptured after 34 Myr ago, when glacial conditions established in Antarctica. The establishment of hyperarid, polar-desert conditions on East Antarctica occurred about 14 Myr ago in the Dry Valleys, but seems to have occurred since ca 8 Myr in NVL.

Glacial deposits and geomorphologic features at the margin of EAIS reflect volume changes of the inland ice in the past. Glacial landforms on nunataks and surveyed in other ice free areas along the Transantarctic Mountains and on the coastal area thus provide a record of EAIS volume changes.

Crustal thermomechanical evolution and ice volume variations will be modelled since the onset of continental-scale Cenozoic glaciation with further focusing on the principal steps of Antarctic glacial history.

**Keywords:** Geomorphological mapping; Landscape Analysis; Glacial history; climate change; Cenozoic; Antarctica

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 744

## HOW DO PARAGLACIAL PROCESSES RESPOND TO RAPID ALPINE GLACIER RECESSION ?

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In the face of rapid climate warming, rapid glacier recession should lead to a marked increase in the spatial extent and intensity

of paraglacial processes operating in glaciated drainage basins: (1) as the glacier recedes, sediment flux becomes less dependent on relatively slow glacier surface transport; (2) proglacial streams are more able to migrate laterally than subglacial streams and so access sediment for transport; and (3) glacier debuttressing may aid the development of gullies that can dissect moraines and so aid hillslope to proglacial zone connectivity. However, we have very few data to quantify these processes at the time-scale of decades. Here, we make use of unique records of sediment export from 5 glaciated basins in the Swiss Alps, provided by records of the flushing of hydroelectric power installations. These records begin in the 1960s and 1970s and extend to present, and so cross a period of stable climate (the 1970s) to rapid warming (notably the late 1980s to early 1990s; and from the late 1990s). Every flush has a known sediment release volume and so we can obtain a weekly to daily record of sediment export. Hydraulic modelling suggested that sediment export was not a simple function of sediment transport capacity. Further, the effects of glacier recession on the rapid evolution of within basin sediment connectivity was found to be countered by negative feedbacks (e.g. within stream sediment sorting, alluvial cone formation beneath moraine-incising gullies). What seemed to be critical were periods of more rapid glacier retreat that leads to a continued supply of unworked glacial till before fluvial reworking of this sediment slowed sediment transfer and hence export rates. Thus, the transient increase in intensity of paraglacial processes following glacier recession seems to invoke geomorphic responses and negative feedbacks that may counter this increase in intensity quite rapidly.

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 770

## GLACIER AREA CHANGE IN THE JANKAR CHHU WATERSHED, CHANDRABHAGA BASIN, NW HIMALAYA BETWEEN 1971 AND 2016 USING SENTINEL 2A, LANDSAT AND CORONA KH-4B IMAGERY

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A glacier inventory of the Jankar Chhu watershed has been generated for the year 2016 using Sentinel 2A and ASTER Global DEM (GDEM V2) as the baseline data for change analysis. The Jankar Chhu watershed consists of 154 glaciers (larger than 0.02 km<sup>2</sup> in size) with a total area of 185.52 ± 3.84 km<sup>2</sup> including 82 glaciers with debris- cover tongue and comprising an area of 20.30 ± 0.42 km<sup>2</sup> (10.94% of total glacierized area) in 2016. Change analysis based on Corona KH-4B (1971) and Landsat ETM+ (2000) along with high-resolution Google Earth (GE) images was restricted to a set of 127 glaciers (covering an area of 181.36 ± 3.61 km<sup>2</sup> in 2016) due to cloud cover. Glacier area changed from 196.02 ± 2.27 km<sup>2</sup> (1971) to 181.36 ± 3.61 km<sup>2</sup> (2016), a decrease of 14.66 ± 4.26 km<sup>2</sup> or 7.48 ± 2.17% (0.33 ± 0.10 km<sup>2</sup> a<sup>-1</sup> or 0.17 ± 0.05% a<sup>-1</sup>). Clean-ice area decreased from 183.38 ± 2.12 km<sup>2</sup> (1971) to 161.56 ± 3.21 km<sup>2</sup> (2016), a decrease of 21.82 ± 3.85 km<sup>2</sup> or 11.90 ± 1.96%. Debris cover ice area increased from 12.63 ± 0.15 km<sup>2</sup> (1971) to 19.8 ± 0.39 km<sup>2</sup> (2016), an increase of 7.17 ± 0.42 km<sup>2</sup> or 56.77 ± 3.33%. Glacier retreat rates in the Jankar Chhu watershed were lower than previously reported studies.

**Keywords:** The Jankar Chhu watershed; Sentinel 2A; Corona KH-4B; Google earth; Debris cover ice

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 791

## PRESENT LANDSCAPE DEVELOPMENT AND GEO-RISKS IN THE THERMOKARST AREAS OF CENTRAL YAKUTIA, NE SIBERIA

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Spatial shifts in permafrost distribution have significant implications for natural ecosystems as well as human occupation habitats. The permafrost degradation may lead to a drastic terrain distortion and restructuring of local geomorphology-hydrology systems and vegetation cover. In Yakutia, the ongoing thermokarst-forming processes generated by the MAT increase of ca. 3C° over the past years induce progressive ground-ice melting and topographical subsidence due to the underground mass loss. From the 1970's, a spatial extension of thermokarst (alas) lakes (presently >16 000) in central Yakutia has been observed accelerated by global climate warming during the last decade. Our recent (2014-2015) field studies point to adependence of lake surface size on the total atmospheric precipitation and annual air temperature volume. Other factors, such as the site geomorphology and surficial geology, slope exposure,

meltwater drainage and vegetation, affecting albedo, may accelerate permafrost degradation and increase water supply into the existing/forming lakes. Analysis of satellite images and morphometric DEM analysis in the Tiungulyu area (50 km east of Yakutsk) show a major most recent albas basin expansion concentrated in places with the predominant SW/southern topographic exposure. Increased regional solar energy supply induces ground-ice retreat and activate thermokarstic processes with sub-surface water flows into the expanding lakes. Effects of collapses of deconsolidated grounds are observed in other settlements, particularly in the lowland locations. Except for the atmospheric warming, the thermokarst lakes experience enhanced level fluctuations also due to anthropogenic actions (pastoralist practices and forest logging) both expanding open lands with a higher thermal capacity because of the intensified summer insolation. A regular monitoring of the permafrost areas is essential for sustainment of local communities, infrastructure maintenance, as well as the central government economic planning.

**Keywords:** Central Yakutia; permafrost degradation; thermokarst lakes; MAT increase, geoenvironmental risks

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 794

## GLACIAL GEOMORPHOLOGY OF CHIRRIPO NATIONAL PARK, COSTA RICA

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The study of the high altitude environments in tropical regions is the key to understanding the climate conditions and their implications on the relief modeling during the Last Glacial Maximum (LGM). Different regions in Latin America: Mexico, Guatemala, Costa Rica and the Andes have imprints of advancing glaciers on the relict landforms that help to reconstruct the climate conditions in the past. The aim of this study was to analyze the glacial geomorphology and identify erosional and depositional glacial landforms in the Chirripó National Park, Costa Rica, using 1:25.000 map and Digital Elevation Model (DEM). Morphological analysis of high elevation environments within the study area resulted in the revising the equilibrium lines altitude (ELA), establishing the limiting elevation of 3195 masl for distribution of glacially modified slopes and identification of 73 lateral moraines within the elevation range of 3029 ± 443 m. These results give the new insights into reconstruction of the maximum expansion of alpine glaciation during the LGM and its impact on development of the surface morphology in the high-altitude region of Costa Rica.

The different studies of the glacial geomorphology of the Chirripó National Park and surrounding areas have been developed since the 1950s but this study gives, for the first time, a mapped area of more than 72 km<sup>2</sup> with high detailed information (1:25.000 scale) and explanation of seven erosional landforms (mountain slopes shaped by glacial action, cirques, arêtes, riegels, glacial capture escarpments, subhorizontal or sloping rocky surfaces with hilly morphology, and fluvioglacial cirques), and four depositional features (lateral moraines, ground moraines, moraine deposits, and glacial lakes). These morphologies give important imprints of the LGM activity in tropical high altitude reliefs.

The ELAs were calculate through the average altitude of lateral moraines resulting in an average of 3029 ± 443 m; with a clear difference in the measurement for each slope, being the Caribbean which has greater altitudes average (3145 m) than the Pacific counterpart with 2876 m. For the limits of the glacial modeled slopes of the Chirripó National Park have being extrapolated from a Digital Elevation Model (DEM) over 40 000 points giving as average of altitude of 3195 masl, surfaces were was evident a differentiation of the páramo vegetation, the presence of large areas of abraded rocks, and glacial morphologies. These glacial modeled slopes were divided in five sectors with different characteristics in their morphology and extent. The first sector has an ELA of 3201 m, the second unit of 3200 m, the third one of 3041 m, the fourth unit of 3269 m, and the fifth sector of 2903 m. This information gives new signals of glacial activity in lower altitudes and a better perspective of the Chirripó National Park.

**Keywords:** Geomorphological mapping, equilibrium line altitude, Last Glacial Maximum, tropical mountains.

THEME: S20 : MOUNTAIN GEOMORPHOLOGY

ABSTRACT NUMBER: 16

## DEVELOPMENTS IN MOUNTAIN GEOMORPHOLOGY OVER THE LAST DECADE

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During the period 2007-2016 three major developments in understanding of mountain geomorphology have occurred. (1) New

techniques for sensing Earth's surface and for characterizing Earth's shape have provided improved precision and accuracy in comparing mountain geomorphology at all spatial scales, especially with respect to morphology; (2) New understandings of disconnectivity in mountain geomorphic systems has led to development of more realistic models of sediment, solute and nutrient flux with focus on energy distribution and geomorphic work done in montane rather than high mountain systems, especially with respect to process; (3) New foci on the geomorphology of densely populated mountain regions has produced new understandings of mountain geomorphology in the tropical and sub-tropical montane biomes of the world, especially with respect to geomorphic "hot spots".

**Keywords:** mountain geomorphology; disconnectivity; energy; geomorphic work; "hot spots"

THEME: S20 : MOUNTAIN GEOMORPHOLOGY

ABSTRACT NUMBER: 129

## COMBINING GEOMORPHIC AND DENDROGEOMORPHIC INDICES WITH NUMERICAL MODELING FOR EVALUATION OF SNOW AVALANCHE ACTIVITY (TATRA MTS., POLAND)

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In the Tatra Mts. about 3700 avalanche paths were identified. The Żleb Żandarmerii, one of highly active and hazardous avalanche paths, with the longest history of avalanche observations, was chosen for studies of occurrence of large avalanches in context of current climate change. The studies examine how can weather data, remote sensing, dendrogeomorphic methods, morphometric analysis, morphodynamic measurements and avalanche modeling be combined to reconstruct avalanche history. It was looked at runout distance, return period, dynamics and geoecological, especially geomorphological implications of avalanches.

Geomorphological and dendrogeomorphic methods as well as modeling with the RAMMS numerical avalanche dynamics simulation software were used to obtain avalanche data. These data were supported by ninety years long series of weather data, archival avalanche observations, topographical maps, orthophotomaps and high-resolution DTM. Morphological and morphometrical analyses were used to identify avalanche effects in runout zone.

The largest avalanches reach the foot of the Żleb Żandarmerii counter slope. Their length, release volume, flow velocity and pressure can exceed respectively 1000 m, 80 000 m<sup>3</sup>, 45 m/s and 600 kPa. The results of study suggest that current climate warming has been accompanied by thinning and shortening of the duration of snow cover, as well as by an upward expansion of the timberline of up to 80 m since the mid-1920s. No distinct temporal trend was identified in the large avalanche return period since 1909, but their mass and intensity have declined.

It was found that ground relief may determine length of avalanche and control its lateral expansion. Oppositely forests and timberline expansion have no influence on the extent of the avalanches. The talus cone at the mouth of the Żleb Żandarmerii, classified as avalanche cone, evidences high avalanche activity.

The studies were financed by NSC project No. 2011/03/B/ST10/06115

**Keywords:** geomorphic and dendrogeomorphic indices; climate change; snow avalanches; Tatra Mountains

THEME: S20 : MOUNTAIN GEOMORPHOLOGY

ABSTRACT NUMBER: 138

## THE CHANGING HIMALAYAN FOOTHILL GEOMORPHOLOGY AND ITS INFLUENCE ON HYDROGEOLOGY: A CASE STUDY IN A PART OF EASTERN HIMALAYA, INDIA

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The Himalayan mountain range and its periphery are tectonically active areas with ongoing tectonic activities. The present study area, a part of East Siang district, Arunachal Pradesh, located along the foothills of Eastern Himalaya, falls under this tectonically active

zone. The HFT (Himalayan Frontal Thrust) passes through the area. Several faults which are splays of the HFT are present in south which uplifted river terraces. The emergence of different levels of terraces in the area may be attributed to the displacements occurring along these faults. Thus due to neo-tectonic activities new landforms like the terraces have evolved in the area. During the study geomorphological maps of the area have been prepared. Moreover, it has been found that a number of springs are associated with the terraces and occur at the base of different terrace levels. Also, some rivers have been observed to have disappeared in the piedmont zone. The springs, associated aquifers and the lost rivers of the area have been studied. From the study it has been observed that the landforms of the area are responsible for the emergence of the springs and development of lost rivers in the area. The terraces evolved due to neo-tectonic activities have influenced the hydrogeologic set up of the area, which would otherwise, in the absence of these landforms might have been different as compared to the present day scenario.

**Keywords:** Geomorphology; Himalaya; neo-tectonic activity; springs; terrace

THEME: S20 : MOUNTAIN GEOMORPHOLOGY

ABSTRACT NUMBER: 299

## TALLI SETHI ROCKSLIDE: AN INVESTIGATION OF STRUCTURAL CONTROL ON ROAD-INDUCED ROCKSLIDE, CENTRAL LESSER HIMALAYA

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The slide is located near Talli Sethi locality in Central Lesser Himalaya and is a classic evidence of neo-tectonic activity in Himalayan terrain. The main aim of this study is to investigate the inherent geo-technical causes responsible for the occurrence of this rockslide and to suggest the mitigation measures which is being exaggerated by anthropogenic activity along geologically sensitive domain. Geological and geotechnical mapping has been carried out along the slide on 1:500 scale. During mapping different rock mass classification parameters have been collected. Based on this investigation the rock mass of this slide has been classified in two rock mass classifications. Rock Mass Rating (RMR) and Slope Mass Rating (SMR) has been calculated. Road construction along this structurally weak zone has exaggerating the slide. The main lithology of this rockslide is quartzite and there is an occasional contact zone of quartzite and slate which again has exaggerated the vulnerability of the zone. The shear zones those parallel to J0 joint and J1 joint are marked as a weak zone as is evidenced by the kinematic analysis. In this area RMR indicates that rock mass of this slide comes under fair (III) category (RMR=44 - 57) and SMR classified the rock mass into III and IV class (SMR=36 - 42). Calculated RMR, SMR and Kinematic analysis of the landslide indicates that it can be mitigated with the help of rock bolting (3-5 m length) and surface short crating. Besides all above calculations the Kinematic analysis also verifies wedge failure due to J0 and J3 discontinuity in the area. Thus, detailed rockslide study indicates that this is controlled by the structure.

**Keywords:** Neo-tectonics; Rock slide; Slope Mass Rating; Rock Mass Rating; Kinematic analysis

THEME: S20 : MOUNTAIN GEOMORPHOLOGY

ABSTRACT NUMBER: 313

## HILLSLOPE HYDROLOGICAL CONDITIONS ALONG DISTURBED SLOPES ON SIWALIKS OF ARUNACHAL HIMALAYA

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Geomorphologically and hydrologically, hillslopes are the fastest routes for surface runoff generation. Antecedent rainfall, soil type and infiltration capacity, gradient of slope, radiant energy for evaporation are some of the factors that affect hillslope hydrological processes, especially soil moisture content along transects. A continuous hillslope facet allows water to flow uninterrupted. An altered hillslope considered to affect the soil moisture regime downslope. In the Siwaliks of Himalayas in Arunachal Pradesh, earth cutting for highways is a primary cause of disturbance on hillslope. Soil moisture measurement at 17 transects were carried out 24 hours after a spell of rainfall; at 20-25m above road (A), near road along upslope transect (B), near road along downslope transect (C) and 20-25m downslope of the highway (D). ANOVA for i) four groups of data (A,B,C,D separately) consisting top to bottom sequences and ii) two groups (A,B) and (C,D) consisting upslope and downslope sides of road have been carried out. The result indicates that there is no

similarity in the soil moisture pattern among the four group moisture readings as well as two groups consisting upslope and downslope sides of the highway. A regression test was conducted for accumulation points (B,D) as dependant on contributing upper sides (A,C) and R square for cubic fit is only 0.234 means a low significance. However, there is a positive increment trend up to 22percent soil moisture both for contributing point and accumulation point, thereafter accumulation point soil moisture plateaus for incremental soil moisture. The centroid of the A,C and B,D is 22.5 and 22.2 and it coincides with the plateauing of downstream section moisture irrespective of higher moisture content in the contributing area. Therefore, it is concluded that disturbance, due to construction of highways on hillslopes, does not affect the hillslope hydrological regime.

**Keywords:** Hillslope hydrology, soil moisture, hillslope disturbance

THEME: S20 : MOUNTAIN GEOMORPHOLOGY

ABSTRACT NUMBER: 324

## EVOLUTION OF LANDFORMS AND SLOPE INSTABILITY ALONG MAIN CENTRAL THRUST IN CENTRAL HIMALAYA (UPPER REACHES OF SARJU WATERSHED)

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The study area encompasses two stratigraphical units, viz. Great Himalaya (crystalline rocks of high grade metamorphism) and Lesser Himalaya (metasedimentary rocks of low grade metamorphism) of Precambrian age. The lithological and structural traits of the study area reflect the control of inner composition upon the evolution of landscape and landform characteristics. It bears the evidences of several thrusts and faults, delimiting different units, viz. Main Central Thrust (MCT), Munsiri Thrust (MT), Berinag Thrust (BT), Loharkhet-Sumgarh fault and Waradhunga fault and diverse tectonic units, viz. Vaikrita group, Almora nappe, Berinag nappe and autochthonous zone. Tectonically the study area is bounded by MCT from northern side and BT from southern side. This study finds out 3-4 sets of joint sets. J0 joint oriented towards NE direction with moderate dip amount. J1 joint dipping S to SE direction with steep dip angle (70°-80°) while J2 joint dipping towards E direction and moderately to steeply dipping. One more joint set, i.e. J3 has high frequency towards MCT and BT while in the central portion of the area; it shows very less frequency and has NW dipping direction. The terrain-profile and river-profile determines: Dhaulibhita stream (weaker plane), sharp nick point (lithological contrast and MCT), erosional valley of Sarju River (two thrust planes BT and MT), table land type landform (Berinag quartzites thrust over Mandhali slate) wide valley (Munsiri schist and quartzites), cliff-slope and high waterfalls (fault plane), high convexity (intensive toe erosion and tectonic instability). The active landslide forms a concave slope (high joint frequency, crushed material and recent degradational processes) while other landslides possess convex slopes. Overall observations indicate that break in slope as well as instability of slope is the product of geological discontinuities of the study area.

**Keywords:** Landform evolution; Thrust; Fault; Joints; Slope instability; Main Central Thrust

THEME: S20 : MOUNTAIN GEOMORPHOLOGY

ABSTRACT NUMBER: 433

## AN INVESTIGATION OF ROAD-INDUCED LANDSLIDES IN PARKHA WATERSHED, CENTRAL LESSER HIMALAYA

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The 'Parkha Watershed' is characterized by the rocks of two groups: Ramgarh Group associated with Nathuakhan formation. Almora Group associated with Augun-Gneiss and Saryu-Gumalikhet -Munsiri Formation. The 'Letibunga - Pokhri' link road passing through Parkha Watershed is a major part of NH - 37. The total length of this link road within the watershed is 19 km. An attempt has been made to study the road-induced landslides in Parkha Watershed through detailed field observation and morphological measurements. The studied slope failure processes are categorized in three groups: debris slide, rock slide and rock slide cum debris slide. The Dip and Dip direction for planer failure were plotted on equal area, lower hemisphere stereographic projection with the help of computer programme Dips 5.1.1 (Rockscience). Area prone for wedge failure and planer failure are identified on the basis of stereographic projection. Friction circle is considered 28° for mylonitic gneiss (Hoek and Bray). Geological cross sections were prepared for every



location where outcrops were exposed. The type of failure identified is wedge and planer failure for Darmoli rock slide, wedge failure for Lwesal1 rock slide, planer failure for Lwesal 2 rock slide while Oji rock slide cum debris slide possesses wedge failure for right bank and planer failure for left bank. Field studies indicate that the landslides are recurring and disrupting the traffic and transport on NH-37 after heavy precipitation during monsoons as well as winters. These road-induced landslides affected both physical and cultural environment of the study area.

**Keywords:** Road-induced; Stereographic projection; Wedge failure; Planer failure

THEME: S20 : MOUNTAIN GEOMORPHOLOGY

ABSTRACT NUMBER: 503

## SPATIAL ANALYSIS OF MASS WASTING INDUCED SURFACE CHANGES AND RELATED GEO-INDICATORS IN TRANS-HIMALAYA: A STUDY IN LOWER PIN VALLEY, LAHAUL AND SPITI

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The Pin valley is situated in the cold desert area of Spiti Sub-Division of Lahaul & Spiti District of Himachal Pradesh, India. Being cold desert high altitudinal area, the geo-climatic factors have a key role to play especially as the winters are severe and the valley experiences very heavy snow fall. The Pin River originating near Pin-Parbati Pass flows in a NE direction for about 50 kms to meet Spiti River. The valley retains the first order topography with the slope forming materials being the quaternary sediments wherein the semi-consolidated to unconsolidated materials on the side-slope are in form of scree / talus / or fan deposition.

In 2013 a debris-flow-slide along a tributary Kirgrang Nala induced a temporary lake upstream of its confluence in the lower Pin valley, covering an area of around 2.5 km breaching the bridge and the main motorable road leaving tribals entirely cut-off from the rest of the world. The debris slide is attributed to a probable glacio-fluvial lake outburst. Initially, the temporary lake formed due to damming of Pin River posed serious threat of flash flood to the downstream areas. This site had experienced heavy discharge of debris flow predominantly consisting fragments of limestone and black shale/soil mass-wasted in the month of July to September every year thereafter. Similar incidences in the valley along different slopes have also been observed. Such incident leads to large scale disruption in the seasonal economy of this region and needs to be addressed.

The study is largely based on field observations in June & October, 2014 and April, 2017 and the satellite data, analysed in a GIS environment assessing the geo-indicators for probable causes of the debris-slide and the remedial adaptation measures from SWOT analysis of human response.

**Keywords:** Mass Wasting; Trans-Himalaya; Pin valley; Debris-flow; Lahaul and Spiti

THEME: S20 : MOUNTAIN GEOMORPHOLOGY

ABSTRACT NUMBER: 586

## MOBILITY OF LANDSLIDES AND PERMAFROST DEGRADATION REVEALED BY MOLARDS: TWO CASE STUDIES IN NORTHERN ICELAND

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Permafrost degradation can affect slope stability, but how thawing ground ice can condition the dynamics of rapid mass movements is still poorly understood. Our study focusses on the effects of degrading ground ice on the morphology and mobility of landslides, using two recent case studies in northern Iceland that are characterised by the presence of a particular landform called “molards”. Analysing

this kind of landslides is important for mitigating the risk that could derive from the potential occurrence of similar landslides in the future. In fact, as a result of recent climate change, ground ice degradation might occur more frequently in the near future in Iceland and other mountainous areas, and could represent a new source of risk for local population.

In 2012 and 2014, two similar landslides occurred in northern Iceland, mobilising up to ~400,000 m<sup>3</sup> of debris. In both cases, the main source of material was ice-rich talus deposits. Immediately after the failures, we found cuboidal blocks of ice-cemented sediments in the landslides' deposits. These blocks subsequently deteriorated into conical mounds of debris, which have been termed "molards" in the literature.

We have characterised the morphometry and spatial distribution of molards in relation to the landslides. We have reconstructed the entire formation history of molards: they result from the decay of blocks of ice-rich sediments into cone-shaped mounds due to the thawing of the ground ice that was previously cementing the sediments. We find that molards are an important landform for understanding the landslides' motion. Isolated molards derive from rock fall processes, while groups of densely-packed elongated molards originate from rotational debris slide. We conclude that molards in cold environments indicate ground ice thaw, and could be used as a marker of degrading permafrost. Furthermore, their morphology and distribution disclose important information regarding the dynamics of landslides.

THEME: S20 : MOUNTAIN GEOMORPHOLOGY

ABSTRACT NUMBER: 615

## ASSESSING FLASH FLOOD SUSCEPTIBLE RIVER REACHES FROM LONGITUDINAL PROFILE – A CASE STUDY FROM THE GANGA RIVER, INDIA

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Geomorphic hazards are normally associated with earth surface processes during meteorological and geological events. Every year, great loss occurs to human life, economy and infrastructure due to natural hazards across the world. Flash floods in mountainous region is one of the major extreme events which affects human settlements, agricultural area, disrupts communication networks and at times causes abrupt topographical changes.

In last decade, northwestern Himalaya witnessed several high magnitude extreme events. In year 2013, between 15th-17th June, extreme flood events occurred in different reaches of the Ganga River. The colossal socio-economic losses in this event raised an important concern to develop a robust approach to predict the susceptible river reaches in a mountain river during flash flood. Though, several studies on disaster mapping have been carried out in the Himalayas, they suffer from several limitations.

In the present study, we use normalized steepness variability by carrying out Chi analysis for the Alaknanda, Bhagirathi and their major tributaries. Advantage of using Chi analysis is that it takes in to consideration the slope and the contributing area at a point that mimics stream power condition at that location. The study focuses on the Higher Himalayas as these are most susceptible to extreme events. The results shows presence of several sensitive reaches viz. between Hanuman Chatti and Govind Ghat in the Alaknanda River, Kedarnath to Sonprayag in the Mandakini River, Sangamchatti to Gangori in the Bhagirathi River etc. We suggest that results of this study can be applied for better disaster management plans in the Himalayas.

**Keywords:** Flash Flood; Susceptible Reaches; Chi Analysis; Bedrock Rivers; Himalaya

THEME: S20 : MOUNTAIN GEOMORPHOLOGY

ABSTRACT NUMBER: 622

## ROCK WALL PERMAFROST ACROSS NORWAY – MONITORING, DISTRIBUTION MODELLING AND GEOMORPHOLOGICAL IMPLICATIONS

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The investigation of rock wall permafrost is of high relevance for geohazards assessment and for understanding cold-climate landscape evolution since its changes over time can cause slope instability and trigger rock falls.

Rock wall permafrost has been investigated since the early 2010s in alpine massifs of western Norway, and has been now extended to a nation-wide scale. In between August 2015 and August 2016, 20 RST loggers were installed at 10 cm depth of 7 selected sites. These loggers are distributed along a latitudinal transect cover various elevations and sun-exposures, and are completed by 4 other loggers installed already in 2009 and 2010. The rockwall surface temperature (RST) time series are used for (a) characterizing the distribution of rock wall permafrost across Norway, (b) running steady-state and transient numerical models of rock wall permafrost at selected sites, and to (c) calibrate a general linear regression model that will be used to (d) predict the spatial distribution of rock wall permafrost at the national scale.

The first analysis shows that RST differs by 3°C between N and S faces in Southern Norway, with mean annual RST as low as -1.9°C at 1700 m a.s.l in a N face (Nordfjord, Sogn of Fjordane) during the measurement year which was about 0.8°C above normal (1981-2010). In Northern Norway, the RST difference between N and S faces is rather around 1.5°C due to the midnight sun and polar night effects, inducing similar RST in both aspects during December, January, May and June.

The presentation will results from two years of measurements, along with empirical modelling of RST distribution in selected areas in Norway. The results will be conceptually discussed in the light of long-term thermal development in such settings, and its relation to landscape development in cold mountain regions.

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 20**

## **MODELLING THE EFFECT OF ARTISANAL GOLD MINING ON PARTS OF THE LANDSCAPE OF ILESA SCHIST BELT, SOUTHWESTERN, NIGERIA**

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Traditionally, the effects of artisanal gold mining activities have long attracted the interest of geomorphologists both in terms of landforms alteration and biodiversity response to change. This study developed a Geographical Information System (GIS) database and mapped the effect of Artisanal Gold Mining on the Landscape of Ilesa Schist Belt, Southwestern, Nigeria using Remote Sensing Technique. This study predicted the terrain deformation and environmental degradation of the study area. A GIS-based engineering-geomorphological analysis was conducted using DEM, Geological Information, Soil Characteristics and Vegetation Index as Input Data. The study showed that 42.0% of the entire basin would be impacted by ponds and mounds, 31.5×106 m<sup>3</sup> of soil will be displaced and 44.1 km of stream/river network will be impacted. The result shows that human-induced activities particularly mining on the weathering intensity of the underlying bedrocks of the basin. The study concluded that artisanal mining could trigger extensive terrain deformation with consequent loss of biodiversity, ecological modification, and increase in sediment delivery ratio and drainage obstruction within the Basin.

**Keywords:** Gold deposit, Landscape deformation, Itagunmodi, Artisanal mining, Nigeria.

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 90**

## **ESTIMATION OF ACTIVE TECTONIC INDEX USING ANALYTICAL HIERARCHICAL PROCESS (AHP) THROUGH GEOINFORMATICS**

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The morphotectonic and geomorphic anomalies are significant indicators of active tectonics which can be analyzed by drainage morphometric parameters. In the recent years, the increasing frequency of earthquakes in Indian sub-continent demonstrates to study the active tectonic process. Several researchers have adopted arithmetic mean method for the assessment of Active Tectonic Index

(ATI) while less work has been carried out through Analytical Hierarchical Process (AHP) which helps to reduce bias in decision making process by preparing a pair-wise comparative matrix. Hence, the present research focuses on the estimation of ATI using AHP methods through geoinformatics.

The quantitative databases of morphometric parameters have been generated for different micro-basins of Tista lower sub-basin, India using satellite images, DEM and field observation data. The correlation matrix has been established to discriminate the influence of parameters towards active tectonics. Based on the correlation value, pairwise comparison matrix has been prepared to determine normalized weight and desire consistency ratio has been achieved by multi-iteration process. Also, normalized rank has been computed for various classes of each parameter and multiplied with normalized weight to produce comparative score. Finally, the aggregation of comparative score produces ATI for each micro basin.

The result shows that very strong and strongly active micro-basins are Kalet, Upper rangpo, Rathong and Great rangit which covers in Greater and Lesser Himalayan sequence where frequent earthquake epicenters have been noticed with significant magnitude. The drainage anomalies, youthful topography, lithological resistance and narrow valleys are the anomalous geomorphic signatures of active tectonics and seismotectonic activity in this region. The moderate and slightly active micro-basins are Lish, Gish, Dharala, Upper chel, Tista lower and Karala which occupies in Quaternary and Siwalik sequence are mostly elongated in shape with asymmetric in nature and have significant evidences of neotectonic deformation.

**Keywords:** Morphometric parameters; ATI; Morphotectonic anomaly; AHP; Geoinformatics

THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY

ABSTRACT NUMBER: 121

## AUTOMATIC APPROACH TO TYPICAL LOCATION-BASED FUZZY CLASSIFICATION OF SLOPE POSITIONS

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Fuzzy classification of slope positions can quantitatively describe the spatial gradation of slope positions. Compared with other existing methods of fuzzy classification of slope positions, the typical location-based method proposed by Qin et al. (2009) takes the advantage of typical locations of each slope position in an area and derive fuzzy slope positions by considering both attribute and spatial information. However, currently this method is not easy-to-use because users need prepare typical locations and specify the parameter-settings of the similarity function on each individual topographic attribute for each slope position according to the characteristics of the study area. In this abstract we automate this typical location-based method through following improvements. First, the frequency distribution of topographic attributes in this area, combining with pre-set domain knowledge, is used to automate both the extraction of typical locations and the determination of parameter-settings for the similarity function on each individual topographic attribute for each slope position type in an area. Secondly, a configurable script is used to organize the whole workflow in this method, including the preparation of topographic attribute input. This means that the proposed automatic approach has only one necessary input, i.e. gridded DEM of the study area. The proposed automatic approach, being much more compute-intensive than the original method, is speeded up through parallel computing. The case study showed that the proposed approach can reasonably and efficiently perform fuzzy classification of slope positions.

THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY

ABSTRACT NUMBER: 124

## MORPHOTECTONIC AND NEOTECTONIC EVIDENCES IN DWARAHAT BASIN UTTARAKHAND INDIA USING REMOTE SENSING & GIS TECHNIQUES

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Considering the central sector of the Indian Himalaya as seismotectonically one of the most responsive sectors of the Himalayan arc, an attempt was made to understand the morphotectonic and neotectonic setting in the Gagas basin of the Kumaun Himalaya. The Resoursat-2 (LISS-4) and CARTOSAT-1 merged data were used to examine geomorphic processes and evaluate morphotectonic indices to identify the tectonic movements. The Gagas basin is longitudinal active tectonic valley through which the River Gagas flows from north to south. The river was dammed due to the upliftment along the Kotiura fault as a result of which a deep gorge was formed on the southwestern side. The two northern faults have displaced the course of the North Almora Thrust (NAT). Due to damming of the Gagas River, a huge lake was formed depositing ~10m thick fluvio-lacustrine sediments and subsequently breached due to sediment filling as a result of a possible tectonic activity along the NAT. Development of the unpaired terraces, pressure ridge, steep fault scarps, triangular fault facets, sinuous channels, V shaped valleys, palaeo channels, meandering of the river and subsidiary thrust with steeper upward block and gently dipping downward block are viewed as the major characteristics of the basin. The pressure ridge, observed near strike slip fault across an area with the displaced topography associated with this fault is evident in the basin. Additionally, the sag ponds, misfit nature and modified drainage are indicative of active tectonism.

**Keywords:** Neotectonic activity; NAT; Shutter ridge; Palaeolake Formation, Geomorphic Indices, Kumaun Himalaya India

THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY

ABSTRACT NUMBER: 169

## DIRECT GRAIN SIZE MAPPING FROM LOW-COST SUAS: A PROOF-OF-CONCEPT

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Measurement of riverbed material grainsizes is now a routine part of fieldwork in fluvial geomorphology and lotic ecology. In the last decade, several authors have proposed remote sensing approaches of grain size measurements based on terrestrial and aerial imagery. Given the current rise of small Unmanned Aerial System (sUAS) applications in geomorphology, there is now increasing interest in the application of these remotely sensed grain size mapping methods to sUAS imagery. However, success in this area has been limited due to two fundamental problems: lack of constraint of image scale for sUAS imagery and blurring effects in sUAS images and resulting orthomosaics. We begin by showing that SfM-photogrammetry can be used in a direct georeferencing (DG) workflow (i.e with no ground validation) in order to predict image scale within margins of 2-4%. We then continue to propose a novel approach to grain size mapping: Direct grainsize mapping (DGsM). DGsM relies on near-ground images with spatial resolutions of mm-scale. The image scale is derived by including the near-ground imagery in a larger photogrammetric block that allows for high quality scale prediction. Once the scale is established, the near-ground imagery becomes suitable for well-researched photosieving methods. The DGsM proof-of-concept presented here therefore establishes a fully robotic workflow for grainsize mapping that rests on low-cost drones and is readily accessible to all fluvial geomorphologists.

**Keywords:** UAV remote Sensing, SfM-Photogrammetry, Fluvial Geomorphology

THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY

ABSTRACT NUMBER: 202

## FIRST WORLD WAR LANDFORMS CLASSIFICATION OF THE VERDUN BATTLEFIELD USING AIRBORNE LIDAR AND MULTIVARIATE ANALYSIS

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In 2013, an airborne LiDAR mission conducted over the Verdun battlefield has brought to light the relief inherited from the First World War that was until now concealed by the Verdun forest planted in the 1930's. The digital terrain model (DTM) collected with centimetre level accuracy reveals the existence of a huge number and range of small-scale anthropogenic landforms covering nearly 10,000 hectares, some of which are the remains of military occupations. Recently, these landforms have been the subject of a morphometric study which

aims to assess their geometry in order to propose an original typology of the landforms of warfare origin in the Verdun forest. The methodology used is threefold: (i) Firstly, it consists in extracting landforms from the DTM by means of a semi-automatic algorithm. This step allows both to map and calculate their geometry; (ii) Secondly, an analysis of these morphometric values is conducted using Kohonen self-organising maps (SOM) in order to group together similar landforms; (iii) Thirdly, a hierarchical ascending classification is used to refine the previous results and to propose a landforms typology. The classification shows a certain diversity and complexity of the conflict-induced landforms. It is all the more important since it represents the field reality, unlike the academic models derived from military manuals, most of which have been little respected in the context of war. Beyond the reproducibility of the proposed method, this study produces directly exploitable resources in terms of management, conservation and heritage enhancement. Thus, the produced maps make possible to better target sensitive areas and to highlight them in a perspective of sustainable management of the forest.

**Keywords:** conflict-induced landforms, LiDAR, morphometry, landform classification, mapping

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 267**

## **THE ROLE OF MORPHOTECTONICS IN GULLY FORMATION: TWO CASE STUDIES IN SEMIARID AREAS**

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Tectonic activities significantly contribute to the formation of the existing drainage systems and hence, to landscape evolution. In this study we assessed the influence of morphotectonics in two semiarid catchments in the Zagros range in the southwestern Iran and in the Makuyuni/ Lake Manyara area in northern Tanzania. Soil erosion and severe gully erosion affect large parts of both study catchments. Earthquake activities and associated uplifting, fracturing and faulting are still active in large parts of the Zagros range. Tectonic processes in the East African Rift System have significantly contributed to the formation of the current drainage systems and landforms.

This study focuses on the morphotectonics with an analysis of topography, drainage networks, stream longitudinal profiles and lineaments. A special focus is on the effects of morphotectonic processes to the vulnerability of geologic formations to gully erosion. The TecDEM software identifies knickpoints showing abrupt changes in the river profiles, hence indicates tectonic activity in turn changing the drainage network.

An investigation of base level and statistical moments of the hypsometric curves provides evidences for the spatial distribution of gully erosion phenomena. The knickpoints act as local erosion base level, and any changes in the knickpoint location leads to a response of erosional processes in the watershed above the knickpoints. Hence gully systems might indicate neotectonic activities as one of the triggering factors in gully formation. These results of regional tectonic instability suggest that tectonic processes are a significant factor for the current landscape evolution in the two basins. We illustrate that severe gully erosion is strongly related to these tectonic processes, especially in the southwest of the Mazayjan catchment (Iran) and in the northeastern and northern part of the Makuyuni catchment (Tanzania).

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

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## **A SPATIO-TEMPORAL ANALYSIS OF CHANNEL MIGRATION USING REMOTE SENSING, FIELD INVESTIGATION AND GIS TECHNIQUES: THE KAMENG RIVER (LOWER REACH), INDIA**

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The Brahmaputra River basin has significant impact on socioeconomic aspects of north-eastern region of Indian subcontinent. The Brahmaputra and its tributaries are characterised by periodic flooding events with significantly high sediment load. The Kameng River (Jia-Bhoreli), originated from eastern Himalaya, is one of the major northern tributary, joins the Brahmaputra River near Tezpur, Assam. The Kameng River shows considerable braiding characteristics (multiple channels, thalweg shifting) throughout its course. The

present study area covers the lower reach of Kameng River, up to the confluence point of Brahmaputra River. The selected lower reach of Kameng River is bounded by northern latitudes 26° 37' 30" to 26° 45' 00" and eastern longitudes 92° 50' 30" to 92° 54' 00". In this study, channel migration of the Kameng River (Lower Reach) is studied using remote sensing, field investigation and GIS techniques. Field investigation has also been carried out in January, 2017 to assess the hydro-geomorphological conditions of the Kameng River (Lower Reach) and several ground control points have been measured across the main river channel to estimate the main channel shift. To achieve the main of the study, processed satellite images (1989 and 2016), field investigation (Ground Control Points) data sets were integrated in the GIS environment to quantify the channel migration. It is evident from the analysis that the Kameng River (Lower Reach) has substantial channel migration (since 1989). The temporal satellite images and field investigation reveals that the main channel migration in the lower reach of the Kameng River is about 2-3km. Such alteration of channel morphology is attributed to substantial effect of bank strength and its impact on rate of lateral channel migration. Further studies need to be carried to integrate regional scale (basin) models to evaluate geomorphological characteristic of such channel migration.

**Keywords:** Channel migration; Kameng River; Remote Sensing; GIS

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 358**

## **INVENTORY AND RECENTLY INCREASING GLOF SUSCEPTIBILITY OF GLACIAL LAKES IN SIKKIM, EASTERN HIMALAYA**

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Climatic changes alter the climate system, leading to a decrease of glacier mass volumes and swelling glacial lakes. Our study provides a new inventory of lakes in Sikkim, Eastern Himalaya, and evaluates the susceptibility of these lakes to Glacial Lake Outburst Flood (GLOF). By using satellite data of high spatial resolution (5 m), we obtain 1104 lakes with a total area of about 30 km<sup>2</sup> of which 35 % are classified as moraine-dammed lakes (including 5 % of proglacial lakes) covering an area about 22 km<sup>2</sup>. Bedrock-dammed, ice-dammed and lakes with combined dams are represented in the region. 8 lakes were not classified. Pre-defined GLOF susceptibility criteria were applied to all the lakes with an area of >0.01 km<sup>2</sup> (n = 472), revealing 21 lakes susceptible to GLOF. The pairwise comparison matrix of the Analytic Hierarchy Processes (AHP) approach further showed that 5 of these 21 glacial lakes have low, 14 have medium and 2 have high GLOF susceptibility. The significant areal growth of these 21 lakes studied in detail was shown in period 1972-2015. Among the 21 glacial lakes, 3 have increased by 30%, 6 have increased by 20% and 12 have increased by 10%. Especially the 16 glacial lakes with high and medium GLOF susceptibility need further attention as they may threaten downstream infrastructure and settlements in case of GLOF.

**Keywords:** Climate change; Sikkim; Glacial Lake Outburst Flood (GLOF); AHP; hazard assessment

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 370**

## **IDENTIFICATION OF GROUND WATER PROSPECT IN BARA TAHSIL OF ALLAHABAD DISTRICT BASED ON HYDRO-GEOMORPHOLOGICAL ANALYSIS USING SATELLITE IMAGERY**

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Water Scarcity is a major problem for villagers' survival as it determines the population density and affects the migration pattern in Bara tahsil, Allahabad district, Uttar Pradesh, India. Hence, for replenishing the ground water resource by establishing the potential water harvesting sites, it is necessary to identify and map the ground water prospect zones. The present study has been carried out using geospatial platforms like Erdas Imagine 2014, ArcGis 10.2.2 and Geomatica 2017 softwares. Sentinel-2 satellite imagery (10 m, 20 m) and Cartosat-1 DEM (2.5 m) data are the major data sources for extracting thematic layers. Geomorphology and lineament maps of

National Remote Sensing Center, District Resource Map of Geological Survey of India, topographic maps, and Google Earth images along with field surveys are the ancillary database. Weighted overlay analysis has been done to extract the ground water prospect zones by overlaying thematic layers of geomorphology, lineament density, slope, geology, drainage density and land use land cover according to their relative influence. Thus, final map showing different zones of ground water prospects in the study region has been prepared.

**Keywords:** Hydro-Geomorphology; Sentinel-2; Cartosat-1 DEM; Weighted overlay analysis

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 383**

## **HYDRO-GEOMORPHOLOGY OF THE TAMIRAPARANI RIVER BASIN: IMPLICATIONS ON THE MANAGEMENT OF GROUNDWATER RESOURCES UNDER CHANGING CLIMATIC CONDITIONS**

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The Tamiraparani river is the lone perennial river of Tamil Nadu with no interstate disputes. Under changing climatic conditions, the water flow is being shrinking and it may lose its status of being one of the perennial river. The hydro-geomorphic units of the Tamiraparani river basin play a major role in the management of water resources especially the groundwater resources. In order to combat against the wrath of climate change, potential groundwater zones are need to be explored for sustaining the water use at a basin scale. In the present study, the geomorphic units such as fluvial landforms, structural features, hydro-geomorphic units along with groundwater fluctuations, recharge, long-term temperature and precipitation, evapo-transpiration and runoff are considered for the exploration of potential groundwater zones using the integrated fuzzy overlay, GIS and remote sensing techniques. The derived thematic layers along with climate data were processed using fuzzy overlay analysis, which combines the fuzzy membership raster data simultaneously with the aid of a gamma overlay type. This overlay type is an algebraic product of fuzzy product and fuzzy sum raised to the power of 0.8. The result reveals that the excellent groundwater potential zones are located along the hydro-geomorphic areas such as the flood plains, deltaic plains and irrigated lands along the riverbanks. Good groundwater potential zones are noticed along the foothills, lineament structures and wash plains. Fair groundwater potential zones are observed along the valley fills, piedmont plains, aeolian deposits. Poor groundwater potential zones are seen in hard rock areas with steep slopes, and settlements. This study provides an insight on the role of hydro-geomorphology and its association with hydrogeology for the exploration of groundwater potential zones using remote sensing and GIS techniques along with climate variables.

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 531**

## **MERGING TOPOGRAPHICAL AND SAR DATA FOR IMPROVED PROBABILISTIC FLOOD MAPPING**

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In recent years, flood management has increasingly profited from the timely availability of remote sensing observations. Data acquired by synthetic aperture radar (SAR) systems have been used for flood mapping for more than a decade. In spite of the maturity of the application, different physical factors still add to confusion between flooded and non-flooded areas, such as flooding below dense vegetation and in built-up areas or water surfaces roughened by wind. More recently, flood mapping approaches based on fuzzy-set theory and probabilistic methods have been introduced to reflect the resulting classification uncertainties in the produced flood maps and to incorporate related information from other sources. Floodplain digital elevation models (DEMs) are of high importance for flood management, especially where no hazard maps derived from hydrodynamic models are available. In the framework of flood extent mapping, DEMs can help to increase the accuracy and better assess the uncertainty of the maps in areas where the capabilities of the SAR sensors are limited, e.g. under vegetated canopies and in urban settlements. Although some approaches have been presented to integrate topographical information with satellite observations for flood mapping, there is still a lack of methods to incorporate the two sources of information in a statistically rigorous and robust manner. Here, a Bayesian framework for flood extent delineation based on SAR is presented, where prior probabilities are modelled using information derived from a DEM, e.g., each pixel's height relative



to the nearest drainage. Posterior flood probabilities are obtained by combining the prior with SAR backscatter acquired at the time of flooding. The approach is tested for flood events, such as the summer 2007 floods along the River Severn in Gloucestershire, UK. DEMs from different sources are considered (LiDAR, SRTM) in order to characterise the impact of DEM accuracy and resolution on the classification.

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 539**

## **EFFECTS OF SENSOR SPATIAL RESOLUTION ON GLACIER VOLUME ESTIMATION USING MULTIPLATFORM DATA: A CASE STUDY OF CHHOTA SHIGRI GLACIER**

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Advancement in space technology and sensor capabilities has enhanced feature extraction. Paul et al., (2013) suggest that extraction of glacier boundary with high accuracy is a challenging task because of several factors (seldom availability of very high-resolution data being one of them). And even after the manual correction of raw outlines of glaciers (if it is a debris-covered glacier), the comparison would be considered as the accuracy assessment of the analyst rather than the algorithm and data used. This work tries to assess the accuracy of glacier boundary extraction as affected by the spatial resolution of the data used i.e. it attempts to assess the effects of sensor resolution (spatial) on glacier length, area, and volume extraction and quantify the error involved in estimation of these parameters. Since manual onscreen digitization technique is used by only one trained analyst, algorithm based inaccuracies are overcome here. Satellite datasets used in this study include WorldView-2 (PAN: 0.46m, MSS: 1.84m), IRS Resourcesat-1 LISS IV (PAN: 5.8m); IRS P6 LISS III (MSS: 23.5m), Landsat TM (MSS: 30m) and IRS Resourcesat-1 AWiFS (56m). All the datasets have been, first of all, co-registered to the same spatial reference system with less than 1-pixel RMSE values. Then all the raster datasets have been altitude and slope with the aid of ASTER DEM (30m) to overcome the altitude related feature extraction errors. For feature extraction, comparison, and accuracy assessment, methods suggested by (Gardelle et al., 2012; Vincent et al., 2013; Paul et al., 2016, 2013) are followed. The results show that increase in spatial resolution of the sensor greatly enhances analysts' capability to extract the glacier outline in case debris covered glaciers like Chhota Shigri glacier. But, availability of such high-resolution data is still a limitation for researchers working in the Himalayas.

**Keywords:** Spatial resolution, multisensor, Chhota Shigri

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 555**

## **USE OF HIGH-RESOLUTION MODELS FOR GULLY EROSION MONITORING A CASE STUDY FROM PAG ISLAND (CROATIA)**

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Gully erosion is one of the most prominent denudation processes at semi-arid coastal parts of the Mediterranean. Understanding of gully erosion rates is essential for the reconstruction of past landscape changes and prediction of its further development, yet studies considering gully erosion in Croatia have been scarce. Here, we present the concept of using ground-based LiDAR and UAV photogrammetry-derived high-resolution DEMs to monitor gully erosion rates on Pag Island, Croatia. To determine the most suitable area for detailed high precision monitoring of gully erosion we performed GIS-MCDA based on different criteria (terrain attributes, land use, vegetation cover, etc.). Extracted high gully erosion susceptibility zones were verified by the field monitoring, and gully Santiš, formed in deep carbonate soils was selected for the detailed survey. Since the gully erosion rates differ over time, depending on bedrock, soil, climate settings, etc., the main research question is how gully erosion can be monitored most accurately at whole gully scale, through the longer time period. Therefore, this research aims to develop the concept of monitoring gully erosion rates through the comparison of periodically made high-resolution DEMs. We presumed that due to poorly developed vegetation and low flight height UAV photogrammetry have potential to generate DEM resolution similar to the resolution of the one derived with LiDAR, and

thus we completed detailed comparison of these two methods through various quantitative measures. Changes in gully morphology and volume are observed, especially in gully head advancement. Precise quantitative model is developed for measurement of horizontal offset of the gully head with exact metrics (RMSE, Min, Max, Range, etc.).

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 594**

## **PLANFORM CHANGE IN DHALAI RIVER, TRIPURA, INDIA**

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The Indian state of Tripura is characterised by five N-S aligned westerly convex anticlines and their intervening synclines belonging to the Chittagong-Tripura Hill Tract (CTFB). The two major anticlines of Atharamura and Longtarai ranges are separated by a synclinal valley in its northern part. This syncline is mainly drained by the Dhalai river. Topographical maps, satellite images, and oral history suggest that the river is changing its planform since 1932-33. The aim of this work is to study this transformation.

The course of the north-flowing Dhalai was digitised from 1932-33 Survey of India topographical sheets, 1973 Landsat-1 MSS data, and 2017 Landsat-8 OLI image. The sinuosity index of the river was calculated for these three years to determine the extent of change.

The results show that the alluvial stretch of the Dhalai, from Ambassa to Maulavi Bazar, markedly shifted its course, and its sinuosity is decreased in general. The channel length decreased from 123.96 km (1932-33) to 101.16 km (2017). Within this, in the southern reach (Ambassa to Halhuli: 28.43 km in 2017), sinuosity decreased from 1.60 (1932-33) to 1.23 (2017), depicting 4.5-time increase in average meander wavelength and 31% decrease in channel length. In the central reach (Halhuli to Sripur: 24.31 km in 2017), sinuosity decreased from 1.67 (1932-33) to 1.28 (2017), showing 3.64% increase in average wavelength and 24% decrease in channel length. Conversely, in the northern reach (Sripur to Maulavi Bazar: 48.42 km in 2017), the sinuosity increased from 1.48 to 1.55 with nominal increase in channel length.

The probable reasons behind the changes might be tectonic upliftment in the CTFB, increase in discharge due to higher rainfall or augmentation in sediment load due to landuse change and/or landslides.

**Keywords:** Chittagong-Tripura Hill Tract, channel sinuosity change

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 646**

## **CHANNEL PLANFORM DYNAMICS AND STABILITY ASSESSMENT OF RAMGANGA RIVER USING REMOTE SENSING AND GIS**

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Frequent channel shift reflects highly sensitive valley floors and increases the risk to infrastructure and settlement along rivers. Therefore, monitoring of channel planform is needed for analyzing channel stability as well as improving river management. The advent of satellite remote sensing has provided a huge opportunity to Geomorphologists to study the temporal planform dynamics of rivers. The repetitive coverage of satellite data is an important archive to reconstruct historical dynamics of alluvial rivers and to understand the causal factors. In the present paper, we assessed the bank erosion and Channel stability of 94 years. The present research reconstructed the planform changes occurring in the lower reaches of Ramganga from 1923 to 2017 using the Landsat archive and historical cartographic records. Sequential river planform maps generated from the time-series revealed the pattern of evolution of the river system over the study period. The study reveals that in all of the evaluated periods, the river has experienced differential rates and amounts of bank erosion. Channel stability for reaches was assessed through analyzing the changes of river indices including braid index, active channel width, and channel activity. An integrated Sensitivity Index was used identifying unstable reaches. The Ramganga river course has been shifting and the overall shifting is towards the south-west direction in different places at lower reach

which leads damage of infrastructure and settlement along rivers. This study shows that satellite image monitoring coupled with river indices analysis could be an effective tool to evaluate spatial and temporal changes in channel stability in highly dynamic river systems. These results may be helpful for the planners for overall river management and planning for future prevention of floods, and loss of properties due to changing courses of rivers.

**Keywords:** River Dynamics; River Channel Stability; Sensitivity Index; Satellite Images; GIS

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 699**

## **TOPOGRAPHIC SIGNATURE OF HIGH INTENSITY DENUDATION PROCESSES IN COMPLEX LANDSCAPES**

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This paper offers new insights on the analysis of the spatial pattern of denudational process in a complex calanchi landscape within a Mediterranean study area. The aims were achieved through the study of topographic signature of landscape's process domains as revealed by statistical and geo-morphometric elaborations of digital terrain models (DTMs). The basin Slope-Area (S-A) function has been adopted to identify local process domains within eight sub-basins tributary to the Formone river, itself a tributary of the river Orcia in southern Tuscany (Italy). The bedrock characteristics (primarily composed of marl and clay) and the local climate regime, combined with the abandonment of agricultural activity, have led to extreme rates of erosion over the last centuries, both of surface wash and a range of active mass movement processes. The combined effects and the nested nature of the last processes have favoured the development of typical calanchi badlands.

We demonstrated that calanchi appear differently on S-A plots than the slopes and valleys of the host landscape and that process dominance domains are identifiable on the S-A plots, characterising the layered and nested nature of the contemporary process suite in a new way. Results of this analysis help to face the present research challenges for the automatic mapping of landforms and processes in natural landscape and for monitoring their evolution on different space and time scales. The analysis proposed in this work needs just DTMs as input data, therefore really represents a low-cost, high-efficiency approach for study process domains in complex landscapes.

**Keywords:** Soil erosion; Process domains; Geo-morphometry; Tuscany; Italy

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND  
GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 776**

## **TEMPORAL VARIATION OF VEGETATION CHANGE IN GANGOTRI AND GORI GANGA VALLEY OF CENTRAL WESTERN HIMALAYA, UTTARAKHAND**

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In the Indian sub-continent, Himalayan mountain system are among the most naturally complex environs with big source of natural resources and ecosystem services. Past few decades ecological environment changes are noticed in these region and to analysis the situation vegetation coverage change is a very important indicator. But in these regions field based research is challenging due to heterogenous relief and high altitude, for this use of remote sensing can provide essential information regarding changes in vegetation cover and its linkages with anthropogenic impacts. In this paper, examination of spatio-temporal patterns in vegetation trends and its association with altitudinal gradient was analysed. We detected the vegetation cover change by retrieving the fraction of the vegetation coverage, using the Normalized Difference Vegetation Index (NDVI) data from Landsat (MSS 1972-1982, TM 1983-2011, ETM+ 1999-2003 and Landsat 8 OLI 2013-2016) images were used to extract the historic extent of NDVI change in the study area in total 16 data set were downloaded from USGS Earth-explorer website (<http://earthexplorer.usgs.gov>) to the period of 1972 to 2016. The study also used MODIS MO13Q1 250m NDVI product, which was acquired from Land Processes Distributed Active Archive Center (LPDAAC).

The study area covers Gangotri the largest glacier valley and Second largest glacier (Milam) valley Gori Ganga with reference to Central Western Himalaya at the elevation of 3000m. To demonstrate green area within this range we took threshold value > 0.1. The number pixel obtained were converted into area using ERADAS image from which time green area was generated. Based on results, we analyzed the annual/seasonal vegetation change, and it was shown that the vegetation cover took on an increase in these two valleys.

THEME: S22 : QUANTITATIVE GEOMORPHOLOGY AND MODELING

ABSTRACT NUMBER: 170

## REVISITING THE DRIVERS OF HYDRAULIC GEOMETRY AT REACH SCALE IN THE HYDROGRAPHIC NETWORK

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The knowledge of temporal variations in river hydraulic characteristics (i.e. width, depth, velocity) across stream networks is a key element for catchment management because hydraulics influence physical habitats and biodiversity, water temperature, nutrient fluxes, sediment transport and associated ecosystem services. At-a-reach hydraulic geometry describes the variation of water depth and width with discharge within a stream reach. Although variations of these relationships between rivers have been widely documented, they are still largely unexplained. This study provides an analysis of a unique data set of at-a-reach hydraulic geometry collected in 570 stream reaches in France. Relationships between the hydraulic geometry parameters and many variables describing catchment- and reach-scale characteristics of reaches were analyzed using stepwise linear regression and discriminant analysis. Results show that width-discharge relationship is well predicted by longitudinal- and lateral-channel shape descriptors (i.e. the ratio of median/bankfull width, the median Froude number, the width to depth ratio) and globally depend on the fluvial dynamic/pattern. Fewer significant relationships explained depth-discharge relationships, despite a weak influence of reach Froude number, flow resistance (i.e. relative grain resistance, relative bedform submergence) and slope. This study suggests that it is possible to explain the parameters of at-a-station hydraulic geometry with variables easily obtainable in the field or by analyzing aerial images. These results allow an improvement of current catchment-management models (e.g. habitat, temperature) using hydraulic geometry. Using more developed statistical approaches and remote sensing tools, involving descriptors of bank cohesion, and better describing all forms of flow resistance are expected to provide improved hydraulic geometry models in the future.

**Keywords:** At-a-reach hydraulic geometry; Channel form; Catchment management

THEME: S22 : QUANTITATIVE GEOMORPHOLOGY AND MODELING

ABSTRACT NUMBER: 272

## ON THE ACCURACY OF STRUCTURE FROM MOTION (SfM) METHOD FOR GRAIN SCALE MONITORING OF FLUVIAL SURFACES

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Qualitative and quantitative illustration of riverbed geometry, which varies in a broad range of scales from grain scale to reach scale, is a key issue in river engineering and geomorphology. To properly describe riverbed morphology, various techniques consists of photogrammetry methods has been widely used. Present study aims to explore application of a novel photogrammetry method, known as Structure from Motion (Sfm), in determining the Digital Elevation Model (DEM) of riverbed in a small-scale (i.e. grains scale). For this purpose, firstly, the DEM of regular geometric shapes such as single cubic, sphere and a bunch of isolated (or coherent) cubes or spheres were explored in a laboratory. Moreover, application of this method in determining the DEM of natural grains, which collected from gravel bed rivers, was surveyed. Results show that the SfM method can fairly describe the DEM of all examined scenarios. This findings as well as considering the simplicity and the low cost of the SfM method represent applicability of this method in field studies on riverbed. However, for the field studies, application of this method in describing the DEM of larger-scales such as dunes, pools and chutes must be investigated.

THEME: S22 : QUANTITATIVE GEOMORPHOLOGY AND MODELING



ABSTRACT NUMBER: 311

## RELATIONSHIP BETWEEN LANDFORM AND VEGETATION IN PANNA AREA, MADHYA PRADESH

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The present study aims to establish relationship between landform and vegetation of Panna district, Madhya Pradesh, which was visited recently. Type and nature of vegetation keep on varying from one climate to another. Again the climate is influenced by the nature of landforms. Thus, vegetation keeps on changing with the change of physical features too. The study area has a good vegetation cover despite having plateau landform. A Topographic Position Index (TPI) maps are generated for two neighbourhood classes of 500 and 1500m based on SRTM DEM. These two TPI maps have been integrated and categorised into 14 classes. Deeply dissected areas with a depth of about 200m and width of about 1km is the major landform class covering about 29% of the total area taken for study. Second extensive landform class is high ridges with narrow level lands covering about 24% of the land of study area. Narrow valleys constitute about 9% of the area. Rest of the 11 categories of landform constitute 37%. Geomorphic units form key environmental determinants vegetation distribution patterns in an area as it controls factors for the growth and sustenance of vegetation. For this the common vegetation index NDVI has been derived from Landsat8. The NDVI values have been classified into 4 NDVI classes of water bodies, bare areas, shrubs and dense vegetation. Water bodies constitute about 15% bare areas constitute about 75% shrubs and grass constitute about 9% and about 1% area is having dense vegetation. It is found that there is an association between canyons and shrubs with small trees. Dense vegetation is associated with escarpments and canyons walls. In plain areas there is a mix up of pixels of various categories leading to a situation where vegetation and landform class cannot be separated easily.

**Keywords:** landform class; topographic position index; NDVI

THEME: S22 : QUANTITATIVE GEOMORPHOLOGY AND MODELING

ABSTRACT NUMBER: 362

## AUTOMATED LANDFORM CLASSIFICATION OF BHIMBETKA AREA, MP AND ITS CORRELATES WITH SETTLEMENT AND LANDUSE.

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The present study aims to classify the landform classification and relate it with settlement and resources around Bhimbetka area of Raisen District, Madhya Pradesh, which was visited recently. Based on the varied characteristics of the landforms in the area, this paper tries for a physiographic classification through an approach of automated landform classification and mapping from DEM. Landsat8 satellite image of the area is used for visualization. Cartosat DEM with 30M resolution is used to extract topographic parameters. Topographic Position Index (TPI) raster layer is generated using two neighborhood classes of 500m and 1500m. These two TPI maps then integrated and categorized into 10 classes. Deeply dissected areas with a depth reaching up to 279 m and highest elevation of 662 m altitude provide a distinct view of the area as well as physiographic variations. Different types of landforms have been identified with basic forms viz. canyon, ridges, valleys, upper slope, lower slope etc. and complex landforms viz. narrow ridges with flat tops, narrow ridges with open slopes etc. which have significant bearing on establishment of settlement, agricultural practice and other activities that require suitable land resources. Highest areal coverage is by small plain areas with incisions that constitutes about 36percent of total area. Plain areas with midslope drainage constitute 11percent; ridges constitute about 3 percent, high ridges with wide open slopes constitute about 26percent of total area of 3656sqkm. Rock shelters from Upper Palaeolithic-Mesolithic-Chalcolithic to medieval times have significant correlation with 'structural origin moderately dissected hills and valleys' which is classified as high ridges with plain tops as per TPI values.

**Keywords:** automated landform classification; DEM, Topographic Position Index, landform, settlement

THEME: S22 : QUANTITATIVE GEOMORPHOLOGY AND MODELING

ABSTRACT NUMBER: 363

## APPLICATION OF SWAT MODEL TO PREDICT SOIL LOSS FROM MIDDLE



## TAPI BASIN, WESTERN DECCAN, INDIA

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Of all the hazards, soil erosion is considered to be one of the most serious one especially in India, which is a tropical country with an agrarian economy. Unlike other parts of the world, soil erosion studies and modeling are still in the stage of infancy. The present paper is an attempt to estimate the sediment yield along a deeply dissected region in the Western Deccan, India, by applying USLE (Universal Soil Loss Equation, Wischmeier and Smith, 1959) derived model SWAT (Soil and Water Assessment Tool), the physically based, watershed scale hydrological model. The model was developed by the USDA-ARS to predict the impact of land management practices on water, sediment and agricultural chemical yields in large, complex watersheds with varying soils, land use and management conditions over long periods of time. The study area is a watershed in Tapi Basin which falls in the semi arid part of Maharashtra, India. The model requires specific inputs about daily weather data soil data, topography, landuse - landcover data. IRS Cartosat I stereo pair imageries and LISS IV multispectral imageries have been used to create DEM and the landuse classification for the model. The soil map of the area was obtained from NBSS & LUP Nagpur and the climatic parameters were obtained from Indian Meteorological Department. The model was run for an area of 8002 km that was divided in to 67 sub watershed and 218 Hydrological Response Unit (HRU's) to calculate yearly sediment yield. The average sediment yield predicted by the model is 3.9 kg/m<sup>2</sup>. The derived figure is close to the soil loss value prepared by National Bureau of Soil Survey & Landuse Planning Department of India. The study has wide scope of application in different application scenarios.

**Keywords:** Cartosat I; IRS; SWAT; Western Deccan; HRU's

THEME: S22 : QUANTITATIVE GEOMORPHOLOGY AND MODELING

ABSTRACT NUMBER: 364

## FOURIER BASED SIMPLIFIED SHAPE ANALYSIS FOR GEOMORPHIC CURVES

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It is in practice to express the planar or curvi-planar geomorphic surfaces by some special terms such as ridge, valley, dune, cirque etc and by them, the geomorphologists can easily conjure up the broad overall feature and shape of the landform. However, many a times it becomes difficult to visualize the shape difference between two or more landforms of same suited terms. Although some distinctions are generally made by specifying prefixes like V-shaped or U-shaped valleys, but still the description remains subjective only. The difference between them may be highlighted if the shapes of the landforms could be expressed quantitatively, which is not so easy, keeping in view of the complicated shapes of the natural landforms in their profile. Therefore, it becomes difficult to understand and express the curvature of these topographic surfaces which are very important in the geomorphic studies. An attempt has been made here to simplify the complexity in geometry of these landforms based on Fourier analysis which is one of the mathematical techniques that are used in analyzing the variation in the curvature with the help of simple x- y functions. It presents a simplified graphical method for plotting of curve shapes on a two dimensional graph. The basic assumptions in this method in analyzing the shapes are that the shapes of the geomorphic surface on vertical profile are smoothened between two sectors of the topography, one at base and other at the summit or inflection; and the shape is simplified in the curved segment of the topography considering them forming a wave pattern and only the quarter of the wave is used for analysis as unit. The quantification can be effectively used in comparing the shape/ morphometry of different curved geomorphic surfaces of a region or different regions.

THEME: S22 : QUANTITATIVE GEOMORPHOLOGY AND MODELING

ABSTRACT NUMBER: 382

## ASSESSING THE FLOOD HAZARD POTENTIAL OF UPPER JHELMUM BASIN, NW KASHMIR HIMALAYA

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Kashmir valley has a long history of flooding; there are records of extreme floods and associated losses that date back to 883 AD. In order to minimise the adverse effects of flooding, it is necessary to assess the various factors contributing to the flood hazard. In the present study general morphometric parameters pertaining to ten sub-basins of the upper Jhelum basin were compared for assessing their comparative flood potential. The parameters, that is, bifurcation ratio, drainage density, stream frequency, relief ratio, drainage texture, Rho coefficient, stream length ratio, sinuosity index, compactness index, form factor, shape index, circularity ratio, elongation ratio, lemniscate ratio, total basin relief, relief ratio and ruggedness number were calculated using ASTER digital elevation model (DEM 30m) and topographic maps (1:50,000) in GIS environment. In general, the results reveal that the tributaries from SE have greater potential to produce peak flows during rain storm events due to high runoff rates, low permeability and less infiltration capacity, high drainage density ( $Dd > 2 \text{ km/km}^2$ ), drainage texture ( $Td > 15$ ), stream frequency ( $Fs > 3.5$ ), ruggedness number ( $Rn > 0.3$ ), relief ratio ( $Rr > 0.07$ ), basin relief ( $Hr > 2850$ ), bifurcation ratio ( $Rb > 4.0$ ), stream length ratio ( $RI > 1.02$ ), elongation ratio ( $Eb > 0.65$ ), shape index ( $SW < 3.5$ ), form factor ( $F > 0.4$ ) and higher number of streams and length of streams than the tributaries from SW. Based on the morphometric parameters all the selected sub-basins were classified into categories of varying flood potential i.e., high, moderate and low.

THEME: S22 : QUANTITATIVE GEOMORPHOLOGY AND MODELING

ABSTRACT NUMBER: 443

## IDENTIFYING NONLINEAR GROUND DISPLACEMENT TRENDS IN BUCHAREST (ROMANIA) BASED ON INSAR

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Detecting nonlinear dynamic in empirical data is a complex process, with several problems to be considered (i.e. the quantity and quality of data, the level of noise and the best metric and topological invariants that can be correctly estimated for the considered data). An important restriction in detecting non-linear ground movements was the lack of a technical support up to the early 1990s. Synthetic Aperture Radar Interferometry technique (InSAR) proves to be a solution for the shortcoming of adequate data, through precise and repetitive measurements over large areas, especially in urban environments, subjects to a high density of coherent points in time. The research focusing on Bucharest was based on SAR data acquired between 1992 and 2014 by ERS-1/-2, ENVISAT, and TerraSAR-X satellites. The recent SAR imagery was validated using terrestrial monitoring techniques. The proposed interferometry methods were the Permanent Scatterers (PS-InSAR) and the Small Baseline Subset (SBAS-InSAR) to provide maps of satellite line-of-sight displacements. A wealth of statistical and numerical tests (stationarity, interpolation, chaos test, Lyapunov and Hurst exponents) was employed on SBAS data to find evidence of nonlinear dynamics and asymptotic attractors. Trends based on the estimated ground displacement in Bucharest are characterised by long-term memory, indicated by Hurst exponents, which in the long-term form interesting closed and limited attractors. We hypothesize these attractors to be an active northwest-southeast oriented transpressional system. The uplift and subsidence patterns depicted by the SAR data suggest the presence of three quasi-parallel NW-SE uplift oriented domains. This data indicates that Bucharest is built in a geodynamic active area, probably influenced by the presence of the Intra-Moesic fault system (located only 40 km east of the city).

**Keywords:** Permanent Scatterers (PS-InSAR), Small Baseline Subsets (SBAS-InSAR), nonlinear dynamic, transpressional system, Bucharest

THEME: S22 : QUANTITATIVE GEOMORPHOLOGY AND MODELING

ABSTRACT NUMBER: 494

## DTM RESOLUTION INFLUENCE ON MODELLING SLOPE INSTABILITY

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One of the methods used to indicate prone areas to shallow landslides is the physically-based mathematical models. Due to the use

of topographic parameters, a digital model that represents the relief is essential, once from this representation is possible to extract the information such as contribution area and slope angle, respectively relevant to soil saturation and instability modeling. Thus, this work assessed the response of physically-based model SHALSTAB when used a Digital Terrain Model (DTM) with 10 and 5 meters' grid resolution. The result shows that the cell distribution of the unconditionally unstable class, as well the two most stable classes, were similar on both DTMs. Particularly is noticeable that the unconditionally unstable class registered a 13% frequency, considering the 10m grid DTM, and a slightly increase to 17% considering the 5m DTM. The two most stable classes registered the larger number of cells on both DTMs: 42% and 45% (10m grid) and 37% and 46% (5m grid). In conclusion, there were similarities in the definition of unstable areas using both DTM resolution. Further investigation must validate both models to see if the evaluation index show significant differences.

**Keywords:** Shallow Landslides; SHALSTAB; Brazil; Serra do Mar

THEME: S22 : QUANTITATIVE GEOMORPHOLOGY AND MODELING

ABSTRACT NUMBER: 515

## FUZZY LOGIC APPLICATIONS FOR GEOMORPHOLOGICAL STUDIES

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The present paper deals with ground assessment and susceptible land slides/slope movements of Jammu & Kashmir Area (Chenani-Nashri slides) and Harshil area ( of Uttarakhand) of Indian fragile Himalayan; by fuzzy logic and Artificial Intelligence ( AI). Both the areas are prominent in land slides whereas Chenani- Nashri land slides is the longest land slide in India which poses great danger to the vehicular traffic.

For ascertaining the land slide, help of GIS also has been taken along with the fuzzy logic and artificial intelligence. Fuzzy logic is all about and relevance to near real true state. The information through computers and probabilities / uncertainties near real time data from local population is of vital importance. Fuzzy logic data is to be taken from occurrences of slope instability as well as land slide occurrences. In recent past the land slide of Harshil area has also devastated many road pavements and near by villages.

In the paper the Chenani- Nashri land slide and its recent construction of tunnel is the remedial measure of landslide hazards. The Chenani- Nashri tunnel length is about 9.28 kilometers constructed with latest techniques. It was opened and inaugurated by Hon. Prime Minister Narendra Modi on 2nd April 2017. The Chenani- Nashri tunnel has reduced the distance between Jammu and Kashmir by 30 kilometers whereas travel time reduced by 2 hours. The remedial measures of Harshil landslides also has been suggested.

**Keywords:** Fuzzy logic, artificial Intelligence, Landslides, Slope stability

THEME: S22 : QUANTITATIVE GEOMORPHOLOGY AND MODELING

ABSTRACT NUMBER: 598

## METRICS FOR COMPARISON OF GEOMORPHOLOGICAL LANDSCAPE EVOLUTION MODELS

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The simulated outputs of landscape evolution models (LEMs) can be compared and contrasted to observed topographies, to simulated outputs of other LEMs, and to simulated outputs from other scenarios using the same LEM. This, however, requires a suitable set of metrics to do perform these comparisons. Currently, no agreed set of such metrics exists, resulting in a wide range of different types of LEM comparisons reported in the literature, which themselves may not be comparable.

A comparison LEM simulation outputs essentially consists of three choices: 1) a choice of what exactly is to measured (e.g. erosion volumes, sediment yield, erosion rate, hypsometry, sediment grain sizes, ...); 2) a choice of how to measure this (e.g. total value, time-averaged value, distribution of values, magnitude-frequency relation, ...); and 3) a choice of comparison metric to compare the two datasets (e.g. Pearson correlation, Nash-Sutcliffe efficiency, root-mean-square differences,...).

Here we compare simulations from three LEMs (CAESAR, LAPSUS and SIBERIA) applied to two very different catchments. We use a range of measures and metrics to compare the simulation outputs, and evaluate which of these most effectively capture the differences



and similarities between model outputs. We propose a new comparison metric, based on the Taylor diagram that is commonly used in climate sciences, and which effectively combines different measures of LEM simulation output and performance. The proposed metric can be used for comparing LEM simulation outputs to both observed data and other LEM simulation outputs.

**Keywords:** LEM; comparison; metric; simulation; modelling

THEME: S22 : QUANTITATIVE GEOMORPHOLOGY AND MODELING

ABSTRACT NUMBER: 634

## SIMULATING THE EFFECT OF CHECK DAMS ON LANDSCAPE EVOLUTION AT CENTENNIAL TIME SCALES

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Check dams are structures to stabilize mountain rivers by decreasing flow velocity and reducing channel erosion. Over long time scales (100 yrs) a series of check dams constructed in a river reach can have significant effects on sediment and water dynamics and river channel responses. Over time the maintenance and replacement of check dams is costly. Given the drawbacks of check dam maintenance, the question then arises: what would happen geomorphologically if check dams were not maintained and allowed to structurally deteriorate? Herein we apply a landscape evolution model (CAESAR-Lisflood) to a Swiss pre-alpine catchment containing 80 check dams that stabilize the main river. These longstanding structures afford a sense of security for downstream communities by mitigating small- and mid-scale flood and debris flow hazards. Using this model we simulate future scenarios of river development at centennial time scales. Scenarios consider the quantity and location of check dams that are neglected, subsequently collapse, and release large amounts of sediment. By doing this we are better able to understand how the neglect of check dams cascades through the catchment and provides information about optimal check dam placement and amount.

**Keywords:** landscape evolution model; check dam; sediment dynamics; hazard; flood risk

THEME: S23 : GEOMORPHOLOGICAL MAPPING

ABSTRACT NUMBER: 70

## IDENTIFICATION OF LINEAMENTS AND GEOMORPHIC FEATURES BY USING DIFFERENT DEM DATA PRODUCTS IN SATPURA-PURNA BASIN, WESTERN VIDARBHA, INDIA

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Lineaments, fault and fractures are essential linear geologic and geomorphic features in the field of structural, applied and environmental geomorphology. These features can give a clue for identifying groundwater potential zones and are also important for various engineering applications such as dam, road construction or determining new settlement sites. Traditional methods of mapping lineaments, faults and fractures require fieldwork investigations. However, fieldwork is usually time consuming and may take up years to complete. On the other hand, remote sensing has the advantage of providing synoptic overviews of the region.

Using digital mapping it is possible to obtain structural and lithological information more efficiently and cost effectively for tectonic areas. Present work is an attempt to identify lineaments and geomorphic features of Satpura Ranges and Purna River Basin of Western Vidarbha region by using different DEM data products and RSGIS techniques. Field investigations have been carried out in selected sites of interest in a region. Lineament analyses was undertaken to examine the orientation of lineament, the relationship between lineaments, geologic structures and geomorphic features. DEM has been used to create the shaded relief and maps for the slope and aspect of the terrain. Results have been compared with the drainage network map at 1:50000 scale and geological map at 1:50000 scale. In addition, geomorphic features were also identified on the basis of tonal and texture variations on the image. The applied methodology has contributed in identifying large lineaments and geomorphic features in Satpura Ranges and Purna River Basin of Western Vidarbha region.

THEME: S23 : GEOMORPHOLOGICAL MAPPING

ABSTRACT NUMBER: 134

## BGS GEOMORPHOLOGICAL MAPPING SOLUTIONS AND SEMI-AUTOMATIC APPROACHES TRANSFERABLE BETWEEN TERRESTRIAL TO MARINE ENVIRONMENT

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Geological mapping methods have evolved significantly over recent decades and this has included the transition to digital field data capture. The British Geological Survey (BGS) has been developing their custom-built data capture and map compilation system since 2001, and the GIS-based BGS\_SIGMAv2015 is now the default toolkit used within BGS. It is used for a wide range of applications, including bedrock and superficial mapping, landslide assessment, geodiversity audits, and building stone studies. SIGMAv2015 is an integrated toolkit, which enables: assembly, interrogation and visualisation of existing geological information; capture of new data and geological interpretations; and delivery of digital products and services. Recently, the SIGMA system has been adapted to apply a two-part classification scheme for seabed geomorphological mapping. This two-part classification scheme ('Morphology' and 'Geomorphology') was developed by the BGS and improved in collaboration with scientists from the Irish and Norwegian marine mapping programmes. Survey organisations require a consistent and standardised method to map and describe the geomorphology of the seabed. This required a classification system that is: i) applicable to multiple and diverse environments, ii) sufficiently detailed and interpretive to be informative, iii) not over-interpreted or mired in detail designations or definitions. Simultaneously, the BGS also developed a semi-automated mapping toolbox, to map seabed features efficiently. This ArcGIS-based toolbox recognises, spatially delineates and morphometrically describes certain seabed features, such as coral mounds, moraines and pockmarks. Although this was primarily developed for the marine environments, this has already been applied to map moraines within the terrestrial environment. These novel digital approaches are facilitating innovative geomorphological mapping and an improved understanding of both terrestrial and marine morphogenetic processes.

**Keywords:** SIGMA; Geomorphological Classification System; Automated-mapping;

THEME: S23 : GEOMORPHOLOGICAL MAPPING

ABSTRACT NUMBER: 236

## HIGH-RESOLUTION RIVER LANDSCAPE MAPPING BY UAV TECHNOLOGY AND COMPARISON WITH TRADITIONAL FIELD MAPPING: CASE STUDY OF BELÁ RIVER REACH, SLOVAKIA

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Paper present high-resolution mapping of river landscape by UAV (Unmanned Aerial Vehicle) technology. For Belá River study area was used hexacopter Hexakopter XL with Sony NEX 6 camera. Images (1820) was processed by Agisoft PhotoScan software and georeferencing was ensured with 38 Ground Control Points (GCP). Three ways of imaging for 3D model of river landscape creation were used: (i) orthogonal, (ii) oblique and (iii) horizontal and total geometry error of 3D models was 80 mm. Presented workflow consists from following steps: (i) recognoscation of mapped site (identification of potential problems, danger areas for fly mission, takeoff and landing points); (ii) pre-flight field works (GCP targeting); (iii) fly mission; (iv) quality check and processing of aerial data (accuracy assessment and software data processing); and (v) operations above processed layers (visualization, landform identification, data and object extraction). Results of data processed were textured point cloud, orthophotomosaic of study area with pixel resolution 5 cm and digital elevation model of channel and floodplain with resolution 6.46 cm. Traditional field research leads to standard schematization of study area with errors from subjective observation and flow pattern variations in contrast to high precision and detailed UAV surface modelling. UAV mapping enable identified polygons with area 0.006861 m<sup>2</sup> and precise vectorisation of bank edges under tree canopy leaned above bank, supervised pixel classification, point cloud classification, woody debris volume identification (931 m<sup>3</sup>), optical grain size analysis, bathymetry and vertical changes in landforms. Dataset obtaining by UAV technology characterizes reach with dominance in-channel structure, LWD accumulation, gravel material storage up to 1 m above river flow and second reach influenced by human interventions (small hydropower plant), with intensive channel incision up to 2 m.

**Keywords:** UAV technology, workflow, point cloud, mapping



THEME: S23 : GEOMORPHOLOGICAL MAPPING

ABSTRACT NUMBER: 252

## RESEARCH AND PERSPECTIVES ON GEOMORPHOLOGY IN CHINA: FOUR DECADES IN RETROSPECT

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Geomorphology is one of main branches of geography. The research achievements and prospects in geomorphology have received considerable attention for a long time. In this paper, a general retrospect of geomorphological research in China over the past 60 years was firstly addressed, especially the research progresses in the last 40 years. Based on a summary of experience and a tendency of development, perspectives of geomorphological research direction in the future were provided. It is concluded that the discipline of geomorphology has made great progress in the aspects of geomorphological types, regionalization, as well as their subdisciplines such as dynamic geomorphology, tectonic geomorphology, climatic geomorphology, lithological geomorphology, palaeogeomorphology. We believe that persisting in the unity principle between morphological and genetic types would be conducive for the development of traditional landforms and integrated landforms. In addition, five perspectives aim to enhance China's geomorphological research capacity. They are: (1) strengthening the research of basic geomorphology theory and the research of integrated geomorphology to expand the research space; (2) focusing more on the research of geomorphologic structure and geomorphologic function to improve the application ability of geomorphology; (3) constructing a comprehensive resource, environmental, and geomorphologic information system and building a sharing platform to upgrade the intelligent information industry of geomorphology; (4) putting more efforts on the research of coastal geomorphology and marine geomorphology to assist the transformation of China from a maritime country to an ocean power; and (5) cultivating talents and constructing research teams to maintain a sustainable development of China's geomorphological research.

THEME: S23 : GEOMORPHOLOGICAL MAPPING

ABSTRACT NUMBER: 266

## GEOMORPHOLOGICAL AND LITHOLOGICAL MAPPING IN A SEMI-ARID ENVIRONMENT

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Geomorphological mapping plays an essential role in understanding surface processes, geo-chronology, natural resources, natural hazards and landscape evolution. Until now there is no uni-formity among geomorphological legends, as different mapping 'schools' independently developed systems for use at different scales in a variety of landscapes. Data collection in the field is important for the compilation of geomorphological maps and the issue of scale is substantial.

In the late 1980s, the use of Geographic Information Systems (GIS) became widespread in geomorphology and GIS technologies have become important tools for landform analysis, data management and construction of geomorphological databases. Digital Elevation Models (DEMs), especially the increasing availability of high-resolution DEMs (1 to 20 m spatial resolution) within the last decade, have promoted quantitative approaches to landscapes. Consequently, GIS are not used solely as mapping tools.

Remotely sensed optical data with a high spatial and spectral resolution like WorldView-2 with a ground resolution of 0.5 m (panchromatic) allow base mapping at scales between 1:2,500 and 1:25,000. Optical satellite imagery and DEMs provide information on surface structure and enables a spectral differentiation and a consistent interpretation. These techniques have been applied to detect geomorphological units and various relief features. Radar imagery can assist in the identification of morphological structures.

The aim of this study is to map the morphology and morphogenesis of the semi-arid landforms of a particular area in northern Tanzania in the scale 1:10,000. We follow a multiscale approach with (i) extensive field mapping, (ii) interpretation of multispectral and microwave remote sensing images (WorldView-2 and TerraSAR-X data) and (iii) the delineation of topographic derivatives (based on SRTM-X). Particular emphasis was given to the identification and mapping of gully erosion. The geomorphological map product is also planned to be a guide for field work from related disciplines with a geoarchaeological focus.



THEME: S23 : GEOMORPHOLOGICAL MAPPING

ABSTRACT NUMBER: 549

## MULTI-LEVEL DIGITAL GEOMORPHOLOGICAL MAPPING USING ORTHOPHOTOS, LiDAR- AND UAV-DERIVED INFORMATION

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Vast amounts of multi-temporal high-resolution orthophotos and fine-scale LiDAR-derived and UAV-based information provide an unprecedented database for manual and automated geomorphological mapping. Clear criteria for selecting the optimum dataset at a given mapping scale are scarce. Sixteen students in Earth Sciences and seven professionals in the field of geomorphology, natural hazards and GIS kindly participated in a test and digitally constructed three separate polygon maps at different levels of detail for a representative 250x250m mass-movement area, using a predesigned mapping protocol, and filled out a feedback questionnaire. The participants were provided with an ArcMap and ArcScene 3D-project containing maps on openness, slope angle and aspect, a composite RGB map of openness and slope angle, and a 1 m resolution hill-shade map. In addition, multi-temporal infrared and true colour orthophotos at 10-25 cm resolution and images and elevation data from a UAV flight at 3 cm resolution were available. Contour-line data and a public-domain digital geological map completed the database.

Landforms of the process groups 'Fluvial' and 'Mass Movement' are recognized and digitized at an overview level. Types of landforms and deposits were mapped on a second level. Fine-scale features and early signs of shallow mass movements were identified at a third, most detailed level. A 'Goodness of Fit' analysis shows that the overview-level maps produced by experts have a higher agreement than those produced by non-experts. Furthermore, maps of participants who included the RGB composite layer for recognition and delineation of map features show a higher spatial agreement than those of participants who did not use these data. Based on the experience and results, the mapping instructions are refined, mainly to encourage mappers to use particular combinations of data layers at each level of detail, to follow a predefined sequence of digitizing, and to recognize landform types.

THEME: S23 : GEOMORPHOLOGICAL MAPPING

ABSTRACT NUMBER: 565

## A GEOMORPHOLOGICAL CHARACTERISATION OF RAVINE AND ITS DYNAMICS: THE STUDY OF A SEMI-ARID CHAMBAL, INDIA.

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Ravine is a severely eroded landscape consists of deep gullies and ravines, a complex biophysical process. It is one of the severe environmental challenges in semi-arid region in India.

Chambal ravine is the most bewildering geomorphic entities covered around 48000-km<sup>2</sup> areas along the river Chambal and its tributaries. The nature of Chambal ravine is very diverse all along the valley. To quantify and characterize the gigantic Chambal ravine is challenging. The rugged complex topography is not accessible uniformly. The objective of this study is to understand the nature, characteristics and dynamics of ravine. Repetitive field survey, using CARTOSAT DEM along with other geospatial data and technology the ravine has been delineate and classified. The complex nature of ravine trenches is diverse. The depth of the ravine varies from 1.5 meters to more than 40 meters, the bed width varies from few meters to 20 meters, the slope of head scarp is gentle to very steep and slope of sub scarps is from 45 degrees to sometime vertical. The longitudinal and cross profile of CARTOSAT DEM of the different sections of the ravine is proved to be useful and helped to validated the field observations. As per these physical characteristics the ravine has been classified as deep, medium and shallow. The study showed that the long narrow ravines are initially formed along the natural drainage line and further progressive transformations under increasing soil erosion, ravines are bifurcated into many branches and develop bulbous pattern with rounded heads and sloping sides which are further enlarges if there are no further control of ravine.

**Keywords:** Chambal valley, Geomorphology of Ravine, Ravine erosion, Geospatial technology, CARTOSAT DEM



THEME: S23 : GEOMORPHOLOGICAL MAPPING

ABSTRACT NUMBER: 589

## INDUCED CHANGES IN SLOPE MORPHOLOGY, SOIL PROPERTIES AND GULLY EXPANSION FROM TRAIL DEVELOPMENT AND ANTHROPOGENIC FOOTPRINT ACROSS A LATERITIC BADLAND GEOMORPHOSITE

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The extensive lateritic badland surface near Garhbeta in Paschim Medinipur district of West Bengal is an Indian geomorphosite. However, its increasing attractiveness to tourists has induced marked alterations, through incremental changes in slope morphology, alterations of pedological attributes and influenced gully-head expansion.

Mapping of the hiking trails and gully field has been done from a 2 metre DTM, corroborated through a Total Station survey. Successive imageries from Worldview 1-2-3, QuickBird-2 and GeoEye-1 satellites, from 2003 to 2016, are used to map trail development over time, ratified through an along-trail GPS survey along with vegetation cover changes over the same time period. Repetitive Structure-from-Motion imaging is used to capture even finer changes in the micro-slope facets, from a ground perspective, allowing accurate measurements of plan-form and volumetric changes between the original surface and the altered trampled paths. Silver-Schmidt Hammer readings also attest to the lowered structural strength of these human trails.

Constant hiking has accelerated erosion rates, with wood-fires for outdoor cooking during picnics, further charring and hollowing out the friable lateritic surface. Stairway construction has exposed scarp faces and the trails serve as newer erosion pathways, through which runoff is channelized and their soil character too differs markedly, being of a finer character. This walking-induced-erosion has not only modified the slope facets along the trails, but by lowering their relative bed elevation in comparison to adjacent gullies, have also induced back-wearing and rilling along their edges, precipitating minor slope failures and faster head-ward gully extension. Consequently, these have gnawed into the laterite with the entire badland tract expanding by 16% in the last decade, during which the trail density has increased four times, with simultaneous thinning of the scrub cover. This forbears the prospect of even more accelerated erosion in the years ahead.

**Keywords:** Badland; Laterite; Geoinformatics; Trail; Geotourism

THEME: S23 : GEOMORPHOLOGICAL MAPPING

ABSTRACT NUMBER: 767

## SURFICIAL GEOLOGY AND GEOMORPHOLOGY OF THE WESTERN SAN JUAN MOUNTAINS, COLORADO

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Mass movement is a recurrent phenomenon in the rugged topography of the western San Juan Mountains, Colorado. Debris flows, landslides, and snow avalanches pose a significant threat to human life and infrastructure in the area. In this study, the surficial geomorphology of the western San Juan Mountains was mapped at a scale of 1:3,000 to determine the spatial distribution of phenomena, which potentially pose hazards from slope failures.

The study area encompasses the USGS quadrangles: Ridgway, Dallas, Mount Sneffels, Ouray, Telluride, Iron-ton, Ophir, and Silver-ton covering an area of approximately 1,615 km<sup>2</sup>. Mapped surficial landforms were categorized as 1) glacial landforms; 2) glaciofluvial landforms; 3) fluvial and water; 4) gravitational landforms; 5) morphological components; 6) outcrop geology; and 7) periglacial landforms. Mapping was completed using a combination of field mapping and air-photo interpretation. Talus and landslide deposits are the dominant landforms in the area. This map provides a detailed understanding of the landscape evolution of the San Juan Mountains. Furthermore, this valuable resource will assist in future geomorphological studies and land-use planning.

**Keywords:** Mass Movement; Geomorphology; Field Mapping; Talus; Landslide Deposits



THEME: S23 : GEOMORPHOLOGICAL MAPPING

ABSTRACT NUMBER: 783

## MORPHOMETRICAL-MORPHOSTRUCTURAL SUBDIVISION OF THE WESTERN CARPATHIANS (SLOVAKIA) BY OBJECT-BASED IMAGE ANALYSIS (OBIA)

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Geomorphological regionalisation has long tradition in Slovak geomorphology. However, in view of high demands for objective approaches in modern geomorphology, the manually elaborated regionalisation currently in use suffers from subjective decisions of its authors. To address the demands, we applied object-based image analysis for semi-automated and objective delineation of the basic, third-order morphostructures of the Western Carpathians, which should approximately correspond with the traditional geomorphological regions. Three morphostructurally meaningful geomorphometric variables derived from the SRTM V4 dataset – slope gradient, vertical dissection of terrain (representing terrain roughness) and elevation (reflecting intensity of vertical tectonic movements) – were used as input into multiresolution segmentation based on the ESP2 tool in the eCognition Developer software. Two processes were repeatedly performed in our object-oriented workflow: automated iterative segmentation and selection (and removal) of distinct individuals based on mean difference in elevation to neighbouring objects. Such repetition of segmentations with decreasing scale used for partitioning of systematically smaller domains proved to be important when delineation of morphostructural features variable in size and homogeneity degree is targeted. As a result, one object level containing several hierarchical levels different in level of detail was obtained. Compared to the traditional geomorphological regions it has quantitative compatibility of 60 %. Statistically incompatible boundaries are not considered as failure of the proposed approach, since most of them still have a morphostructural meaning either in terms of their alternative interpretation or as more- or less-detailed substitution. Some inconsistencies were visually attributed to uncertainties present in the traditional regions, which cannot be dealt with algorithmically, e.g. boundaries that do not follow the obvious morphological contrast or were determined lithologically. Our subdivision can be used as a more objective alternative for the traditional regionalisation, with strongly reduced influence of subjective decisions in the process.

**Keywords:** geomorphometry; multiresolution segmentation; object-oriented approach; objective mapping

THEME: S24 : GEOMORPHOLOGY AND ALLIED DISCIPLINES: MUTUAL CONTRIBUTIONS FOR THE PROGRESS OF INTEGRATED ENVIRONMENTAL AND DISASTER STUDIES

ABSTRACT NUMBER: 154

## FLOODPLAIN MAPPING AND VULNERABILITY OF KASHMIR VALLEY USING HEC-RAS AND ARC GIS : A CASE STUDY OF UPPER RIVER JHELUM, KASHMIR INDIA.

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The present study demonstrates the relevance of the HEC RAS model for the formulation of the detailed floodplains maps of the Kashmir basin, which will provide an immense assistance to planners in formulating the flood management and development plans in Kashmir valley, as the study area experienced unprecedented floods throughout its history, the recent flood of September 2014 which created havoc, exposed the vulnerability extent of the valley and place forwards need of the detailed management plan. The HEC RAS model used in the present study is known for its precision. A detailed terrain modelling of River Jhelum has been carried out using RTK GPS for preparation of the Digital Elevation Model, which was subsequently used for the extraction of the geometrical data of river Jhelum. In the present investigation gauge records of annual peak flows (1956-2014) of two gauging stations i.e., Sangam (upstream) in south and Ram Munshibagh (downstream) in central reaches of the river, were used to carry out the flood frequency analysis (FFA) of the Jhelum River by Gumbel and Log-Pearson type-III (LP3) probability distributions, as revealed by the goodness of fit test (Chi-square and Kolmogorov Smirnov), Log Pearson Type-III was found to be the best fitted probability distribution. The results obtained from the frequency analysis were used as an input to find out the corresponding flood levels likely to be in the river Jhelum. The outputs from the HEC RAS were transferred to Arc GIS 10.2 for the preparation of the floodplain maps in accordance with their return period. These maps were then attributed with various social parameters to get the complete vulnerability profile of Kashmir valley. Analysis of these maps revealed that 1505 (9.43%) square kilometre with 22% population found to be vulnerable.

**Keywords:** Flood Frequency, HEC RAS, Arc-GIS

ABSTRACT NUMBER: 209

## EVALUATION OF SPATIAL AND TEMPORAL DRYNESS CHARACTERISTICS IN TURKEY AND THEIR POSSIBLE IMPACTS ON SOIL DEGRADATION

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Drought may occur in almost every climatic region on Earth at any time. Understanding the nature and magnitude of the dryness and drought events are crucial mainly in semi-arid regions characterized by water shortage and warm/hot and dry Mediterranean type climate. The present article analyses the major patterns of the spatial and temporal characteristics of the climatological dryness in Turkey.

The present study adopts a relatively new approach for characterizing the dryness over a certain region; dry days since last rain (DDSLR). The DDSLR in a certain place can be evaluated using three different metrics; its severity, its consistency and its temporal uncertainty enabling to present intra and inter-annual variations of the dryness. The DDSLR is also coupled with the Mediterranean Climate Index (MCI) approach, measuring the seasonality of rainfall. Analyses were based on daily precipitation data recorded at 69 principal climatological and synoptic meteorological stations of the Turkish Meteorological Service (TMS) network during the period 1970 to 2011.

The spatial distributions of the MCI and the various DDSLR metrics are presented and analysed. Overall, the three metrics of the DDSLR show their highest values in southern parts of Turkey along the Mediterranean and the borders with Syria and Iraq. These dryness indices are even larger than in central Turkey which receives less annual rainfall. On the other hand, dryness is at its minimum along the Black Sea in northern Turkey.

Logarithmic equations of the type  $f(\text{DDSLR}) = a \cdot \ln(\text{MCI}) + b$  were fitted to describe the dependence of these metrics on the Mediterranean Climate Index. All regressions are highly significant and enable to evaluate these metrics even in regions without daily data. Finally, linear trends of the longest DDSLR in each year were calculated and reveal trends toward more severe dry conditions in north-western Turkey and less severe dry conditions in east Turkey.

ABSTRACT NUMBER: 304

## OBJECTIVE AND SUBJECTIVE REALITY: AN INTEGRATIVE RESEARCH ON NATURAL HAZARDS EVENTS AND PERCEPTION IN ALPINE VALLEYS

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Alpine regions and their population are particularly vulnerable to natural hazards. These hazards are not isolated natural events, they are connected with the social system.

In this study, we investigate the knowledge, perception and communication of local residents with regard to the natural hazard situation in three Alpine research areas in Austria: the Johnsbach valley, the Sölk valleys, and the St. Lorenzen/Schwarzenbach valleys. More precisely, we address the following research questions: (1) How do people living in Alpine valleys perceive natural hazards in their home regions? (2) Is there a gap between recorded hazardous events and the perception of the local population?

By assessing the knowledge and perception of the inhabitants, the objective is to get insight into their expertise in dealing with natural hazards and how these hazards influence their living. The empirical data is derived from a questionnaire survey with almost 300 respondents as well as qualitative information from 25 semi-structured, problem-centred interviews with local stakeholders.

The recorded data from past natural hazard events is taken from the official torrent and avalanche cadastre, which shows that the hazardous processes in the research areas are mainly water-based hazards (floods, fluvial sediment transport and debris flows) and

snow avalanches. To achieve an integrative perspective, we set this data (“objective reality”) in context with the perception of the local population (“subjective reality”) in order to identify and analyse the gap between these two sides.

Results show different perspectives of the inhabitants depending on where they are living (e.g. in a hazard zone or not) or for how long they are living in the valleys, amongst other criteria. These results may further be used for risk communication adaptations, the improvement of the acceptance of natural hazard planning and the development of future protective structures.

*THEME: S24 : GEOMORPHOLOGY AND ALLIED DISCIPLINES: MUTUAL CONTRIBUTIONS FOR THE PROGRESS OF INTEGRATED ENVIRONMENTAL AND DISASTER STUDIES*

**ABSTRACT NUMBER: 345**

## **EVALUATING LAND USE CHANGES AND GEO-HYDROLOGICAL RESPONSE IN SMALL MEDITERRANEAN CATCHMENTS WITH OUTSTANDING CULTURAL AND NATURAL VALUES**

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Climate change adaptation and geo-hydrological risk mitigation strategies, particularly in urban and peri-urban areas are amongst the world's greatest challenges of this century.

Urban settlements along the Mediterranean are very ancient and current cultural and ‘natural’ landscapes are the consequence of centuries of human intervention.

Original hydrogeological balances were modified by a series of factors such as the building of agricultural terraces on the slopes, the modifications of the hydrographical network and land use changes.

This research assesses solid transport and run-off parameters in relation to land-use changes of the last centuries in the catchments of San Fruttuoso di Camogli (Park of Portofino, Italy). This territory was greatly influenced by the Benedictine abbey of San Fruttuoso, founded in the Early Middle Ages; through the centuries, the steep slopes around the abbey were terraced and many land use variations occurred, in relation to socio-economic changes.

The catchments of San Fruttuoso are historically characterised by geo-hydrological risk: the flood of 25th September 1915 damaged the abbey and formed the beach of San Fruttuoso, while more recently some flash floods and soil slips occurred.

Land use settings today, in the 1970s, the 1930s and in the nineteenth, eighteenth and sixteenth century were reconstructed with the analysis of archival papers, historical maps, photographs and remote sensing images; land use conditions before human settlement were then hypothesised.

This contribution is part of the European Interreg Project “TrigEau”; it is aimed to identify the best present and past land use conditions in relation to Curve Number and Sediment transport parameters for a better management and mitigation of geo-hydrological risk through prevention measures.

**Keywords:** Land-use change; heavy rainfall; sediment transport; Portofino National Park

*THEME: S24 : GEOMORPHOLOGY AND ALLIED DISCIPLINES: MUTUAL CONTRIBUTIONS FOR THE PROGRESS OF INTEGRATED ENVIRONMENTAL AND DISASTER STUDIES*

**ABSTRACT NUMBER: 413**

## **RAIN WATER HARVESTING IN THE DROUGHT PRONE REGION– A WATERSHED SCALE STUDY IN BANKURA DISTRICT OF WEST BENGAL**

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Undulating terrain, coarser and bare soil, location in the interfluvium between the Kangsabati and the Shilabati together lead to immediate



drainage and water scarcity in the area under study during prolonged dry period, inspite of receiving sufficient rain. A water budget has been constructed after careful estimation of rain input, infiltration and evaporation loss. Result shows that retention of 5-8% of annual discharge can effectively meet the demand in dry period. Modification of gradient for effective intervention along the path of both surface and sub-surface flow by constructing check dam, contour trenching and bunding, excavation and renovating ponds, plantation, and roof-top rain water storage may be effective to address the problem. Calculation shows that a reservoir of 6445 litre size may be effective to manage water demand of a family of four-members in worst drought condition that may arise in 20 years' recurrence interval.

**Keywords:** Water Scarcity; Concentric Rain; Water Retention; Roof-top Water Harvesting

*THEME: S24 : GEOMORPHOLOGY AND ALLIED DISCIPLINES: MUTUAL CONTRIBUTIONS FOR THE PROGRESS OF INTEGRATED ENVIRONMENTAL AND DISASTER STUDIES*

**ABSTRACT NUMBER: 418**

## **ENVIRONMENTAL INFLUENCE ON AGRICULTURE: A STUDY OF WEST BENGAL**

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Environmental factors like morphology of land, climate and soil are predominantly influencing upon the agricultural practice in West Bengal. Those tri factors together have a direct impact on crop productivity, crop yield. Present study aims to understand the trend in crop productivity from 1995 to 2012 in West Bengal and its relation to geomorphology, climate and also soil to identify site specific role in positive and negative trends of crop productivity. Crop productivity index is calculated after enyedi(1964) and MANN-KENDALL test is followed for analysing trends of rainfall and temperature. The result indicates that the areas having significant positive rainfall, fertile soil and elevation ranging from 0 to 100 m with well drain condition have high productivity in Aman, Boro, Jute, Potato etc. In Comparison to areas with low fertile soil, more climatic variability, negative trend of rainfall and high elevation have low productive rate in various crop. Various agricultural inputs like irrigation facility, fertilizer are the main adaptive strategy for maintaining the high productivity in those areas of West Bengal.

**Keywords:** Crop Productivity; Agricultural inputs; MANN-KENDALL test

*THEME: S24 : GEOMORPHOLOGY AND ALLIED DISCIPLINES: MUTUAL CONTRIBUTIONS FOR THE PROGRESS OF INTEGRATED ENVIRONMENTAL AND DISASTER STUDIES*

**ABSTRACT NUMBER: 419**

## **WATER LOGGING AND LAND USE - A DIALECTIC RELATIONSHIP: STUDY ON CHUNDIA RIVER BASIN, WEST BENGAL**

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In Chundia river basin of Purba and Paschim Medinipur district of West Bengal, experiences intensive water logging during rainy season that leads to transformation of land use from agriculture to fishery. The objective of the present study is to assess the interplay between water logging and land use. Prepared land use and land cover map of dry and rainy season of the year 2005 and 2015 based on Google earth quick bird satellite imagery with the help of Arc-GIS (10.1) software shows that agricultural land is reduced by 2.83% and 0.81% and fishery or shallow water bodies are increased by 2.62% and 0.61% in dry and rainy season respectively during this period. Introspection on the causes of water logging shows that length of the embankment is increased by 24.92 Km during 2005-15 for the sake of fishery, that again leads to further water logging. Loss of productivity due to continuous water logging, in turns, leads to land use conversion.

**Keywords:** Water logging, Land use change, Fishery, Embankment

THEME: S24 : GEOMORPHOLOGY AND ALLIED DISCIPLINES: MUTUAL CONTRIBUTIONS FOR THE  
PROGRESS OF INTEGRATED ENVIRONMENTAL AND DISASTER STUDIES

ABSTRACT NUMBER: 421

## LONG-TERM MULTIDISCIPLINARY INVESTIGATIONS ALONG THE NW COAST OF MALTA (CENTRAL MEDITERRANEAN SEA)

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Rock spreading and block sliding are probably the less investigated geomorphological processes in coastal areas. This is due to their reduced rate of movement which make them apparently less hazardous. Nevertheless the increasing number of extreme natural events, as a result of climate change, oblige to deepen the knowledge of other instability processes which might be related to such landslides.

Rock spreads and block slides are common along the NW coast of Malta (central Mediterranean Sea) and are favoured by the overposition of two lithotypes characterized by different mechanical properties, such as limestones (above) and clays (below). The edges of the limestone plateaus located along the coast are widely affected by rock spreading which often evolve into block slides. The latter are witnessed by the presence of scattered blocks lying on the clayey slopes and extended even below the sea level.

This paper presents a multidisciplinary approach aimed to investigate the geomorphological evolution of the above mentioned landslides in order to (i) understand the paleo-environmental conditions under which the landslides developed, (ii) identify their conditioning and triggering factors, (iii) assess landslide hazard and (iv) outline risk scenarios. The investigations carried out since 2005 included geological and geomorphological surveys, geophysical campaigns, GNSS surveys and A-DInSAR (Advanced Differential Radar Interferometry) analysis. The research carried out on emerged coastal landslides was integrated with identification and mapping of submarine landslide deposits by means of a Digital Elevation Model based on a multibeam survey coupled with an airborne bathymetric LiDAR (Light Detection And Ranging) survey. In addition, the time frame of possible landslide onset was determined by means of Cosmogenic Radionuclide Exposure dating (CRE).

**Keywords:** coastal landslides; multidisciplinary investigations; Malta; Mediterranean Sea

THEME: S24 : GEOMORPHOLOGY AND ALLIED DISCIPLINES: MUTUAL CONTRIBUTIONS FOR THE  
PROGRESS OF INTEGRATED ENVIRONMENTAL AND DISASTER STUDIES

ABSTRACT NUMBER: 456

## LONGTIME: AN INTERDISCIPLINARY PROJECT TO EVALUATE THE LONG TERM IMPACT OF ANCIENT AMERINDIAN SETTLEMENTS ON GUIANESE FORESTS AND ITS CONSEQUENCES FOR BIODIVERSITY CONSERVATION.

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A growing bulk of evidence suggests that Amazonian rainforest might have been much more densely occupied and intensely modified by Amerindian societies before the arrival of European than previously thought. Several studies in central and western Amazonia have already confirmed that the impact of pre-Columbian societies is still locally perceptible in soil and forest structure and composition, and should be considered as one of the potential drivers influencing present-day biodiversity and soils. Such studies are, however, rare in French Guianan rainforests. The LongTime project aims at filling this gap by bringing together human scientists (archaeologists, anthropologists, ethnoecologists) and environmental scientists (geomorphologists, ecologists, foresters, pedologists), as well as Amerindian experts, in a landscape-scale study of areas where ring-ditch archaeological sites have been recently detected. Such sites, probably created and occupied around 1000 AD, currently under a dense rainforest cover, appear as more or less circular excavated ditches (2 m x 2 m) enclosing the top of lateritic hills (around 1-ha areas). Although their function is still unclear, their presence indicates a permanent or semi-permanent occupation by Amerindian societies, which have most probably also modified the surrounding environment (agriculture or agroforestry, soil modification, hydraulic engineering). Geomorphology and geoarchaeology

thus play a key role in the project as they allow to map and characterize the impact of such activities on soil structure and fertility. LongTime will help understand the origins of present-day biodiversity patterns in French Guianese rainforests, thus providing key elements for environmental policy makers and for the modeling of forest changes in response to future land use and climate changes. Moreover, understanding how ancient Amerindians were living in their environment, and how they used forest resources might help us protect Amazonian rainforests.

**Keywords:** Amazonian rainforest; Past human occupation; Environmental impacts; Integrated research; Historical ecology

*THEME: S24 : GEOMORPHOLOGY AND ALLIED DISCIPLINES: MUTUAL CONTRIBUTIONS FOR THE PROGRESS OF INTEGRATED ENVIRONMENTAL AND DISASTER STUDIES*

**ABSTRACT NUMBER: 564**

## **GEOMORPHOLOGICAL CHANGES DUE TO ANTHROPIC ACTIVITY IN THE HIGHLY URBANIZED FLOODPLAINS OF SMALL LIGURIAN MEDITERRANEAN BASINS (ITALY)**

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The Ligurian slopes facing the Tyrrhenian Sea extend along the coast for nearly 300 km between France border to Tuscany: this stretch of territory presents more than a hundred catchments characterized by small floodplains. The slopes are very steep, while the alluvial plains are typically narrow and elongated.

Ligurian catchments, except for the Roja and the Magra rivers, have common features: they can be distinguished in very small (<15 km<sup>2</sup>), small (15-150 km<sup>2</sup>) and medium basins (150-500 km<sup>2</sup>).

Ligurian alluvial plains are historically characterized by floods that have caused damage for million of euro and tens of casualties. Over the last decades, an increase in alluvial events has been observed, both due to the variation in rainfall regime and in changes of land-use, which have heavily influenced the geomorphological processes.

The great part of Ligurian urbanized areas are located in floodplains: these large areas represent the expansion of the small historical settlements and their original road connections.

Through a comparison of old maps it was rebuilt the morphological evolution of Ligurian floodplains in historical times. Using historical maps of XVIII and XIX century, and regional maps for second half of XX century, the land-use and riverbed changes in the last centuries have been evidenced. The current status was assessed by Google Earth Pro platform.

The secular human activities in Liguria have clearly modified the floodplain environment. The main channel, and even the minor hydrographic network, have showed major transformations over time. In many cases a narrowing and riverbed covering has been detected, especially in the medium-terminal stretch, with the aim to create new urbanizable areas for buildings and roads. Other widespread changes finally concern deviations and displacements of the riverbed, progradation of the coastline due to fills.

*THEME: S25 : FUTURE EARTH: RESEARCH FOR GLOBAL SUSTAINABILITY*

**ABSTRACT NUMBER: 493**

## **CHALLENGES OF A PRESENT-DAY AND FUTURE LANDSLIDE RISK ASSESSMENT AT NATIONAL SCALE IN ROMANIA**

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Geomorphology provides scientific services to a wide range of stakeholders in fields such as geomorphological mapping/zoning, laboratory/field experiments, geomorphologic assessment/ modelling. Through its objectives found under Dynamic Planet and Knowledge-Action Network research themes, Future Earth Platform provides a framework where Geomorphology can be involved in terms of risk reduction in regions with high human pressure and respond to society's needs offering solution-oriented research aimed to increase society resilience to extreme events. An example of such direction is the landslide risk assessment; this paper aims to present a case-study developed in Romania within the transdisciplinary project RO-RISK (Disaster Risk Evaluation at a National Level; 2016;

coordinator Romanian General Inspectorate for Emergency Situations; financed - European Social Fund, Operational Programme for Administrative Capacity). In this context, through the geomorphological research on landslides, synthesis data on landslide hazard and risk at national level have been produced as a support for decisions undertaken by civil protection in managing this risk. Landslides are ranked among the potentially-endangering geomorphic hazards in Romania in terms of both spatiotemporal distribution and direct/indirect damages to the human and natural environment. The purpose of this paper is to outline the complexity and the uncertainties of a landslide risk assessment at national scale, reflected by a continuous correlation among data (in terms of quantity and quality as a reflection of their various sources), method (a consistent input of expert knowledge into the statistic analysis) and working scale (the requested national level). The successive steps within hazard assessment (inventory, susceptibility, triggering factors, hazard scenarios) are discussed in terms of methodological reasoning, data handling, spatial zonation and results interpretation through regional expert-judgment. The landslide risk is analyzed through a detailed (LAU2 level) exposure and vulnerability assessment, leading to a risk scenarios prioritization. The uncertainties are discussed in terms of nature, location and level.

*THEME: S25 : FUTURE EARTH: RESEARCH FOR GLOBAL SUSTAINABILITY*

**ABSTRACT NUMBER: 712**

## **AN ACCOUNT OF CLIMATIC OSCILLATIONS IN FRAGILE GEOMORPHOLOGICAL SETTINGS OF HIMALAYAN FOOTHILLS, INDIA**

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The study area is located along the foothills of the Eastern Himalayas with an assemblage of forest cover, popularly known as Duars or Dooars region of India. It is extended from the river Tista, West Bengal to the river Dhunseeree in Assam state. Within this broad outline, the areal extension between rivers Tista to Sankosh covering West Bengal is known as Bengal Duars or Western Duars and rest of portion as Assam Duars or Eastern Duars. It had been reported earlier by Hamilton (1838) that the temperature of the foothill zone never exceeded 27°C, later it increases gradually specially in summer seasons and the highest one was recorded 40°C. Climate change is considered as one of the most extensively researched and discussed topic nowadays. Differential variability of regional climate is causing incomplete understanding of future climate, particularly Indian Monsoon. Climate is not always changing in a linear fashion; rather climatic oscillation is apparently clear in the studied region. In the present research work multi decadal variability and trends of climatic events (temperature and rainfall) in Duars region (more than 100 years) has been analysed. Further, the level of future climatic extremeness and its impact on geomorphological set up has also been addressed systematically.

*THEME: S26 : CONNECTIVITY IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 83**

## **CONNECTIVITY RESPONSE UNITS: A CLUSTERING-BASED APPROACH FOR ASSESSMENT OF HYDROLOGICAL CONNECTIVITY OF A WETLAND (KAABAR TAL, NORTH BIHAR PLAINS, INDIA)**

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The concept of connectivity has played an important role in the hydro-geomorphic studies in the last couple of decades. It has developed as a multi-scale concept, capable of explaining the phenomena of runoff generation, water and sediment transport, as well as landform transformations. One way to investigating connectivity is by calculating connectivity indices (ICs) as proposed by previous workers. These connectivity indices usually follow per-pixel approach and indicate the connectivity potential of that particular pixel. However, the per-pixel approach promotes the pixel-individuality and lacks any spatial pattern. Here we propose to utilize the spatial patterns of connectivity as manifested in Connectivity Response Units (CRUs) to help understand the responses of different landscape elements and the impact of land-use/land-cover on connectivity structure better. This paper presents a method for the transformation of a IC map into a CRU map by clustering the pixels with similar IC values. The clustering has been done by applying the diffusion-kernel interpolation and the 'Jenks natural breaks classification' scheme. The method has been applied to investigate the impacts of seasonal land-use/land-cover changes over the hydrological connectivity of a water-stressed wetland namely Kaabar Tal, which is situated in the Kosi-Gandak interfan region of north Bihar, India. We conclude that the prevailing land-use patterns, especially the present farming practices, have contributed significantly to modifying the connectivity structure

and the development of the water-stressed condition of the wetland. We suggest that the CRUs are a viable option for designing rehabilitation strategies in such coupled human-landscape systems.

**Keywords:** Connectivity response unit; Hydrological connectivity; Diffusion kernel Interpolation; Alluvial wetlands; Ganga plains

THEME: S26 : CONNECTIVITY IN GEOMORPHOLOGY

ABSTRACT NUMBER: 131

## BEDROCK STRUCTURAL CONTROL ON CATCHMENT-SCALE CONNECTIVITY AND SEDIMENT SUPPLY TO TRIBUTARY-JUNCTION ALLUVIAL FANS IN THE HIGH ATLAS MOUNTAINS OF MOROCCO.

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Lithology is acknowledged as important in sediment delivery to, and processes on alluvial fans, yet structural configuration of the bedrock is rarely considered. We will examine young (<100 year old) and active tributary-junction alluvial fan systems from the Dades Valley in the High Atlas of Morocco. They occur on the same lithologies (limestones and interbedded mudstones) but different passive structural configurations (tilted and structurally thickened beds). The fans react differently to modelled historic peak discharges (20-172 m<sup>3</sup>/sec). Catchments containing tectonically thickened limestone units develop slot canyons that compartmentalise the catchment by acting as barriers to sediment transfer, encouraging fluvial deposition on the fan. Syn-dip catchments tend to boost connectivity and sediment delivery from bedrock landslides as a result of the steep channel gradients, encouraging debris flow processes on the fan. In contrast bedrock landsliding in strike-oriented drainages impedes longitudinal connectivity through constricting valley width. Downvalley connectivity is further inhibited by bedrock suppressed channel gradients that encourage localised backfilling. Associated fans thus have more fluvial characteristics than may be expected. Karst springs controlled by structural thickening, tilting and discontinuities (bedding, jointing) suggest groundwater contributions may also play a role in defining water:sediment in some flows.

**Keywords:** coupling, connectivity, bedrock landsliding, tributary junction, alluvial fan

THEME: S26 : CONNECTIVITY IN GEOMORPHOLOGY

ABSTRACT NUMBER: 232

## MULTITEMPORAL APPROACH TO MEASUREMENT COARSE SEDIMENT CONNECTIVITY (CASE STUDY OF A BRAIDED-WANDERING RIVER)

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The aim of the article is to present the post-flood period coarse sediment connectivity measurement (POPSECOM) approach based on the holistic ideas of the interpretation of long-term coarse sediment connectivity (CSC) in river channels. The seven sets of remote sensing data (1949-2009) were used as basic information sources for the study of CSC along the braided-wandering Belá River. Conefor Sensinode 2.6 software using patch-graph theory was adopted as the tool for the assessment structural connectivity. The bar areas (connection nodes), 200 m direct links between them, and the attribute of deflection angle of a link to flow direction served as parameters for the estimation of the integral index of connectivity (IIC), bar area (BAI) and bar link (BLI) importance indices. The potential functional CSC is inferred from variability of values obtained by balance indices (B1, B2). Eight modifications of the potential functional CSC based on balance indices and the deduction of processes conditioning channel-floodplain and in-channel CSC linkages were identified. The coefficient of determination of IIC values was used for the interpretation of reaches behaviour in relation to flood periods. The higher values of IIC fit with a good developed bar system. Conversely, the values of IIC decrease due the progressive degradation of the braided pattern. Based on the coefficient of determination all reaches exhibit decreasing trend in IIC values and variable behaviour (from sensitive to robust). In general, CSC in the Belá braidplain in years 1949 – 2009 decreased due to both, internal and external drivers.

**Keywords:** connectivity, sediments, patch-graph, floods, river

THEME: S26 : CONNECTIVITY IN GEOMORPHOLOGY

ABSTRACT NUMBER: 353

## SPATIAL NON-CONTINUITY OF HYDROLOGICAL AND ECOLOGICAL PROCESSES IN ARID AND SEMI-ARID HILLSLOPES

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The aim is to present the results of studies that investigated non-continuities within the system of rainfall – soil – runoff – vegetation relationships in arid and semi-arid hillslopes.

Regarding hydrology – overland flow is of Hortonian type and it is discontinuous because of the spatial differences in infiltration rates that are controlled mainly by the spatial distribution of shrubs, stones and grazing, and resulted in a pattern of "source" and "sink" patches. The pathway of overland flow is tortuous and in most cases it infiltrates into a "sink" after a short distance. On top of this, the probability of overland flow that was generated at the upper part of hillslopes to reach the channel is very low due to the relatively very short rain showers. This means that the channel flow is fed by overland flow from a relatively narrow strip at the bottom of the hillslopes.

Regarding ecological processes – they are controlled by the spatial distribution of soil moisture which is affected, firstly, by the direct rainfall all over the hillslopes. Relative high values of soil moisture are typical to the sink areas due to overland flow infiltration. In case of similar soil type all over the hillslope - no differences are expected between the upper and lower parts of hillslopes . The biological activity over the hillslopes is, accordingly, of a spatially uniform pattern of "fertility islands".

THEME: S26 : CONNECTIVITY IN GEOMORPHOLOGY

ABSTRACT NUMBER: 425

## INFLUENCES ON CONNECTIVITY IN FLUVIAL SYSTEMS AND THEIR EFFECTS ON STRATEGIES AND GOALS OF SUSTAINABLE LAND AND WATER MANAGEMENT

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Identifying and quantifying connectivity is key to understanding delivery of water and sediment to any point in a fluvial system and can form the basis for sustainable management strategies. The information required for quantification and understanding patterns in the landscape is identified and methods are reviewed briefly. Using examples, types of sources of water and sediment and their relative importance in different settings are assessed. Transmission down through a system is controlled by hydraulics and by channel and valley morphology; influences on the hydraulics of pathways, including vegetation, are exemplified. The effects of anthropogenic and natural structural features are examined in different physical and cultural settings and their relative influence under different conditions and over time are evaluated. The impacts of disturbance or alteration on connectivity within catchments and channels are demonstrated. Assessment of the extent to which actions and changes increase or decrease connectivity is a key component of designing strategies for sustainable land and water management. However, what is desirable varies with the management goals and differing goals may be conflicting in an environment. The contribution of the various influences and changes in connectivity on achieving different goals is discussed.

**Keywords:** sustainable land management; sustainable water management; sediment; structural connectivity; functional connectivity

THEME: S26 : CONNECTIVITY IN GEOMORPHOLOGY

ABSTRACT NUMBER: 516

## POTENTIAL INTERACTION BETWEEN TRANSPORT AND STREAM NETWORKS OVER ALLUVIAL RIVER BASIN

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Extension of transport networks supports good accessibility and associated with the development of a region. However, transport lines have fragmented the regional landscape and disturbed the natural interplay between rivers and their floodplains. Spatial analysis using multiple buffers provides information about the potential interaction between road and stream networks and their impact on channel morphology of a small watershed in the Lower Gangetic Plain. Present study is tried to understand the lateral and longitudinal disconnection in headwater stream by rural roads with the integration of geoinformatics and field survey. Significant ( $p < 0.001$ ) growth of total road length and number of road-stream crossing in the last five decades (1970s – 2010s) contribute to making longitudinal and lateral disconnection in the fluvial system of Kunur River Basin. Channel geometry from ten road-stream crossings shows significant ( $p = 0.01$ ) differences between upstream and downstream of crossing structure and created problems like downstream scouring, increased drop height at outlet, formation of stable bars, severe bank erosion, and make barriers for river biota. The hydro-geomorphic processes are also adversely affected due to lateral disconnection and input of fine to coarse sediments from the river side growth of unpaved road (1922%). Limited streamside development, delineation of stream corridor, regular monitoring and engineering efficiency for the construction of road and road-stream crossing might be effective in managing river geomorphology and riverine landscape.

**Keywords:** Fluvio-Geomorphic Investigation; Road-Stream Interaction; Fluvial Connectivity; Road Curvature Index; Road-Stream Crossing

THEME: S26 : CONNECTIVITY IN GEOMORPHOLOGY

ABSTRACT NUMBER: 529

## DEFINING FUNDAMENTAL UNITS IN HYDRO-GEOMORPHIC CONNECTIVITY RESEARCH: A WETLAND EXAMPLE USING REMOTE SENSING DATA

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Connectivity is an important concept for understanding the transport of water and sediments in hydro-geomorphic systems. In order to characterise connectivity within such systems it is vital to identify meaningful fundamental units (FU) of study which we call 'geomorphic cells', i.e. structural entities consisting of land elements with similar hydro-geomorphic potential. The hydro-geomorphic potential of such a cell is determined by factors that influence its capability to store and transfer water and sediment (e.g. topography, land cover/vegetation, soil type), while the actual hydro-geomorphic cell state depends on the degree of water saturation.

In this study it is hypothesized that in wetland systems, the hydrologic state of geomorphic cells is reflected by the degree of surface soil moisture and flooding state, which can be further used as a proxy for their hydro-geomorphic potential and thus to identify and delineate FU. Remote sensing data can provide spatially explicit information on such hydrological variables. In particular, synthetic aperture radar (SAR) data have a high sensitivity towards surface soil moisture and surface water dynamics. In the context of this study, SAR image time series – in combination with information on topography and land cover – are used to identify the temporal behaviour of geomorphic cells in terms of their soil moisture and inundation dynamics within wetlands, such as the Plum Island Sound (USA) and the Kafue Flats (Zambia).

**Keywords:** connectivity, fundamental unit, remote sensing, SAR, wetlands

THEME: S26 : CONNECTIVITY IN GEOMORPHOLOGY

ABSTRACT NUMBER: 574

## 1950 AD: THE GREAT ACCELERATION OF EROSION AND SEDIMENT FLUX?

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A number of different onsets of the Anthropocene Epoch have been proposed in the literature reflecting the different disciplines and criteria regarding when human activities first began to play an important role in shaping the earth's ecosystems. In this study we focus our research on the sedimentological and geomorphological responses of earth ecosystems to human society, as a response to agricultural changes over the 20th century in Western Europe.

In the absence of long-term records of sediment transported by river systems, sediment deposited in lakes represent an asset for reconstructing and quantifying changing patterns of sediment yields in response to environmental changes. We used paleolimnological methods to reconstruct trends in sedimentation in 11 middle-age ponds located in small agricultural headwater catchments of the French Loire River Basin (117000 km<sup>2</sup>). These study sites reflect a large variety of land cover/land use changes (arable land, livestock farming, vine-growing...) and landscape morphologies (lowlands to mountainous areas).

The first results of this study concern lowland landscapes. Sediment cores show a sharp and general increase of sediment production from the second half of the 20th century. It can be attributed to the intensification of land management after WWII (land consolidation, stream redesign, edge removal or agricultural drainage implementation). They highlight a major increase in the sedimentary production with an increase of sediment fluxes by one order of magnitude after WWII. Despite a stabilization of sediment fluxes during the last 20 years in the sediment cores, the sediment deposits do not record a significant decrease of sediment production. In contrast with the previous sediment records of human activities (e.g. Maya civilization, Roman civilization...), and according to other studies, this post-WWII acceleration of sediment production seems to be recorded at the global scale.

**Keywords:** land use change; erosion; pond sediments; anthropocene; agricultural catchment

THEME: S26 : CONNECTIVITY IN GEOMORPHOLOGY

ABSTRACT NUMBER: 575

## SEDIMENT FLUXES AND PROCESSES IN A LOWLAND AGRICULTURAL CATCHMENT

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Lowlands are considered as stable landscapes, and as such were rarely the focus of erosion studies. But in these specific environments, a large increase of the sediment connectivity has been provoked by stream redesign and implementation of agricultural drainage networks since the second half of the 20th century. Streams and water bodies are submitted to elevated sediment inputs, with potentially severe consequences on water quality. There is a lack of knowledge on the processes and magnitude of sediment transfers as well as their origin in these environments that prevents the implementation of efficient mitigation strategies.

We present here the results of an integrated approach at the catchment scale that aims at unravelling some of these issues. The 25 km<sup>2</sup> Louroux catchment is located in central France. It is a typical lowland, intensively cultivated, tile-drained catchment with an XIth century pond at its outlet.

The magnitude of sediment transfers has been addressed both at short/long term timescales, through pond sediment coring and dating, and instrumentation for high frequency monitoring of discharge and suspended sediment concentration in the pond tributaries. The origin of sediments has been determined through the use of sediment fingerprinting and morphometric techniques.

Results show a large increase of the sediment transfers shortly after WWII, with current sedimentation rates still 60 fold higher than the pre-1950 period. Sediment fingerprinting studies show that most of the sediment yield currently originates from surface erosion and exports from the drainage network, mostly during flood events, whereas bank erosion contribution was much higher in the years following the large landscape changes. Specific sediment yields measured at the monitoring stations are very low (< 40t.km<sup>-2</sup>.yr<sup>-1</sup>), but sufficient to cause, with eutrophication processes, a filling of the millenary pond that should be complete in 50 to 100 years.

**Keywords:** erosion; lowlands; sediment; fingerprinting; catchment



THEME: S26 : CONNECTIVITY IN GEOMORPHOLOGY

ABSTRACT NUMBER: 692

## GETTING THE RIGHT PICTURE: A DETAILED SEDIMENT BUDGET FOR AN ABANDONED TERRACED AND GULLIED HILLSLOPE

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A small terraced hillslope (5ha) was studied with regard to its sediment budget for an abandoned area in SE Spain. The sediment budget was determined for each individual terrace, but also in relation to the connectivity between the cascading terraces. Furthermore, we looked at the impact of transport and re-deposition on material properties such as structural stability.

The irrigated terraces were abandoned in the early 1990's and the plastic cover was not removed nor ploughed after abandonment. The dispersive soils were developed in lacustrine deposits with soil types depending on their distance to the salt containing ground and lake water (Calcisol-Gypsisol-Solonchack catena).

By looking at sediment thickness deposited on top of the plastic cover as well as by looking at erosion features such as rilling, gullying and piping, a sediment budget per terrace was constructed at a very fine scale, using a drone derived DEM, dGPS, detailed sampling and GIS techniques. Samples were also analysed for bulk density, organic carbon and aggregate stability.

Despite our initial hypothesis that erosion is very important on these terraces, based on the observation that gullying and piping is very prominently present, deposition was found to be as important or even larger for several terraces. This means that just mapping gullying or erosional features as indicators for degradation rates can be misleading and that sedimentation rates can be just as important as erosion. Such information is also crucial to get reliable erosion models especially on fine spatial scales.

THEME: S27 : SEDIMENT BUDGETS (IAG-WG SEDIBUD)

ABSTRACT NUMBER: 213

## HUMAN IMPACT ON SUSPENDED SEDIMENT LOAD IN A SMALL CARPATHIANS CATCHMENT DURING THE YEARS 1970-2010

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Suspended sediment transport (SS) in the rivers is the result of the complex interaction between natural and human factors, at both local and regional scale. SS in small mountain streams shows high spatial and temporal variability. Assessment of the suspended sediment load (SSL) trends is difficult due to short series of observations.

The longest observation series of SS in the Carpathian Mountains has the Research Station in Szymbark, Institute of Geography and Spatial Organization Polish Academy of Sciences (IGSO PAS), located in the Bystrzanka catchment (13 km<sup>2</sup>). The aim of the study was to determine the impact of human activity on suspended sediment transport in the small mountain catchment, during the years 1970-2010. This period covers two stages of socio-economic development with contrasting forms of human activity: the communist system up to the 1989 and a period of free market economics. SS was measured using the grab sample with one-liter bottle, and erosion was calculated using RUSLE model.

A decrease of cultivated land by 70% and increase grassland area by 90% was noted in the Bystrzanka catchment in 1969-2010. The average annual erosion decreased in the catchment, from 8.3 t/ha/year (the 1970s) to 2.9 t/ha/year (the 2000s). The mean annual SSL in 1970-1979 was 11% higher than in 2000-2009 but 24% lower than in 2001-2010 due to high SSL in 2010.

The analysis showed that different human activities such as land use change, engineering works, road and building construction played a major but complex role in the sediment load changes in the small mountain catchment. Based on the double mass curves of precipitation and SSL calculated that the human activity contribution of SSL is 66%.

**Keywords:** suspended sediment load; human activity; land use changes; mountain catchment, Carpathians

THEME: S27 : SEDIMENT BUDGETS (IAG-WG SEDIBUD)

ABSTRACT NUMBER: 224

## ASSESSING THE HYDROGEOMORPHOLOGICAL FUNCTIONING OF A SMALL ALPINE CATCHMENT BY APPLYING A SEDIMENT BUDGET ANALYSIS: THE PEYNIN SUB-CATCHMENT (UPPER-GUIL CATCHMENT, SOUTHERN FRENCH ALPS)

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The combination of predisposing factors (schist bedrock, slope gradient and hillslope-channel connectivity) makes the Upper-Guil catchment prone to torrential and gravitational hazards such as floods, debris flows, landslides and avalanches. Most catastrophic torrential flooding events (June 1957 and 2000; October 2000; June 2008 and 2011) were associated to Lombarde easterlies. During such events, damages are mainly related to important volume of sediments carried by streams. However, according to hydro-meteorological chronicles, extreme rainfall events do not systematically imply a strong sedimentary response.

To determine the respective role of water and debris supply in floods impacts, we focused on the present hydrogeomorphological functioning of the catchment by studying its more representative and active sub-catchment: the Peynin catchment ( $\approx 15 \text{ km}^2$ ). First, the sediment cascade was formalized and sediment transport processes were characterized (avalanches, debris flows, landslides etc.). A focus was made on debris flows due to their importance in this catchment (grain-size analysis, hydrological measures, Pit-Tags monitoring, and meteorological records). Then, temporary sediment storages were characterized (type, material), mapped (geomorphological mapping) and quantified. A sediment budget at 20 years' time scale was proposed to display and quantify sediments production, transfer and export. Finally, a preliminary analysis of functional connectivity (i.e. process-based connectivity) was made with Vensim® software to estimate the respective role of threshold and processes frequencies in the sediment response of the catchment.

Results show the prominence of debris flows in the seasonal renewal of sediment storages. The Desynchronization between hydro-meteorological signal and sedimentary response is explained by a time recharge to have matured sediment storage. Finally, for the last 20 years, the volumes of sediments produced by weathering in the Peynin catchment were estimated to 183.103 m<sup>3</sup>, those stored to 166.103 m<sup>3</sup> (90%) and those exported downstream to 17.103 m<sup>3</sup> (10%).

**Keywords:** sediment budget; torrential activity; hillslope-channel connectivity; Southern French Alps

THEME: S27 : SEDIMENT BUDGETS (IAG-WG SEDIBUD)

ABSTRACT NUMBER: 259

## QUANTITATIVE ASSESSMENT OF EROSION/SEDIMENTATION RATE TRENDS IN DIFFERENT SCALES: PROBLEMS AND POSSIBILITIES (BY THE EXAMPLE OF THE EAST-EUROPEAN PLAIN)

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The East-European (Russian) Plain is the largest agricultural region in Europe. Erosion processes within its arable lands here are very sensitive to climate and land-use changes. The economic conditions that emerged after the collapse of the Soviet Union led to significant reduction in arable land area and crop rotation changes and should have affected (with the climate warming since 1980s) the soil erosion intensity.

The erosion rates within the arable lands were evaluated at different scales: for river basins and small dry valley catchments within the basins. Seven river basins located in the steppe, forest-steppe and forest (southern subzone) landscape zones were chosen for the assessment. The calculations were performed for two time slices (1985 and 2015/2016) using the modified version of USLE model (rainstorm runoff) and the model developed by the Russian State Hydrological Institute (meltwater runoff).

The erosion rates trend for the small catchments was estimated based on: a) detailed assessment of sedimentation rates in the small

dry valley bottoms using the environmental radiocaesium-137 (global (the peak fallout in 1963) and Chernobyl (1986)-derived) as a chronomarker; b) assessment of morphometric characteristics of the valley bottoms; c) mapping of sediment delivery pathways from the arable lands to the valley bottoms; d) analyzing of granulometric and other characteristics of the valley bottom sediments.

There has been a reduction in soil losses due to water erosion over the last 30 years (1985–2015) almost in all key basins. At the same time, the reduction from basin to basin varies greatly, changing according to the calculation results from 12% to 50%. In small dry valley catchments the erosion rates reduction since 1963–1986 to 1987–2015/2016 was more significant (by 2.5-5 times).

**Keywords:** erosion; sedimentation; recent trend; river basin; climate change; land use; East-European (Russian) Plain

THEME: S27 : SEDIMENT BUDGETS (IAG-WG SEDIBUD)

ABSTRACT NUMBER: 481

## ENVIRONMENTAL SIGNIFICANCE OF SEDIMENT GRAIN SIZE FROM THE HOLOCENE GREAT RANN BASIN AT THE WESTERN CONTINENTAL MARGIN OF INDIA

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The Great Rann comprises a geomorphologically unique and intriguing Quaternary terrain of Western India that was formed due to the infilling of a large, almost landlocked shallow gulf during the late Pleistocene and Holocene. To study the paleoenvironmental conditions in the Great Rann two continuous cores were raised from Dhordo (60 m depth) and Berada (50 m depth). The cores were sampled at 2 cm interval and selected samples were analyzed for grain size and sediment characteristics. Both cores show strikingly similar lithological characteristics in the sense that they comprise dominantly clayey silts and silty clays. Sand content is found to be negligible in both cores. Major part of the cores show very fine millimeter scale laminations. The overwhelmingly fine grained nature of the Great Rann sediments as encountered in the cores point to a low energy tide dominated depositional conditions expected in an embayed gulf. This is in conformity with the adjoining present day Gulf of Kachchh and Gulf of Khambhat which shows tide dominated environment with large tidal amplitudes. We infer similar depositional conditions in the former embayed gulf that occupied the Great Rann basin during the late Pleistocene and Holocene. The formation of fine laminations is attributed to modulation by tides leading to interbedding of silts and muds. The persistence of clayey and silty sediments throughout the length of the cores suggests that these conditions persisted in the Great Rann for long period of time with minor fluctuations.

**Keywords:** Grain size; Palaeoenvironment; Shallow marine gulf; Great Rann

THEME: S27 : SEDIMENT BUDGETS (IAG-WG SEDIBUD)

ABSTRACT NUMBER: 490

## SEDIMENT BUDGET OF THE OPAK RIVER CATCHMENT FOUR YEARS AFTER THE 2010 LARGE VOLCANIC EVENT OF THE MERAPI (INDONESIA)

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The October 2010 eruption of the Merapi volcano (Indonesia) was a large explosive event (VEI 4) that killed more than 400 people, mainly due to basal avalanches and PDCs that reached up to 16 km from the top of the volcano. During the four phases of the eruption up to 0.06 km<sup>3</sup> of pyroclastic material was deposited on the western and southern flanks. In the Opak River catchment the 2010 deposits covered an area of 34 km<sup>2</sup> with a total volume of 49 Mm<sup>3</sup>, amongst which 38 Mm<sup>3</sup> corresponded to valley and channel fills. The years following the eruption, the tropically humid climate of central Java contributed to the formation of numerous lahars that dispatch pyroclastic sediment further downstream in the river systems.

Our aim is to analyze the remobilization of the sediment supplied by the 2010 events. To better understand the river functioning and

assess the risk for the downstream population a sediment budget of the upper Opak River catchment was calculated 4 years after of the eruption. The sediment budget is based on field surveys and aerial image analysis. Sediment inputs arise mainly from the basal avalanches, PDCs and tephra falls but also from lateral and vertical erosion of the river bed. Despite the large sediment transport capacity of the river, the adjustments of the riverbed are rather low four years after the eruption. Human infrastructures such as sabo-dams and irrigation dams, as well as activities such as sand and gravel extractions may be responsible for this surprisingly low sediment yield in the downstream part of the catchment.

**Keywords:** volcano, lahar, sediment budget, gravel extraction, dam

*THEME: S27 : SEDIMENT BUDGETS (IAG-WG SEDIBUD)*

**ABSTRACT NUMBER: 587**

## **MULTI-TEMPORAL LiDAR DATASETS REVEALING DIFFERENT STYLES OF DEBRIS FLOW TRIGGERING AND EVOLUTION IN THE WESTFJORDS OF ICELAND**

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A debris flow is a fast-moving body of poorly sorted debris material, mixed with water and/or air, which moves down-slope because of gravity. Distinguishing the different mechanisms of debris flow initiation and the associated geomorphic features may help in anticipating new potentially destructive events. A debris flow can initiate by sudden slope failure or by the “fire hose” effect. Slope failure is characterised by discrete failures that evolve into debris flows, favoured by steep slopes and high pore-water pressures. The “fire hose” effect arises when debris accumulated within a pre-existing channel is remobilised and transported by a surge of water; the slurry of water and debris can then develop into a debris flow.

Here we identify the geometric and geomorphic evidence that allows us to distinguish between the initiation of debris flows via slope failure and via the “fire hose” effect. We analyse the case of debris flows above the town of Ísafjörður in the Westfjords of Iceland. The topographic bench that dominates the slope above the town is covered with a debris mantle up to 35 m thick. These deposits are unstable at the bench margin, where debris flows are generated every 4-5 years. We compare airborne LiDAR elevation models and aerial photographs collected in 2007 with those collected in 2013. Between 2007 and 2013, new debris flow tracks were created and material was also remobilised along active tracks. We report that the generation of new debris flows is initiated by slope failure of deposits from the edge of the bench, meanwhile the older generations may also be regenerated by the “fire hose” effect when debris accumulated in channels is remobilised by a later injection of water. These older channels in particular can store deposits at rest angles over 35°, and form a potential hazard for inhabited areas downslope.

*THEME: S27 : SEDIMENT BUDGETS (IAG-WG SEDIBUD)*

**ABSTRACT NUMBER: 639**

## **SPATIO-TEMPORAL VARIATION OF SEDIMENT GRAIN SIZE OF RIVER TISTA**

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The sediment grain size of river Tista changes from upstream gravel to relatively fine grains in the downstream which is determined by the lithology of the basin, topography, geomorphology, hydrology, discharge condition as well as impact of modern depositional environment like, recent climate change and anthropogenic activities. The present study examined the longitudinal changes (upstream to downstream after Gazaldoba barrage to Indo-Bangladesh border of 100 km. stretch) of sediment grain size and comparative spatio-temporal distribution pattern analysis of grain size textures on River Tista. Total 56 samples have been analysed to examine the grain size variation while historical satellite images have utilised to determine the spatio-temporal distribution of sample sites. The old preserved (TOP) of sediment grains identified from the old stable banks or islands of the river while the new deposits or modern bars

are considered as recent (TNP) preserved and in between recent and old there is moderate or middle deposits (TMP) as the 10 to 15 years of old islands. The statistical techniques and median value comparison found that the grain size not only varies from upstream to downstream with spatio-temporal changes but also changes within each profile of the island or bar sections from bottom to top. The present study of spatio-temporal variation of grain size may have implication in terms of climate and anthropogenic impact on the river that may be the probable reason behind changing depositional environment of the river reflected from the grain size distribution analysis.

**Keywords:** sediment grain size, spatio-temporal variation, Tista River, climate and human impact

*THEME: S27 : SEDIMENT BUDGETS (IAG-WG SEDIBUD)*

**ABSTRACT NUMBER: 640**

## **IMPACTS OF CLIMATE CHANGES AND ENVIRONMENTAL CONTROLS ON SEDIMENT FLUXES THROUGHOUT THE HOLOCENE EPOCH IN MOUNTAIN CATCHMENTS OF EASTERN CANADA**

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The Appalachian Mountains, Eastern Canada, are prone to natural hazards in regard to the geology and the nearby presence of large water bodies that influence the climate. Overimposed on this rugged terrain are the impacts of ongoing climate change, which may increase the magnitude, frequency, occurrence and duration of an array of hillslope phenomena. In that regard, the quantification of sediment fluxes at various spatiotemporal scales appears a prerequisite to reduce the exposure of infrastructure and communities. Here I report a quantitative modeling of sediment fluxes on several scree slopes throughout the Holocene Epoch. In spite of the short term observations (30 years) and the low-resolution of dendrochronology and <sup>14</sup>C dating, these data allowed to better understand (i) how the sediments are eroded and routed through these mountain catchments; (ii) how past climatic variations exert a control on spatiotemporal dynamics of hillslope processes, and (iii) what is the influence of environmental factors, such as geology and vegetation dynamics, on sediment fluxes and landform development. These analyses reveal a decrease of sediment fluxes during the Holocene, reflecting the reduction of sediment production and availability following a negative exponential function, as shown by an exhaustion model of paraglacial sediment release. However, very contrasted results appear related to environmental factors such as the sensitivity of rockwalls to freeze-thaw cycles. On fine-grained scree slopes, individual particles tend to accumulate near the rockwalls (talus shift of 15 cm/year) until mobilised by cold season dynamics, which account for 95% of the yearly sediment budget. Even recent extreme events do not seem significant in the overall sediment budget at a longer timescale. Elsewhere, the mobility of sediment was restricted to a short period following deglaciation, corresponding to the rock glaciers construction. These discrepancies will be discussed more thoroughly regarding also past climate variations in the Holocene.

*THEME: S27 : SEDIMENT BUDGETS (IAG-WG SEDIBUD)*

**ABSTRACT NUMBER: 695**

## **ASSESSING IMPACTS OF EXTREME RAINFALL EVENTS ON SUSPENDED SEDIMENT EVACUATED FROM GLACIERS OF UPPER GANGA BASIN, GARHWAL HIMALAYA**

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Himalayan Rivers provide great potential for Hydropower generation due to their steep gradient, steep topography and fragile geology. There are heavy sediment load during snowmelt and monsoon season which is a challenging problem because of high head power plant located in these rivers. Normally suspended sediments do not pose any problem to the operation of the Power plants. However, in practice, large amount of silt in suspended sediment passes through the runner of the turbine resulting in heavy damages to the under water components particularly run-of the river projects. Other than cost the erosion of runner blade due to silt results in loss of efficiency of the turbine and some day may result in unimaginable transfer of sediment load during extreme rainfall events. Glacial debris falling beneath successive layers of accumulating snow moves down when ablation starts. When this process occurs throughout the melting seasons debris is transported into the basal zone through crevasses and glacial bed itself. As a result generation of subglacial sediment may be transferred toward the snout of glacier through the subglacial and englacial meltwater streams. Therefore four (Gangotri, Dokriani, Dunagiri and Bangni) glaciers having varying glacierized and catchment areas in upper Ganga basin have been selected for study source of sediments and its distribution with time. Sediments evacuated from glaciers have been considered

worldwide as the subject of significant glaciological research when combined to meteorological extremes. Results suggest that snow and glacier melt significantly contributed high sediment transfer during rainfall extremes observed from upper Ganga basin. Sediment evacuation pattern revealed high sediment yield and erosion rate (varies from 0.6 to 2.7 mm y<sup>-1</sup>). The particle size analysis shows dominance of medium silt-sized to fine sand-sized particles corresponding to 70–80% without any significant seasonal variation.

**Keywords:** Snowmelt; Monsoon season; sediment yield; erosion rate; extreme rainfall

THEME: S27 : SEDIMENT BUDGETS (IAG-WG SEDIBUD)

ABSTRACT NUMBER: 697

## CONTROLS ON THE FORMATION AND ABANDONMENT OF THE TISTA MEGAFAN (WEST BENGAL, INDIA), A MAJOR TRANSIENT SEDIMENT TRAP IN THE HIMALAYAN SOURCE TO SINK SYSTEM

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The Himalayan foreland is characterized by a number of Quaternary megafans, of which the formational mechanisms remain debated. The Tista megafan spreads over more than 16,000 km<sup>2</sup>, is strongly incised, and stores sediments produced in the Sikkim Himalaya. We have studied the controls on formation and abandonment of the Tista Fan, and estimate its efficiency as a transient sediment trap in the Himalayan source-to-sink system.

We propose a scenario for the formation and abandonment of the Tista megafan based on new <sup>10</sup>Be cosmogenic and IRSL age constraints, and discuss the potential controls on its evolution. Two distal lobes developed successively downstream from a common proximal lobe. The western distal lobe of the megafan was deposited early in the history of the megafan and was abandoned in the early Holocene. The eastern, recent lobe was built after the main Tista drainage system shifted eastward and can be considered still active. Approximately synchronous incision between terraces in the hinterland and megafan surfaces suggests that incision propagated rapidly through the system. Tectonic processes seem to play a minor role in driving incision of the megafan. Aggradation and incision episodes appear more compatible with a climatic control, through changes in monsoon intensity and associated sediment flux. Depositional episodes in the Tista megafan, as elsewhere in the Himalayan foreland, appear to correlate with periods of strong monsoon precipitations and high sediment flux toward the foreland. Abandonment and incision of megafan surfaces and hinterland terraces appear associated to the onset and the ending of phases of strong monsoon precipitation. A comparison between present-day sediment flux from the Tista catchment and the sediment volume stored in the megafan suggests that it was an efficient sediment trap during its operation, collecting about half of the sediment flux evacuated from the Sikkim Himalaya.

THEME: S27 : SEDIMENT BUDGETS (IAG-WG SEDIBUD)

ABSTRACT NUMBER: 749

## LABORATORY EXPERIMENTS TO PREDICT EVOLUTION OF SEDIMENT SIZE DISTRIBUTIONS BY ABRASION AND FRAGMENTATION IN TRANSPORT

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Sediment particles carry information about upstream tectonic, climatic, geologic, and geomorphic conditions, encoded in the distributions of particle sizes, shapes, and rock types, and in the degree of chemical weathering. However, some information is lost due to abrasion and fragmentation of particles in transport, which reduce the size and alter the shape of individual particles. Despite the importance of particle wear in modulating the signals of upstream conditions many fundamental knowledge gaps remain. I report experimental results designed to enable prediction of particle wear rates, and shape evolution, in specific field settings, based on knowledge of rock strength, rates of energy expenditure in transport, and the initial particle size distribution. Facilities and methods include a set of 4 rotating drums up to 4.0 meter diameter, vertically-oriented abrasion mills, and free-fall particle drops. Rock strength was measured by the Brazilian tensile splitting test, and particle shape and angularity were quantified from photographs. Particle size distributions were measured by weighing individual clasts and by sieving. Abrasion scales with the inverse square of rock strength. Wear rates are not influenced by other particles of differing strength. Production rate of fine particles scales with the rate of energy

expenditure, a result that can be used to extrapolate to field settings where intensity of particle motion can be estimated. Wear rates decline as particles become less angular, at rates that correlate with cumulative travel distance and mass loss. This result enables estimation of initial particle size and distance from source. Drop experiments quantify how fragmentation probability varies with impact energy. Fragment sizes collapse to a single non-dimensional particle size distribution. Experimental results can be used in field settings to distinguish the effects of particle wear from size-selective transport in downstream fining, and to infer the initial size of sediments supplied to channels by upstream hillslopes.

*THEME: S28 : TROPICAL RIVERS (IAG-WG)*

**ABSTRACT NUMBER: 61**

## **FIRE, FLOODS AND FOREST: IMPACT ON INDIAN RIVERS OF THE TOBA SUPER-ERUPTION**

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Toba volcano in Sumatra erupted 74,000 years ago and was the biggest eruption of the past two million years. The volume of rock equivalent ejected from this eruption was up to two orders of magnitude greater than that produced in the historic eruptions of Tambora (1815), Krakatau (1883), Agung (1963) and Pinatubo (1991). The extent of its impact on global and regional climate has been hotly contested, as has its impact on ecosystems, rivers and lakes, and prehistoric humans. Close to the eruption, in Indonesia, fires destroyed the forest. The impact further afield in India was also significant.

Toba ash was discovered in India in 1980 and has since been found across India as far west as Gujarat. The ash from Toba covered India in a layer 10-15 cm thick. This ash would have seriously disrupted photosynthesis and damaged the plant cover, leading to accelerated runoff and erosion. Within a few years the ash was washed off the hill slopes and accumulated in the valley bottoms and other topographic depressions to form channel-fill deposits several metres thick. Coarse gravels lie immediately above these reworked ash deposits at sites on either bank of the Son River in north-central India, pointing to a major change in river regime.

Analysis of the carbon isotopic composition of pedogenic carbonate nodules in fossil soils above and beneath the ash layer in a 400 km transect in north-central India from the Son to the Narmada revealed the presence of forest and woodland before the eruption and of open woodland and grassland after the eruption. Pollen grains preserved in a marine sediment core from the Bay of Bengal show a similar pattern of vegetation change. The geomorphic impacts of these ecosystem changes have yet to be investigated across India.

**Keywords:** Toba volcano, ash, Son, Narmada

*THEME: S28 : TROPICAL RIVERS (IAG-WG)*

**ABSTRACT NUMBER: 435**

## **HOLOCENE ALLUVIAL RECORDS OF THE NORTHEAST-MONSOON DOMINATED RIVERS OF SOUTH INDIA**

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The region around the coastal Chennai area, India, is drained by three rivers that drain and meander parallel to each other and debouch their sediments into the Bay of Bengal. The rivers hold signatures of past phases of aggradations and incision and these features have been studied along the three parallel meandering rivers near the coastal Chennai region. Detailed mapping and logging of the fluvial litho sections stratigraphy supported by grain texture and sediment structure, <sup>14</sup>C and OSL dates have been used to infer the different periods of aggradation and incision. The dated alluvial sequences show that a major period of aggradation occurred in early Holocene 9000 to 8400 yrs BP, mid Holocene period 6000-5000 yrs BP and late Holocene to recent historical periods (2000 and 1300 yrs BP, 800-600 yrs BP and around 200 yrs back). These aggradations phases were punctuated by incision events cutting down to the present riverbed. The younger ages of the southern flowing streams such as the Cooum and the Palar indicate that they have not preserved older terraces, eroding them due to subsidence and late Holocene meandering. The rivers are laterally stacking sediments rather vertically and the possible causes for the periods of aggradation and incision in the context of early to mid Holocene northeast monsoons and preservation of older terraces is discussed.

**Keywords:** Coastal rivers, Parallel meandering, Aggradations, Incision, River avulsion, North East monsoon

THEME: S28 : TROPICAL RIVERS (IAG-WG)

ABSTRACT NUMBER: 519

## CONTROLS ON PROCESS-FORM WITHIN A LOW-RELIEF LANDSCAPE

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Rivers dissecting low-relief landscapes exhibit morphological variability especially when flowing across heterogeneous lithological complexes. As against temperate regions, rivers draining tropical climes are devoid of glacial history therefore process-form interactions are mostly influenced by lithology, valley settings and climate. Reviews on controls on morphological variability in a single river basin is currently inadequate because it has been revealed that controls on morphological variability should be studied region to region basis especially in tropical climes and less active tectonic regions. This study seeks to identify existing controls on identified domain processes within the river morphology and valley settings across the Upper Ogun Basin in Southwestern Nigeria. Recognition of such dominant controlling parameter(s) will assist in spatial linkages and interdisciplinary studies within a watershed. A total of 54 reaches were surveyed across three third-order basin in a humid tropical region using established procedures at bankfull level for measuring morphological variables. Using discriminant analysis, 85% of the alluvial channel was correctly classified and 50% of the bedrock channel was correctly classified, overall, 76% of the original grouped cases were correctly classified. Here, the R<sup>2</sup> and F values show that Width is by far the most single explanatory value. As regards valley settings (unconfined, partly confined and unconfined), 60%, 67% and 61% were correctly classified respectively. Overall, 67% of the original cases in valley setting configurations were correctly classified. The explanatory variable is grouped into two. For confined and unconfined valley settings three explanatory variables were highly loaded - width, width-depth ratio and velocity while for the partly confined a single explanatory variable was identified - Discharge. This study presents an aid to interdisciplinary studies and creates a clear understanding of spatial linkages within a watershed as an essential toolkit for assessing response of channel to disturbance(s).

**Keywords:** tropical, low-relief, controls, process-form, discriminant

THEME: S28 : TROPICAL RIVERS (IAG-WG)

ABSTRACT NUMBER: 703

## A GEOMORPHOLOGICAL ASSESSMENTS OF THE DISTRIBUTION OF SEDIMENT SINKS ALONG THE LOWER AMAZON RIVER

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Floodplain sediment storage budget is examined along the 1,000 km reach of the lower Amazon River based on extensive sets of remote sensing data and field measurements. Incorporating the washload discharges at gauge stations at the main channel and major tributaries, we analyzed the roles of vast floodplain on the Amazon River seasonal variability in sediment discharges. Annual washload accumulation rate on floodplain along the reach in between Manacapuru and Obidos is estimated to be 79 Mt over inter-annual average. Period that the net loss over to the floodplain of washload coincide with discharge rising phase of the Amazon River at Obidos, when the river water level rises to make hydrologic connections to floodplain. Only during the early falling phase (July-August), 3.6 Mt of washload net gain occurred in a year, which was less than 5% of the annual net loss to the floodplain.

To assess the spatial distribution of sediment sinks along the lower Amazon, we incorporated various hydro-geomorphic factors regarding floodplain geomorphic styles and morphometric parameters, such floodplain width, levee heights, water-saturated area, suspended sediment distribution over floodplain and distribution of impeded floodplain. Impeded floodplain that contains numerous large rounded lakes is the definition of active sediment sinks along the lower Amazon, which seasonally stores most of the water and traps sediment from the river. The results of these hydro-geomorphic factors collectively indicate that the extent and magnitudes of sediment sinks becomes larger downstream (from Manacapuru to Monte Alegre), which is proportionally related to the development of the water-saturated floodplain. This indicates the nonlinear geomorphic evolution of the Amazon floodplain through its longitudinal profile since the late Holocene that downstream reaches are still to be infilled with sediments (incomplete floodplain) thus acting as sediment sinks.



THEME: S28 : TROPICAL RIVERS (IAG-WG)

ABSTRACT NUMBER: 710

## ARE SEDIMENT LOADS OF INSULAR SOUTH EAST ASIA OVERESTIMATED? - CLUES FROM BORNEO

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Global studies have ascertained that relatively small drainage basins of Sumatra, Java, Borneo, Celebes, and Timor, which represent only 2% of the land draining to the ocean, may discharge about 4200 million tons/year of sediment. It means approximately 25% of the global sediment export to the ocean (Milliman and Farnsworth, 2013). With an area of 750,000 km<sup>2</sup>, Borneo, the 3rd largest island in the world (after Greenland and New Guinea) could export from to the ocean approximately 910 Mt/y. About half (459 Mt) of the island discharge is from rivers draining Sarawak (Malaysia) to the South China Sea; while the other half (450 Mt) drain Kalimantan to the Java, Makassar, and Celebes Seas (Milliman and Farnsworth, 2013).

However, there have been no used direct measurements of suspended sediments in Borneo and the calculations of sediment yields and transferences to the ocean have been based on probabilistic curves.

We hypothesize that the available data on the volume of sediment discharge are overestimated.

Here we provide evidence to support our hypothesis through geological/geomorphological mappings, surveys and analyses on the channel stability, river plumes modeling in the coastal zone, and suspended sediment samplings.

Our initial assessments on sediment budget indicates that Borneo could produce and supply to the Ocean less sediment than previously estimated by other authors, and that the role of SE insular Asia at the global scale is smaller than previously assumed.

References - Milliman and Farnsworth (2013), Appendix F (Asia) and G (Oceania), In River discharge to the coastal ocean, 289-329.

**Keywords:** Sediment yield, global sediments, sediment budgets, tropical rivers

THEME: S28 : TROPICAL RIVERS (IAG-WG)

ABSTRACT NUMBER: 711

## THE PARADOX OF LARGE ALLUVIAL RIVERS: EQUILIBRIUM AND FLOODPLAINS EVOLUTION

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Large alluvial rivers exhibit large floodplains, very gentle slopes, a good selection of bed materials (generally sand), low specific stream power, and could represent the ultimate examples of “dynamic equilibrium” in fluvial systems. However, equilibrium can be discussed at different temporal scales. When analyzing the Quaternary fluvial belts of large rivers at the millennium scale, paleohydrological changes and modifications in floodplain constructional processes or erosion are usually related to late Quaternary climatic changes. However, the study of several of the largest rivers demonstrates that climatic changes and fluvial responses are not always working totally in phase and those direct cause-consequences relations are not a rule. Since the last deglaciation, many of the largest fluvial systems had not enough time to reach equilibrium conditions along whole the river and present several stages of “incomplete floodplains”. Furthermore, minor climatic changes during the Holocene have possibly also affected their fluvial style, producing additional and partial adjustments. A main concept presented here is that large rivers achieved equilibrium conditions mainly from upstream to downstream by partially filling up their valleys and local sedimentary basins/sediment sinks (e.g. wide valleys, flood basins and permanent water saturated floodplains, tectonic sunken blocks, among others) with a variety of morpho-sedimentological processes, and transferring equilibrium conditions from upstream to downstream. When the “available space” (sedimentary sink) becomes as full of sediments as possible, the rivers adjust on a more efficient corridor of channels in quasi-equilibrium conditions. Because most results in the literature are focused on small to medium size rivers, these results intend to open a new discussion about floodplain mechanisms of construction, demystifying some traditional concepts relating floodplains and equilibrium, and climatic changes and river responses in large rivers.

THEME: S28 : TROPICAL RIVERS (IAG-WG)

ABSTRACT NUMBER: 732

## HOW OLD IS THE COURSE OF THE NIGER RIVER AT BAMAKO, MALI?

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Field investigations on the banks of the Niger River at Bamako revealed that prior to the formation of the current course of the Niger River, a lacustrine environment has prevailed, recorded as lacustrine laminated silts. Tributaries used to flow into this lake as testified by the alternation of fluvial sands and lacustrine peats on the left bank of the River. The base of the profile showing this alternation was dated using Optical-stimulated Luminescence to 600 ka. The 27 meters high lacustrine deposits found on the right banks of the Niger River were dated to 310ka at his foot, 280 ka at the middle and 176 ka at the top. After this date, continuous fluvial deposits cover the laminated lacustrine deposits. Therefore, before 176ka, the Niger River upstream of Bamako used to flow into a lake that was formed as the dolerite sill of Sotuba, nowadays known as the Sotuba rapids used to block the water flows downstream. The profiles and the sediments deposited reveal that before 176ka, the upper Niger River was flowing into a Lake which deposits constitute the current setting of the city of Bamako, the capital of Mali. After 176ka, the river was able to cross the Sotuba sill to form the current unified course of the Niger River. The reason of this change is still under investigation, but the presence of soft sediments deformation structures on the lacustrine sediments dated to 250 ka suggest an important role played by neotectonics.

THEME: S28 : TROPICAL RIVERS (IAG-WG)

ABSTRACT NUMBER: 775

## MATERIAL FLUX DYNAMICS IN A HEADWATER CATCHMENT IN NORTHERN THAILAND: HYSTERESIS, HIGH YIELDS, AND HOT SPOTS

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An automated river monitoring network has been established on the Sa River of northern Thailand since 2004. High sediment, carbon, and nitrogen loads in river indicate the catchment is a hotspot for these potential riverine pollutants (when in high concentrations) that are transported into downstream water bodies, including rivers, reservoirs and the ocean. Bedload rates range from 9-25% (81-279 Mg km<sup>-2</sup> y<sup>-1</sup>) of the total load (730-1313 Mg km<sup>-2</sup> y<sup>-1</sup>), with TSS ranging from 649 to 1037 Mg km<sup>-2</sup> y<sup>-1</sup>. The transport of all these solid materials is characterized by complex hysteresis patterns across various timescales. Hysteresis is related to the location of their sources and rainfall variables including storm size and spatial distribution. Further, measured concentrations of the variables demonstrate multiple-fractal (universal) scaling properties that allow for the potential for predictive relationships to be developed to extrapolate between scales. The range of C:N ratios for particulate matter transported during monitored event is typically high (3-80, depending on size of material), demonstrating that different types of (carbon) source material are transported for different sizes of storm events, and potentially at different times of the year (early versus late monsoon periods). Annual yields vary greatly: 5.0 to 22.3 Mg POC km<sup>-2</sup> y<sup>-1</sup> and 0.48 to 2.02 Mg PON km<sup>-2</sup> y<sup>-1</sup>. The 22.3 Mg POC km<sup>-2</sup> y<sup>-1</sup> yield is the highest reported for any river on the Asian continent. Sediment tracking using rare earth elements and selected isotopes demonstrate that sediments (and sorbed pollutants) entering the stream at the study site are derived primarily from subcatchments where intensified agricultural activities are occurring. Support vector machines (an artificial intelligence technique) perform the best for filling gaps in measured stream variables. This technique also allows for a reasonable simulation of streamflow for data time series with missing data.

THEME: S29 : GEOMORPHOLOGY OF ROCKY COASTS (IAG-WG)

ABSTRACT NUMBER: 115

## HARD ROCK CLIFF EROSION IN BRITTANY (FRANCE): IMPACT OF SUBAERIAL AND MARINE AGENTS AND PROCESSES ON ROCK MICRO-FRACTURING

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In times of recent and anticipated climate change it can be expected that the morphodynamics of rocky coasts will have an increasingly noticeable effect on society and infrastructure.

This project focuses on the identification and quantification of environmental controls on hard rock cliff erosion with an emphasis on discriminating the relative contributions of subaerial and marine processes and their possible importance for the evolution of rock micro-fracturing as a potential precursor to cliff failure.

A monitoring field experiment (February-May 2017) is carried out at a 20 m high hard rock cliff-face located at the macrotidal embayed beach of Porsmilin (France). In-situ monitoring of cliff micro-fracturing is accomplished using crack- and tiltmeters placed on the cliff-face and tri-axial geophones installed in boreholes. Wave impact is monitored by a video system in combination with pressure and wave load sensors that are installed directly at the cliff toe. Additional pressure sensors deployed on the beach in the intertidal zone provide wave height and wave spectra. A seismometer installed at the clifftop records ground deformation in order to assess vertical loading exerted by waves on the platform in front of the cliff. Local weather and groundwater conditions are monitored by a weather station and a piezometer deployed at the clifftop. The monitoring program is complemented by topographic data collection using an UAV and a TLS to survey the selected cliff section, and by DGPS profiles of the beach section in front of the cliff.

Preliminary results show a clear relationship between the number of microseismic events recorded by the geophones and the peak of high tide during periods with a high tidal coefficient. However, a high number of microseismic events is also recorded during low tide, revealing noticeably different seismograms and potentially different triggers.

**Keywords:** hard rock cliff erosion; rock micro-fracturing; subaerial/marine agents; Brittany

THEME: S29 : GEOMORPHOLOGY OF ROCKY COASTS (IAG-WG)

ABSTRACT NUMBER: 200

## RECENT PROGRESS IN ROCKY COAST SYSTEMS EVOLVING IN POLAR ENVIRONMENTS

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Significant sections of polar coastlines are rock-dominated, but only few studies have focused specifically on this environment. Classic papers on cold region rock coasts systems emphasize the role of icefoot, sea ice, permafrost and snow cover as key controls of shore platform and cliff face geomorphology. This paper presents the results of several years of investigations into the processes controlling the development of rock coast systems in Svalbard (Arctic) and South Shetland Islands (Antarctic). A suite of nested geomorphological and geophysical methods have been applied to characterize the functioning of rock cliffs and shore platforms influenced by lithological control and geomorphic processes driven by periglacial and paraglacial environments.

Observations of rock surface change using a traversing micro-erosion meter indicate that significant changes in erosion rates occur at the junction between shore platform and the cliff toe, where rock erosion is facilitated by frequent wetting and drying and operation of nivation and sea ice processes (formation and melting of snow patches and icefoot complexes). ERT surveys have been used to investigate permafrost control on rock coast dynamics and reveal the strong interaction with marine processes in polar coastal settings. Rock hardness, quantified by Schmidt hammer rebound tests as well as rock surface microroughness demonstrate strong spatial control on the degree of rock weathering of selected rock coasts varying in lithology, wave exposure and history of glaciation.

The results are synthesised to propose a new conceptual model of polar rock coast systems, with the aim of contributing towards a unifying concept of cold region landscape evolution.

Paper is the contribution to National Science Centre project: "POROCO - Mechanisms controlling evolution and geomorphology of the rock coasts in polar climates" (OPUS NCN UMO-2013/11 / B / ST10 / 00283)

**Keywords:** rock coast; periglacial processes; paraglaciaton; cryo-conditioning; Arctic; Antarctic

THEME: S29 : GEOMORPHOLOGY OF ROCKY COASTS (IAG-WG)

ABSTRACT NUMBER: 214

## SOUTHERN CALIFORNIA COASTAL CLIFF RESPONSE TO THE 2015-2016 EL NINO

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The 2015-2016 El Nino was one the strongest ENSO events on record. Strong El Nino events in California are usually associated with elevated winter precipitation, wave heights, and sea levels, resulting in increased coastal erosion, flooding and damage. This study provides a regional-scale (~300 km) assessment of southern California coastal cliff erosion and forcing mechanisms associated with the 2015-2016 El Nino using airborne LiDAR. The studied cliffs are often fronted by beaches, which act as a buffer to wave-driven cliff erosion. Conditions during the 2015-2016 El Nino generated record high water levels in San Diego and eroded some beaches to record lows. Several large wave events occurred, however many of these events occurred during periods of low and moderate high tides. Annual precipitation during the study period was about 30% below average, despite the El Nino conditions. The average overall cliff change was about 1 m<sup>3</sup> of erosion per meter alongshore (0.03 m of average cliff face retreat) and was concentrated along about 12% of the cliff length. Much of the observed cliff erosion was located at the cliff base, and only two locations experienced significant cliff top retreat. Despite elevated wave and water levels combined with depleted beaches, cliff erosion and retreat was relatively limited because of asynchronous large swell and high tides, and/or below average precipitation.

**Keywords:** coastal cliff; erosion; LiDAR; California; El Nino

THEME: S29 : GEOMORPHOLOGY OF ROCKY COASTS (IAG-WG)

ABSTRACT NUMBER: 217

## THE EROSION OF THE SHORE PLATFORM RAISED BY THE COSEISMIC COASTAL UPLIFT AS A RESULT OF THE NEVELSK EARTHQUAKE OF 2007, MW = 6.2

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As a result of the Nevelsk earthquake in 2007, Mw = 6.2 in the vicinities of Nevelsk, a shore platform with an area of 0.75 sq km was raised. We hope that field observations of the evolution of this phenomenal part of the coast will allow us to more reliably estimate some evolutionary properties of the rocky coast.

On the central part of the coastal platform raised by 0.8 -1.0 m, an observation network was constructed, consisting of 97 registration marks on 14 cross sections. Digital relief models are built on the basis of microrelief scanning in the millimeter range. The size of the scanning area is 2, 2 m<sup>2</sup>. The model is constructed with respect to the sharp-pointed top of the registration mark in the center of the site. At present time, 8 observation cycles, deduced from the bottom to the day surface, have been performed on this site.

The maximum rate of destruction obtained during the observation period (averaged value over the observational site of 2. 25 m<sup>2</sup>) is 170 mm. The change in the rate of destruction of the shore platform established by the profile of the observation cross sections does not yet allow making any unambiguous conclusions about the decisive contribution of subaerial weathering or wave processes dominate shore platform evolution. However, it should be noted that tangible difference in the rates of destruction of the surface of the shore platform was not marked. Areas flooded with different periodicity are destroyed almost at the same speed.

At present time, the sea edge of the platform still more and more acquires a concave profile, because the sites located 15-20 meters from the edge of the platform are destroyed with maximum speed.

**Keywords:** rocky coast, coseismic coastal uplift, shore platform, subaerial processes, rates of erosion.

THEME: S29 : GEOMORPHOLOGY OF ROCKY COASTS (IAG-WG)

ABSTRACT NUMBER: 226

## 45 YEARS OF SHORE PLATFORM RESEARCH AT KAIKOURA - AN UPLIFTING EXPERIENCE

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Since 1973 micro-erosion meters (MEM) have been used at Kaikōura Peninsula to determine shore platform lowering rates. Rates measured over two, two year periods (1973-1975 and 1994-1996) and at decadal scales (20-30 years) are derived from the same population and surface lowering is on average 1.1 mm/yr. The 14 November 2016 Kaikōura magnitude 7.8 (Mw) earthquake caused an instantaneous uplift of ~1.01 m of the peninsula. The uplift offers the rare opportunity to examine how such an event alters processes and rates of erosion on shore platforms. Since the 1 m uplift, 45 MEM sites have been measured four times during 2017 and show widely varying responses to uplift. Erosion rates are at some MEM sites are three times the previous annual rate while other sites show significant amounts of surface swelling (3-4 mm in 6 months). The coseismic uplift has fundamentally changed the process regime operating on the platforms. Zones of maximum wetting and drying have migrated seaward causing previously slow eroding (< 1 mm/yr) MEM sites to accelerate to twice the pre-earthquake rates. Erosion rates on MEM sites demonstrate rapid adjustment of the platform surface to this disturbance and illustrate how uplifted marine terraces can be rapidly eroded despite being above sea level. The preservation of the new marine terrace is probably dependent on further uplift within the next 300-400 years, otherwise erosion by lowering and backwear will remove the new surface. This scenario has significant implications for marine terrace preservation and the recording of coseismic events in the landscape.

**Keywords:** Kaikōura Peninsula; Micro-erosion meter; coseismic uplift; marine terrace; shore platform

THEME: S29 : GEOMORPHOLOGY OF ROCKY COASTS (IAG-WG)

ABSTRACT NUMBER: 355

## EROSION OF COHESIVE SHORELINES: NEW INSIGHTS FROM 10 YEARS OF PLATFORM DOWNWEARING MEASUREMENTS; LONDON CLAY, KENT COASTLINE, UK.

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Cohesive shorelines occur widely around the coast of the UK and other mid- and high-latitude coastlines. Rapidly eroding cliffs, composed of semi-consolidated cohesive materials, are fronted with extensive shore platforms. Research has focussed on understanding and measuring cliff retreat rates rather than platform downwearing. Yet, irreversible platform downwearing is thought to be a primary cause of beach lowering, a key driver of cliff retreat and contributor of large volumes of fine-grained sediment to the coastal budget. Despite this, few direct measurements of clay platform downwearing exist and current understanding of the erosion mechanisms of cohesive shore platforms is limited.

This paper presents new findings from downwearing rates, measured over a ten year period across a shore platform in London Clay at Warden Point, Isle of Sheppey, Kent, UK using the specially designed Traversing Erosion Beam. The platform is 300 m wide with a gradient of 0.5 degrees and is backed by 48 m high cliffs. A thin, low-mobility, mixed-sediment beach, ~ 8 - 20 m wide and 0.1 m deep, covers the landward edge of the platform.

Mean annual downwearing, on the upper to lower mid-shore, 2005 - 2015, is  $17.49 \pm 9.78$  mm/yr. The highest downwearing rate,  $35.54 \pm 7.54$  mm/yr, was recorded on the upper platform. The results provide evidence of the contribution that platform downwearing makes to cliff erosion and the coastal sediment budget. Key findings are: variations in downwearing are seasonal; there are notable variations across the platform, with maximum rates on the upper platform; subaerial weathering processes are key drivers of downwearing; no statistical difference was found between erosion rates measured over 2 years and the full study period supporting the view that shore platform lowering rates measured over 2 years are representative of decadal scales.

**Keywords:** shore platform, coast erosion, weathering, cohesive clay

ABSTRACT NUMBER: 423

## FORMS AND PROCESSES OF ROCKY CLIFFS IN THE PONZA ISLAND COAST (ITALY)

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Ponza Island is located offshore of central Italy in Tyrrhenian Sea. A detailed geological survey, also performed by boat, has permitted to identify forms and processes modelling its amazing coast. It is characterized by cliffs cut off in volcanic rocks, mostly sub-vertical, with heights ranging from about 10m to over than 130m. Not lacking at the base of them, as well as inside inlets and bays, often coinciding with secondary craters, sandy-pebbly beaches. The concentration of energy on the headlands has also allowed the formation of arches and sea stacks. Evidences of marine abrasion, active since the Early Pleistocene, are present in some relics of surfaces at different altitudes. To these raised surfaces are respectively associated gravelly beach deposits, strongly altered paleosoils and weakly cemented aeolian deposits.

Marine erosion takes place at the foot of the cliffs, whereas on the face of them works the abrasion of wind, the runoff of the water and its infiltration in the lines of weakness, the weathering of the rock by meteoric agents, and, even, the seismic action. The lithological nature of the volcanic formations, characterized by high fracturing as well as fault planes and fractures, which also isolate blocks of considerable size, determines conditions of great danger with frequent falls involving rock masses from small to extremely large sizes. The continuous retreat of the cliff is proved by:

- the constant presence of accumulations of debris at their foot, despite the wave action;
- absence or lack of evidence, on the exposed walls, of notches or sea terraces immediately above to the present sea level, related to eustatic sea level changes occurred in the latest Pleistocene;
- the presence of suspended valleys;
- the uncovered of the underground ducts of the Roman age.

**Keywords:** Rocky Cliffs, Coastal Geomorphology, Cliff Retreat, Ponza Island, Italy

ABSTRACT NUMBER: 500

## MECHANISMS AND CONTROLS OF SHORE PLATFORM DOWN-WEARING

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Erosion of shore platforms determines how much wave energy arrives to the cliff toe, effectively controlling coastline evolution. Simplified platform erosion is included in coastal evolution models, but its mechanisms and controls are poorly understood which makes it difficult to assess how good coastal change predictions are.

Platform down-wearing has been traditionally monitored with micro-erosion meter (MEM), whose utility have been often questioned due to its small size (and hence representativeness), topographic requirements (flat surface, no cracks) and limited amount of information which can be obtained (erosion rates and their variability across platform).

Here we present a novel method to monitor platform down-wearing using Structure-from-Motion, which we optimised to be able to detect vertical change of 1 mm. We developed it for a shale/sandstone shore platform of Staithes, North Yorkshire, UK. Over one year we monitored monthly 15 sites of diverse tidal level, rock type, structure (joint density) and relief (plain/slope/step).

Observed erosion rates of 10-1-100 mm/year roughly agree with the ones recorded at the same area by Robinson (1977) using MEM. However, increasing monitoring site 60 times in respect to MEMs allowed us not only to record erosion but also to perform a wide range of magnitude/frequency and spatial analyses. For both rock types dominant mechanism of erosion is plucking due to hydraulic action rather than abrasion. We observed propagation of erosion (once occurred at one spot, erosion often develops at the same location), exploration of topography rather than structure (concentration of erosion at micro-steps and rock protrusions rather than along cracks/joints) and the control of rock micro-structure (shale flakes and sandstone layering) on sizes and shapes of eroded material.

Understanding mechanisms of erosion and controls on its rates and distribution will allow better account for platform down-wearing in coastal evolution models.

**Keywords:** rocky coasts, shore platform, micro-erosion, Structure-from-Motion

THEME: S29 : GEOMORPHOLOGY OF ROCKY COASTS (IAG-WG)

ABSTRACT NUMBER: 512

## LINKING NEARSHORE AND ONSHORE EVIDENCE FOR EXTREME WAVE IMPACTS ON ROCKY SHORES IN MALTA

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Increasing numbers of studies are reporting evidence of extreme wave, including tsunami, impacts on rocky coasts. They are commonly based on characterisation, occurrence and distribution of tsunami landfall signatures of both erosional and depositional origin. Many analyse the signatures in seeking to identify the nature and magnitude of the events which formed them. As such, extreme wave signatures can provide valuable estimates of potential future risk.

Such studies, however, have focused almost exclusively on terrestrial signatures, and hitherto few studies have sought evidence from the adjoining submerged nearshore zones. Pioneering observations are here presented from the rocky nearshore zone of the Maltese Islands, based on the results of scuba diving surveys at a series of locations. These include both depositional (boulder) and erosion (socket and scarp) signatures. The study investigates the character and distribution of these forms, especially depositional forms with the potential to facilitate the definition of a distinct nearshore tsunamiite facies.

In recent years researchers have started to search more holistically for distinct erosional and depositional evidence with an emphasis on spatial patterns across a coastal landscape, as previously shown by the authors. Potentially, such studies can provide additional insights into formative events from detailed local-scale variations when that evidence is preserved on terrestrial backshores undisturbed by human activities.

Examples of terrains impacted by extreme waves are presented for sites with previously recorded and interpreted terrestrial evidence, for which submerged nearshore evidence is now also available. A remarkable complementarity is shown between terrestrial and nearshore patterns. In this manner, the additional insights generated from interpretation of the nearshore observations, in the context of the terrestrial evidence, can be highlighted. The authors conclude by reviewing the potential merits and pitfalls associated with using the nearshore data to inform research on extreme wave impacts.

**Keywords:** Tsunami, signature, nearshore, tsunamiite, complementarity

THEME: S29 : GEOMORPHOLOGY OF ROCKY COASTS (IAG-WG)

ABSTRACT NUMBER: 660

## INFLUENCE OF SHORE PLATFORM AND ITS GEOMORPHOLOGY ON COASTAL EROSION RATE OF BEACH TERRACES, SOUTH SHORE OF THE ST-LAWRENCE ESTUARY, CANADA

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The foreshore is a coastal component rarely considered in coastal hazard evaluations in the Quebec province, Canada. The purpose of this study is to determine if the foreshore geomorphological characteristics influence the shoreline movement rate on beach terraces of the St-Lawrence marine estuary and identify them. This study is also the first to quantify their influence on multiple spatial scales. A foreshore classification adapted to the maritime Quebec has been developed and applied by photointerpretation and validated with field data. Afterwards, morphometric characteristics have been calculated based on LiDAR data on 2176 foreshore transects, and then linked to the shoreline annual movement for the 1993-2009 and 2009-2012 periods. Comparisons between twelve rocky foreshore profiles have revealed four different platform geometry types. Results clearly show an existing relation between the shoreline movement

and the main morphometric characteristics of the foreshore, which are: slope, roughness and width of the foreshore and the shoreline altitude. The force of these relations varies according to foreshore composition and spatial scale. Also, platform geometry plays an important role on shoreline movement rates of beach terraces where the foreshore has a mixt composition or mostly rocky. General trends indicate that short and steep rocky or mixt foreshores with high roughness are associated to a more important shoreline retreat for the 1993-2009 period. However, we generally observe reverse trends for the 2009-2012 period marked by an exceptional storm in 2010. Foreshore morphometric and composition seems to be the key factors of the foreshore geomorphology that explains best the shoreline movement rate measured on the study site. In the light of this study's results, it would be relevant to include these foreshore parameters in the erosion hazard cartography method for the next researches on coastal erosion hazard management.

**Keywords:** Coastal geomorphology; foreshore; beach terrace; shore platform; Quebec

THEME: S30 : SUBMARINE GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 7

## SUBMARINE LANDSLIDE INFLUENCES ON THE DEVELOPMENT AND MORPHOLOGY OF 'EMPTY BUCKET' VERSUS 'FULL BUCKET' VARIETIES OF PACIFIC ATOLLS

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New models have recently been proposed to explain variations in the formation of Pacific Ocean atolls through the Late Cenozoic. Some models have the explicit aim of accounting for contemporary differences in atoll lagoon morphology, namely the 'empty bucket' and 'full bucket' atoll varieties, which refer to deeper lagoons and shallower sediment-filled lagoons, respectively. Models of atoll development tend to emphasise reef accretion, carbonate dissolution, sediment transport and vertical motion as the primary influences in final atoll form. However, the influence of volcanic flank collapse and submarine landslides on atoll evolution has largely gone ignored. This is surprising, given that, through improved bathymetry, multiple slope failures are now known to exist on the submarine slopes of many Pacific atolls.

Our modified Darwinian model includes the effects of atoll flank collapse. The expression of a submarine landslide scar on atoll morphology is the associated 'arcuate bight-like structure' (or ABL) observed in the plan shape. Sequences of adjacent ABLs characteristically produce a scalloped atoll margin, whereas atolls lacking in ABLs tend to exhibit less indentation. When large submarine landslides affected a significant portion of a palaeo-atoll rim, this had the potential to open up an atoll lagoon, allowing much freer circulation between the lagoon and the surrounding ocean. This provides an additional mechanism for an atoll lagoon that was originally enclosed during a glacial low sea-level stand to then become a 'leaking bucket' system, and subsequently more likely to evolve into the 'empty bucket' form with later post-glacial sea-level rise. The significance of any differences in contemporary atoll morphology cannot realistically be explained without due consideration being given to submarine mass failures, which are a common and yet poorly understood geomorphological process.

**Keywords:** submarine landslides; atoll flank collapse; atoll evolution; atoll morphology

THEME: S30 : SUBMARINE GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 135

## GEOMORPHOMETRIC CHARACTERISATION OF POCKMARKS ACROSS THE EUROPEAN GLACIATED MARGIN BY A USING GIS-BASED SEMI-AUTOMATED TOOLBOX

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Pockmarks are seabed depressions that can occur in vast numbers in many marine and lacustrine environments. These features, developed by fluid flow processes, shape more than 50 percent of the seabed in some areas of the Barents Sea, where the density of pockmarks can be locally more than 600 pockmarks per square kilometre.

Manual mapping of these features can be extremely time-consuming and subjective. To efficiently map pockmarks the British Geological Survey developed a semi-automated mapping toolbox. This ArcGIS-based toolbox recognises, spatially delineates and morphometrically describes seabed features including pockmarks. Since it was first developed, several thousands of pockmarks have



already been mapped and characterised around the UK continental shelf, especially, within the central North Sea. More recently, tens of thousands were also semi-automatically mapped within the Barents Sea.

The characterisation of such vast numbers of pockmarks with multiple morphological characteristics allows an unprecedented statistical analysis of their morphology. Combining this statistical analysis with the geological and oceanographical knowledge of individual areas provides insights into the processes responsible for their development and the influence of local seabed conditions. The results revealed, for example, where: 1) certain morphological trends reflect the local hydrodynamic regime; 2) the density and spatial distribution of pockmarks are mainly attributable to differences in shallow gas availability and deeper geology as opposed to variation in the nature of seabed sediments and 3) vertical relief reflects the thickness of the upper sedimentary package.

The application of this method to different datasets, over a wider range of water depths, seabed sediments types, and geological settings would significantly increase the understanding of formation and evolution of these common but still poorly understood seabed features.

**Keywords:** Pockmarks; Automated-mapping; Glaciated Margin

THEME: S30 : SUBMARINE GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 157

## SHAPING MECHANISMS AND LONG-TERM EVOLUTION OF SUBMARINE CANYONS. LESSONS TAKEN FROM FIELD, NUMERICAL AND EXPERIMENTAL STUDIES

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Submarine canyons are deep incisions observed along most of the world's continental margins. Their topographic relief is as dramatic as that of any canyon or river valley on land but is hidden beneath the surface of the ocean. Our knowledge of canyons has therefore come primarily from remote sensing and sampling, and has involved contributions from various oceanographic disciplines. Canyons represent a critical link between coastal and shelf waters and abyssal depths; water masses, sediment, nutrients, and even litter and pollutants are carried through them. Advances in technology continue to provide new insights into canyon environments by pushing the frontier of deep marine observations and measurements. In this presentation we will describe the main geomorphic features of submarine canyons and what is known about their formation and the fundamental processes controlling their long-term form and dynamics. We will discuss the intriguing resemblance between submarine canyons and river valleys and – drawing from work on upland drainage networks – present mathematical and experimental models of submarine landscapes (or “seascapes”) that successfully capture the main formative processes driving canyon growth.

Keywords: submarine canyons; long-term morphodynamics; fluvial analogy

THEME: S30 : SUBMARINE GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 308

## GRAVITY DRIVEN SEDIMENT TRANSPORT ALONG THE NW-AFRICAN CONTINENTAL MARGIN

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The passive NW-African continental margin shows abundant morphological features formed by gravity driven sediment transport. The margin is well known for the occurrence of large-scale but infrequent submarine mass wasting. The largest landslides between southern Senegal (ca. 12°N) and the Agadir Canyon (ca. 31°N) are the Dakar Slide off Senegal, the Mauritania Slide, the Cap Blanc Slide, the Sahara Slide off Western Sahara and the Agadir Slide south of Agadir Canyon. All slides are characterized by complex scars suggesting multiple failures. The failures resulted in two types of mass movements; spreading and translational sliding. At least one major failure (Sahara Slide) occurred in the late Holocene contradicting the postulate of a stable slope off NW Africa during times of relative stable sea-level high stands. The areas between major failure areas are undisturbed and only show sporadic local failures

but abundant submarine canyons and channels. The canyons/channels may act as effective pathways for regular downslope sediment transport by turbidity currents preventing the accumulation of thick, potentially unstable, sedimentary successions; hence no large landslides occur in these sections. There are only a few places where a direct interaction between open slope landslides and channeled sediment transport has been observed. A major landslide destroyed a canyon off Dakar (Senegal), which resulted in a reorganization of sediment transport pattern in this region. The Agadir Slide (off Morocco) enters the Agadir Canyon in about 2500 km water depth. Despite a significant increase in slope angle, the landslide did not disintegrate into a turbidity current when entering the canyon but moved on as landslide for at least another 200 km down the canyon.

THEME: S30 : SUBMARINE GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 317

## TOPOGRAPHICALLY-DRIVEN METEORIC GROUNDWATER: AN IMPORTANT GEOMORPHIC AGENT?

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Offshore groundwater has been proposed as an important agent in the geomorphic evolution of continental margins and the canyons that incise them. However, a definitive link between landscape form and groundwater processes remains poorly quantified. The main challenges to solving these problems include a lack of mechanistic understanding of groundwater erosion/weathering, and limited information on offshore groundwater architecture and dynamics. MARCAN is a new 5 year ERC-funded research project that addresses the role of offshore groundwater in the geomorphic evolution of continental margins. MARCAN's multi-scale approach incorporates detailed characterisation of offshore groundwater systems to test groundwater erosion potential in continental margin geomorphic evolution models. The project results are expected to guide future investigations of offshore groundwater systems, add a new dimension to continental margin research, and bring about a step-change in our understanding of some of the most widespread and significant landforms on Earth. Direct mapping of offshore aquifers in MARCAN has a strong applied relevance through improvements to offshore groundwater assessment techniques that can lead to the exploitation of offshore freshwater as a source of drinking water.

**Keywords:** offshore groundwater; submarine canyon; continental margin evolution; New Zealand; Malta

THEME: S30 : SUBMARINE GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 380

## A NEW GENETIC CLASSIFICATION AND MAPPING APPROACH FOR LITTORAL TO ABYSSAL FEATURES ON THE AUSTRALIAN MARGIN

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In 2008, Geoscience Australia developed the first complete geomorphic map of the Australian seafloor for the primary purpose of ecosystem-based management. Since then, acquisition of a range of marine geophysical and remote sensing data types with improved resolution has intensified (e.g. multibeam echo-sounding, sub-bottom profiling, LADS & LIDAR). This progress brings an opportunity to classify and map the Australian seafloor in greater detail, using methods that preserve links between processes and morphology. This has particularly important applications for improved resource and risk management.

The development of Geoscience Australia's new genetic classification scheme aims to be seamless from terrestrial to marine, using inter-tidal extent and coastal compartment modelling to extend mapping into littoral environments, and multibeam sonar to map the shelf and beyond. The classification scheme draws on the Harris et al. (2014) scheme used to update the geomorphic map of the world's oceans where the top-most hierarchical levels of the marine environment are shelf, continental slope, abyss and hadal zone. A range of existing classification schemes will be used to divide these zones into hierarchically arranged subcomponents.

Each primary zone (littoral, shelf, slope and abyss) is divided into hard (reefs) and soft (depositional systems and bedform fields) geomorphic features, each of which are divided into component features. The continental slope is also divided according to large-scale features, including mass movement features and canyons, and these are similarly subdivided into their sub-components. For example, canyons can be subdivided based on a range of topographic metrics, fluvial connection and shelf-incising status. For abyssal environments, seamounts and knolls are our initial priority features for classification.

This is not an exhaustive list of the target features to be included within our new framework. Rather, it provides a starting point for evolving the Harris et al (2014) scheme towards improved geomorphic fingerprinting.

THEME: S30 : SUBMARINE GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 518

## DIRECT MEASUREMENT OF THE IMPACT OF SUBMARINE GRAVITY FLOWS ON SEAFLOOR MORPHOLOGY: PRELIMINARY RESULTS OF THE MONTEREY COORDINATED CANYON EXPERIMENT

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Submarine sediment gravity flow events are among the most important sediment transport processes on Earth. Until recently, technological limitations have prevented measurements of the magnitude of individual events and their effect on seafloor morphology. To rectify this understanding gap, the Coordinated Canyon Experiment (CCE) sought to capture gravity flow events using multiple sensors deployed in the axis of Monterey Canyon, offshore California, with repeated mapping of the canyon floor providing bathymetric grid resolutions ranging from 1 m to 1 cm. Instruments were distributed from 270 to 1,850m water depths including: six moorings carrying downward-looking acoustic Doppler current profilers (ADCP); a benthic instrument node holding ADCPs of three different frequencies recording on a common time base; an array of benthic event detectors (smart boulders) that record transport within the base of a flow; and triangulation beacons to assess creep within the canyon floor. The instrument array and mapping tools successfully recorded the down-canyon evolution of powerful flows and the resulting changes in seafloor morphology in spectacular detail. During the CCE's first year, nine sediment transport events were recorded, with seven of them restricted to <520m water depths. Two sediment-laden flows ran out for >50km with average velocities of 5.4 and 4.2m/sec. Individual moorings and instruments moved down-canyon up to 7.8 km in one event. The repeated mapping revealed  $\pm 3$ m depth changes in the seafloor which occurred during these flow events along a continuous well defined  $\sim 100$ m wide band running down the canyon axis. Centimeter-scale scours and burrows mapped on the exposed seafloor probably formed between events. The development of technologies allowing monitoring and quantitative high-resolution imaging of the seafloor offers the possibility of expanding detailed geomorphological studies to include the processes occurring over the submarine portion of the Earth's surface.

**Keywords:** Turbidity Currents; Gravity Flows; Seafloor Mapping; Submarine Canyons; Mapping Technology

THEME: S30 : SUBMARINE GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 601

## ROV-BORNE MICRO-BATHYMETRY REVEALS THE ROLE OF REEF FRAMEWORK-FORMING COLD-WATER CORALS IN SHAPING THE NORTH-EASTERN IONIAN MARGIN FROM LATE PLEISTOCENE TO PRESENT TIME

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The north-eastern Ionian margin hosts one of the largest Mediterranean province of living CWC, which greatly contributed in forming a spectacular landscape dotted by more than 1000 sub-conical and elongated coral-topped mounds, located in water depths of 500-900 meters. Thriving colonies of *Lophelia pertusa* and *Madrepora oculata* formed indeed patchy distributed reefs on the exposed summits

and flanks of mound-like structures (up to 300 m wide and 25 m high), originated as a result of Pleistocene mass wasting events. The province receives water-masses coming from NE and formed in the Adriatic Sea, which is one of the major deep-water formation sites in the Mediterranean. A bathymetry data set with sub-metric resolution (i.e. microbathymetry) was acquired on a single coral-topped mound, using the Remotely Operated Vehicle (ROV) VICTOR6000, equipped with a high-frequency multibeam sonar (Reson Seabat 7125) and deployed from the R/V Pourquoi Pas? during the 2007 MEDECO Expedition (October 2007). Fine-scale bathymetric profiles and geomorphometric analysis on the obtained Digital Terrain Model (DTM), coupled with published data on periods of coral accretion and demise in the study area, well imaged how coral growth enhanced the mound elevation with respect to the surrounding seafloor, from the onset of cold-water coral growth at ~13.4 cal kyr BP (as indicated by the oldest dated coral reported in literature) to the present time. In addition a number of small scale bedforms, indicative of NE/SW directed benthic currents, were mapped and helped in figuring out how the local oceanographic pattern likely had a major influence in determining the overall growth structure of coral reefs over the gross mound morphology.

**Keywords:** Cold-water corals, microbathymetry; seafloor mapping; submarine geomorphology

THEME: S30 : SUBMARINE GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 676

## SUBMARINE CHANNEL MORPHOLOGICAL SCALING RELATIONSHIPS: A PREDICTOR FOR ARCHITECTURAL HETEROGENEITY AND A COMPARISON TO SUBAERIAL/RIVER SCALING RELATIONSHIPS

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Submarine channels are common and persistent features in the modern seascape and stratigraphic record, and represent fundamental reservoir architectures in petroleum systems. Utilizing morphological, kinematic, and architectural (stratigraphic) data, this study documents planform and vertical scaling relationships for submarine channels. We also compare these scaling relationships to subaerial channels (i.e., rivers) to illustrate differences and similarities in morphology and stratigraphic architecture.

Using modern bathymetric, 3D seismic, core/well, and outcrop data, we have developed an extensive database of planform and vertical channel scales and measurement metrics for submarine channels. Multiple scales of channelized features were extracted and analyzed, including: the geomorphic channel form (e.g., width, depth, planform metrics), oxbow-cutoffs, channel trajectory/mobility, and preserved deposit thickness. Geometric statistics resulting from these features were used to derive planform and cross-sectional scaling relationships, which are coupled with additional data (e.g., basin type, slope morphology, net-to-gross) to identify and highlight the first order physical controls on channel morphology, kinematics, and resultant architecture. These controls form the basis for a classification of submarine channels that is objective and quantitative. This classification system is process-based and allows for the prediction of scale, architecture, and heterogeneity of submarine channel deposits of all scales.

Subaerial and submarine channels exhibit qualitatively similar morphology, but their stratigraphic record is known to be quite different. Submarine channel scaling relationships use many of the same metrics as those developed for river systems, allowing for the quantification of differences and similarities. Comparative analysis of these scaling relationships indicates that (1) submarine and subaerial channels have very similar width/depth relationships, and (2) submarine channels are about twice as wide as subaerial channels, given the same planform shape (i.e., half wavelength) and channel belt dimensions.

**Keywords:** submarine channel; river; scaling relationships; channel morphology; multibeam

THEME: S30 : SUBMARINE GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 681

## THE LEVANTINE MARGIN DURING THE MESSINIAN SALINITY CRISIS: SLUMPS, INCISIONS, TECTONICS AND MORE

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During the Messinian Salinity Crisis (MSC, 5.97±0.01–5.33 Ma) the Mediterranean Levant margin experienced major eustatic and

sedimentary cycles as well as tectonic motion along the nearby Dead Sea fault plate boundary. New structures formed along this margin with morphology responding to these changes. Our study focuses on changes in this morphology across the margin. It is based on interpretation of three 3D seismic reflection volumes from offshore Israel. Late Messinian morphologic domains include: (a) continental shelf; (b) 'Delta' anticline, forming a ridge diagonal to the strike of the margin; (c) southward dipping 'Hadera' valley, separating between (a) and (b); (d) 'Delta Gap' - a water gap crossing perpendicular to the anticline axis; (e) continental slope. Drainage across the margin developed in several stages. Remains of turbidite flows crossing the margin down-slope were spotted across the 'Delta' anticline. Rising of the anticline, above the then bathymetry, either blocked or diverted the turbidites to the transverse Delta gap which was carved through the Delta ridge. In-situ evaporates, in the distal end of 'Hadera' valley are overlain by a fan-delta complex which contains eroded evaporites and Lago-Mare fauna. Its top is truncated by dendritic fluvial channels that drained towards the Delta Gap.

We propose that during the first stages of the MSC (5.97±0.01–5.59 ma) destabilization of the continental slope due to oscillating sea level produced gravity currents that flowed through the pre-existing Delta anticline. Subsequent folding of the anticline diverted several flows towards the Delta Gap during peak MSC desiccation phase (5.59-5.5 ma). This resulted in sub-aerial incision of a canyon across the gap that outpaced the tectonic uplift of the anticline. During the Lago-Mare regression (5.5-5.33 ma) a fluvio-marine sequence was deposited in the already formed Hadera valley. Another transgression before the Zanclean flood eroded the top of this sequence.

THEME: S30 : SUBMARINE GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 683

## MASS WASTING EVIDENCES ON A SMOOTH SEAFLOOR RIDGE OF THE SOUTH WEST INDIAN RIDGE; 28°S – 64°E

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In this work, we present the first results of a micro-bathymetric survey carried out during the ROV-SMOOTH 2016 cruise (PI Mathilde Cannat on board of the IFREMER R/V Pourquoi Pas?). The high-resolution (1 m) micro-bathymetry (and backscatter) was acquired with the multibeam echosounder Reson Seabat 7125 mounted beneath the ROV Victor 6000.

The investigated area is a 2500 m-high ridge bounding the northern side of the axial valley of the South West Indian Ridge (SWIR) between the longitudes 64°-65°E and latitudes 27°-28°S. This portion of SWIR represents an end-member of melt-poor and ultra-slow mid-ocean ridge where seafloor formation occurs mainly through mantle exhumation by means of large detachment faults.

The investigated area is set in the upper slope of the south-facing axial valley wall, representing the footwall of the presently active axial detachment. This detachment fault is exhuming mantle-derived serpentized peridotites. The microbathymetry (and backscatter) survey highlighted that on the west, the south-facing hill of the uppermost crest of the ridge is sloping about 35°-40° and is constituted by the outcrop of brecciated peridotites, partially or totally serpentized. On the east, the crest shows gentler slope and the second dive highlighted an almost flat seafloor on the ridge top, completely covered by fine sediments. Moving downhill the slope results to be covered by a thick deposit constituted by large blocks, heterogeneous in shape, in a matrix of fine sediment. These features have been interpreted as large mass wasting processes controlling the morphology of most of the southern slope of the axial-valley wall. This is probably related both to deformation structures associated with detachment faulting and the exhumation of serpentized mantle-derived peridotites for the evolution of slow spread and magma poor seafloor.

**Keywords:** Morphology mid-ocean ridge; Submarine landslides; Detachment faults; South West Indian Ridge

THEME: S30 : SUBMARINE GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 784

## MULTIBEAM BATHYMETRIC MAPPING OF SUBMARINE CANYONS OFF VISAKHAPATNAM, EASTERN CONTINENTAL MARGIN OF INDIA

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Investigations of continental margins have become the prime focus of coastal states because of their scientific, environmental, and economic significance. Quite often continental margins are being revisited employing advance techniques, even-though they have been mapped to some extent in the past. This is mainly because of the high-resolution capabilities and improved swath coverage of present days surveying tools. In this study, we present the results of multibeam bathymetric mapping of the central part of the Eastern Continental Margin of India, off Visakhapatnam. Over five decades ago, during the International Indian Ocean Expedition (IIOE), single-beam echosounder profiles acquired over this part of the continental margin, had revealed the presence of submarine canyons. The region was recently revisited with high-resolution multibeam swath mapping sonar to map the extent of canyons and describe their geomorphology. The bathymetric maps revealed existence of a system of canyons, encompassing the three canyons that were discovered during IIOE. Interpretation of the bathymetric data reveals that the shelf break occurs between 90-110 m owing to the presence of canyon head at the shelf edge. The lengths of the canyons vary from 25 to 40 km and widths from 1 to 10 km. The maximum channel valley depth in the canyon system is observed to be 675 m. The thalweg slope of the canyons in general, is steeper towards the canyon head having slopes of the order of 1:6, which diminishes to 1:16 in the lower part of the channel. Based on the cross-sectional and planer-form of geo-morphological analysis, the numerous scours observed along the thalweg of these canyons designate them to be a part of an energetic and evolving canyon system. The geo-morphological characteristics of the canyons and the adjacent seafloor is described here.

**Keywords:** geo-morphology; margin; bathymetry; mapping; canyons

*THEME: S31 : LANDFORM ASSESSMENT FOR GEODIVERSITY: GENERAL GEOMORPHOLOGY, GEODIVERSITY, GEOCONSERVATION (IAG-WG)*

**ABSTRACT NUMBER: 76**

## **THE MUSTANG GRABEN (NEPAL HIMALAYAS): LANDFORMS DIVERSITY AND DYNAMICS VS. ECONOMIC DEVELOPMENT. OPPORTUNITIES OR THREAT TO GEODIVERSITY?**

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The Himalayas mountains, the highest in the world, offer exceptional landscapes, characterized by a large bio-geo-diversity that should be preserved. Besides UNESCO World Heritage Sites, National Parks and Conservation areas have been created by the Nepal Government, with the aim of integrating protection, education and sustainable development, protecting environmental heritages, together with local culture and history, hence encouraging better knowledge and perception of the landscape elements by the visitors in connection with local people.

The Himalayas, the product of India-Asia plates collision, are both a real outdoor laboratory and museum, where past and present geodynamic activity is expressed by specific landforms. Here we focus on the outstanding Mustang-Thakkhola graben, and its potential for geomorphosites, located in the northern, dry, continental Himalaya. We show how its whole environmental value might be progressively endangered with the development of tourism and a new road.

We present successively (1) the geo-tectonic context of this semi graben and its 850m-thick, colorful detrital filling of Mio-Plio-Pleistocene age, then (2) the present landforms characterized by deep gorges, narrow cliffs and dramatic gullies cut into yellow-orange-grey material. (3) Geo-cultural heritages such as natural caves carved into consolidated debris, used as shelters by early dwellers (>3000 y.), then by Buddhist ascetics. (4) Upper Mustang is the core of the Annapurna Conservation Area, an area with many endangered and protected species.

The opening of upper Mustang to foreigners in 1992, then the completion of a carriage, dust road in 2015, was an opportunity to promote these exceptional landscapes. However, unexpected, adverse impacts, related to the environment resources and quality (biodiversity, water, wilderness), have to be considered in the new tourist-based economy in a context of climate change. This may threaten the exceptionally rich geo-diversity, as illustrated by a few, selected geomorphosites.

**Keywords:** Graben filling; Geomorphosites; Development; Mustang; Nepal Himalaya

THEME: S31 : LANDFORM ASSESSMENT FOR GEODIVERSITY: GENERAL GEOMORPHOLOGY,  
GEODIVERSITY, GEOCONSERVATION (IAG-WG)

ABSTRACT NUMBER: 161

## THE GEODIVERSITY OF PROCESSES AND LANDFORMS: HOW CAN THEY BE INTEGRATED AT WORLD HERITAGE LEVEL?

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The UNESCO World Heritage convention identifies geological processes and the landforms created by them as part of the geological criterion (viii). An important question raised by this is, what landforms reflect what process? Some processes are easy at first sight to ascribe, such as the Vredefort Dome, as a witness to extraterrestrial impact, or the Stevn Klimt site in Denmark, where the KT boundary is well displayed with faunal changes across the boundary. However, many major Earth processes are represented by surface processes and landforms quite different from those that form them at depth. For example, a hot spot is never seen as such, or a subduction zone is hidden by many kilometres of ocean. In these cases, it is the processes that shape geodiversity as the surface that bear witness to what goes on a much larger scale. In this presentation we chart the main processes that operate in the Earth and which could (or should) be considered for World Heritage, we then link these to assemblages of surficial processes and their landforms, to provide an appreciation for the types of assembled geodiversity that can represent the major global processes. We take some existing and some nominated World Heritage properties as examples, including the Grand Canyon, Kamchatka volcanoes, Lake Turkana, Virunga, and the Chaîne des Puys - Limagne Fault.

**Keywords:** geodiversity; World Heritage; tectonic processes

THEME: S31 : LANDFORM ASSESSMENT FOR GEODIVERSITY: GENERAL GEOMORPHOLOGY,  
GEODIVERSITY, GEOCONSERVATION (IAG-WG)

ABSTRACT NUMBER: 229

## EXPLORING GEODIVERSITY OF ISLANDS IN RELATION TO TECTONIC SETTING AND AGE

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Comparative geodiversity research and analyses techniques on global, continental and national scales is still scarce, in contrast to regional and local scale studies. To compare patterns of geodiversity index values of islands and their surrounding seafloor, freely available elevation datasets such as SRTM and bathymetry are used in combination with tectonic-geological, geomorphological and soil data. The aim is to investigate if geodiversity index values reflect the stage of island evolution within the tectonic setting of the sea/ocean floor. As an example geodiversity index values of the Canarian and Hawaiian hot-spot island archipelagos are calculated and compared. The age of the individual islands is relatively well-known as they underwent accretion, maximum growth and degradation over time. In general, the geodiversity index values of islands at maximum growth have high geodiversity, while younger and older islands have lower or intermediate geodiversity. In the geologically complex case of Tenerife, an island at maximum growth, its intra-island geodiversity pattern confirms that the oldest parts of the island are hot-spots of high geodiversity, in contrast to the younger parts. To extent islands geodiversity to the sea/ocean floor, sea floor geomorphology and bathymetry has been used to include their position in relation to different tectonic provinces. Preliminary outcomes indicate that islands on hot spot, in subduction zones, in continental settings and in tension zones differ in geodiversity.

The results indicate that freely available datasets and simple index-based geodiversity mapping methods may lead to meaningful macro geodiversity index maps. The method can be extended to mountains and lowland areas in which age relationships are important as well. The outlook is to integrate finer scale geodiversity data and apply the results in studies on the effects of sea level fluctuations on islands, in (macro)biogeographical studies or in habitat conservation initiatives.

**Keywords:** geodiversity index; volcanic islands; sea-floor geomorphology; bathymetry

THEME: S31 : LANDFORM ASSESSMENT FOR GEODIVERSITY: GENERAL GEOMORPHOLOGY,  
GEODIVERSITY, GEOCONSERVATION (IAG-WG)

ABSTRACT NUMBER: 293

## GEOMORPHOLOGICAL LANDSCAPE IN THE NORTHERN MOROCCO REGION: INVENTORY OF GEOMORPHOSITE, EVALUATION, MAPPING AND VALORIZATION

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This work consists of an inventory geomorphosites, applied to the northern Morocco region, which are characterized by a diverse geomorphological setting and exceptional amazing natural environment. The willingness to undertake such research stems from two observations: firstly it falling deep gaps in knowledge of the general public in the field of Earth Sciences; geomorphology also has an inadequate consideration in land use policies and protection of nature, while the geomorphological component of the territory suffers increasing pressure from human activities. On the other hand, the geomorphological heritage, often spectacular, has a great potential for tourism development; thus feels a change in the expectations of certain categories of tourists, with a growing demand for leisure activities related to nature. This trend is reflected in the emergence of geo-tourism, which aims to promote Earth Sciences by tourism. To promote awareness of geomorphological heritage of our territories and improve its recognition in the various public policies, it is necessary, first time, an overview of it. For this we have taken advantage of the relatively recent concept of geomorphosite, which identifies the most interesting forms of geomorphological landscape.

Our approach consisted first in our inventory geomorphosites among the many geomorphological forms of the territory and then evaluates them using a proven methodology, developed at the Institute of Geography of the University Lausanne (IGUL), with some additions of author suited the study area. We finally proposed some valuation tracks of this heritage.

Using this approach in a mountain region rich in diverse geomorphological heritage, we seek actually to discover to what extent, and especially how the geomorphosite inventory tool can contribute to the development of the geomorphological heritage and his valuning.

Keyword: Geomorphosite; Inventory; Northern Morocco; Valorization; IGUL

THEME: S31 : LANDFORM ASSESSMENT FOR GEODIVERSITY: GENERAL GEOMORPHOLOGY,  
GEODIVERSITY, GEOCONSERVATION (IAG-WG)

ABSTRACT NUMBER: 346

## MAN-MADE LANDFORMS AND GEODIVERSITY WITHIN OLD GENOA CITY (ITALY): AN UNIQUE AND COMPLEX GEOMORPHOLOGICAL LANDSCAPE IN MEDITERRANEAN AREA

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Genoa city is internationally known for its seaport, which is the largest in Italy and the second one in Mediterranean.

Genoa, capital of a Maritime Republic from 1099 to 1815, shows elements of aesthetic, historical, cultural, socio-economic and scientific value, with an extraordinary geodiversity linked also to built-stone heritage.

The geomorphological layout of the city has contributed to the success of Republic of Genoa over the centuries: today the urban landforms are not immediately recognizable, because they are characterized by several stages of urban growth.

In this research, the results of a geomorphological survey of Genoa historical amphitheatre are presented. The area developed in the Middle Ages and it was surrounded by the seventeenth-century walls which protected the old port between the Promontory of the Lighthouse to W and Carignano hill to E.

The amphitheatre's area is 8.5 km<sup>2</sup>, with seven small and steep catchments characterised by high degree of urbanization.

The study was carried out by multi-temporal cartographic and photographic comparison, with on-site observations, and through the interpretation of hundreds of drill surveys carried out for construction work.

An original geomorphological map, with specific attention to man-made landforms, was produced. The map highlights three main





issues of urban geomorphology, reflecting the major changes of the landscape due to man-made activities: sea embankments, mainly for the construction of port and facilities; river networks modifications and particularly culverts, diversions and canalizations; slope construction excavations and backfills, both on stream networks and roads.

The identification and mapping of geomorphological heritage sites could contribute to their popularisation and to the establishment urban geotourism itineraries: guided tours along alleys, main roads, promenades and underground environments could unveil to the public the geological and geomorphological features of historical centres and the evolution of urban areas through the centuries.

**Keywords:** urban geomorphology; geodiversity; man-made landforms; Genoa

*THEME: S31 : LANDFORM ASSESSMENT FOR GEODIVERSITY: GENERAL GEOMORPHOLOGY, GEODIVERSITY, GEOCONSERVATION (IAG-WG)*

**ABSTRACT NUMBER: 484**

## **ASSESSMENT AND ENHANCEMENT OF GEODIVERSITY IN THE PIEMONTE REGION (ITALY): “FROM ROCKS TO STONES, FROM LANDFORMS TO LANDSCAPES”**

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As scientists we are called to respond to the UN and UNESCO demand for raising and spreading awareness on Earth's resources. Nevertheless, lack of conservation policies including the non-living elements of natural heritage makes it hard to encourage public respect for geodiversity. According to these needs our project is developing a comprehensive methodology for promoting knowledge on geodiversity, enhancing protection and best management practices of geoheritage at a local and regional scale: “from rocks to stones, from landforms to landscapes” (project funded by Progetti di Ateneo/CSP 2016 program).

Analyses of the rich geodiversity of the Piemonte Region (NW-Italy, including the upper Po plain, Langhe and Monferrato Hills, and the Western Alps) have been performed by means of up-to-date scientific literature, historical documents, field mapping and remote sensing, with the assistance of both researcher and local stakeholders (park rangers, environmental technicians and cultural managers) fostering exploration of hypothetical geodiversity and restoration of conditional geodiversity.

Geo-environmental and human components of geodiversity have been mapped at the regional (RGA: Regional Geological Approach”) and at the local scale (LMA: “Local Morphodynamic Approach”) according to the EU-INSPIRE standards of the GEOPiemonteMap (CNR-IGG). Both “static” and “dynamic” conditioning factors have been assessed, causing significant geodiversity changes during human lifetime (e.g. new rock outcrops created where glacier retreats, and other climate-related changes in soil use and human activities at higher elevations). Moreover, temporal and spatial occurrence of tectonic, gravity, water, ice and snow-related processes (earthquake, landslides, weathering, floods, avalanches, ...) and impacts by various human activities have been analyzed as the main vulnerability factors, causing geodiversity loss, erosion and damage of geoheritage.

*THEME: S31 : LANDFORM ASSESSMENT FOR GEODIVERSITY: GENERAL GEOMORPHOLOGY, GEODIVERSITY, GEOCONSERVATION (IAG-WG)*

**ABSTRACT NUMBER: 610**

## **EVIDENCES OF QUATERNARY ENVIRONMENTAL CHANGES IN THE AREA OF KANCHENJUNGA BIOSPHERE RESERVE IN SIKKIM HIMALAYA AND OUR STRATEGY FOR MANAGEMENT**

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Kanchenjunga Biosphere Reserve, located in the Northwestern part of Sikkim and occupying about 40% of this state, is one of the most important nature reserves in India. This reserve covers an area of 2,655.26 km<sup>2</sup>. The reserve extends over the altitude ranging from 1,220m to over 8,550m. A wide range of Quaternary geomorphological landforms in the form of Periglacial and Glacial landforms occur in this part around the Kanchenjunga summit complex. This presentation examines the landforms of these two types based on



field observations which reveals that almost all the periglacial features are now preserved above the tree-line (appx. 4,000m) up to the snow line (appx. 5,000m). Major large scale periglacial features include Block Slope, Debris Slope, Talus Slope and Pro-talus ramparts. With paleoclimatic inferences development of these large scale features in the periglacial domain has been attributed to a harsh climatic condition in the past and with climatic amelioration through the Holocene they have now become relict. Only small scale periglacial features have been found active in the present day. Remarkable changes in the glacial environment of this region have been detected. Morainic drift limits around the two distinguished glaciers, namely Rathong and Onglaktang, nourished from the neveé field of the Kabru Dome (6,600m) of Kanchenjunga summit complex suggest that during the Pleistocene period they extended down through the Rathong Chhu and Prek Chhu valleys for a considerably long distance and started retreating since beginning of the Holocene. Occurrence of fresh morainic drifts, extending down to about 1.5km from the existing snout of the glaciers, has been attributed to the glacier readvanced during the little Ice Age. All these glaciers are now shrinking rapidly under the present state of global climate change. Strategy for management of this biosphere reserve has also been discussed.

**Keywords:** Quaternary, morainic drift, neveé field

*THEME: S31 : LANDFORM ASSESSMENT FOR GEODIVERSITY: GENERAL GEOMORPHOLOGY, GEODIVERSITY, GEOCONSERVATION (IAG-WG)*

**ABSTRACT NUMBER: 700**

## **GEOPARK AS A LINK BETWEEN GEOMORPHOLOGY AND SOCIETY**

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Geoparks aim to conserve landscapes not only by preventing landscapes with environment and scientific values from intentional or unintentional damage, but by making these educationally and academically valuable sites the cornerstone for the sustainability of human society.

Taiwan is a typical example to demonstrate such a link. With its isolated marine environment in a sub-tropical zone, Taiwan presents a huge biodiversity and limited natural resources. Thus conserving natural resources and landscapes becomes crucial in order to maintain environmental and social sustainability. Landscape conservation is meant to protect our living environment, to improve overall living quality and to develop a sustainable society. Landscape conservation is important for protecting both natural beauty and habitats, and soil and water resources. A sustainable living environment can only be achieved if the fundamental resources of land, water and air are properly cared for in the island state of limited areas and resources.

For the past quarter of a century, Taiwan has undertaken landscape conservation in different ways and formats. In order to achieve the aims for sustainable socio-economy and environmental development, the means and objectives have had to be constantly and progressively redefined throughout time. This paper demonstrates such movements in Taiwan.

*THEME: S31 : LANDFORM ASSESSMENT FOR GEODIVERSITY: GENERAL GEOMORPHOLOGY, GEODIVERSITY, GEOCONSERVATION (IAG-WG)*

**ABSTRACT NUMBER: 709**

## **TIMELINE MAP FOR ANALYZING TRENDS IN THE USE GEODIVERSITY ASSESSMENT METHODS**

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Geodiversity is a dynamic concept either in the sense of contents or methods. For better understanding of development and application of this concept, the geodiversity assessment methods are presented here as a timeline map. The timeline map is a three-dimensional diagram based on three axes: X) a line showing temporal distribution of papers dealing with geodiversity assessment methods, by year of publication; Y) a line taking into account the different categories of geodiversity assessment methods, as well as their sub-categories; Z) a line displaying the frequency of using a given method. Preliminary issues to be addressed for timeline map construction were the categorization of methods and the sorting of examples from literature. We systematized geodiversity assessment methods published since 1992 in three categories: 1) qualitative, 2) quantitative and 3) qualitative-quantitative. Qualitative methods are usually descriptive methods that are suited to nominal and ordinal data. Quantitative methods use a different set of parameters and indicators to determine the characteristics of diversity in the area being investigated. Qualitative-quantitative methods are based on a combined collection of quantitative data (i.e. digital) and cause-effect data (i.e. relational and explanatory). Evaluation of the popularity of geodiversity

assessment methods has been performed by analyzing the background of published papers in successive years. Based on the above-described parameters, data on geodiversity assessment methods have been then represented in the timeline map. It offers a visualization of methodological development, indicating chronological trends in the use of each geodiversity assessment method; also, it enables better understanding of methodological context of geodiversity assessment; moreover, it identifies how different factors influence success and challenge use of specific methods into a broader geoheritage context. Timeline map indicates that geodiversity indices are the most popular method, but GIS-based qualitative-quantitative methods are the most advanced and detailed ones.

*THEME: S31 : LANDFORM ASSESSMENT FOR GEODIVERSITY: GENERAL GEOMORPHOLOGY, GEODIVERSITY, GEOCONSERVATION (IAG-WG)*

**ABSTRACT NUMBER: 740**

## **EVALUATION OF ANTHROPOGENIC DEGRADATION OF PEATLANDS FROM THE VIEWPOINT OF THEIR OCCURRENCE GEODIVERSITY. CASE STUDY OF PEATLAND IN THE POLISH CARPATHIAN MOUNTAINS.**

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Anthropogenic degradation of peatlands results in decrease of their area, decrease of the volume of peat deposit and the amount of water contained in the peat, which is discerned as a negative impact of human on abiotic environment. Changes in relief of peatland areas result in unprecedented diversity of land morphology, water properties of peat, microclimate and peat soils. From this point of view they lead to the increase of peatland geodiversity. Some of these areas become revitalized which causes additional changes in geodiversity. Problems of geodiversity were studied in the area of the largest concentration of raised bogs in the Polish Carpathians called Podhalańsko-Orawskie Peatlands. Changes in the peatbogs were caused by the following types of human activity: peat burning, withdrawing of fossil tree trunks, peat mining, creation of ditches draining peatland area, regulation of river channels. Basing on LiDAR data, the following types of landform were recognized: peat dome relicts, vertical or step-like peat escarpments modelled by peat landslides and peat mud flows, pits on post-peat areas, drainage ditches often cut to mineral substratum. Meander channels of watercourses were partly changed into straight channels or braided channels. In post-peat areas, the pits grown by peat moss and filled with water are adjacent to dry peat. Revitalization of the peatbogs causes flattening of anthropogenic relief, rise of ground water and increase of water resources in peat. The conducted evaluation of anthropogenic changes in the abiotic environment of the peatbogs indicates decreasing geodiversity of their occurrence areas as a result of progressive revitalization of the peatland.

**Keywords:** raised bogs; anthropogenic degradation of peatbogs; peatland geodiversity, Western Carpathian Mountains

*THEME: S31 : LANDFORM ASSESSMENT FOR GEODIVERSITY: GENERAL GEOMORPHOLOGY, GEODIVERSITY, GEOCONSERVATION (IAG-WG)*

**ABSTRACT NUMBER: 741**

## **TIMBERLINE AS A LINK JOINING AREAS OF VARIOUS GEODIVERSITY IN MOUNTAIN ENVIRONMENT. CASE STUDY OF BABIA GÓRA MASSIF, WESTERN CARPATHIANS**

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The timberline is one of transitional zones separating altitudinal belts of different geodiversity in the mountains. Empirical timberline and higher located treeline may be distinguished. Elements of abiotic environment determining the geodiversity show differences between the alpine belt and forest belt, and the zone of their interpenetration is delimited by treeline ecoton included between the timberline and treeline. The differences of their courses in local mountain scale on the opposite slopes of ridges of different slope angle and various geodiversity, are rather poorly known. The analysis of LiDAR data covering Babia Góra massif (1725 m a.s.l.), Western Carpathian Mountains, lets to understand this problem. This massif is formed as a homoclinal ridge, orientated in W-E direction, with northern slope of cuesta type. The timberline on the N slope is located at 1106-1462 m a.s.l., whereas on the S slope it is located at 1330-1508 m a.s.l. Treeline ecoton is included in the same altitude intervals. The slopes above timberline are modelled by deep-seated landslides and on the N slope also by shallow debris landslides, debris flows and snow avalanches. Traces of glacial and nival forms occur on the N slope, and on the both slopes periglacial forms are visible. On the slopes below timberline, fluvial and denudation

forms occur with large number of springs, dense stream system, large number of tiny lakes and bog-springs on landslide forms. Quality classification of abiotic nature objects indicates larger geodiversity on the slopes above timberline, which is mainly influenced by geology and relief of the massif. Contemporary course of timberline only emphasizes this contrast in abiotic environment of the massif.

**Keywords:** timberline; treeline ecoton; geodiversity; Babia Góra massif; Western Carpathians

THEME: S32 : PLANETARY GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 195

## ALTERNATING GLACIAL AND GULLY EROSION ON MARS

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The mid-to-high latitudes of Mars host assemblages of landforms reminiscent of a receding glacial landscape on Earth. It is hypothesised that these landforms are a result of dramatic changes in climate brought about by swings in Mars' orbital obliquity, which can vary between 15° and 35° on timescales of ~100,000 years. At the highest obliquities it is thought that water ice is driven off the two permanent polar caps (which have combined mass equivalent to the Greenland icesheet) and redistributed to lower latitudes, and as the obliquity swings to lower values water ice is transported in the opposite sense. Here, we report on the relationship in time and space of two suites of landforms: gullies and glacial landforms. Gullies are kilometre-scale erosion-deposition systems comprised of a source alcove, a transportation channel and a deposition apron or fan. The glacial landforms we describe here fall into two categories – extant viscous flow features where ice could still be present and relicts of glaciation including arcuate ridges commonly interpreted as moraines. Both gullies and glacial landforms are particularly common at the mid-latitudes and show similar trends in orientation with latitude – hinting at a common climatological origin. Our previous work has shown that dense concentrations of extant glacial forms are anticorrelated with dense gully-populations, yet gullies are found very commonly associated with relict glacial landforms. Other authors have already highlighted the possibility that this landscape assemblage could result from a similar suite of processes to that experienced in paraglacial environments on Earth. We present the results of our work which attempts to place bounds on the active processes, erosion rates and relative chronology associated with this landscape assemblage.

THEME: S32 : PLANETARY GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 239

## SEDIMENTATION OF FINE PARTICLE CLOUDS IN WATER ON MARS

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Gravity affects flow hydraulics and thus limits the application of simple models for sediment transport developed for Earth on Mars. The significance of the differences in sediment settling between Earth and Mars has been demonstrated for sand-sized particles by measuring settling velocities using video-imaging during parabolic flights with reduced gravity. While sandstones are good archives for flow hydraulics, they are not considered to contain and preserve biosignatures very well. Information on the sedimentation of finer particles is therefore required. The video approach used for sand during sedimentation experiments in simulated reduced gravity does not work for finer particles because they cannot be distinguished individually on a video. Tracking of fine sediment clouds is also difficult using videos because changes in density and associated dynamic flow hydraulics inside the cloud are often obscured. Photometers, on the other hand, are able to capture differences in turbidity and offer the potential to measure the settling behaviour of clouds of fine and differently-sized sediment particles. In this study, the first results generated by a settling-tube photometer developed by the University of Basel and used during a parabolic flight with reduced gravity are presented. Apart from an assessment of the feasibility of the instrument and experiments on parabolic flights, the relevance of the effect of reduced gravity on sediment transport and sorting are discussed.

THEME: S32 : PLANETARY GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 268

## ALLUVIAL FANS ON MARS: FROM ORBITAL DATA TO GROUND TRUTH

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Among fluvial landforms, alluvial fans are clear indicator of overland flows controlled by local topography. On Mars, they are observed in impact craters of the southern highlands. They are up to 50 km in length, have a slightly concave topographic profile with an average slope of 0.5°-4° similar to that observed on Earth (Howard et al., JGR-Planets, 2005). A specific characteristics is that most alluvial fans formed relatively late in the early Mars history, from the Early Hesperian to the Early Amazonian (~3.4 to ~2.5 Ga) based on the well-preserved morphology of their host craters (frequently Hesperian in age, Mangold et al., JGR-Planets, 2012). The abundance of Hesperian alluvial fans shows that Martian aqueous activity did not stall at the optimum observed at the Late Noachian (~3.7 Ga), but extended into the Hesperian. After its landing on Mars in August 2012, the Curiosity rover was able to analyze directly on the ground one of these fans. The rover landed in Gale crater, downhill of a 10 km in length, ~80 km<sup>2</sup> in area alluvial fan (Palucis et al., JGR-Planets, 2014). At this site, the rover has analyzed conglomerates providing the first in-situ evidence for fluvial activity on Mars (Williams et al., Science, 2013). No sign of aqueous alteration has been identified from the in-situ analysis of conglomerates at Gale crater, suggesting a relatively cold climate with fluvial flows, but the diversity of the pebbles was used to show the various composition of the local crust (Mangold et al., JGR-Planets, 2016). The consistency between interpretations from orbital and ground data enables to develop (1) further understanding of fans in other regions of Mars, especially the identification of larger, longer-lived fans, and (2) provides the opportunity to build detailed comparisons between Earth and Mars to better understand the processes shaping alluvial fans.

THEME: S32 : PLANETARY GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 326

## AN IN-SITU INVESTIGATION OF THE EFFECT OF IMPACT PROCESSES ON ROCK BREAKDOWN USING SUB-MM RESOLUTION DEMS AT METEOR CRATER, ARIZONA

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Impact cratering is an important geological process that affects all planetary bodies in our solar system. For planetary bodies in our solar system (incl Earth and Mars) the impact rate was much higher than today. As rock breakdown is an important process that contributes to the evolution of landforms and sediments on many planetary bodies, it is important to assess the role of inheritance in the subsequent breakdown of impacted rocks.

The shock pressure of several gigapascals generated during the impact can exceed the effective strength of target lithology by three to four orders of magnitude and is responsible for melting, vaporisation, shock metamorphism, fracturing and fragmentation of rocks. Our laboratory analysis (XRD, SEM, X-ray CT) on impacted rock samples from Meteor Crater, show that rock porosity and permeability changes during impact. Environmental conditions and heterogeneities in rock properties exert an important control in rock breakdown. Similar to other subaerial rocks, impacted rocks are affected by a range of rock breakdown processes.

A Structure from Motion photogrammetry survey of micro to meso-scale (mm-m) breakdown features was undertaken to generate sub-mm resolution DEMs (with sub-mm accuracy) of weathered Moenkopi Sandstone surfaces at the Meteor Crater field site in Arizona. For comparison, similar data was also collected at control sites closely by that have similar rock lithologies and share similar climate histories but did not undergo impact. The DEMs of rock surfaces were analysed using a series of areal surface roughness parameters, fractal analysis, and geomorphometric classification methods. This allowed high-resolution morphometric characterisation and quantification of 3D breakdown forms at a range of scales. Our preliminary findings suggest a significant difference in rock breakdown style and intensity between Meteor Crater and the control sites.

**Keywords:** Impact cratering; rock breakdown; Structure from Motion; geomorphometric analysis; Areal surface roughness and fractal analysis

THEME: S32 : PLANETARY GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 560

## VARIATION OF MORPHOLOGICAL CHARACTERISTICS OF LIGHT-TONED MATERIALS IN VALLES MARINERIS, MARS: INSIGHTS INTO THE DEPOSITION, DIAGENESIS, AND POST-DEPOSITIONAL CONDITIONS

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Light-toned materials, a suite of sedimentary rocks, dispersed in various settings all over the equatorial belt of Mars, remain elusive in terms of their origin. One way to decipher their formation conditions is to study the features exposed on the surface of these rock bodies, which could be related to their deposition, diagenesis, and post-diagenesis deformations. We report three such features from the light-toned mounds and deposits in Valles Marineris, which are- layering styles, polygonal cracks, and a new feature which we call a 'chiselled' surface.

Layering in the light toned rocks is defined by tonal alterations between light and dark. The scale of the layering is variable from several meters to sub-meters. The layering, a primary feature, indicates cyclic deposition of light and dark toned sediments which could have taken place subaerially or subaqueously. The variation of layer-thickness, and the source and nature of the light and dark toned sediments are important characteristics which can shed light on the depositional mechanism and sediment source for these rocks.

The 'chiselled' surface, is found on most exposed surfaces of the light-toned rocks and indicates some form of mechanical anisotropy, affecting the entire volume of these deposits. These are different from the polygonal cracks in that, these are not defined by fracture or joint planes. The cause of these features is possibly diagenesis.

Polygonal cracks, a secondary feature, often associated with light-toned rocks, could be desiccation cracks, or generated due to stresses. Spatial variations in the dimension and shape of these would help us infer the post-depositional events that affected these rocks, and how those varied from one locality to another.

In this way, the above three features, help us to gain bit of understanding of the way these light-toned rocks evolved from sediments.

**Keywords:** Light-toned materials; Layering; Cracks; Chiselled surface; Mars

THEME: S32 : PLANETARY GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 571

## A KARSTIC ORIGIN FOR THE NORTH POLAR LAKES REVEALS A SOLUBLE TITAN

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Titan is the only place in the Universe other than Earth known to harbor stable surface liquids. While much has been studied and predicted about the liquid composition and distribution, the question of origin of the basins that the lakes occupy remains unanswered. We use spatial regularity derived using the morphology of these lakes to test the hypothesis that they could be karstic in origin. Karstic lakes on Earth are closed depression landforms that form as a result of dissolution of bedrock. Karstic depressions have several distinct features, such as their elongation index and their diameter distributions. These are lognormal, a relationship that holds under the assumption that these lakes originated and evolved over a comparatively short period of time. Furthermore, the spread in sizes of depressions is small, indicating tightly constrained formation processes. In our study we use these statistical observations to ascertain whether the Titan lakes follow similar karstic geomorphometric patterns. Observations of 224 lakes in the north polar region of Titan using Cassini images show that the equivalent radii of these lakes indeed follow a lognormal distribution, revealing similarities with the terrestrial features and allowing for a karst-like origin.

**Keywords:** Titan, Lakes, Karst, Morphology

THEME: S32 : PLANETARY GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 588

## GEOMORPHOLOGY OF CRATER FLOOR IMPACT MELT DEPOSITS ON THE MOON: INSIGHTS INTO THE IMPACT CRATERING PROCESS

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The morphological character of impact melt deposits holds important clues to understand the process of impact cratering. Data from recent and current lunar missions are providing an unprecedented view of the impact melt deposits on the Moon with spatial resolution approaching < 1 m in many cases. We are systematically mapping the impact melt deposits on the floors of large (20 - 150 km diameter) and geologically young (< 1 billion years old) lunar impact craters with the aim to identify scientifically interesting morphologies and decipher repeatable trends that could provide insights into the cratering process.

Our mapping effort has led to a diversity of new information on the lunar impact melt deposits. We have identified multiple, near-continuous sheets of impact melt at the floor-wall interface with lobate margins, similar to wave fronts. These melt-sheets could be the result of coherent melt movement from the crater interior to the floor margin. If true, this finding has important implications for impact melt mobility. Another important result is the occurrence of smooth melt deposits on the floor, consistently in the downrange impact direction. These locations also have the lowest elevation on the floor implying their formation by accumulation of the last dregs of mobile melt. We have also identified melt-coated large blocks, several kilometers across, which could be collapsed wall margins but in some cases, could also represent subdued sections of the central uplift. The latter has important implications for deciphering the mineralogy of the subsurface since central uplift represents the exposure of the deepest crustal material within an impact crater.

These findings are providing important clues in understanding the impact cratering process which is one of the most fundamental and pervasive process in the solar system.

**Keywords:** Impact Cratering; Impact Melt; Moon; Geological Mapping

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 13

## LATE PLEISTOCENE-HOLOCENE GEOMORPHOLOGY AND CLIMATE OF THE MOGAN BASIN (CENTRAL ANATOLIA), TURKEY

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Mogan Basin is a Plio-Pleistocene sedimentary basin in the semi-arid Central Anatolia that includes two km-sized lakes in very close vicinity to capital city Ankara. This basin has been considered Pliocene age regarding stratigraphic correlation of its infill with better-known neighbouring basins and its deeply incised valleys. The age and mode of formation of two lakes have remained obscure until recently.

Landscape of the basin is characterised by a north-flowing 30-80 m incised meandering valley called Imrahor Valley that has many confluents from both sides, but two larger of which are more prominent since the sediments they brought damped the main valley and caused lakes formation.

Our morphological investigations revealed that the modern fluvial drainage is incised in a highly denuded yet recognisable alluvial fan complex and its aggradational axial fluvial counterparts. Altitudes of alluvial apexes in the faulted eastern margin of the basin is decrease toward south. Similarly, paleocurrent data from the contemporaneous axial river sediments show river flow to the south. Cosmogenic radionuclide <sup>36</sup>Cl dating of an outsized andesitic block at the top of the alluvial-fan complex yielded 68±12 ka of exposure age, whilst the OSL dating of fluvial sands close to the top of the axial fluvial package gives 50±8 ka of deposition age. In other words, the shift from sediment accumulation to denudation in the Mogan basin occurred around 55-60 ka at the beginning of the previous interglacial period probably as the result of the capture of the Mogan Basin by Ankara Creek in the north. Two drill holes at the margin of the existing lakes and the radiocarbon dating of the basal lake sediments demonstrate huge volume of sediment accumulation (30-40 m thick) following formation of lakes ca. 7000-8000 yr before present.

**Keywords:** Alluvial damming; Central Anatolia; denudation; exposure age; Late Quaternary; OSL

ABSTRACT NUMBER: 111

GEOMORPHOLOGICAL PROCESSES, IN RELICT LANDSCAPE OF TECTONIC TERRACES IN DAGHMAR-DIBBAB COASTAL AREA, (NE OMAN)

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The arid coastal area between Daghmar and Dibab (NE Oman) has been affected by Neogene tectonic processes that continued during the Upper Pleistocene. The study area was uplifted up to 200 m due to different tectonic kinematics which can be easily detected from the diversified elevations of the coastal cascading tectonic terraces formed primarily due to tectonic movements.

The combination of methods such as geodatabase creation, multi-criteria analysis of the landforms through the processing of the study's area DEM, field work-samplings and laboratory analysis (XRF, thin sections, datings), combined with semi-automated geomorphological mapping and the differential GPS profiles and measurements, and SAR interferometry (InSAR), contributed in the data processing. The results of the multi proxy methodological approach are used as tools for understanding the geomorphological evolution of the Neogene to Quaternary relict landscape, where landforms are presented as indicators of the area's evolution and define the processes that formed the current situation of the relief. At least three tectonic terraces were detected, in addition to a karstified planation surface is well formatted at the highest relief in carbonate rock formations of Eocene age.

The preliminary results of this relict landscape indicate a heterogeneous uplift of the study area, divided into different at least two tectonic blocks, with uplift rates averaging in approximately 2 mm/a. Uplift and sedimentary infilling in tectonic terraces confirm a swift transformation of the coastline area at least from the MIS 3 (+/- 40,000 a BP), until the mid-late Holocene.

**Keywords:** Tectonic terraces, Oman, multi-proxy methods, arid areas, InSAR

ABSTRACT NUMBER: 150

MORPHOSTRATIGRAPHIC CONSTRAINTS VERSUS THERMOCHRONOLOGICAL DATA. LESSONS FROM GEOMORPHOLOGICAL STUDIES IN NORTHEAST BRAZIL

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In the last decade, detailed geomorphic analyses of northeast Brazil led the authors to publish a model of landscape development in which long-term landform evolution was driven by regional swell-like uplift post-dating Early Cretaceous rifting and the formation of the Atlantic passive margin in Aptian times. Post-Campanian uplift caused an inversion of Cretaceous basins and generated a landscape in which the most elevated landforms correspond to resistant Mesozoic sedimentary caprock, and to eroded stumps of Cretaceous footwall uplands. Denudation in the last 70 My created a low erosion surface below residual ridges and topographically inverted sedimentary basins. It reached 600 m at most and did not exceed mean rates of 10 m•My<sup>-1</sup>. Age relationships in the regional morphology and the lack of any remnant of post-Cenomanian sediments in the major part of the study area suggest that no younger sedimentary cover ever existed there. However, according to recent models based upon the results of thermochronological analyses (apatite fission tracks analysis), two slices of 1,000 m to 2,500 m would have been deposited over the present pile, respectively in Campanian and Oligocene-Miocene times, before being totally removed. We examine here the diverging scenarios of geomorphological evolution respectively based upon morphostratigraphy (our model) and upon low temperature thermochronology, submitting them to evidence provided by geomorphological and sedimentological approaches, and trying to decipher some of the bias that might lead to inappropriate interpretations. We stress the fundamental importance of taking into account the results of geomorphic approaches in any interpretation of thermochronological data used for reconstructing long-term landscape evolutions. This is the condition for improving the trust one can have in their results, which may bring complementary or unique information, peculiarly in places where sedimentary or volcanic markers are missing.

**Keywords:** long-term landform evolution, low temperature thermochronology, morphostratigraphy, northeast Brazil, passive margin



THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 153

## CONSISTENCY OF DRAINAGE PATTERN WITH STRAIN PORTIONING ACROSS HIMALAYA

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Tectonics has long been recognised as a predominant controlling factor of drainage pattern and landform evolution. We assess the pattern of drainage network in relation to strain portioning and recorded seismicity across Himalaya. Multiple MODIS Terra (250 m) true colour imageries, earthquake data from USGS catalogues, and recent published GPS observations of Himalaya have been used in the present study. We report that the rivers in general exhibit two different deflection arrangements over larger distances of tens to thousands km in NW and SE Himalaya. In the NW the rivers descend anticlockwise towards plains (south) with westward convexity; whereas, rivers in the SE reveal consistent clockwise course with eastward convexity. The phenomenon is noticeable across the width of the Himalayan mountain chain; however, more dominant along the northern and southern margins of the Himalayan arc. Two major rivers i.e., Indus and Tsangpo (Brahmaputra) are the best examples from the west and east respectively. Pertinently, the spatial behaviour of the rivers is in agreement with distribution of earthquake epicentres and crustal velocity revealed by the recent GPS data. We decipher that the spatial arrangement of the rivers has evolved mainly as a result of oblique convergence towards the eastern and western syntaxis with respect to the central Himalaya.

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 159

## A GLOBAL FRAMEWORK FOR VALUING AND COMPARING TECTONIC GEOMORPHOLOGICAL SITES

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Tectonic-related landforms form the largest features of our planet, and many of the solar systems rocky and icy planets and moons. They allow us to work out how the Earth works, and lead to the discovery of continental drift and thus plate tectonics. They continue to be windows into the Earth processes. In order to fully appreciate the interactions and processes behind tectonic landforms a global view is needed. This is not only important for our science, but equally so for outreach and communicating the importance of tectonics and tectonic landforms is shaping and maintaining our environment. To help capture the global picture, we have drawn up a global framework that places each tectonic environment and lithospheric context in relation to the other spheres and processes that make up the Earth system. This can be now used, and adapted to put any site in context, and to compare sites on the basis of their contrasting environments and processes. We see the framework as being similar for geology, as the periodic table is for chemistry, exhibiting the order and the interactions possible within the system. We will illustrate the use of this framework with a comparison of the geomorphological processes if tectonic rifts in the various tectonic environments of the Earth, Venus, Mars and Mercury.

Keywords: Global Geological framework; Plate tectonics; Planetary Science; Earth Systems

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 189

## ALLUVIAL RIVERS AND RESPONSE OF ACTIVE TECTONICS: A CASE STUDY ON THE KHARI RIVER SYSTEM, WESTERN BENGAL BASIN, EASTERN INDIA

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Through the altering of channel slope active tectonics plays an important role in controlling the fluvial system. The Khari, a high meandering, piedmont zone river, draining the alluvial plain of Western Bengal Basin (WBB), has been affected due to ongoing tectonic activity. WBB, a peripheral shelf, is western tectonic province of larger Bengal Basin covered by thick sediments which have been sequentially developed and influenced by complex convergence of Indian plate with Eurasian (in north) and Burmese-Andaman arc (in east). The collision is still active at the rate of 18 mm/y along the boundary. Resultant an enormous accretionary prism has been developed on eastern part of WBB with westward migration trend and faults over WBB deforming by this oblique motion. The relative flat plain of Khari River System is divided into two major tectonic blocks by these active faults and each block is characterized by fluvial anomalies i.e., hierarchical anomaly, variation of drainage pattern, offsetting of channels across the fault lines, channel incision, knick point, anomalous sinuosity, sudden change in flow direction and location of longitudinal seasonal lake. Zones of such anomalies of morphotectonic features have been identified by basin and hydrological parameters. Data has been quantify and explained through statistical analysis to understand the nature of tectonic.

Result shows high stream hierarchy with downstream changes of dendritic to parallel and semi circular drainage pattern is the result of lateral tiltation, differential upliftment and subsidence of tectonic blocks. The tectonic block between Basin Margin fault and Damodar fault down warped with southward tiltation and these two faults behave like dextral fault. The block between Memari Debogram fault and Damodar fault upwarped with left lateral slip and the nature of faults like sinistral fault. Other faulted blocks are probably normal fault blocks.

**Keywords:** Quaternary alluvial plain; Fluvial anomalies, Active tectonics

*THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)*

**ABSTRACT NUMBER: 241**

## **MORPHOTECTONIC STUDIES IN EARTHQUAKE SWARM ACTIVITY PRONE SW SAURASHTRA, WESTERN INDIA**

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The Saurashtra peninsula is a distinct tectono-geomorphic entity bounded by the North Kathiawar Fault (NKF), West Cambay Basin Margin Fault (WCBMF) and the Narmada-Son Fault (NSF) in the north, east and south respectively. It comprises dominantly of trappean lava flows with associated structurally controlled dykes of late Cretaceous to Paleocene age and Mesozoic sedimentary rocks with thin Tertiary and Quaternary in the fringes. Geomorphologically, it is a large plateau with highest elevations in the centre and radial drainage pattern. The SW region have experienced periodic earthquake swarm activity witnessed in 2001, 2004 and from 2007 onwards of magnitude 5.0 and less. We carried out geomorphic studies in the area with a view to map various faults influencing landscape configuration and provide a geological perspective of the swarm activity. The area is drained by southward and SW flowing incising rivers viz. the Hiran, Saraswati, Singwada, Sangawadi, Rupen, Machundri, Rawal, Malan, Raidi and Dhantarvadi that flow through Deccan Trap formation followed successively by Tertiary sediments of Gaj formation, Quaternary miliolite sediments and recent coastal deposits. The major faults demarcated during the study are developed in the Deccan Trap Formation trending NNE-SSW and ENE-WSW. All faults show prominent scarps with striations along fault planes, tilting, shearing and folding of lava flows. The neotectonically active nature of the faults is evidenced by the youthful fault controlled topography, bedrock incision, knickpoints formed over Quaternary miliolites, variable coastal geomorphic system (mudflat to beach-dune complex to rocky coastline), two levels of raised notches along the coastline and the development of asymmetric drainage basins. Our morphotectonic data suggests that the compressive stresses generated by the northward movement of the Indian plate is distributed in a complex manner along various faults which is responsible for the earthquake swarm activity in SW Saurashtra.

*THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)*

**ABSTRACT NUMBER: 261**

## **GEOMORPHIC SIGNATURES OF POSSIBLE CAUSATIVE FAULT IN EARTHQUAKE SWARM ACTIVITY PRONE AREA, NORTHERN SAURASHTRA, WESTERN INDIA**

**Prabhuti Tiwari<sup>1\*</sup>; Naimisha Vanik<sup>1</sup>; Deepak Maurya<sup>1</sup>; Mohamedharoon Shaikh<sup>1</sup>; Laxman Chamyal<sup>1</sup>**

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Northern Saurashtra has experienced infrequent swarm type of seismic activity ranging in magnitude from 3.5-5.0 since last two

centuries. However, faults and precise geological features responsible for the swarm activity are not known. To identify the possible causative geological features of earthquake swarm activity, we carried out a detailed geomorphological analysis of three northward flowing river basins named Sasoi, Und and Nagmati. The area is broadly divided into three geomorphic divisions as the upland zone, northward sloping pediment surface and coastal zone. The uplands comprise mainly basaltic flows of Deccan Trap Formation while the Quaternary aeolian miiolites occur in the valleys and foothills. The valley-fill or sheet miiolites occur as discontinuous capping over the sub-horizontal Deccan Traps in the pediment zone which extends almost up to the coastline. The rivers flowing through this pediment surface appear to be in rejuvenation phase as evidenced by bed rock incision and localized reaches of enhanced river gradient, rapids, knickpoints and waterfalls. Significantly, the most prominent knickpoints and waterfall reaches are located along a NE-SW trending zone passing through the central part of the pediment zone. We infer a NE-SW trending fault along this zone that continues up to the area south of Jodiya and further east up to Sanala which marks the zone of documented swarm activity. Anomalous right angle bends along with two palaeochannels, one to the north of Lalpur and the other to the south of Jodiya indicate strike slip component as well. We presume that this fault further joins up with the ENE-WSW North Kathiawar Fault (NKF). Overall, the rejuvenated nature of rivers and alignment of waterfalls and rapids suggest ongoing uplift which is attributed to reactivation of the NE-SW trending fault delineated in the present study.

**Keywords:** Fluvial Geomorphology; Active Fault; Deccan Trap; Earthquake Swarm; Northern Saurashtra

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 265

## VARIABILITY OF NEOTECTONIC ACTIVITY ALONG THE SEGMENTED NARMADA-SON FAULT (NSF): EVIDENCE FROM GEOMORPHOLOGY AND LATE QUATERNARY SEDIMENTS

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The ENE-WSW trending Narmada-Son Fault (NSF) is a major crustal scale fault passing through the central part of the Indian. In Gujarat region, the NSF is divisible into four morphotectonic segments delimited by N-S trending transverse faults. The fault is morphologically expressed by north facing youthful range front scarps developed in Deccan Trap Formation. Eastwards, the surface trace of the NSF includes scarps in deformed Neogene rocks and a linear ENE-WSW trending palaeobank of the Narmada river formed in Late Pleistocene fluvial sediments that extends up to the coastal zone. Integrated geomorphological and stratigraphic studies on the incised Late Quaternary alluvial sediments in the downthrown block indicate strong control of the neotectonic activity along the NSF. The late Quaternary sediments comprise two phases of alluvial fan sedimentation which was confined to two segments of the NSF. The variable depth of incision and elevation of the alluvial sediments in the different segments suggest varying intensity of post-depositional neotectonic activity along the NSF. We conclude that multiple phases of reactivation with varying intensities in various morphotectonic segments have played a major role in the Late Quaternary sedimentation and post-depositional geomorphic evolution of the NSF zone.

**Keywords:** Neotectonics; Geomorphology; Quaternary Sediments; Narmada-Son Fault (NSF); Western India

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 279

## MORPHOTECTONIC STUDY IN AND AROUND AIZAWL, MIZORAM, INDIA.

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Aizawl is situated in one of the anticlinal ridges of Mizoram fold belt which follows regional north-south trend. The topography is shaped by active subduction of Indian plate beneath Burmese Plate and prolong denudation process. Morphometric study of the region is important to recognize active tectonic features and their role in evolution of the geomorphic landforms. The study has been carried out around Aizawl to understand the tectono-geomorphic setting and their influence in evolving Aizawl city's landscape. Asymmetric Factor (AF), Transverse Topographic Symmetric Factor (T), Basin Hypsometry (HI), Basin shape index (Bs), and Stream Length gradient index (SL) are the parameters that have been evaluated for 120 basins covering an area of ~4800 sq. km; distributed along four NS trending ridges, including the Aizawl anticline. The streams flowing through these basins are drained through different valley before reaching to four structurally controlled rivers viz. Gutur or Tut River, Tlawng or Dhaleswari River, Tural River and Tuirini Lui River. Most of the basins show |AF| range of III to IV, indicating presence of active tectonics in the area which is also supported by T values.

Bs values attaining near circularity for basins which are of range I (symmetric). Hypsometric integral and curves indicate different evolution stages of the basins which can be explained by variation of lithology and active tectonics. The superimposed SL values on stream profile for each basin exhibit anomalous zones which are correlated with the structures present in that particular basin. This is also evident by the lineament map of the area, as anomalous zones have association with both macro and micro lineaments. Tectonic activeness of the area can also be indicated by presence of earthquake epicenters.

**Keywords:** Tectonics; morphometry; Aizawl anticline; lineaments

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 281

## STREAM RESPONSE TO ACTIVE TECTONIC DEFORMATION OF THE SUB-HIMALAYAN WEDGE: INFERENCES ON GEOLOGICAL STRUCTURE, TECTONICS AND SEISMIC HAZARD.

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Drainage is extremely sensitive to minor changes in the surface topography and tends to adjust their behaviour by modifying their geometry. Morphometrics of drainage and tectonic landforms form the key evidences which can be used to extract spatial information on the crustal deformation processes. For a better spatial control and improved understanding, the two (morphometry and spatial distribution of tectonic landforms) are used as complementary tools and inferences are drawn accordingly. In this article, we focus on the outermost ranges of the Sub-Himalayan belt, proximal to the Himalayan Frontal Thrust (HFT). In these ranges, the changes in surface topography have been successfully linked to the active deformation processes. The streams originating here are smaller (lower order) and mostly ephemeral in nature. However, any analyses carried out in these ranges benefits from the fact that streams flow over similar lithologies and permit spontaneous correlation with active tectonic deformation. The inferences drawn from morphometric analysis carried out using DEMs suggest areas/segments of variable active tectonics and enabled detailed investigation using remote sensing imageries. The study presents the presence of numerous closely spaced active fault segments that are often splays of the major underlying faults. These fault splays act as conduits to release tectonic stresses, thereby having major implications on the seismic hazard by modulating the surface topography. Also, the results are significant in the larger perspective of the India-Asia tectonics where these smaller (splay) faults are often limited by orogenic segmentation. They tend to accommodate the active tectonic convergence as well as lateral differential movement between segments by virtue of their structural geometries.

**Keywords:** Morphometrics ; Tectonic Landforms ; Himalayan Frontal Thrust ; Fault Splays ; Tectonic convergence

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 329

## PALAEOSEISMOLOGICAL INVESTIGATION ALONG THE BACK THRUST OF HFT, SOAN DUN, NORTHWEST HIMACHAL HIMALAYA, INDIA

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The Himalayan belt had been evident for many devastating earthquakes in the historical past including the CE 1505, CE 1803, the 1905 Kangra earthquake (Mw 7.8); 2005 Balakot event (7.6); and the Kashmir event 1555 7.6. The area of present investigation is located toward the hinterland of Januari anticline where approximately 110 km long intermontane Quaternary basin was developed. The anticline is a product of fault related fold growth, where several folds are interlinked and giving rise to a single ~100km long anticline. The NW-SE oriented Soan dun is controlled by back thrust to the southwest and Soan Thrust to the northeast. Several geomorphic features such as linear offset of streams, vertical displacement of alluvial fans and fluvial terraces with linear mountain fronts, ponding of streams, back tilting, and triangular facets have been identified in the area. Conventional morphometric indices such as SL, Ks, and AF are used to evaluate the tectonic scenario of Soan valley. High resolution satellite (CARTOSAT-1) data have been used for mapping of active landforms and carried out Paleoseismic studies to identify paleoearthquake. The exposed section along the back thrust shows 2.5m displacement of sediments along a SW dipping thrust fault. Based on stratigraphic offset of sedimentary units; two traces of

NNE-SSW oriented NE dipping normal faults with 53cm slip have been identified. A trench excavated across the back thrust, revealed evidences of at least two palaeoseismic events during the Late Holocene. The trench investigation suggests that the earthquake during the recent past were accompanied with surface rupture. Studies shows the crustal shortening between MBT and HFT ranges from  $11 \pm 5$  mm/yr to  $21 \pm 5$  mm/yr. The integrated results reveals that the landform development within the Soan dun area is controlled by vertical tectonic forces generated by crustal shortening between MBT and HFT.

*THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)*

**ABSTRACT NUMBER: 371**

## **TECTONIC GEOMORPHOLOGY OF THE KALAHARI**

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Much has been reported on the ages of Kalahari landforms in particular fossil dunes and shorelines of Botswana, Namibia and Zimbabwe. The region is generally regarded as a stable shield area which is subject to neotectonic modification along western branches of the East African Rift System (EARS) including the Okavango Rift Zone (ORZ) and its associated fan delta. In this study we examine the surface expressions that are indicative of recent and ongoing tectonic modification beyond the Okavango. A number of areas can be highlighted.

The first region of interest, in north eastern Botswana, accommodates the Makgadikadi Rift Zone (MRZ). We demonstrate that the area north of the Makgadikadi has been modified by “piano key” type fault blocks which has resulted in paleo shorelines featuring vertical offsets detectable in Shuttle Radar Topography Mission data. The second area in north eastern Namibia hosts “horsetail” fracture patterns possibly in response to an incipient rift systems west of the Okavango Graben and Gumare fault line. Here fossil dunes forms depict tectonic deformation including faulting, shearing and rotation.

We are able to demonstrate that the Kalahari surface is not just a function of lateral physical processes such as past wind and water action but also depicts recent and possibly ongoing vertical processes including tectonics uplift, collapse and leaching.

*THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)*

**ABSTRACT NUMBER: 378**

## **RECOGNITION OF ACTIVE STRIKE-SLIP FAULTING FROM OFFSET RIVER CHANNELS: THE QINGCHUAN FAULT, THE NORTHEASTERN SEGMENT OF THE LONGMEN SHAN FAULT ZONE, CHINA**

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The 250 km-long Qingchuan Fault, the northeastern segment of Longmen Shan Fault zone, is located in the northeastern marginal zone of the Tibetan plateau. In this study, we systematically analyzed offset river channels along the fault mainly on the basis of the watershed interpretations of Digital Elevation Models (DEMs) and field investigation. Our quantitative results reveal that the horizontal component of the slip rate along fault increases from the southwest to the northeast, while the vertical component is decreasing. The fault can be further divided into the southwest section (with higher strike-slip rate) and northeast section (with lower strike-slip rate), which is probably caused by the interaction with the adjacent Beichuan Fault. The slip rate distribution along Qingchuan Fault provides first order constraint on the role the fault plays in accommodating eastward movement of the eastern Tibet Plateau. Our results confirms that the topographic features of displaced river channels are reliable indicators for the understanding of active strike-slip fault activity.

*THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)*

**ABSTRACT NUMBER: 466**

## **TECTONIC AND CLIMATIC CONTROL ON THE EVOLUTION OF THE INTERMONTANE KANGRA BASIN, NW HIMALAYA**

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Millennial timescale fluctuations in sediment routing from active orogens can be triggered by changes in the climatic conditions. With this case study in the Kangra Basin from the Himachal Himalaya, we show how the variations in Indian Summer Monsoon (ISM) have impacted the sediment routing over the last 60 ka and its' potential implications on regional tectonic scenario.

The Kangra Basin is bounded by the MBT and Sub-Himalayan Jwalamukhi Thrust (JMT) in the north and south, respectively and contains ~200-m-thick basin-fills reflecting two distinct aggradation phases; following aggradation, several fluvial terraces were sculpted into these fan deposits. <sup>10</sup>Be-based terrace exposure dating provides an age of 53.4±3.2 ka for the highest-preserved terrace; subsequently, this fill was incised until ~15 ka, when a second fan initiated. This aggradation phase was succeeded by Holocene incision, creating at least four terrace levels. Our study points that during strengthened ISMs and post-LGM glacial retreat, aggradation occurred in the Basin, likely due to high sediment flux, whereas periods of weakened ISM and lower sediment supply coincided with renewed re-incision.

However, the fluvial terraces in the Kangra sector are also forced by tectonic processes. Offset of the 10ka-old terrace level indicates a shortening rate of 5.6±0.8 to 7.5±1.0 mm.a<sup>-1</sup>. This study reveals that late Pleistocene/Holocene thrusting along JMT accommodates 40-60% of the total 14±2 mm.a<sup>-1</sup> shortening partitioned throughout the Sub-Himalaya. Importantly, the JMT records lower activity rates over longer timescales indicating out-of-sequence activity along JMT since Holocene. Re-activation of the JMT could be related to changes in the tectonic stress field caused by large-scale sediment removal from the basin: while major aggradation would trigger foreland-ward propagation of the deformation front, whereas, removal of ~80-85% of the stored sediment would trigger the retreat of the deformation front.

**Keywords:** terrestrial cosmogenic nuclide; terrace; Indian Summer Monsoon; out-of-sequence thrust.

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 548

## LATE QUATERNARY ACTIVITY WITHIN THE MARIÁNSKÉ LÁZNĚ FAULT ZONE AS REVEALED BY TRENCHING SURVEY; CHEB BASIN, BOHEMIAN MASSIF (CZECH REPUBLIC)

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The NNW-SSE trending Mariánské Lázně Fault (MLF) zone is situated in the western part of the Bohemian Massif (Czech Republic, central Europe) and controls the eastern limit of Cenozoic Cheb basin. The Cheb basin is famous for present-day earthquake swarms with maximum magnitude  $M=4.5$  and abundant occurrences of mantle-derived carbon-dioxide emanations. The MLF borders Cheb basin towards the Krušné hory Mts controlling their morphologically pronounced mountain front. However, no large earthquakes that are required for forming tectonic morphology ( $M>6$ ) and that would be responsible for the mountain front formation have been recorded. Thus, to study Quaternary tectonic activity and potential pre-historic earthquakes on the MLF, we excavated seven trenches at Kopanina site. We also used shallow 2D and 3D geophysics (electric resistivity tomography, ground penetrating radar) to trace the fault and extrapolate geological information obtained from the trenches. First trench revealed repeated movements along several faults of various ages within the MLF, which displaced basin sediments deposited since Oligocene. The youngest fault cuts and deforms Holocene layers dated by radiocarbon dating as 5.3-1.1 cal kyr BP with maximum vertical displacement of 0.45 m. As revealed deformations suggested strike-slip kinematics of the MLF, we excavated six more trenches later, including fault-parallel ones, to obtain also horizontal offset values. Further trenching showed complex fault behaving under transpressive stress regime at probably restraining bend and only one strand of the youngest fault could be followed for horizontal slip. Two exposed Holocene rill infill deposited within the fault were horizontally displaced by 1-1.5 m. Based on empirical relationships between magnitude and displacement, that faulting would correspond to earthquakes of  $M=6.8-6.9$ . Thus, our study revealed the youngest proved surface faulting in central Europe and the largest one reported from the Bohemian Massif so far.

**Keywords:** paleoseismology; shallow geophysics; Mariánské Lázně Fault; Cheb basin; Bohemian Massif

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 596

## LATE QUATERNARY TECTONICS OF THE PAMIR-TIAN SHAN CONVERGENCE ZONE, NW CHINA

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The Pamir-Tian Shan collision zone in the western Tarim Basin, northwest China, formed from rapid and ongoing convergence as a delayed response to the Indo-Eurasian collision. The arid landscape preserves suites of fluvial and alluvial terraces that cross structures active since the Late Neogene, creating fault and fold scarps that record Quaternary deformation. Using geologic and geomorphic mapping, dGPS surveys of deformed terraces, and OSL and <sup>10</sup>Be depth profile dating, we create a synthesis of the active structures that defines the timing, rates, and migration of Quaternary deformation during the ongoing convergence. Integrated with previous work in the region, new deformation rates on eight faults and folds illuminate the spatial and temporal migration of deformation within the Pamir-Tian Shan convergence zone throughout the Late Quaternary. Terraces dating from ~130 to ~8 ka record deformation rates between ~0.1-6 mm/yr on individual fault and folds. In the far western Tarim Basin where the Pamir and Tian Shan are already juxtaposed, the fastest rates occur on actively deforming structures at the interface of the Pamir-Tian Shan orogens. As the distance between the Pamir-Tian Shan orogens increases farther east into the basin, the deformation has not been concentrated on a single leading structure. Instead, deformation appears to have been concurrently distributed across a number of faults and folds in the Kashi-Atushi fold-and-thrust belt and along the NE Pamir margin, where individual structures record unsteady shortening rates during the Quaternary. Although numerous structures accommodate the shortening and the location of deformation shifts during the Quaternary, the total shortening across the Pamir-Tian Shan collision zone approximately matches the current geodetic rate of 6-9 mm/yr and is interpreted to have remained approximately steady over this period.

**Keywords:** Pamir, Tian Shan, continental collision, terrace, strain partitioning

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 613

## ESTIMATING RELATIVE RATES OF UPLIFT AND EROSION ON THE MAIN FRONTAL THRUST, CENTRAL HIMALAYA, USING THE INTEGRAL METHOD OF CHANNEL PROFILE ANALYSIS

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In this study we use chi analysis to investigate relative rates of uplift and erosion on various segments of the Main Frontal Thrust (MFT) along the central Himalayan front. The study area is located in central Nepal and comprises of the Frontal Siwalik Ranges that bound the Chitwan intermontane valley, present to the south west of Kathmandu. The frontal ranges are defined by 7 MFT segments that either merge linearly or form distinct overlapping thrusts. The chi profiles of 35 streams originating from the Frontal ranges and crossing the MFT mountain front are analysed. In general, they show high steepness index (>1) along most segments suggesting continued uplift. The variation in steepness of the chi slopes along strike indicates a variation in uplift and erosion rates; low values at times indicates that the streams are antecedent to the growing structure and at times it corresponds to the size of the basin. It is also observed that the uplift rates are comparatively lower on relatively older segments which results from initiation and growth of younger overlapping thrusts. Comparing the chi slope with hypsometric integral does not show any link even though both the parameters are used to evaluate the dominance of uplift and erosion; this is due to the original configuration of the basin developing on the growing fold. The study concludes that the chi analysis is a useful tool to identify zones that are uplifting at greater rates along the Himalayan front.

**Keywords:** Central Himalaya; Chitwan Intermontane Valley; Main Frontal Thrust; Frontal Siwalik Range; Chi Slope

ABSTRACT NUMBER: 651

## “POP-UP” LIKE REJUVENATION OF SATPURA RANGE CAUSING SEISMICITY IN CENTRAL INDIAN CRATON? - A STUDY WITH TECTONIC GEOMORPHOLOGICAL APPROACHES

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The mighty Satpura range of the central Indian craton bounded by Son-Narmada-South Fault (SNSF) in the north and Gavilgarh-Fault-Zone (GFZ) in the south has experienced a number of seismic fault movements and shows high heat flow values measured in hot springs. Earlier workers interpreted the Satpura Mountain as a structural horst bounded by normal faults, which is inconsistent with the present day shortening rate of ~2mm/yr across the mountain range. In a field of compression, active normal faulting in regional scale being very unlikely, we tried to characterize the nature of movement along the two aforesaid bounding faults.

Hypsometry Integral (HI) for the area was calculated in regular squares of 1 sq.km size. Distribution of the HI values was mapped using a hot-spot analysis (G\*i statistic). The resulting maps showed linear occurrences of high HI values surrounding the lineaments indicating instability of the topography there, which is possibly a result of active tectonic movement along them. Sinuosity-index, width-depth ratio of river valleys, longitudinal profile/chi- profiles, S-L index and HI of the rivers flowing north to south across the GFZ and south to north across SNSF suggest that the Satpura mountain range was tectonically uplifted along its bounding faults. Luminescence dating of sediments from river terraces and calculation of knickpoint migration rates in the rivers indicate the occurrence of multiple neotectonic events in GFZ at ca. 65-80 ka, ca. 50 ka, ca. 30-40 ka, and ca. 14 ka. Gondwana sediments within Satpura are found to be asymmetrically folded against GFZ and SNSF indicating compression generated reverse faulting. Therefore, collectively, all these evidences suggest that the Satpura mountain range, in the present tectonic configuration, is not a ‘Horst’ but a “pop-up” structure bounded by two neotectonically active reverse faults, potentially responsible for seismicity.

**Keywords:** Neotectonics; Luminescence dating; Morphometry; Indian craton; Satpura Mountain

ABSTRACT NUMBER: 656

## GEOMORPHOLOGICAL INDICATORS OF NEOTECTONIC DEFORMATION ALONG THE EASTERN HIMALAYAN FOOTHILLS: CASE STUDIES FROM TWO AREAS IN WEST BENGAL AND ARUNACHAL PRADESH, INDIA.

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Neotectonic activity along the foothills of the eastern Himalayas is well revealed by the prominent geomorphic indicators. The Himalayan front is sinuous and recognized as salient, normally associated with mountain front and the recesses, open to the foreland forming longitudinal piedmonts. Our study records geomorphic features indicating tectonism during the Quaternary between Main Boundary Thrust (MBT) and Himalayan Frontal Thrust (HFT) in two areas:

- Mal-Diana interfluvium (Jaldhaka recess)
- around Itanagar (Itanagar salient)

The Mal-Diana interfluvium is characterised by E-W trending both south and north facing scarps namely Chalsa, Matiali and Thaljhara, interpreted as manifestation of HFT and MBT associated with transverse lineaments through which major antecedent drainages like Neora and Jaldhaka flow. Similarly the Banderdewa scarp, marked by the mountain front, represents the HFT near Itanagar. These are the shorter limbs of the ramp anticlines over the blind thrusts. In both the areas the characteristic radial drainage of alluvial fan changes to subparallel to parallel pattern. The raised river terraces indicate episodic upliftment of older surfaces. The unpaired terraces, shifting and bending of courses of Neora, Jaldhaka and Dikrang River indicate tectonic control on drainage. The tilting and warping of the Quaternary fan surfaces and river terraces are related both to the Himalayan thrust systems and the transverse faults. In the Jaldhaka-Diana interfluvium the deformed fan surface has formed a wrinkle-ridge system. In Itanagar a NE-SW trending transverse fault has shifted the mountain- front towards NE resulting development and deformation of piedmont in the east of Dikrang River.

Preparation of 1:25000 scale geomorphological and drainage maps, documentation of the sedimentary record, quantification of



change in slope of both the surfaces and river-beds helps understand the tectonic activity during the Quaternaries and predict the vulnerability of these areas in future earthquakes.

**Keywords:** Tectonics; Geomorphology; Scarps; Terraces; Drainage

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 718

## ALLUVIAL TERRACES OF THE CHEL RIVER VALLEY, FOOTHILLS OF DARJEELING HIMALAYA, INDIA: IMPRINTS OF GEOMORPHIC AND TECTONIC PROCESSES

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A number of rivers draining the Darjeeling-Sikkim Himalaya meet the low-gradient foreland alluvial plain, where the terraces are formed due to aggradation and degradation of river systems over a period of time driven by the interplay of forces of tectonics and climate.

The present study was to evaluate possible role of tectonics and other autogenic processes in the formation and present disposition of the Chel River terraces, in a 7 km long valley-confined stretch at the foothills of Darjeeling Himalaya. Six fill terraces are recognized and can be categorized in two groups: a) two older, unpaired, east-bank terraces (T6, T5) that occur 300 to 450 m above the modern river; b) a set of four younger, paired terraces (T4-T1) occurring at lower elevations. High (>5.1°) slope of T6 and folding of T5 is probably related to the movement along the Gorubathan Thrust (GBT). The younger set of terraces (T4-T1) converge southward at the mountain front with slope varies between <3.2° to 2°. The coarsening upward gravelly successions of T4 and T3 are inferred to be deposited by progradation of valley-bound telescopic fan. Relatively finer gravels of T2 and T1 were deposited in braided alluvial plains. Hypsometric analysis of the Chel catchment basin does not reveal any influence of tectonic movements. The present study infers that the southward convergent pattern of the younger terraces is a result of decreasing slope of the fan-river system in response to progressively increasing water:sediment ratio in the precursor streams, not tectonic tilting. And this was probably driven by changes in climate, sediment supply and geomorphology of the catchment basins. The disposition of the upper, unpaired terraces and the proposed non-tectonic origin of the downstream convergent lower Chel terraces has important bearing for timing of movement along GBT (~35-40 ka).

**Keywords:** Himalaya; Terrace morphology; Climate change

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 782

## PHYSICALLY-BASED SEGMENTATION OF THE LAND SURFACE FOR MORPHOTECTONIC ANALYSIS

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Use of input geomorphometric variables that directly reflect basic physical-geomorphic categories is a basis of physically-based land surface segmentation. Definition of input morphometric variables depends on the character of target geomorphic objects. For identification of basic morphotectonic units (morphostructures) of the Western Carpathians we used elevation of envelope (original) surface as a measure of detectable unit endogenous geomorphic work, Glock's available relief as a measure of detectable unit exogenous geomorphic work, and ratio of amplitude (relief) and half of wave length (double of mean distance from the stream) as a measure of available gravity force of formed land surface. Concept of topographic grain should be used to determine the computational windows. The variables were derived from the SRTM V4 dataset as well as from the TanDEM-X dataset. We subsequently applied our original object-oriented workflow consisting of multiple iterative segmentations based on the ESP 2 tool and classifications in the eCognition Developer software. Results of the segmentation do not principally differ from the segmentation using the related variables as elevation, vertical dissection, and slope; however, morphotectonic interpretation is more straightforward. Ratio of endogenous and exogenous work reflects, in line with existing geochronological data, age and rapidity of the uplift. Spatial differentiation of geomorphic works and their ratio enables to test the hypothesis of different sequentiality of the dome-like neotectonic uplift of the Western Carpathians as well as development of particular 'delayed' (later uplifted) mountains. Additional consideration of available gravity force of formed land surface is important from the point of view of influence of lithological differences on formation of the morphostructures.

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**Keywords:** geomorphometry, OBIA, geomorphic work, Western Carpathians

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 787

## MORPHOTECTONIC OF REGOLITH LANDSURFACES IN CAMEROON (CENTRAL AFRICA): WEIGHTING THE EVIDENCES OF LATE CRETACEOUS UPLIFT AND CLIMATIC DEEP WEATHERING AND STRIPPING

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In the last few decades, a range of regolith-related issues highlighted their usefulness on assessing landform dynamics for better understanding and quantifying earth surface processes. A model for the evolution of weathered landsurfaces in Cameroon is developed using available tectonic evidences and geophysical anomalies (i.e. crustal thickness and gravimetric anomalies), sedimentological data and regolith morphology. On deformed orogens, the model demonstrates the pivotal role of uplift, consequent volcanic cover and rheology-dependent gravitational collapses in inducing large scale compartmentalization. In areas of tectonic quiescence, it enhances a well known predominance of deep weathering and stripping resulting in a morphogenetic sequence similar to that of climate-dependent dynamics on the West African craton. These schemes in accordance with regional correlations allow determining four regolith landsurfaces recognizable with their actual relicts and their specific petrogeochemical patterns. These are the high glacis, the widespread Intermediate ferricrete, the African bauxitic surface, and the modern bauxites developed on Neogene volcanics across the so-called Cameroon Volcanic Line. These findings provide a unique geomorphic record resulting in interplay between late Cretaceous epeirogeny, heterogeneity of uplifted basement, and climate variability. It helps narrowing a gap on understanding the dynamics of the complex geomorphic system of the African tropical belt, and specifically in Central Africa where no tectonic input were considered in old issues. It also stands as basis for assessing denudation rates and their comparison with weathering-limited steady cratonic denudation of West Africa, and to investigate Cenozoic drainage rearrangement and stabilization as a consequence of uplift.

**Keywords:** regolith landsurfaces; epeirogeny; gravitational collapses, climate variability; Cameroon

THEME: S33-A : TECTONIC GEOMORPHOLOGY OF KACHCHH BASIN

ABSTRACT NUMBER: 246

## SCARP DEVELOPMENT AND NEOTECTONIC RESPONSE OF UPLIFT INDUCED EROSIONAL LANDSCAPE ALONG THE SEISMICALLY ACTIVE KACHCHH MAINLAND FAULT (KMF), WESTERN INDIA.

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The Kachchh Mainland Fault (KMF) is a roughly E-W trending fault in the seismically active Kachchh palaeorift basin. The present study deals with the western part of the KMF where strike of the fault swings to WNW-ESE. The fault delimits a chain of asymmetrical domes composed of Mesozoic rocks characterized by sub-vertical to vertical northern limbs forming the KMF scarp and the southern limbs with gentle dips. The domes studied include the Jumara, Jara, Bana, Mundhan, Ghuneri and Karanpur domes. All domes show rugged, hilly topography with northward flowing incised bedrock rivers. The geomorphic and stratigraphic evidence suggest a progressively westward decreasing magnitude of uplift from Jumara dome in the east to Karanpur dome in the west. Development of another E-W trending Jaramara scarp to the south of the KMF scarp conforms to the higher magnitude of uplift in the eastern part. The Jaramara scarp, higher in elevation than the KMF scarp, is a simple cuesta scarp, formed in the gentler southern limbs of the Jumara, Jara and Bana domes. We attribute the development of the Jaramara scarp to comparatively higher magnitude upliftment of the Jumara, Jara and Bana domes. The formation of the Jaramara scarp was accentuated by the presence of a large intrusive body, the Ukra intrusive on the back slopes of the scarp. Deeply incised Quaternary miliolite deposits, deep gorges and knickpoints in the Jaramara scarp provide evidence of post miliolite uplift of the domes in response to coseismic movement along the KMF.

**Keywords:** Scarp morphology; Jaramara scarp; Neotectonics; Kachchh Mainland Fault (KMF); Kachchh basin

THEME: S33-A : TECTONIC GEOMORPHOLOGY OF KACHCHH BASIN

ABSTRACT NUMBER: 328

## EVOLUTION OF DRAINAGE IN RESPONSE TO BRITTLE - DUCTILE DYNAMICS AND SURFACE PROCESSES IN KACHCHH RIFT BASIN, WESTERN INDIA

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The eastern part of Kachchh Rift basin was activated after 2001 Bhuj earthquake Mw 7.7 and continuous seismicity has been recorded since then. The northern part of Wagad upland also experienced moderate earthquakes  $M_w \geq 5.7$  in February 2006 and March 2007. These moderate to Major Intraplate earthquakes provide a unique opportunity to study the effects and linkage between brittle - ductile dynamics, surface processes and drainage evolution. The area between Bharudia Fault and Gedi Fault (GF) in northern part of Wagad upland have been investigated in detail. We presented a geomorphological analysis of northern part of Wagad upland providing new constraints on the evolution of river network. We examined topographic features such as swath profiles, local relief and the river network (river longitudinal profiles) for twenty seven river basins. Several conventional geomorphic attributes namely, stream length gradient index (SL), steepness index (Ks), hypsometry integral (HI), asymmetry factor (AF), basin shape (BS) and a single index of relative active tectonics (RIAT) are used to understand the degree of activeness. The shallow to deeper nature of fault and their response to development of hydrological networks has been analyzed using seismic tomograph. Based on surface drainage offset and seismic structures several E-W oriented faults controlling fluvial dynamics are identified. From seismic structures and drainage offset it is clear that the fluvial dynamics is controlled by shallower to deeper faults. The estimated attributes are well supported with seismic structures and focal mechanisms solutions. Based on fluvial offset and seismic structure analysis a new tectonic model has been proposed for northern Wagad region. The tectonic model shows that the faults in northern Wagad region are well connected at deeper level and generated negative flower structures and significantly controlling surface fluvial dynamics.

THEME: S33-A : TECTONIC GEOMORPHOLOGY OF KACHCHH BASIN

ABSTRACT NUMBER: 406

## ODDS OF EARTHQUAKE HAZARD IN KACHCHH: REVEALED BY THE TECTONIC GEOMORPHOLOGY OF KACHCHH

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The study of landforms produced or modified by tectonic processes can provide vital information about the structure and activity along that particular structure. Fault-generated mountain fronts are the major tectonic landforms where active tectonics and surface processes coexist. Such landforms are very responsive to the rates of active tectonics, surface processes and rock strength. Spatial and temporal variations in the rate of active tectonics and related surface processes lead to the development of mountain fronts with characteristic shapes and sizes. One of the most fundamental yet under-rated component of seismic hazard analysis is the estimation of maximum potential earthquake along a fault. This is carried out using available regression equations which tend to correlate fault length, rupture length, fault area with magnitude. The information about rupture length is seldom available for longer periods, especially in intraplate settings which are invariably, scantily studied. In present study we employ the length/area of faults to estimate maximum potential earthquake in a particular fault or fault segment. The study highlights the significance of transverse faults, as how they tend to regulate the maximum potential earthquake generation capacity of a fault/fault segment. We take the example of Kachchh which is an intraplate setting and estimate maximum potential earthquake magnitude using length and area of the various segments. The results suggests that the no major known active fault in Kachchh can produce earthquake with  $M_w > 7.0$ , except Allah Bund Fault. This is contradictory to the prevalent understanding which suggests KMF and SWF as being major source of seismic hazard to western India and capable of producing earthquake  $M_w > 8$ . The study also reports that the 2001 Bhuj earthquake occurred along a blind thrust, and not along KMF or SWF as believed.

THEME: S33-A : TECTONIC GEOMORPHOLOGY OF KACHCHH BASIN

ABSTRACT NUMBER: 458

## COASTAL GEOMORPHOLOGY OF THE KACHCHH, WESTERN INDIA: ROLE OF TECTONICS AND SEDIMENT DISPERSAL SYSTEM

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The Kachchh region of Western India manifests a strong control of neotectonic activities along the well established faults like Island Belt Fault (IBF), Kachchh Mainland Fault (KMF), Katrol Hill Fault (KHF) and transverse faults expressing the stress distribution due to the movements along aforesaid faults, over the overall geomorphic evolution of the region. Studies have documented tectonic geomorphology of the Great and Little Ranns of Kachchh, Northern Hill Range and Katrol Hill Range. The coast has been although studied for its geomorphological attributes, lack an in depth evaluation of the complex interplay between the tectonics of the hinterland and sediment dispersal system that finally shape out the coastal geomorphology. We present here the studies on sediment texture and composition from various geomorphic attributes of different parts of the Kachchh coast to address its provenance, transit, redistribution and deposition in light of the Gulf of Kachchh current dynamics. Accordingly, the western part that characteristically show sandy and partly cliffy coast between Koteswar and Pingleswar exhibits a strong input from Indus derived sediments; the coast further eastward upto Mandvi is dominated by the hinterland derived sediments largely redistributed under strong littoral drift along the mouth of the rivers like Kharod and Rukmavati. The inner gulf coast between Mundra and Kandla is muddy and is a main repository of suspended sediments. The role of the Median high has been advocated in the past on evolution of the Kachchh coast. Activities along the KHF and other faults in southern Kachchh have further controlled the sediment dispersion and resultant geomorphic features at macro and meso scale on the Kachchh coast.

**Keywords:** Tectonic geomorphology; Sediment dispersion; Kachchh coast

THEME: S33-A : TECTONIC GEOMORPHOLOGY OF KACHCHH BASIN

ABSTRACT NUMBER: 636

## ROLE OF IGNEOUS BODIES IN SHAPING THE PRESENT DAY LANDSCAPE OF KACHCHH BASIN-WESTERN INDIA.

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The Landscape of Kachchh is a result of two major Geological Processes: Tectonic and Climatic. Since Kachchh is a Seismological active Paleorift Basin the Geomorphic Features of Kachchh are well associated with the major structure like basinal Faults Viz. Kachchh Mainland Fault, Island Belt Fault, South Wagad Fault and Katrol Hill Fault. The Geomorphology runs therefore with the tectonic, so as an ideal landscape for tectonic Geomorphology. Kachchh has the lithological variation from the Jurassic to the present day through the Cretaceous mostly affected by the Deccan Volcanic Province (DVP).

The Landscape of Kachchh is rugged and made up of several Domes associated with major Faults. The aim of the present work is to understand the Influence of Igneous Dykes and Plugs on Geomorphology, As the Deccan Trap intrusion and Extrusion have major role in shaping the structural landscape, but they also affected the cretaceous sandstone and made them resistant to erosion forming linear ridges and conical hills or radial hills. Intrusive in the sandstone lead to making ridges and an uplifted topography at the core of the dome associated with the major fault system of the Kachchh Basin are pushed by the igneous body. In the present day landscape the dyke and igneous bodies are hard enough to stand against the climatic processes and form linear ridges which meet to the major fault in Basin.

The Igneous Plugs and Dyke in the Kachchh Mainland is studied and presented here to Understand Geomorphic Significance of Intrusive in Kachchh

**Keywords:** Intrusive; Kachchh; Igneous Plugs; Linear Ridges

THEME: S33-A : TECTONIC GEOMORPHOLOGY OF KACHCHH BASIN

ABSTRACT NUMBER: 644

## MORPHOTECTONIC EVIDENCES OF RECENT TECTONIC ACTIVITY ALONG WESTERN KACHCHH MAINLAND FAULT, WESTERN INDIA.

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Kachchh is a pericratonic rift basin experiencing reverse as well as strike-slip tectonics since Tertiary to Quaternary period. Structural, tectonic and sedimentological history and frame-work of Kachchh Basin and associated primary fault system has been known for last three decades. Further, a significant work on Quaternary tectonics along the primary fault like Kachchh mainland Fault (KMF), Island Belt Fault (IBF) and also along the secondary fault like Katrol Hill Fault (KHF) has been attempted by several workers. There is a certain lacking of adequate data on the observation and documentation of Neotectonic features along the western segment of KMF. In the present work, we have documented some convincing neotectonic features along a western segment of KMF and related structural features. Western segment of KMF is displaced by several transverse faults. Several morphotectonic and palaeoseismic evidences are traced along these segment and its associated transverse faults. The activeness of this segment is further reflecting by various seismic activities in last decades. Our result reflects active nature of western KMF and it needs detail paleoseismological investigation for future earthquake hazard assessment in the region.

**Keywords:** KMF, Neotectonic, Transverse Faults

THEME: S33-A : TECTONIC GEOMORPHOLOGY OF KACHCHH BASIN

ABSTRACT NUMBER: 649

## GEOMORPHOLOGY OF ACTIVE INTRA-PLATE AND PASSIVE MARGIN KACHCHH BASIN IN WESTERN INDIA

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Kachchh is an intra-plate paleo-rift basin, traversed by E-W trending faults and transverse faults across them. The geomorphology of the basin is shaped by episodic uplifts/ subsidence and concurrent cyclic erosion of the terrain from Tertiary to Quaternary period. The syn-rift and post-rift Mesozoic sediments of Kachchh basin engaged into reversal phase in post collision period, whence the marginal sags created the embayment for Tertiary marine sediments depicting distinct transgressive and regressive sediments. Mesozoic sediments uplifted to make fault controlled first order topography and scarp dominated parallel questa type ridges that structurally known as tilted horsts and half grabens dividing them. The northernmost Island Belt Uplift, Wagad Uplift and Kachchh Mainland Uplifts are rocky uplands respectively controlled by Island Belt Fault, South Wagad Fault and Kachchh Mainland Faults. The Katrol range is a subsidiary one within the Mainland uplift controlled by the Katrol Hill Fault. Initially normal tectonics has been turned to reverse and strike-slip in post collision till Quaternary period. Active nature of the landscape and faults are exhibited by questa scarps, deranged, deflected, offset streams, deep bedrock gorges, flexuring in Quaternary sediments, offset alluvial fans, linear fault ridges, fluvial terraces, warping and tilting, knick points and exposure of faults. The intensity of such features are high in young terrain near a comparative more active faults while only a dominance of first order topography depicts less tectonic activity. The half grabens are best grounds for vast Quaternary depositions forming recent fluvio-marine basins as 'Ranns' – the salt playa lands between the questa ridges. Gullied erosion and juvenile streams in the uplifted, tilted Rann sediments and abandoned channels suggests late Holocene tectonic and climatic fluctuations. Such a distinct geomorphic expression by the slow geological processes appears to be inimitable in an active intra-plate passive margin Kachchh basin of western India.

THEME: S33-A : TECTONIC GEOMORPHOLOGY OF KACHCHH BASIN

ABSTRACT NUMBER: 658

## CLIMATE OVERPRINTS TECTONICS ON OPENING EPIGENETIC GORGE IN CRETACEOUS FLUVIAL SANDSTONE OF KACHCHH, WESTERN INDIA.

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Kachchh in western India falls in an arid climatic zone. Epigenetic gorges in the tectonically active landscape are recognized by bedrock geometry and its valley pattern. They are coupled with paleo-channel deposits due to fluvial aggradations and in later phase the river was forced to occupy the tectonically generated epigenetic gorge. The present study of north flowing Khari River segment is carried out to understand the role of climate in carving the ~20m deep NE-SW trending bedrock gorge in post 30ka period. The epigenetic gorge exhibits six pairs of bedrock terraces. Quaternary chronology of paleochannel indicates early aggradational phase between 50ka to 30ka. Tectonic episode of post 30ka abandoned the paleochannel with opening and widening the epigenetic gorge. Later climatic phase formed T3 and T4 bedrock terraces with pot holes and flutings. The turbulent flow of the river develops the eddy current which enters the initially minor depressions on the bed form. The shear flow drags the sediments inward into the depressions and grind against the sides and bottom to form potholes suggesting intense wet climate with high discharge rate. Depositional terraces downstream have been correlated with this wet phase. It contains coarse, unstratified angular sand grains and fragments of sandstone country rock. Continued tectonic phases uplifted the terrain to incise the epigenetic gorge to the level of T4 and T5 with distinct strath surface on the older ones and subsequent formation of hanging valley downstream cutting much younger deposition terraces. The most recent deposits in the lower reaches of valley are indicative of weak climatic condition during the middle to late Holocene period. The major opening of the gorge due to the strong climatic episode is deduce to be post 30ka i.e. pre and post LGM strong wet climates may be responsible for the gorge development.

**Keywords:** Epigenetic gorge

*THEME: S33-A : TECTONIC GEOMORPHOLOGY OF KACHCHH BASIN*

**ABSTRACT NUMBER: 667**

## DEVELOPMENT OF QUATERNARY LANDSCAPE ALONG MEDIAN HIGH ACROSS KACHCHH BASIN: WESTERN INDIA

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The surface manifestation of Kachchh rift basin in western peninsular India is a result of interplay of tectonics, climate and sea level changes. Slow tectonics along the master faults and slow erosion since early Tertiary have resulted into the formation of E-W trending highlands along the up thrown block facing lowland along down thrown blocks. The landscape of Kachchh is traversed by several N-S, NNE-SSW to NNW-SSE trending transverse fault system. One of the most remarkable expressions of such geodynamic interaction is presence of NNE-SSW oriented ~160km long and ~ 50 km wide meridional high region, in the central part of the basin. This geomorphic high is referred to as Median High (MH). Studies reveal that the MH was developed during the Upper Jurassic within the axial zone of the basin. This ridge passes transversely across both positive and negative elements of the Kachchh rift basin. Several small scale normal faults accompanied by basic dykes are well exposed on the crestal part of MH. Dykes along MH form isolated linear ridge supported by several extensional transverse faults. These conjugate transverse fault system has resulted into formation of graben and horst structures in the hinge zone. Several late Quaternary aggradational and degradational climatic events are well exposed along the MH. In the present work, emphasis is given on the erosional and depositional features to understand the effect of MH during Quaternary time. The Quaternary erosional and depositional surfaces and their association with local and regional structure were mapped extensively. The sedimentological, geomorphic and chronological record shows that the MH was activated during the Quaternary. The geomorphic expressions and chronological records show that the tectonic activity along MH is active since Late Jurassic to Quaternary.

**Keywords:** Median High; Axial zone; isolated linear ridge; Kachchh

*THEME: S33-A : TECTONIC GEOMORPHOLOGY OF KACHCHH BASIN*

**ABSTRACT NUMBER: 671**

## TECTONIC GEOMORPHOLOGY ALONG THE WESTERN SEGMENT OF SOUTH WAGAD FAULT, KACHCHH: WESTERN INDIA

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Kachchh basin is a seismically active paleo-rift graben with typical geometry of an evolved rift basin. It is designed by E-W trending basin and range structures along master faults viz. Nagar Parkar Fault, Island Belt Fault, South Wagad Fault (SWF), Kachchh Mainland Fault, and North Kathiawar Fault. Blocks uplifted along these faults gave rise to sub-parallel linear ridges such as Nagar Parkar Uplift, Island Belt Uplift, Wagad Uplift (WU), and Kachchh Mainland Uplift. These uplifts are affected by several secondary faults of different generations. SWF defines the southern margin of northerly tilted WU. SWF hill range consist a chain of closed structures at the edge of the uplift. These close structures are domes, anticline, syncline, nose and basin etc. The present work has attempted to understand active tectonism along Western segment of SWF. Domes and anticline along uplifted block and Quaternary depositional and erosional surfaces along downthrown block of western SWF were investigated for identification of morphotectonic features of active tectonism. The work focuses on the study of Quaternary sediments and structures, Quaternary landforms and drainage systems, which are direct expressions of the ongoing tectonic processes along SWF. Using topographical / geological maps, remote sensing data and Geological / Geomorphological Mapping in field, geomorphic features of active tectonics have been documented and mapped. These features are manifestation of recent tectonic over buried SWF.

**Keywords:** Wagad; tectonism; Kachchh

THEME: S34 : GEOARCHAEOLOGY (IAG-WG)

ABSTRACT NUMBER: 6

## ANCIENT QUARRIES AS INDICATORS OF PALAEOGEOGRAPHICAL EVOLUTION OF WESTERN NAXOS ISLAND (CYCLADES)

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In the west coastal zone of Naxos ancient quarries were found, providing evidence for the paleogeography of the area for the last 1500 years. In particular, on Manto island of the Laguna, an aeolianite quarry is found nowadays at the coastal zone of the island and continues down to a depth of 2 m. In the area of Plaka quarrying traces were found on beachrocks to a depth of 2 m. The quarrying material appears to have been used for ancient Yria and the ancient wall of Chora. The location of these quarries is not accidental, as they are found near the sites of use and their transport was facilitated by boat.

The sea level was 2 m lower than at present 1500 years ago and the shoreline of that time may be followed from the beachrocks protecting both the Laguna and the area of Plaka. In this paper, an attempt is made to study the paleogeography of the area through the use of ancient quarries found in the coastal and submarine area of NW Naxos.

**Keywords:** Naxos; ancient quarries; sea level changes; palaeogeography

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THEME: S34 : GEOARCHAEOLOGY (IAG-WG)

ABSTRACT NUMBER: 15

## LATE QUATERNARY GEOMORPHOLOGY, CLIMATE AND HUMAN INTERACTIONS IN THE KUREYŞLER AREA (KÜTAHYA, W CENTRAL ANATOLIA), TURKEY: PRELIMINARY FINDINGS

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The Kureyşler Area in W Central Anatolia hosted many civilisations from the Early Bronze Age to modern Turkish Republic. In order to unravel the complex relations between the past human societies, climate change and geomorphology, we carried out a multi-



disciplinary study involving geological and geomorphology, surface dating and drilling, coupled with archaeology in the vicinity of several Early Bronze Age tells.

Our geological and geomorphological investigations showed that a Late Miocene-Early Pliocene alkaline lake was captured presumably due to regional tectonic turn-over by an external drainage. From that time onward, a series of strath terraces have been developed, the oldest yet still undated of which stands at 140 m above the present floodplain. We documented Paleolithic tools only on terraces T3 (40 m above riverbed) and the older terraces. To check the Late Holocene history of the area, we applied 5 drillholes in the fill of the Kureyşler Valley. According to data we obtained from the hole KS-6 in very close proximity to the Ortaca Tell, the fluvial aggradation started ca. 12 ka on the Miocene carbonate rocks, and deposited about 8 m thick sediments up-to-date without any apparent break. The core shows an increase in Total Organic Carbon (TOC) content, Pinaceae pollen percentage and a decrease in Asteraceae pollen percentage around 11 ka. This signals a climatic shift toward more humid conditions. Around 6 ka, another decrease in TOC accompanied by mild decrease in Pinaceae pollen percentage proves an aridification trend. Soon after, Early Bronze Age communities began their occupation around 5.3 ka. Around 4 ka, Oleaceae pollen appeared for the first time proves a warmer climate compared to today. General decrease in Pinaceae pollen percentage since 6ka would indicate the increasing anthropogenic pressure over the environment.

**Keywords:** Aridification, Early Bronze Age, Middle Paleolithic, pollen, strath terrace

THEME: S34 : GEOARCHAEOLOGY (IAG-WG)

ABSTRACT NUMBER: 68

## SHELL MOUND FORMATION PROCESSES: A GEOARCHAEOLOGICAL PERSPECTIVE

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Large mounded deposits of shell are prominent archaeological features across the north Australian tropical coast. Many are composed almost entirely of the bivalve *Anadara granosa* (Linnaeus 1758), a food source for Aboriginal people in the past. A relatively long history of inquiry into the nature and significance of the shell mounds has focused primarily on analysing the shell component as clues to Australian Aboriginal coastal economies. This paper presents results of new analyses on the non-shell sediments of mounds located near Weipa in far north Queensland, examining physical and chemical signatures to obtain insights into how the mounds were formed, and how their morphology, structure and content may have changed since they ceased accumulating. We also consider how such changes might relate to past and present environmental conditions. The mounds we studied are primarily located on topographic high points, such as cliffs, hillslopes and beach ridges, though a proportion are located on estuarine floodplains at low elevations. Terrestrial Laser Scanning (TLS) of a sample of 51 shell mounds demonstrates substantial variation in mound size and shape, and suggests patterning in mound form related to age as well as position on the landscape. However, radiocarbon chronologies demonstrate that the mounds do not conform to a model of linear formation of a shell deposit, suggesting mound histories are variable in both the nature of shell deposition as well as post-depositional processes. Soil physical and chemical analyses indicate that post-depositional diagenetic alteration has strongly influenced the present day composition and form of the shell mounds, in particular the accession of carbon and silica to the mounds by environmental burning aided by strong leaching under seasonally high rainfall conditions. Shell mounds today are therefore as much, if not more, a product of formation processes that post-date human agency.

**Keywords:** geoarchaeology; Australia; shellmound; formation; Holocene

THEME: S34 : GEOARCHAEOLOGY (IAG-WG)

ABSTRACT NUMBER: 181

## THE LATE HOLOCENE GEOMORPHOLOGY AND GEOARCHAEOLOGY OF MAYA WETLAND AGROECOSYSTEMS IN GLOBAL CONTEXTS

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The geomorphic study of agroecosystems has entered a period of great dynamism with many advances of scientific methods, expansion of LiDAR mapping, and renaissance of excavation. In 2016 we acquired nearly 300 square km of LiDAR imagery that covers large areas of ancient Maya wetland fields for the first time, which had previously been hidden by tropical forest canopy. The coverage indicates



both widespread wetland canal and field systems and intensive, polycultural complexes of upland terraces and wetland fields. Over the last 15 years, we tested many such systems with excavations and multiple proxies for how these formed over the millennia, how the ancient Maya used them, and when and how they became abandoned. But, the new imagery allows us to map beneath the canopy and shows wetland systems are much more extensive than we had previously mapped. We present the current state of knowledge based on excavations over a 100 km transect of the coastal plain of Belize and the high resolution LiDAR mapping and modeling. Based on these, we present models to understand wetland agriculture both diachronically and synchronically within the framework of Maya History. We also compare these ancient, tropical agroecosystems with those developed in Asia, such as ancient paddy rice systems.

**Keywords:** LiDAR, ancient Maya wetland agroecosystems, wetland formation, karst, soil and water chemistry

THEME: S34 : GEOARCHAEOLOGY (IAG-WG)

ABSTRACT NUMBER: 244

## TROPICAL GEOARCHAEOLOGY AND ITS ROLE IN ASSESSING PALEOENVIRONMENTS AND SOIL FORMATION PROCESSES: GEOMORPHOLOGY, PEDOLOGY AND ARCHAEOLOGICAL SITES IN SE BRAZIL.

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Deep tropical soils (Oxisols) in SE Brazil are commonly regarded as being formed by in situ weathering. Even when charcoal particles are found in the soil profile, explanations tend to invoke the massive action of burrowing animals (ants, termites, armadillos) and plant roots. In this communication we will present two case studies: Sumidouro site, Minas Gerais State and Lagoa do Camargo site, São Paulo State. Both sites are deeply buried (up to ca. 2m deep) and dating from the early Holocene. Sumidouro site is located near a lake shore, whereas Lagoa do Camargo is located in the upper portion of a gentle slope, close to the watershed. The aim of the communication is to show how data coming from archaeological excavations can provide exclusive and valuable information about paleoenvironments, soil formation and slope processes in tropical settings. The somewhat counterintuitive nature of the data should be of interest to geomorphologists, soil scientists and archaeologists dealing with deeply buried sites.

**Keywords:** Tropical Geoarchaeology; Geomorphology; Phytoliths; Oxisol; Slope Processes

THEME: S34 : GEOARCHAEOLOGY (IAG-WG)

ABSTRACT NUMBER: 325

## THE ENVIRONMENTAL EVOLUTION OF THE TRADE SITE OF KOTA CINA, IN NORTH SUMATRA (INDONESIA), BETWEEN THE XITH AND THE XIVTH CENTURIES AD

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In Indonesia, palaeoenvironmental studies associated with archaeological settlements are unusual. However geoarchaeological studies can help to understand the stratigraphical and environmental frameworks of human occupations. The study of the Kota Cina archaeological site (North Sumatra) is a pioneer work that aims to reconstruct the environmental changes that have affected the site between its initial occupation and its abandonment.

Kota Cina is an ancient trade site located on the coast of the Strait of Malacca. It was active between the XIth-XIVth centuries AD. Nowadays, it is located at 7 km from the coast in marshy lowland. Its current position inland implies a marked evolution of the shoreline.

The study is based on geomorphological approach. Some 200 soil borings were performed associated with a study of 18 stratigraphic profiles from 9 archaeological excavation squares. A set of 120 sedimentary samples was performed for grain size and radiocarbon analyses. The results were interpreted and discussed versus the archaeological study.

Three main phases of environmental changes are identified: (1) before the first human settlements, the site was probably close to the coastline and characterized by a volcano-sedimentary sequence associated with a widespread fluvial reworking; (2) during the 11th

century AD, the first inhabitants settled Kota Cina. The site was established in a swamp wetland covered by a mangrove and crossed by channels in an estuarine land; (3) between the XIIth and the XIIIth centuries AD, Kota Cina developed. Boats and houses on stilts were discovered, religious buildings and coastal wetland infrastructures were built. The estuarine land was gradually silted and the site was isolated from waterways. Kota Cina was abandoned in the XIVth century AD.

The environmental changes in Kota Cina resulted from a regional silting associated with a coastal progradation. This phenomenon is complex and due to natural and anthropogenic factors.

*THEME: S34 : GEOARCHAEOLOGY (IAG-WG)*

**ABSTRACT NUMBER: 340**

## **THE BATTLEFIELD GEOMORPHOLOGY OF ANCIENT THERMOPYLAE (CENTRAL GREECE)**

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The battle of Thermopylae that was fought by a few hundred soldiers led by King Leonidas of Sparta, defending Greek city states against the invading Persian army of the emperor Xerxes II, in 480 B.C. was one of the most famous battles in Greek and European history. This research is an attempt to investigate the geomorphological evolution of the battlefield terrain in the large scale of a narrow passage and to compare it with the descriptions of ancient writers. Detailed geomorphological research supported by drilling data, AMS dating, macro/micro-paleontological analysis and geophysical survey, revealed the main landforms that constituted the battlefield morphology. Also, detailed environmental data from the ancient coastal zone can show the environmental conditions of the inner Malian Gulf and the battlefield proximity to the sea. The research overcame the large scale delta evolution of Sperchios River, the large thickness of the chemical (carbonate) sediments deposited due to the presence of a thermal spring, the elevated artesian aquifer and the lack of archaeological data below the modern carbonate sediments of the field. The research showed that the narrow passage of the Hot Gates (Thermopylae) was leading to the foothills of Kolonos hill, a fortified location with steep slopes and a relative elevation to the ancient path of 20m higher than today. This steep morphology supported the fortification of the hill, while it is proved from the geophysical survey that the width of the passage was the narrowest at the same point. On the other side of the hill an alluvial fan with gentle slopes was used for the Greek camp, where the pass was widening. Finally, on the eastern side of the fan a near shore to shallow marine paleoenvironmental conditions occurred, supporting the description of Herodotus that a ship could be in close proximity to the battlefield.

*THEME: S34 : GEOARCHAEOLOGY (IAG-WG)*

**ABSTRACT NUMBER: 348**

## **BENTHIC FORAMINIFERAL RECORDS OF MIDDLE-LATE HOLOCENE COASTAL PLAINS IN THE AEGEAN SEA (GREECE): A REVIEW**

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Holocene successions of several coastal plains have been studied, using benthic foraminiferal data integrated with radiometric dating, in order to reconstruct the paleoenvironmental evolution in the different Aegean coastal settings. All studied sites are affected by sea-land interaction and transgressive / regressive trends. Benthic foraminiferal analysis reveals, that the lower part of each sequence bears an open lagoonal fauna which presents upwards oligohaline affinities, showing clear similarities to modern Aegean closed lagoons. It is evident that a transition from open to inner lagoonal conditions has taken place, due to a slowing rate of sea level rise associated with increased input of fluvial and deltaic sediments. This transition is partly diachronous, depending on local tectonic and geomorphological settings, and has taken place in-between 7500-3500 cal yr BP. The Holocene sedimentary sequences present an evolutionary succession that closely agrees with the proposed model of relative sea level in the coastal areas of the Aegean Sea, with a reduction in the rate of sea-level rise recorded at ~4000 cal yr BP due to paleoclimatic changes and regional tectonic effects. The higher rate of sea-level rise before ~4000 cal BP can be associated with the on-going, albeit weak, mid Holocene monsoonal activity that is expressed with the warm and humid paleoclimatic conditions recorded between ~5400-4300 cal yr BP in the Aegean Sea.

THEME: S34 : GEOARCHAEOLOGY (IAG-WG)

ABSTRACT NUMBER: 352

## COASTAL ZONE PALEOGEOGRAPHICAL RECONSTRUCTION OF MOLYVOTI PENINSULA ANCIENT SETTLEMENT, N. AEGEAN SEA, GREECE

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The ruins of an ancient city inconclusively identified as ancient Stryme are situated on the small peninsula of Molyvoti at the Thracian coast of the northern Aegean Sea, 25 Km SW of the modern city of Komotini. The ancient city is located on a diachronically changing coastal environment consisted of beaches, coastal cliffs, salt marshes, lagoons and fresh water swamps. The aim of this research is the paleogeographical and palaeoenvironmental reconstruction of the coastal zone during the city habitation. The geoarchaeological research was realized in a three years project and supported by geomorphological mapping, vibracoring, 14C-AMS dating, Macro-Micro paleontological, stratigraphical, palynological analysis, magnetic susceptibility, and Geophysical survey. The city was founded on the northern part of the peninsula towards the low hilly terrain with open valleys of the mainland; consisting of Neogene- Quaternary sediments. The research showed that the city was always in connection with the mainland through a narrow natural isthmus. Southwards the city a sand barrier was the diachronic connection of the city with the rocky (mica schists) hill of Molyvoti. It was created by the work of waves after the accumulation of clastic sediments (sands, gravel) over the paleorelief during the Holocene sea-level rise. This strip of land gradually isolated the inner part of a palaeo-valley from the open sea, forming a lagoon west of the city. Vibracoring along the west side of the sand barrier traced a continuous lagoonal paleoenvironment up to ~5000 BP. The sea level curve for the area indicates a diachronic proximity of the city to the sea. The Molyvoti Peninsula was surrounded on the east side by the sea, forming a shallow marine bay that gradually silted by the prograding Delta of Filiouris River and the subsequent coastline migration southwards.

THEME: S34 : GEOARCHAEOLOGY (IAG-WG)

ABSTRACT NUMBER: 375

## IDENTIFICATION AND STUDY OF LONG-TERM CULTIVATED SOILS IN SEMI-ARID ENVIRONMENT: CONSTRUCTION OF A PEDO-SEDIMENTARY AND GEOCHEMICAL REFERENCE COLLECTION (OASIS OF MASAFI, UNITED ARAB EMIRATES)

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The Masafi oasis, in ophiolitic al Hajar mountains (United Arab Emirates, Fujairah), has been excavated since 2007 in the framework of the French archaeological mission (Dir. S. Méry). Excavations have revealed an occupation spanning from the Iron Age to the late Islamic Period, structured on the exploitation of agro-pastoral products and copper. To understand environmental context and subsistence strategies, geoarchaeological test pits have been dug in the palm grove since 2014. While they have revealed cycles of cultivation and abandonment for the last 3000 years, the farming activities themselves remain poorly understood and the agrarian patterns need to be clarified.

The present study aims to improve our knowledge of ancient agrosystems by identifying new proxies in soils to 1- characterize phases of occupation versus abandonment, 2- estimate soil fertility, implementation and nature of soil enrichment products, and the impact of agriculture on soil resilience, 3- assess land cover, 4- detect paleo-pollutions linked with human activities. To this end, shallow test pits were dug in the current Masafi oasis in abandoned areas and in cultivated plots possibly representative of ancient agricultural landscapes: irrigated plots with palm trees, fruit trees or cereals; plots with manure, ashes, or carbonates. Systematic samples were taken for laboratory studies: elementary and isotopic analyses, loss on ignition, pH, electrical conductivity, magnetic susceptibility. Statistical analyses allowed for the creation of agricultural facies characteristic of agricultural modes.

This reference collection is a powerful analytical tool to study agrosystems as a whole, from socio-environmental dynamics (identification of cultivated soils and agrarian patterns) to technical systems (agricultural strategies, gestures and heritage). This will be applied to the study of the 3000 years old Masafi oasis, with the aim to enlarge its use to ancient agricultural soils in semi-arid environments in Arabia.

**Keywords:** oasis; agrarian geoarchaeology; soil analysis; elementary and isotopic geochemistry

THEME: S34 : GEOARCHAEOLOGY (IAG-WG)

ABSTRACT NUMBER: 387

## WHAT FIELD WORK AS “EXPERT KNOWLEDGE” BRINGS TO THE SOURCING STUDIES? CASE OF OBSIDIAN FROM NEMRUT VOLCANO AND ALATEPE VOLCANIC AREA. SESSION S34 GÉOARCHÉOLOGIE

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Obsidian sourcing is based on one fundamental principle which is the corresponding chemical signature between archaeological artefacts and geological sample due to the unique chemical signature of a volcano. Based on this principle artefacts can be attributed to a source or a volcanic complex to trace the contact between prehistorical populations. In order to answer precisely this question it is necessary to know precisely the location and the characteristics of the sources. But what if there is more than one vent on the volcanic complex or if there are more than one obsidian formation on the volcano? To be sure about the source, obsidian sample are needed and sampling has to be exhaustive. But it is also very important to know the context of outcropping to determine the accessibility, the extractability and the quality of the raw material. These criteria are best illustrated by the Nemrut case. During our investigation on the Nemrut volcanic complex we reveal the existence of a new obsidian outcrop which presents different characteristics from the other outcrops. Field work enhance this outcrop as the best candidate as a source on this volcanic complex. Occupation of the territory and preferential diffusion of obsidian from one source to another is illustrated by the Alatepe volcanic area case. Indeed, obsidian from Alatepe are known as obsidian from Bingöl B source which represent a vast area made of several dome with obsidian. These domes present each their own chemical signature. Our investigation enhance 1) the exploitation of two of the four domes (Zel tepe and Çilek tepe) and 2) obsidian from Zel tepe are preferentially in the lithic assemblage from eastern archaeological sites whereas obsidian from Çilek tepe are preferentially in the lithic assemblage from western archaeological sites, In Near East.

Keyword: field approach, obsidian sourcing, new method

THEME: S34 : GEOARCHAEOLOGY (IAG-WG)

ABSTRACT NUMBER: 390

## LATE HOLOCENE RELATIVE SEA-LEVEL CHANGE AND CLIMATE CHANGE IN THE NORTHERN ADRIATIC (CROATIA)

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The late Holocene is the most intensively studied period in palaeo-sea-level research. This research increased during last two decades along the eastern Adriatic as well. Sea level curves are obtained by using various methods and are based on different markers which are often combined. Those are primarily archaeological coastal remains as well as geomorphological and sedimentological markers. However, most of the methods used till now do not provide enough precision. As the studying period is short the error bars are often too large. In order to provide more precision and better accuracy of sea-level curves the latest research along the eastern Adriatic has been centred on algal rims as sea-level markers. Fossil bio-constructions on rocky coast have proven to be precise sea-level indicators in microtidal environments. Algal rims formed by alga *Lithophyllum byssoides* (Lamarck) Foslie allow us to study the relative sea level change with much more consistency and accuracy. Under favourable conditions *Lithophyllum byssoides* build reef like bioconstructions just above the biological mean sea-level which can be <sup>14</sup>C dated. Algal rims from different locations in the Northern Adriatic have been analysed. The obtained <sup>14</sup>C ages of algal carbonate samples have been further corrected for the marine radiocarbon reservoir effect. The obtained relative sea-level curve starts at the beginning of the 5th century when the relative sea level was  $-70 \pm 10$  cm below the recent mean sea level what confirms our previous findings obtained combining geomorphological and archaeological markers. We have also established a close link between relative sea-level change and periods of rapid climate changes during the last 1.5 ka. This research was supported by the Croatian Science Foundation (project no. HRZZ-IP-11-2013-1623, Reconstruction of the Quaternary environment in Croatia using isotope methods – REQUENCRIM).

**Keywords:** sea-level; algal rims; tidal notch, archaeological markers

THEME: S34 : GEOARCHAEOLOGY (IAG-WG)

ABSTRACT NUMBER: 455

## A GEOARCHAEOLOGICAL APPROACH OF THE RAINFOREST LANDSCAPE EVOLUTION UNDER PRE-COLUMBIAN IMPACT: THE EXAMPLE OF RING-DITCH SITES (MONTAGNES COURONNÉES) IN FRENCH GUIANA.

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It is now recognized that pre-Columbian human occupations have played a key role in modeling the Amazonian rainforest landscape. In French Guiana, only few studies were conducted to understand this ancient human impact. Inspired by studies in the Brazilian Amazon on Terra Preta, using a geoarchaeological approach to identify formation processes of pre-Columbian anthropogenic soils allows evaluating both ancient human activities and landscape modification associated with ring-ditch sites (Montagnes Couronnées). Such sites are widespread all over the French Guiana territory, but still lots of questions remain about their origin and use. They correspond to lateritic hilltop under tropical rainforest, surrounded by a circular excavated ditch (2 m x 2 m). The implementation of a combination of micromorphological observations, magnetic susceptibility and physicochemical analyses conducted on soils inside, outside the ditches, and on ditches infillings, enables to investigate both direct and indirect anthropogenic markers. This study reveals that the natural pedogenesis has been impacted by pre-Columbian activities as demonstrated by anthropogenic microtraces such as charcoals, pottery fragments, and heated soil aggregates originating by repeated surface burning as shown by magnetic susceptibility. Anthropogenic activities probably also contributed to the process of clay leaching via the presence of fire-induced ashes contributing to soil pH modification. In addition, the presence of micro-pedofeatures related to Pontoscolex corethrurus shows that pedofauna activity is linked to human actions. This work, pioneering for French Guiana, makes assumptions about pre-Columbian events that could have taken place in ring-ditch sites, such as fires episodes. Combining geoarchaeological methods allows differentiating domestic fires and fires related to cultivation or to clean the forest areas for new settlements. Micromorphological and physicochemical results permit to propose a spatial model of occupation, regarding the location of refuse areas behind the supposed houses and near the ditch.

**Keywords:** Amazonian Geoarchaeology; Micromorphology; Terra preta/Terra mulata; French Guiana

THEME: S34 : GEOARCHAEOLOGY (IAG-WG)

ABSTRACT NUMBER: 487

## INTEGRATING GIS, TRENCH MAPS, LiDAR AND ARCHAEOLOGICAL APPROACH FOR THE WWI LANDSCAPES SURVEY OF THE CHAMPAGNE FRONT (FRANCE).

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World War I (WWI) strongly marked the landscapes at the different theatres of war, especially along the 750 km Western Front in Belgium and France. In this contribution, a typology of landforms related to the WWI, the so-called "polemo-forms", is defined in the Champagne sector of the front (115 km long) and the degree of conservation of the landforms. The approach which we will present in this paper combines three different research methods. First of all the historical war landscape is mapped and analyzed with contemporary trench maps. Over 13,000 kilometers of trenches were mapped. This corresponds to an average density of 113 km of trenches per km of front. Secondly, the surface morphology caused by the war is studied, using high-resolution LiDAR dataset (8 to 12 points per m<sup>2</sup>). Automatic processing is carried out on these LiDAR data (100 km<sup>2</sup>) over three different substrates; the sandstone "gaize" of Argonne, the chalky Champagne and the Tertiary formations to the west of Reims. By using LiDAR it is possible to remove the tree coverage in the study area and investigate both the extent and the preservation of this vast conflict landscape and gain insights into the preserved vestiges in relation to their position within the defensive network. In the areas without tree cover most of the trench networks were leveled in the post-war years. The fields are now used by agricultures and LiDAR shows no surface features of the Great War. To investigate these areas archaeological excavations are carried out that uncovers the conflict archaeological traces of the Great

War, permitting a study of the sedimentary filling with cross sections and dynamic penetrometry. The conservation of “polemo-forms” depends on their classification in the post-war “red zone”, as well as the agricultural and silvicultural practices.

THEME: S34 : GEOARCHAEOLOGY (IAG-WG)

ABSTRACT NUMBER: 637

## HYDROLOGICAL AND SOCIO-ENVIRONMENTAL DYNAMICS IN SUBTROPICAL MAYA LOWLANDS: ALLUVIAL GEOARCHAEOLOGICAL APPROACH OF THE WETLANDS (BAJOS) AROUND NAACHTUN DURING THE LAST 4 MILLENNIUMS (PETEN, GUATEMALA).

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Our knowledge of regional climatic and societal changes arisen during the late Holocene in subtropical Maya lowlands has significantly changed over the last decades. In this study, the hydro-socio-system is in close proximity to Naachtun, a large Classic Period Maya city (AD 250-950), in geomorphological context of karst poljes wetlands named bajos. It represents a real laboratory to study the complexity of past diachronic local socio-environmental dynamics. How evolved water and soil resources under external drivers control, as climate and/or anthropogenic factors? Did environmental and societal changes (availability, use, management of these resources) result in socio-environmental crises for local populations? This study focuses on the last 4 millenniums and particularly the Classic Period Maya (AD 250-900), with the emergence, growth and decline of Naachtun.

The approach is systemic and multi-scaled, based on interdisciplinary works with geoarchaeological, geomorphological, paleoecological, geomatic and archaeological developments. Field works (boreholes, excavations) are associated with spatial analysis studies (LiDAR DEM analysis, spatial modelling), laboratory analysis [sedimentology, geochemistry, micromorphology, bio-indicators and geochronology]. It includes the characterization of current hydrosedimentary dynamics (actualism).

Results show that sedimentary records archived in the bajo “El Infierno” have a good potential for reconstruction of the past environmental and socioenvironmental dynamics: thickness, sedimentary facies variability (alluviums/colluviums), bioindicators content. The created model reveals multi-centennial evolutions of water balance and soils erosion within these wetland watersheds. During the last 4 millenniums, several fluctuations of lake level and of Maya clays sedimentation rates were reconstituted. Their climatic control (temperatures, rainfall patterns) and/or anthropogenic control (man’s pressure/land abandonment) is discussed. Paleogeographic consequences are modelled (spatial models). Socio-environmental implications in terms of resources managed by populations are analysed. During the Classic Period, the hydro-socio-system was changed for domestic and agricultural water use and it partially controlled the settlement and development of Naachtun.

**Keywords:** Hydro-socio-system; Wetlands; Subtropical; Mayas; Geoarchaeology

THEME: S34 : GEOARCHAEOLOGY (IAG-WG)

ABSTRACT NUMBER: 661

## NEOTECTONICS INFLUENCE ON BABADAG AND ENISALA SETTLEMENTS SINCE ANTIQUITY (SOUTHERN DANUBE DELTA)

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Danube delta and its neighborhoods have always been wanted locations to stay because of their natural richness as both space for living and as a food basket (e.g. fish, salt, wood). Yet, human communities had to continuously adapt to landscape and societal dynamics forged by fluctuating riverine water and sediment supply, frequent storminess or earthquakes, which repeatedly generated avulsions and deltaic lobes switching or accelerated coastal dynamics affecting the shoreline position, and multiple barbaric invasions. Such events are often invoked by hypothesis about lost settlements (i.e. documented by written texts or random and scarce archaeological findings) and sometimes called for settlements reorganization.

In this study, we address the case of Enisala and Babadag ancient settlements and the surrounding Babadag and Razelm Lakes formation and evolution and their impact on nearby human settlements. Geoscientific data (i.e. geophysical, sedimentological, stratigraphical, paleo- faunistic) together with recent archaeological findings since the Roman and Medieval period buried in recent sediments or submerged in lakes water and historical accounts report dramatic transformations of the deltaic landscape associated with local subsidence.

The high but time-varying rates of local subsidence are documented by both ERT which show limestone basement drowned ca. 25 m along a fault line (which generated and maintained the connection between Razelm and Babadag Lakes), and by cores showing multiple alternations between brackish and freshwater environments documented by specific faunistic assemblages and chronologies of the sediments archiving these changes as well as by the intense socio-economic activity documented mainly during Byzantine and Ottoman occupation (4th-17th centuries).

Our results show the manifestation of intensive subsidence was favorable to the maintenance of an open water surface (in front of Enisala) and consequently of the naval access, as well as the persistence of water bodies (lakes) since the Bronze Age when brackish conditions prevailed.

**Keywords:** delta evolution, subsidence

THEME: S34 : GEOARCHAEOLOGY (IAG-WG)

ABSTRACT NUMBER: 686

## CONTRIBUTIONS OF THE GEOMORPHOLOGY ON THE SPATIAL ORGANIZATION OF THE NEOLITHIC HYPOGEA : THE EXAMPLE OF "MARAIS DE SAINT-GOND"

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The valley of the Petit-Morin is renowned for being the first hydrographic capture described between two rivers at the beginning of the twentieth century. Due to this hydrographic capture, a swamp developed upstream of the Petit-Morin valley : the Marais de Saint-Gond. Nowadays, this area constitutes the interface between the chalky Champagne at the East, and the Tertiary formations at the West (Brie Champenoise). The catchment area of Marais de Saint-Gond (285 km<sup>2</sup>) owns numerous archeological sites of cultural interest on the face of the Ile-de-France cuesta and on its buttes. This small catchment area concentrates 120 hypogea on the 150 situated in the departement of the Marne (8 000 km<sup>2</sup>). These neolithic burial chambers, dug in the chalk, are the object of several multidisciplinary scientific researches. The aim of this contribution is to understand the spatial organization of hypogea, particularly within the catchment area of the Marais de Saint-Gond. A cartographic inventory of hypogea, plus a geomorphologic and geologic cartography associated to geological investigations and a modeling of the water table allow to reveal a specific spatial organisation of hypogea (hilltops and outcrops in the chalk, in the zone not saturated of the aquifer). The archeological excavations of hypogae, associated to topographies by photogrammetry valued by 3D diagrams, show a favourable geomorphological context (chalk bio-altered with flint, lack of slope formations and lack of landslides). Once we have identified all the factors occurring in the presence of hypogaea, an analysis multicriteria realized by means of the tool SIG allows to identify zones of interests and to propose a zoning of the archaeological potential of the region.

**Keywords:** Chalk; Neolithic; Hypogea; Geomorphology; Champagne

THEME: S34 : GEOARCHAEOLOGY (IAG-WG)

ABSTRACT NUMBER: 730

## RELATIVE SEA LEVEL CHANGES AND HUMAN OCCUPATION DURING HOLOCENE IN ABU DHABI, UNITED ARAB EMIRATES

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The Arabian Gulf is characterised by important sea level glacio-hydro-isostatic fluctuations during Late Pleistocene and Holocene. Between Late Glacial Maximum and 6 000 years BP, the Gulf basin is relatively quickly flooded, through an important post-glacial marine transgression. So far, researches has considered this sea level drop as globally homogeneous. However, coastline lateral geometry variations are much more complex, especially because of uplift processes and diapiric dynamic. Holocene human occupation of Western Abu Dhabi coastal areas remains still quite poorly known, in spite of archaeological survey and excavation programs. Reconstructing these coastline local variations become thus a key issue to characterize coastal palaeo-environments during Holocene and identify the spaces settled by human populations. In order to adress these issues and bring elements of response, we relate geological, geomorphological and archaeological data, by using ArcGIS10.1. A review of the archaeological sites of the region, allowed us to define the spatial and temporal indicators of human coastal occupation. On the other hand, a fieldwork has been conducted in specific coastal places, identifying coastal geomorphological landforms (beachrocks, beach ridges) as sea level indicators during Holocene. Selected samples were dated by <sup>14</sup>C AMS method. Crossing and relating all these data allow us to model relative sea level variations, comparing with the glacio-hydro-isostatic model of Lambeck, and determine the evolution of western Abu Dhabi coastline area and its human occupation through Middle to Late Holocene.

**Keywords:** UAE; Abu Dhabi; relative sea level changes; Holocene

THEME: S34 : GEOARCHAEOLOGY (IAG-WG)

ABSTRACT NUMBER: 772

## ENVIRONMENTAL CHANGES IN BACTRIA SOGDIANA AND MARGIANA (CENTRAL ASIA, AFGHANISTAN, UZBEKISTAN, TURKMENISTAN) FROM NEOLITHIC TO THE LATE BRONZE AGE : INTERACTION WITH HUMAN OCCUPATION.

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During the Neolithic and the Late Bronze Age, global climate changes involving a regional and local aridification. There is a consensus (Chen et al. 2008) to consider that in Central Asia the Holocene climate was dry at the beginning, wetter or less dry from early to mid-Holocene and moderately wet in the upper part of the Holocene. These rapid climatic events identified from many fossil sequences (Mayewski et al. 2004) had necessarily an impact on human occupation. However, the correlation between the abrupt collapse of civilizations and the shift to more arid conditions is clear for some authors (Cullen et al. 2000, Kaniewski et al. 2013) and less obvious for others (Knapp and Manning 2016). Our researches, done in the framework of the MAFTUR, MAFOuz-Protohistory, DAFA and MAFAC and MAFOUB on river changes in Uzbekistan (the Zerafshan river in the Bukhara Oasis and the Kara Su river near the archaeological site of Dzharkutan), Afghanistan (Balkh river in Northern Afghanistan), and Turkmenistan (Ulug Depe) demonstrate that due to avulsion process after a flood, or due to an earthquake or mass movement slopes, rivers can change their course in a very drastic way. In order to study the environment impact on human settlement between Neolithic and the end of the Late Bronze Age period, we need to consider that sedentary communities were strictly dependent on perennial rivers with permanent discharges for irrigation. Consequently, both phenomena should be considered: increase in aridity and drastic changes in the course of rivers before explaining any collapse by one cause.

**Keywords:** Geoarchaeology, Holocene, Fluvial Geomorphology, Tributary Migration, OSL dating

THEME: S35 GEOMORPHOLOGICAL HAZARDS AND RISKS (IAG-WG): RISK MITIGATION THROUGH NEW TECHNIQUES UNDER THE CHALLENGES OF ENVIRONMENTAL CHANGES

ABSTRACT NUMBER: 12

## MODELING OF MASS MOVEMENTS RISK AND ASSESSMENT BY GIS. CASE OF AIN EL HAMMAM AREA, BASIN OF TIZI-OUZOU,(ALGERIA)



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The Mass Movement risk is linked to the presence of an event or hazard which is the manifestation of a geomorphologic phenomenon but also to the existence of issues that represents all consequences or losses that can affect the environment (loss of life and damage to property, economic activity, livelihood, environment and heritage). These consequences are based on exposed elements and their vulnerability, frequently expressed in terms of damage degree; however, as it is often difficult to quantify a level of vagaries, only the susceptibility of land to morphogenic processes is analyzed.

In many related published papers, most authors discuss the landslide hazard but not the mass movement risk. They define the criteria, especially geotechnical and rheological but either natural or human criteria available to all.

In our study of risk assessment and its spatialization, we adopted the natural and human criteria, considering both terms of risk: hazard and vulnerability.

This study introduces a three-step approach to assess the risk of mass movements, combining several model of spatial analysis. At first, the two components of risk mass movements, hazard and vulnerability, are evaluated by a model of utility theory. This model evaluates each action potential  $A$  (all potential actions) according to a set of attributes and perspectives criteria  $i$ ,  $i = 1 \dots n$ , from  $g_i$  scales. The criteria are the environmental factors predisposing mass movements and risk environment elements (issues). In a second stage, the risk is appraised by the product of its two components. Finally, spacialization of mass movements risk is established by combining the susceptibility (hazards) and consequences (vulnerability) maps. The methods have been tested in areas of Ain El Hammam in the Neogene basin of Tizi-Ouzou (Algerian Tell).

**Keywords:** Mass movement, Modeling, Risk, Ain El Hammam, Algeria

*THEME: S35 GEOMORPHOLOGICAL HAZARDS AND RISKS (IAG-WG): RISK MITIGATION TROUGH NEW TECHNIQUES UNDER THE CHALLENGES OF ENVIRONMENTAL CHANGES*

**ABSTRACT NUMBER: 28**

## **CONTRIBUTION OF NUMERICAL MODELLING IN THE RISK MITIGATION IN BUJUMBURA / BURUNDI: CASE OF THE 'BANANA TREE' LANDSLIDE ALONG THE KANYOSHA RIVER**

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In Bujumbura, environmental risks have become a major challenge for the population and their effects are among the most devastating in terms of economic losses and human lives. In February 2014, more than 70 people were killed during floods associated with mass movements. Very often, people try to manage each disaster and they struggle for survival. However, risk mitigation focusing on the potential risk that may strike at any moment is important to preparedness and improvement of measures for risk adaptation. Thus, this study was conducted as a solution for risk assessment in order to reduce the effects of disasters on society. Results highlighted the city sensitivity to the consequences of a landslide commonly called 'the banana tree landslide' located in the surrounding mountains, on the south side of Kanyosha River. The study considered the situation of the city Bujumbura, straddling the western branch of the East African Rift and took into account the topographic configuration, the climatic context and especially the frequency of natural hazards. The first step was the landslide modelling using the Universal Distinct Element Code (UDEC). That highlighted scenarios related to the landslide triggering as well as its current state of stability and its evolution. Results also revealed that a landslide-induced dam may occur under some conditions. The second part of the study used those results to analyze the effects of the dam on the hydrodynamic behavior of the Kanyosha River and especially on the risk of flooding in the city of Bujumbura. We used WOLF software, a powerful device, including a physically based hydrological model, a 1D flood routing and a 2D shallow-water solver. Results are of a great interest to the population in general and policy makers in particular, especially for sites in a multi-risk environment.

**Keywords:** flood; landslide; rainfall; modelling; Bujumbura

ABSTRACT NUMBER: 40

## HUMAN INTERVENTION ON FLUVIAL HAZARDS: A CASE STUDY OF THE NAGAVALI RIVER ALONG THE RAYAGADA DISTRICT, ORISSA

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The Hathipahar near Rayagada Town, Orissa is a rocky waterfall and is famous for its scenic beauty. It is located in the upper catchment of the Nagavali River. A canal was digging unscientifically from the river to construct a dam as well as a hydel power project. On 3rd July, 2006 Hathipahar and its surrounding areas experienced a devastating flash flood due to heavy downpour. This flash flood created another opening of the Nagavali River through that canal in softer alluvium, leading to a sudden shifting of its course and huge loss of land of about 0.54 km<sup>2</sup>. The aim of the present study is to analyze the role of human intervention on aggravating fluvial hazards in the Nagavali river. For such analysis high resolution satellite data from Google Earth, Bhuvan image and SRTM DEM are used to demarcate the location and to detect the spatio-temporal changes of the river and its surrounding areas. Climatic and hydrological data have been collected from different sources and field survey has been carried out in order to record the present hydro-geomorphic scenario of the area. The length of the Nagavali River in the Hathipahar area is increased from 2.67 km to 2.87 km due to this hazard and the river is shifted 557.17m westward during 5 years period (2006-2011). The newly formed course is also possessing seasonal high stream energy and is very active in head-ward and valley bottom erosion. Bank erosion is still continuing along the Nagavali River during every monsoon season and it is extended up to 9.84 km upstream from the study area.

**Keywords:** Flush flood; Humans impact; Hilly topography; Course shifting; Bank erosion

ABSTRACT NUMBER: 93

## SIMULATION OF GEOMORPHIC PROCESS CHAINS IN MOUNTAIN AREAS: PROGRESS AND CHALLENGES

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Some of the most severe landslide disasters in history were related to process chains, where initial events high up in remote areas amplified through cascading –often involving water bodies such as glacial lakes– and entrainment of material, evolving into long-runout flows or avalanches of debris and mud. Even more than for “ordinary” landslides, the anticipation of possible future process chains –and the associated reduction of the related risks– remains a challenge (i) due to the low frequency or singularity of events; and (ii) due to threshold effects leading to a highly chaotic behaviour. Risk managers often rely on computer simulations.

Using the new GIS-supported two-phase flow model application r.avaflow for generic and real-world simulation experiments on process chains, we note the following:

-Generally, we arrive at a reasonable degree of empirical adequacy. We carefully conclude that model development has arrived at a stage allowing to simulate complex interactions of spatial processes, such as the impact of a landslide into a water body, from a physical point of view.

- Due to the large number of key parameters governing the processes, adequate parameterization remains a challenge.
- Interactions of landslides with lakes induce highly sensitive effects: small changes in the initial landslide volume and flow model parameters may decide whether dam overtopping and erosion occur, governing the occurrence, magnitude, and behaviour of a

process chain downstream.

- Consequently, using fixed values of uncertain parameters bears a high risk of being off target. It is therefore essential to consider scenarios or to statistically derive impact probabilities or indices, using combinations of parameter ranges instead of fixed values.

Future work shall be directed towards (i) further improvement of the physical concepts; and (ii) systematic sensitivity tests and simulation experiments aiming at the verification of physical plausibility and at the definition of guiding parameter values/ranges.

*THEME: S35 GEOMORPHOLOGICAL HAZARDS AND RISKS (IAG-WG): RISK MITIGATION THROUGH NEW TECHNIQUES UNDER THE CHALLENGES OF ENVIRONMENTAL CHANGES*

**ABSTRACT NUMBER: 263**

## **LAND USE/COVER AND CLIMATE CHANGE EFFECTS ON STREAMFLOW AND SEDIMENT YIELD: A CASE STUDY OF KAN BASIN, IRAN**

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In this study, we focused on quantifying both the combined and isolated impacts of LULC and climate changes on surface runoff and sediment. In the present study, to investigate climate change first three synoptic station in Karaj, Mehrabad and Dushan with SDSM model to predict the period of 2016-2045 was performed. And the impact of climate change on the hydrological conditions of the KAN basin with the help of SWAT model was simulated. The result of this study showed IN addition to confirmation of SDSM model in predicting and hydrological simulation model SWAT That in the future climatic conditions for the period 2016-2045 will be decreasing rainfall and increasing temperatures. The average rainfall is 545 mm in the current period. But in the forecast period, this amount has decreased to 251 mm. Evaporation rate in the current period is less than the forecast period, Its value in the current period 219 mm and 96.7 mm in the forecast period. Flow rate and surface runoff in the basin during the current period of 10/59 mm But the rate for the forecast period due to increased urbanization and changes in land uses was estimated at 27/21 mm. Given that land use and soil is the same for both periods so the curve number (CN) has not changed. The rate of sedimentation in the basin upstream in the current period over the forecast period from 0/02 to 0/01 has decreased. The results showed that, if all uncertainties are minimised, a well calibrated SWAT model can generate reasonable hydrologic simulation results in relation to land use, which is useful to water and environmental resources managers and policy and decision makers.

**Keywords:** change climate, sds, swat, curve number, land use/cover

*THEME: S35 GEOMORPHOLOGICAL HAZARDS AND RISKS (IAG-WG): RISK MITIGATION THROUGH NEW TECHNIQUES UNDER THE CHALLENGES OF ENVIRONMENTAL CHANGES*

**ABSTRACT NUMBER: 323**

## **THE LANDSLIDE OF AGRIGENTO HILL CASE HISTORY: DATA COLLECTION AND ANALYSIS**

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Usually earth scientist assess landslide by means of fieldwork observation, investigation of aerial images and geotechnical data analysis. In order to evaluate the impact of landslide also studying of historical records and data is necessary. Unfortunately, both investigation fieldwork and historical data are different in structure and spatial density and for this reason, it is difficult to compare them directly. The aim of this paper is to reconstruct the landslide phenomenon, occurred in the northern side of the Agrigento hill, by combining of the results of recent investigations and of the historical data. The Agrigento hill is made up of a typical Plio-Pleistocene marine transgression, in which are recognizable clays of the M. Narbone formation, calcarenites, sands and clayey sands of the Agrigento formation. Since 1315, the landslide have involved periodically the calcarenites on which, the ancient Cathedral (11th Century) and other buildings of historic interest built. On March 7, 2005 this quiescent landslide was activated producing a systems of cracks both in the calcarenitic rocks foundations and in the historical structures. In the last decade in order to stabilize, the landslide and preserve the cultural heritage was conducted several studies, which have used different investigation techniques (interferometric, aerial and satellite images analysis, geognostic and geo-physical surveys, etc.). We compared and joined the data derived from these studies in order to obtaining a geological model of the area and classifying the landslide movement in accordance with the new update of the Varnes classification of landslide.

**Keywords:** landslide; cathedral; Agrigento; cracks; data

ABSTRACT NUMBER: 331

## GEOMORPHIC EFFECTS OF EXTREME FLOODS ON RIVER CHANNELS: THE SEPTEMBER 2015 EVENT IN THE NURE RIVER CATCHMENT (NORTHERN ITALY)

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The occurrence of large floods leads to sudden channel changes, determining damages and casualties in inhabited areas. Post-event campaigns documenting channel changes and linking them to hydrological and morphological factors bear enormous value for the scientific community and river management agencies.

This study analyses the geomorphic response of the Nure River (catchment area 467 km<sup>2</sup>) and 9 tributaries to a high-magnitude flood, which occurred on September 2015. Spatial distribution of rainfall showed that highest intensities were located in the upper sectors of the catchment. The unit peak discharge in the middle sector of the Nure was 8.82 m<sup>3</sup> s<sup>-1</sup> km<sup>-2</sup> and ranging between 5.2 and 25 m<sup>3</sup> s<sup>-1</sup> km<sup>-2</sup> in the tributaries. Return period exceeded 300 years.

The multi-disciplinary approach encompassed: (i) hydrological and hydraulic analysis; (ii) analysis of sediment delivery to the channel network by means of landslides mapping; (iii) assessment of morphological modifications of the channels, including both channel width (multi-temporal orthophotos) and bed elevation (by comparing pre-event topographic and post-event LiDAR cross-sections).

Results show that widening was the most important effect, particularly evident in channels with narrower initial width. In fact, in the tributaries, the ratio between post-flood and pre-flood width averaged 3.3, with a maximum approaching 20. In the Nure, the ratio was < 5. Bed elevation variation was 0.9 m on average, with a maximum value of 2.5 m.

Planimetric and elevation changes showed a good correlation, mainly due to the fact that reaches affected by higher sedimentation were also those featuring intense widening. Statistical analysis on the relationship between widening and both morphological and hydraulic controlling factors indicates that unit stream power and confinement index were the most relevant variables, whereas sediment input seems to have a localized influence.

**Keywords:** flash flood; channel widening; lateral confinement; unit stream power

ABSTRACT NUMBER: 474

## GEOMORPHOLOGICAL APPROACH FOR HAZARD ANALYSIS OF SINABUNG VOLCANO ERUPTION IN KARO NORTH SUMATRA INDONESIA

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Sinabung Volcano in Karo North Sumatra is one of active volcano in Indonesia. The eruption that occurred on August 29, 2010 was the beginning of the re-appearance of volcanic activity of Sinabung after 1600. Sinabung Volcano erupted again in September 2013 until now that has not stopped its activity. The research objectives are to analyze the characteristics of eruption hazard of Sinabung Volcano based on geomorphological approach and to map the distribution of the characteristics of eruption hazard of Sinabung Volcano.

The geomorphological characteristics were analyzed based on satellite image interpretation, geological map interpretation, and field survey. Delineation of landform unit and data analysis used Geographic Information System (GIS). Characteristics of volcanic eruption hazard were analyzed based on geomorphological characteristics because volcanic eruption is one of geomorphological process. Moreover, the research results were analyzed as descriptively and spatially.

The results show that the eruption hazard characteristics of Mount Sinabung consist of primary and secondary hazards. The primary

hazards of eruption of Mount Sinabung include the flow of pyroclastic (hot clouds), the fall of pyroclastic (volcanic ash and rocks), and lava flows. The main danger threatens the southern, southeastern and southwestern regions of Mount Sinabung. Meanwhile, the secondary danger of volcanic eruption of Sinabung is the lava flow along the Lau Borus River. Moreover, the distribution of the characteristics of eruption hazard of Sinabung Volcano was illustrated on hazard map of Sinabung eruption.

**Keywords:** eruption; hazard; volcano; geomorphology; Sinabung

*THEME: S35 GEOMORPHOLOGICAL HAZARDS AND RISKS (IAG-WG): RISK MITIGATION TROUGH NEW TECHNIQUES UNDER THE CHALLENGES OF ENVIRONMENTAL CHANGES*

**ABSTRACT NUMBER: 480**

## **INTEGRATED APPROACH TO ASSESS VULNERABILITY AS A MEANS TOWARDS QUANTIFYING LANDSLIDE CONSEQUENCES AT A NATIONAL LEVEL (ROMANIA)**

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Vulnerability and consequence assessments are meant to contribute to disaster preparedness and damage prevention. At the same time, they can support decision makers in identifying risk management capabilities and the necessary priorities for risk reduction. With the aim of strengthening risk prevention and management in Romania, the RO-RISK (Disaster Risk Evaluation at a National Level; 2016) project focused on assessing the main hazards and risks occurring on the Romanian territory, including landslides. This paper presents the approach used within the project in order to assess various types of direct and indirect vulnerabilities as a means towards achieving national-level quantifications of landslide consequences. From the multitude (40) of landslide hazard scenarios designed in the frame of the project, based on probability and impact criteria, two precipitation-driven landslide hazard scenarios also incorporating expected future environmental changes were prioritized for an in-depth assessment of vulnerability and consequences. Landslide vulnerability was assessed by integrating the different perspectives specific to social, environmental as well as natural science communities. This allowed to develop several assessment phases: estimation of intrinsic vulnerability classes based on a set of socio-economic indicators; identification of hazard-specific vulnerabilities, incorporating exposure; quantification of the degree of loss using recent historical information on landslides-induced damages. The latter stage was needed in order to derive first estimations on the locations and levels of expected consequences on population, built-up environment and transportation network. The methodology also allowed for the integration of expert-judgment interpretations and refinements of results. The obtained national-level vulnerability and landslide consequence maps associated to the selected scenarios allow for comparisons among the various country regions and municipalities and the identification of those most needing prevention measures for reducing future landslide risk. Results achieved are expected to serve the decision-making process in landslide disaster response and management.

*THEME: S35 GEOMORPHOLOGICAL HAZARDS AND RISKS (IAG-WG): RISK MITIGATION TROUGH NEW TECHNIQUES UNDER THE CHALLENGES OF ENVIRONMENTAL CHANGES*

**ABSTRACT NUMBER: 761**

## **LANDSLIDE RISK ZONING AT A MACRO SCALE USING ANALYTICAL HIERARCHICAL PROCESS**

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In the present world, countries are becoming more pro-active towards mitigating disaster risk, as reflected in Sendai declaration which aims to reduce risk substantially by 2030. Estimation of risk, thus becomes an important component in disaster risk mitigation. In this paper a qualitative model for estimation of landslide risk on a macro scale (1:50,000) for 400 sq. km area in Mandakini valley of Higher Himalayas is presented. Risk is estimated for elements at risk (EatR) located in both initiation zones and run-out paths of potential landslides. For landslide hazard assessment the following information was derived: (1) landslide susceptible initiation zones, obtained using landslide inventory up to 2012, (2) landslide susceptible runout zones, obtained by integrating slope-facet and susceptible initiation zones, (3) temporal probability estimated using mean recurrence of landslide incidences for a 5-year time period, and (4) landslide domain, zoned using landslide types, geology and geomorphology. The vulnerability of EatR was subjectively

assessed in different landslide domains based on limited historic incidents. A qualitative estimate of a landslide hazard was obtained by heuristically combining landslide susceptibility and temporal probability in a 1 km × 1 km grid. The direct specific risk to properties were calculated using Analytical Hierarchical Process by considering hazard (ranked based on frequency of landsliding), EatR (ranked on the vulnerability in terms of construction/restoration costs) and landslide domains (used as proxy to vulnerability and ranked depending upon their ability to create damage to elements). The results indicate that about 1.4% area comes under high, 18.6% under moderate and 80% under low risk zone. The risk model could successfully validate about 60% of the damages inflicted to buildings and roads during 2013 landslide event. The presented model can be used as an optimal technique for macro scale landslide risk mapping in Himalayas.

**Keywords:** Landslide domains, Risk, Mandakini valley

THEME: S36 : GEOMORPHOSITES AND GEOTOURISM (IAG-WG)

ABSTRACT NUMBER: 27

## SUSTAINABLE CULTURAL HERITAGE THROUGH ENGAGEMENT OF LOCAL COMMUNITIES PROJECT (SCHEP), WADI RUM, JORDAN: A TRAINING PROGRAM ASSESSING GEOLOGIC STABILITY OF ROCK ART AND GEOTOURISM MANAGEMENT

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A UNESCO World Heritage Site, Wadi Rum (Jordan) hosts outstanding natural and cultural landscapes replete with sandstone monoliths, arches, sand dunes, fossils, Nabataean ruins, Bedouin culture, and petroglyphs/rock inscriptions spanning millennia. While tourists visit Wadi Rum for its geology and ties to Lawrence (of Arabia), the last several years has seen a growing interest in other cultural sites, including the thousands of rock art (petroglyphs) panels scattered within and outside the WHS boundaries. This project, funded through USAID and ACOR (American Center for Oriental Research), focuses on creating a long-term, sustainable tourism system, run by local staff of the Wadi Rum Protected Area. The project trains local heritage professionals in Wadi Rum how to recognize, evaluate, and record specific rock decay forms using the Rock Art Stability Index (RASI), enter those data into a GIS (for in-depth analyses by the site manager), and perform related photogrammetry to both document sites and establish a baseline for future photogeomorphology assessments. Experts in these techniques and methods puts commercial off-the-shelf GIS and mobile data-collector solutions in the hands of local Wadi Rum managers, and takes the first steps in creating a high-resolution database of the truly vast rock art and epigraphic heritage in Wadi Rum that will complement the national-level Mega Jordan GISystem. This presentation reviews the Project's rationale, evaluates its outcomes since implementation in spring 2017, and assesses the first-ever integration of RASI, GIS, and photogeomorphologic applications in a high-profile World Heritage Site.

THEME: S36 : GEOMORPHOSITES AND GEOTOURISM (IAG-WG)

ABSTRACT NUMBER: 60

## GEODIVERSITY AT THE CHAPADÃO DO DIAMANTE AREA. A RICH HYDROLOGICAL GEOMORPHOSITE REGION IN MINAS GERAIS STATE - BRAZIL

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The Chapadão do Diamante is the eastern part of Serra da Canastra Fold Bels which is located in the southwestern portion of the State of Minas Gerais (Brazil) reaching altitudes up to 1500 meters above sea level, with cliffs with up to 350 meters of height and encompassing the springs of 2 large hydrographic basins, São Francisco and Paraná. The structural arrangement is associated with pre-Cambrian folds, having as main rocks quartzites and phyllites, strong presence of lineaments and cliffs. The process of evolution of the relief in this area generated a set of geomorphosites associated with the presence of waterfalls, lookouts and rocky outcrops. An evaluation of the geodiversity values was applied to the geomorphosites, where were found 33 waterfall (hydrological geomorphosite), demonstrating that there are differences between the typologies of falls when evaluating the position of each waterfall and its association with rocky typology. Also a few numbers of others geomorphosites were found, as river sources and lookouts. The geotourism is not very important in the area, despite the great potential of geomorphosites, due to the great isolation of the area, which is far from large population centers and difficulties of access by the low road network and part of the waterfalls are located in the interior or in the border of Serra da Canastra National Park, which has access restrictions. With the increase of the visitation activities in the last two decades,

some points with greater visitation were consolidated: the Casca d'Anta Cachoeira, with more than 180 meters of fall, the historical source of the São Francisco River, the Cerradão Waterfall and Serra Brava viewpoint as well as two sites with stone buildings: Garagem de Pedra and the Curral de Pedra, as vestiges of the former pastoral occupations.

**Keywords:** geodiversity, geomorphosites, waterfalls, Serra da Canastra, Brazil

THEME: S36 : GEOMORPHOSITES AND GEOTOURISM (IAG-WG)

ABSTRACT NUMBER: 133

## MAN MADE LANDSCAPE ON THE ISLAND OF USHANT, FROM THE LATE BRONZE AGE TO PRESENT

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The island of Ushant at the western most extreme of continental France has been settled since the late bronze age (about 800BC) and human impact has, from that moment on, been so important that the present coastal landscape may be considered, at least locally, as a man made feature. This paper will show how the building of fish traps and quays has modified the extension of storm surges and the effects of long shore drift as early as 2890 BP. The studied sites, all along the island coasts display the impacts of these ancient man made structures with various intensities. The most intense of these ancient impacts are compared with present impacts of tourism. As the island is included into a protected area, the present impacts are less considerable than the ancient ones.

**Keywords:** coasts, human-impact, Bronze Age, present, Ushant

THEME: S36 : GEOMORPHOSITES AND GEOTOURISM (IAG-WG)

ABSTRACT NUMBER: 139

## CLASSIFICATION AND GEO-CODING OF GEOMORPHOSITES IN INDIA

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In the Indian subcontinent, diverse geological and geomorphological features of geoheritage significance occur due to remarkable differences in the rock types, ages, tectonic styles and geomorphic processes. Some of the features are of global importance, such as the Lonar Meteor Crater, the Western Ghat Escarpment, the Ganga-Brahmaputra Delta, the Leh Valley, the Siachen Glacier, the Kosi Megafan, the Rann of Kachchh, etc. Instead of using the oft-adopted ranking or scoring method for the assessment and classification of geomorphosites, a simple ten-digit geo-coding system has been applied to some of the numerous oft-visited geomorphosites in India. The geo-coding system is a simple numerical scheme based on nine criteria, namely geomorphic province, rarity/abundance, scientific/intrinsic value, additional value, integrity, accessibility, potential threat and management, the geomorphological diversity and the dominant geomorphic process (IUCN's themes). The adopted coding system has the potential to easily identify or sort geomorphosites on the basis of a single or multiple criteria. It is suggested that a similar coding system should be adopted for all the globally significant geomorphosites for the benefit of students, teachers and researchers as well as geo-tourists interested in natural wonders.

**Keywords:** geomorphosites, geoheritage, classification, geo-coding, India

THEME: S36 : GEOMORPHOSITES AND GEOTOURISM (IAG-WG)

ABSTRACT NUMBER: 162

## THE UPHILL EXPERIENCE OF NOMINATING A LANDSCAPE OF WORLD HERITAGE

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Using my 10 year experience in setting up and defending a UNESCO World Heritage geological nomination, this presentation aims

to give a personal insight into this international process and the differential use of science, subjective perception (aesthetic and 'naturalness'), and politics. At this point in the process, new protocols have been tested in order to improve the dialogue, accountability and transparency between the different stake-holders. These are, the State parties, the IUCN, the scientific community, and UNESCO itself. Our proposal is the Chaîne des Puys - Limagne fault ensemble, which illustrates a complete rifting process through its different morphologies. The project's essence is a conjunction of inseparable geological processes, underpinned by continental rifting. This unique concentration of diverse forms that reflect processes, creates the value of the site. From the start, we proposed a combined approach, where a property is seen in its entirety, and the constituent features seen as interlinked elements reflecting the joint underlying phenomena. The UNESCO committee in 2016 re-referred the nomination, acknowledging the potential Outstanding Universal Value of the site and requesting the parties to continue the upstream process (i.e. collaborative work, including an unprecedented independent technical mission). Meetings with the IUCN are continuing as our challenge is to find the right balance between sound science and World Heritage language, being able to determine what this concept of heritage refers to.

**Keywords:** World Heritage, UNESCO, Chaîne des Puys – Limagne Fault, upstream process

THEME: S36 : GEOMORPHOSITES AND GEOTOURISM (IAG-WG)

ABSTRACT NUMBER: 234

## THE IMPORTANCE OF DETAILED GEOLOGICAL AND GEOMORPHOLOGICAL MAPPING FOR THE MANAGEMENT OF TOURIST AREA: CASE STUDY OF A NATURAL RESERVE OF EMILIA APENNINES (NORTHERN ITALY)

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This paper shows the results of a detailed geomorphological research carried out in the Natural Reserve of Salse di Nirano which is located in a low hill territory of the Modena Apennine margin about 30 km from Modena (northern Italy). The Natural Reserve of Salse di Nirano, instituted since 1982, hosts one of the best developed and largest mud volcano field of the entire Italian territory and among the largest in Europe. The area where the Nirano mud volcanoes are located was called "the beautiful place", due to the high aesthetic value of hilly landscapes forming the foothills of the Apennines. For its global scenic value this area represents a tourist attractiveness as testified by the increasing number of visitors and tourists in last decades (70,000 visitors in 2016). Beside this, from a geomorphological point of view, the area is also characterised by active, historically well-documented, mud volcanoes and different geomorphological hazards - mainly landslide and flash- floods - may threaten the safety of visitors and tourists. In particular, fast-occurring processes may involve directly tourists in proximity to the sites of interest or affect indirectly access roads and footpaths.

In this context, the detailed and updated geological and geomorphological map presented in this paper, represents a useful tool both for land-use planning and management and for its popularisation and communication. Updated maps were carried out within a study funded by the local municipality, aiming at analysing the effects of mud-volcanoes activity from a multi-disciplinary point of view, highlighting triggering mechanisms of these geological phenomena in the Natural Reserve of Nirano.

**Keywords:** Geological and Geomorphological Mapping, Geotourism, Geomorphological Heritage, Protected area, Italy

THEME: S36 : GEOMORPHOSITES AND GEOTOURISM (IAG-WG)

ABSTRACT NUMBER: 298

## GEOMORPHOSITES ASSESSMENT FOR THE DEVELOPMENT OF GEO-TOURISM IN NORTH AND MIDDLE ANDAMAN'S, INDIA

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Andaman and Nicobar Islands are well known Historical and Ecotourism destination. Cellular jail, reminiscent of the old British regime in Ross island, ruins of a gallows in Viper Island, clear blue seas, coral reefs, swaying palms, tropical forests, volcanic mountains and gently undulating landscape. The islands offer exciting historical and ecotourism sites with natural and cultural settings. But these islands have much more to offer i.e. numerous geomorphosites like mud island and limestone caves in Baratang. Living volcano at Narkondam island and many more. Indian government is now focusing on to develop these islands as maritime and tourist hub and



in 2016 10,000 crore Rs plan was prepared for the transformation of these islands. The islands are eco sensitive, seismically unstable and vulnerable too therefore experts suggested that any plan have to be undertaken after geomorphosites assessment which not only includes assessment of their scientific, cultural, aesthetic and social/economic values but the impact on environment and finally to protect them under a legal framework. Geomorphosites assessment is an emerging area in India. In the present study evaluation card develop by Reynard in 2006 is used for geomorphosite assessment of different sites located at North and Middle Andaman. This study also provides an insight about how geomorphosites assessment can contribute to the development of geo-tourism. The geomorphosites assessment not only highlight the scientific value of a geomorphological landform but also develop the methods and techniques that permit the transfer of scientific knowledge to a larger public (scientific mediation) looking at the tourists' needs.

**Keywords:** Geomorphosites, Geo-tourism, Geomorphological landscape

THEME: S36 : GEOMORPHOSITES AND GEOTOURISM (IAG-WG)

ABSTRACT NUMBER: 396

## INTEGRATING GEOLOGICAL AND INDUSTRIAL HERITAGE FOR THE REHABILITATION OF DISMISSED QUARRY AREAS IN THE NORTHERN APENNINES, ITALY

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The purpose of this paper is to discuss the relationships between the geological and industrial heritage of the Rio della Rocca valley (Northern Apennines, Italy), taking into account the impact of raw material exploitation on the geological environment.

The study area is located at the foothills of the Apennine chain and is characterized by the presence of two main lithologies showing different geo-mechanical behaviour (sandstones and clays) that have determined a great variety of landforms and a high scenic landscape value, as well as a significant economic interest for their suitable technological properties.

Quarrying activity has deeply modified the pristine landscape of the Rio della Rocca catchment. Between the end of 1950s and the beginning of the 1960s clay pits were exploited, in order to satisfy the needs of the nearby tile making district of Sassuolo, the largest in the world. In the 1970s also sandstone quarries were widely exploited for building purposes. Today, dismissed quarries left untreated make the area degraded and rather unsafe due to the state of abandonment.

However, former quarries can be considered as elements of the geological and industrial heritage reflecting the productive/industrial history of the country. As an added value, in many cases, quarries host valuable habitats and constitute important ecological refuges.

Based on the recognition, selection and enhancement of the most significant features, a community Masterplan aiming at the territorial upgrading of the valley has been proposed. In this context, a preliminary action consisted in the enhancement of geological and industrial heritage through a geotourist trail connecting sites of remarkable geological interest with areas witnessing notable evidence of past industrial activities.

**Keywords:** geological heritage; industrial heritage; quarries; Northern Apennines; Italy

THEME: S36 : GEOMORPHOSITES AND GEOTOURISM (IAG-WG)

ABSTRACT NUMBER: 471

## THE PLACE OF THE GEOMORPHOSITES IN THE INVENTORY, THE PROTECTION AND THE VALORIZATION OF THE GEOHERITAGE IN THE AUVERGNE-RHÔNE-ALPES REGION (FRANCE).

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In accordance with the focal theme of the ICG 2017 dedicated to the relationships between geomorphology and society, this presentation aims to assess the place and role of geomorphological sites in the inventories and the actions of protection and valorization of the

geoheritage of the Auvergne-Rhône-Alpes Region. The choice of this Region, which extends over four physiographic domains - Massif Central, Saône-Rhône Valley, South Jura and Alps - is justified by its great richness in geodiversity and in geoheritage sites, with more than 450 sites selected in the National Geological Heritage Inventory.

This work is derived from a more general study, founded by the Ministry of Environnement local delegation, to assess the state of play of the geoheritage inventories, as well as the state of the protection and the valorization (for educative and geotouristic purposes) existing in the Auvergne-Rhône-Alpes Region. The research is based on the statistical processing of inventories data and on representative case studies using surveys. The results show the great importance of geomorphosites as a type of geological site in the inventories: at least a quarter of the Auvergne-Rhône-Alpes' geosites present in the National Geological Heritage Inventory are listed as sites of main geomorphological interest. This ratio is increasing if we consider the geosites presenting a secondary geomorphological interest, or those which the main geological interest embeds a geomorphological aspect (e.g. volcanism). The study aims also to highlight the specificities of the inventoried geomorphosites in regards to the issues of protection (scale effects, landscape stakes, types of protection status) and of their valorization (e.g. landforms used as scenic gateway to introduce the geoheritage to the public). These results should make consider geomorphosites a real asset and a lever for sustainable territorial development.

**Keywords:** Geomorphosite; Inventory; Protection; Valorization; Auvergne-Rhône-Alpes Region

THEME: S36 : GEOMORPHOSITES AND GEOTOURISM (IAG-WG)

ABSTRACT NUMBER: 545

## MAPPING GEOHERITAGE ON THE OFFICIAL ITALIAN GEOMORPHOLOGICAL MAPS: A PROPOSAL FROM THE ITALIAN SCIENTIFIC COMMUNITY

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At an international level there is currently a great variety of geomorphological legends which differ one from the others in their content, adopted symbols and scale of representation, since a single, universally recognized legend has not yet been implemented. Similarly, there are also numerous examples, at an international level, of thematic maps concerning geomorphosites, especially directed to a public of non-specialists.

Recently the Italian Association of Physical Geography and Geomorphology (AIGeo) is undergoing the revision of the official Italian geomorphological legend at different scales. Within this framework, the AIGeo Working Group "Geomorphosites and Landscape" is dealing with the proposal for the inclusion of geomorphosites in the official geomorphological maps at 1:50000 scale covering the entire Italian territory. The AIGeo Working Group on Geomorphosites puts in evidence the importance of indicating, on the official geomorphological maps and, in particular, on documents used for territorial planning, those landforms assessed as geomorphosites.

The innovation introduced with this methodological proposal just concerns mapping geomorphosites in the official geomorphological documents and the novel method for their representation. Being the process of surveying and assessment of these landforms more exposed to subjectivity, the criteria followed by operators for geomorphosites selection must be made clear and reported in proper illustrative notes associated to the official geomorphological maps.

The effectiveness of the methodology is going to be tested by means of cartographic essays by several researchers of the Working Group, coming from different Italian Universities (Milano, Trieste, Modena, Genova, Urbino, Roma, Sannio, Napoli, Cagliari, Sassari). The essays cover most of the morphogenetic and morphoclimatic contexts of the Italian territory, mirroring its significant geodiversity. The purpose is to verify and validate the methodology facing the complexity of many different typologies of landforms and highlighting its strengths and weaknesses in order to improve it.

**Keywords:** Geomorphosites; Mapping; Italy

THEME: S36 : GEOMORPHOSITES AND GEOTOURISM (IAG-WG)

ABSTRACT NUMBER: 623

## GEOMORPHOLOGY AND GEOHERITAGE PROMOTION ISSUES IN SEORAKSAN MOUNTAINS, KOREA

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Seoraksan is a mountain massif in the Republic of Korea, located in the north of the country, overlooking the Japan (East) Sea. Peaking at 1708 m a.s.l., it is a very steep terrain, with slopes typically exceeding 30°. Seoraksan is built predominantly of granite and metamorphic rocks which support distinctive, and different from one another, assemblages of landforms. Cretaceous granites in particular are associated with spectacular morphology, including domes and vertical, joint-bound serrated rock ridges, massive boulder accumulations resultant from rock slope failures, fluvial gorges, slot canyons and waterfalls. The latter landforms point to vigorous fluvial erosion, apparently as a response to geologically recent uplift. Other granite variants produce widespread block fields and blockslopes. Thus, Seoraksan represents a high-relief mountain morphology that has developed without a contribution of glaciation. The role of extreme meteorological events is significant in the current shaping of the mountains, with widespread debris flow deposits in the valley floors. These events often cause damage to tourist infrastructure. Seoraksan is a popular tourist destination and a system of trails crosses the highest parts of the range. In the past an application to the Global Geopark Network was considered, whereas the mountains are also on the UNESCO World Heritage tentative list. Scientific and scenic values of the area create excellent opportunities to add educational multi-theme geotourist component, barely present now, to the already existing tourism. Critical issues to consider are selection of localities to develop educational geotourism, acceptable level of intervention while erecting interpretation facilities in the field, and safety of visitors in the highly unstable terrain.

**Keywords:** Geoheritage; granite geomorphology; geotourism; geoeducation

THEME: S36 : GEOMORPHOSITES AND GEOTOURISM (IAG-WG)

ABSTRACT NUMBER: 668

## GEOMORPHOSITES OF KACHCHH: AN APPROACH FOR GEOTOURISM IN WESTERN INDIA

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The landscape of Kachchh in Western India is an asset for those who study dynamics of geomorphology and arid to semi-arid landscape processes. It is a collage of non-orogenic, block-faulted and residual hills, ranges, pediments, bajadas and vast Quaternary plains with salt marshes. The uplands are rugged hilly terrain with thin vegetation, exposing the Mesozoic rocks bordered by thin strips of gently dipping Cenozoic rocks, which form the rocky coastal plains. The lowlands are extensive plains, alluvial or mud and salt flats (Rann) and grassy flats (Banni). The geomorphology of Kachchh is a result of long geological processes viz. basin formation during Gondwana rifting, deposition of Mesozoic sediments during northward and anticlockwise movement of Indian plate, volcanic eruption (Deccan Traps) at the end of Cretaceous. Cenozoic period is characterized by both open sea sedimentation and slow uplift of the rift sediments forming the first order topography of the basin. Quaternary climate, tectonics and eustatic sea level changes resulted landscape into its final order. The present paper highlights genetically and academically crucial geomorphic features of active intra-plate geological basin. We tried to portray Kachchh basin as an inimitable geomorphic segment with textbook type tectono-geomorphic units. The basin is a vital field treasure for dynamics of geomorphology that needs a legal, political and academic authenticity for the protection for future generations. Further, the terrain would also be a source of income for the regional government if projected as geotourism hotspot in the western India.

**Keywords:** marshes; tectono-geomorphic; academically crucial; Kachchh

THEME: S36 : GEOMORPHOSITES AND GEOTOURISM (IAG-WG)

ABSTRACT NUMBER: 790

## GEOMORPHOLOGY AND GEO-HERITAGE OF EAST KAZAKHSTAN

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Opposite to general cultural heritage awareness, national conceptions of geo-heritage aimed at preservation of unique landscape forms and geological formations of particular countries is still a relatively new trend. The Republic of Kazakhstan, situated in the North of Central Asia, inspires attention due to its varied, World-unique relief. The territory of East Kazakhstan belongs to most picturesque and physiographically diverse with a complex Quaternary history reflected by intensive geomorphic processes related to the past climate evolution in conjunction with the regional orogenic activity. Marked environmental shifts are evidenced by well-preserved palaeo-landscape forms in mountain, steppe and semi-desert regions, and by sedimentary geology, palaeoecology and geoarchaeology records. Spectacular mountain valley glaciofluvial terraces indicate presence of extensive ice-dammed lakes subjected to cataclysmic drainages during the final deglaciation being most dramatic geomorphic processes in the latest Earth' geological history. The region is also known for rich archaeological places dating back to the Pleistocene. The cultural sites are often associated with extraordinary landscape forms (prehistoric rock-art, deep canyons with ritual archaeological sites, etc.). The recently uncovered localities bear witness of the Palaeolithic inhabitation and adaptation to local environments. The most eloquent monuments are linked to the Bronze Age and the early historical times. The latter are best-represented by stone-laid royal burial mounds sealed in permafrost, isolated ritual structures, and rock-engraved petroglyphs assigned to the Scythian Period (6th – 2nd Centuries BC), being the most famous of this region as a part of the UNESCO World cultural heritage. The geographic distribution of the archaeological sites shows a broad topographic range (500-3000 m asl) of previously occupied landscapes. All these geo-sites have major potential not just for scientific research, but primarily for the national geo-heritage promotion programs.

**Keywords:** East Kazakhstan; geomorphic diversity; geo-heritage; early cultural monuments

THEME: S37 : DANXIA GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 41

## ANALYZING SURFACE CHANGES OF BADLAND SEDIMENTS DURING WEATHERING: A NEW APPROACH USING IMAGE ANALYSES

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Weathering is a process during which chemical, physical and mineralogical properties of rocks exposed on the surface of the Earth are altered. Weathering processes can be studied both in the field and laboratory conditions. The aim of this paper is to show how image analyses can be used to determine the disintegration process of a sediment sample that undergoes dominantly physical weathering process. In this study the possibility to use different parameters that can be obtained from the photographs and determine the change in size and shape of fragments during the weathering experiment were explored. An unweathered sample of clay-rich badland material was put on a tray on the building roof to provide natural conditions. Experiment lasted for 140 days and photographs of sample were taken every day under same conditions. Colour photographs showing the decomposition of sediment sample were used. In this way prepared images were processed in the program Image-Pro Plus 6.0. Manual selection of Region Of Interest (ROI) was performed, using the Count and Measure tool. Segmentation, performed in this way, differs from image to image and it was therefore necessary to proceed to the manual refining of selected areas. Finally, the counting and analysing the size (mm scale) and shape of fragments was conducted. Obtained results showed that image analyses proved to be a very useful tool for studying sediment disintegration during weathering experiment without disturbing the sample. Change in size and shape of fragments throughout the experiment was recorded and trends and correlation between parameters were obtained. The error that has to be taken into account using image analyses for determining fragmentation of a sediment sample during the weathering experiment is that a three-dimensional objects are analyzed using a two-dimensional photograph. However, this did not interfere with the found trends and correlations.

THEME: S37 : DANXIA GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 219

## EVALUATION OF DANXIA LANDFORM TOURISM RESOURCES IN HUOSHAN MOUNTAIN, GUANGDONG PROVINCE

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Huoshan Mountain is one of the seven famous mountains in Guangdong Province with a reputation of “the second Mount Danxia”. The tourism resources of Danxia landform in this mountain are abundant, which includes “Twenty-seven Rocks”, “Forty-eight Peaks”, “Eleven Spring Pools”, eight caves and other landscapes, in which the “Huoshan Mountain ten Spots” are the most famous, i.e. “Watching the Sunrise at the Prow”, “Jade Unicorn Playing the Moon”, “Wine Jar Reaching the Clouds”, “the Lion Roaring the Dragon”, “the Cross Rock Looking at the fogs proudly”, “a glim of Light”, “Long Yu Stone”, “Seven immortal Springs”, “Monk Sha Celebration Birthday” and “Tieguai Li Picking Gourds”. The scenery of Huoshan is beautiful with great momentum, rising spiky peculiar peaks and thousands of postures steep stones as a national AAA class tourist area. This study evaluate the tourism resources of Huoshan from three aspects: resource occurrence, ecological environment and development conditions using the fuzzy comprehensive evaluation method. The results indicated that Huoshan is a resource based tourist attraction with poor infrastructures for lack of investment, and its tourism content is monotonous with only climbing mountain and short of other experience and entertainment contents. Therefore, some strategies were put forward to develop the tourism for Huoshan, 1) introduce some powerful and experienced enterprises to improve the grade of scenic spots and construct the infrastructures; 2) enrich the tourist experiences and tourism products to attract more tourists; 3) protect the tourism resources of Danxia landform and develop ecotourism to promote tourism sustainable development in Huoshan.

**Keywords:** evaluation; Huoshan Mountain; Danxia landform; tourism development; ecotourism

THEME: S38 : EXTREME EVENTS IN GEOMORPHOLOGY

ABSTRACT NUMBER: 77

## EFFECT OF A QUATERNARY METEORITE IMPACT IN INDO-CHINA ON THE SURFACE SEDIMENTARY RECORD

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Quaternary sediments have been examined in northern & central Cambodia, in southern China & in north-east Thailand. These locality lie within the Australian strewn tektite field reliably dated to 0.77-0.78Ma BP just before the 0.80Ma BP Brunhes/Matayama reversal. The location of the primary impact crater (if any) is uncertain but a local major crater may lie within central Laos. The described sections are considered distal from the main impact. Stratigraphic evidence indicates a temporal sequence of catastrophic stripping of alluvial-gravel followed by catastrophic redistribution of gravel (incorporating tektites), followed by deposition of atmospheric dust. Grain-size & grain-density trends, XRD, spherule distributions, luminescence profiles, tektite, & microtektite & shock quartz assay, are used to with the stratigraphic evidence to examine an hypothesis that the sections represent the distal effects of a meteorite. Additional insight is gained with respect to prior claims that large accumulations of woody debris in Thai Quaternary river terraces were due to blast & are burnt. Fossil evidence for the local extirpations of Quaternary mammals within the region might also be related to the impact event.

The stratigraphy includes: erosional antidunes, blast-induced debris flow incorporating tektites, catastrophically-broken laterite pavements & mud layers with reversed magnetism. Sedimentological evidence in favour of impact includes: the presence of delicate thin translucent-tektites that must be in situ from initial fallout as reworking would destroy them, graded spherule distributions, highly-stressed quartz grains & microtektites. Grain size data, including X-ray & CT-scanning analysis, can be used to support the impact hypothesis but alone these data are not conclusive. XRD data is inconclusive. On balance the stratigraphy & sedimentology support the notion that the sediments represent the distal effects of a meteorite in the region.

**Keywords:** meteorite impact; tektites; shock quartz; SE Asia

## GEOMORPHOLOGICAL RESPONSE AND DAMAGE RESULTING FROM THE APRIL-MAY 2015 EARTHQUAKE SEQUENCE IN SOLUKHUMBU DISTRICT (NEPAL).

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The unpredictability and low frequency of large earthquakes, together with the disturbance they introduce into geomorphic systems and in the life of local population, lead us and inhabitants to consider them as extreme events. This is illustrated by the recent earthquakes (Mw 7.8 and 7.3) that struck Nepal during April-May 2015. The study focuses on the eastern margin of the zone affected by the earthquakes, i.e. the Dudh Kosi section (Pharak), an area which straddles the Main Central Thrust zone and the upper Lesser Himalaya, and displays remnants of giant rockslides. Methods of investigation include field mapping (before and after the events), cross-checking with satellite images interpretation, and interviews with local people.

Main results stress the role played by earthquake triggered landslides. (1) Though shallow, landslides permitted a large removal of debris, amplified by the following monsoon rainfall. (2) Quaternary deposits and unconsolidated material presented higher susceptibility to ground shaking. (3) Large block fields seem to represent legacies of former, still undated seismic events. (4) Cascading processes ensured the transfer of debris downslope, locally resulting in temporary valley damming and perturbation in regular river flow. (5) Large bank failures along the Dudh Kosi River occurred, and their distribution show they have reactivated former collapses initiated by another extreme event, the 1985 Dig Tsho GLOF.

Collectively, these different geomorphic responses have seriously impacted buildings (private and public, shops, tourism lodges) and trails. It also significantly affected water resource and its spatial distribution (drying up or burying of springs, new springs outlet), and produced serious damage to water related infrastructure such as canals, water pipes, water mills and hydropower plants. Adaptations (canal realignment, relocation of mills, etc.) are urgently required in order to maintain agricultural and tourism based livelihood options, a specificity of this area.

**Keywords:** Earthquake; landslides; water resource; Nepal Himalaya

## FLOOD, VILLAGE TRANSFORMATION, AND MYTHS

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All Taiwanese rivers originate from mountains over 3,000m in altitude, yet fall to sea level within less than 100km horizontal distance. The results are steep riverbeds and short streams. Chosui River shares the same characteristics.

In order to utilize the abundant water resources provided by Taiwan's longest river, the largest irrigation system in Taiwan was built in 1719, supporting the development of the most important rice basket in Taiwan. However, the major issue concerning Chosui River, is the level of sediment concentration. The sediment concentration level in Chosui River is not only the highest in Taiwan, but also ranks at top among rivers originating from mountains over 3000m world wide. Therefore, the natural diversion of watercourses often results in major disasters. Villages along the Chosui Riverbank bear the most impact in the country.

This article focuses on the most serious inundation in the past century in Taiwan—the flood of 1898, due to Chosui River's diversion. Through literature review and field work, I will examine the impact of the flood on local residents at the downstream of Chosui River, and reconstruct a picture of the transformation of villages and conditions of damage. I will also discuss particular myths and folk religions—namely, “water” worship—created by people who were living under the constant threat of the flood.

**Keywords:** Flood;Village Transformation;water worship;sediment

ABSTRACT NUMBER: 486

## INVESTIGATING THE ROLE OF LARGE RUNOFF EVENTS IN (RE)SETTING SUSPENDED SEDIMENT SUPPLIES IN WATERSHEDS IN NORTHEASTERN UNITED STATES

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Suspended sediment yield is elevated after major runoff events (snowmelt, rainfall), the duration and magnitude of elevated suspended sediment concentration (and thus yield) is a function of sediment supplies in the catchment and their connection to the channel. Intense storms (i.e., extreme events) can both transport sediment that is easily accessible (e.g., highly connected) and activate hillslope processes that lead to increased sediment supplies, which may elevate suspended sediment yield in a future event. In 2011, two major tropical storms (Irene in August, Lee in September) moved across Northeastern United States. The flooding was intense, and suspended sediment transfer was elevated for several months afterward. This study proposes that these storms, although devastating, did not significantly alter sediment availability directly, but rather generated indirect effects (e.g., increased slope instability) that continue to alter sediment supply, although disproportional to the magnitude of the 2011 storms. Using discharge and suspended sediment records from several catchments in Northeastern United States, suspended sediment transfer following significant runoff events (e.g. 100-year+ magnitude runoff), landslide activation, and more moderate events (e.g., landuse changes, seasonal storms) is investigated in an effort to understand sediment supply dynamics and the potential for legacy sediment supply availability. These records serve as case studies for understanding the role of climate change and climate variability in shaping the geomorphic response (i.e., establishing sediment supplies) to extreme events. In addition, this work points to the importance of stream network and sediment supply connectivity characteristics as a means to understanding the lasting impacts of elevated sediment supply to downstream environments (e.g., detrimental to ecosystems and water quality, increased infrastructure costs, increased hazards).

**Keywords:** Suspended sediment; sediment hysteresis; hillslope-channel connectivity; catchment processes

ABSTRACT NUMBER: 47

## WIND - THE UNNOTICED CLIMATIC ELEMENT IN SOIL EROSION MODELLING

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Soil loss has challenged human livelihoods since the beginning of permanent settlement, attendant population growth and development. Soil erosion research has evolved since the initiation of the Universal Soil Loss Equation (USLE) in the 1960s. The USLE was updated to the Revised Universal Soil Loss Equation (RUSLE). The Soil Loss Estimation Model for Southern Africa (SLEMSA) was propounded in the late 1970s. These are few of the several soil loss models that depict the enormity and variability of the soil erosion challenge. With the world population nearing the 8 billion mark, more land is needed for both settlement and agriculture. This is pushing more people towards encroachment and the utilisation of marginal areas which are severely prone to erosion. Such marginal areas include mountainous regions where gradient is steep, soils and vegetation cover thin and weather elements stronger. This has made the need for the quantification and identification of erosion and erosion hazards more important than ever. The challenge to accurate soil erosion and erosion hazard quantification using the current soil loss models is the non-recognition of the importance assigned to wind as an important soil erosion agent. While water is generally regarded as the main agent of soil erosion, geomorphological research has proven that wind plays a significant role as far as soil erosion is concerned. It is the purpose of this paper to revisit the three most common soil loss models and establish the contribution of wind in soil loss with special focus on mountainous environments. An atmospheric circulation models for the mountainous area is employed to analyze wind circulation over the region. Adding the wind element and employing the factor analysis in structural equation modelling, we seek to establish the relative contribution of each of the factors that drive soil erosion.

**Keywords:** soil; erosion; mountainous; climate

THEME: S39 : LAND DEGRADATION AND HAZARDS IN A CHANGING ENVIRONMENT

ABSTRACT NUMBER: 52

## SOIL DEGRADATION IN THE ISLAND OF SARDINIA (ITALY): A STATE-OF-THE-ART

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Soil degradation may be considered as the loss of soil or soil quality for specific functions. Consequently, soil degradation is strongly affecting soil ecosystem services as well. The characteristic of the geography of Sardinia and its pronounced Mediterranean climate result in the island soil's being notably fragile and extremely sensitive to degradation. The findings of the studies carried out in Sardinia have shown that, although some degradation processes may occur naturally, anthropogenic factors are the leading cause of soil degradation in the island. Various types of human activities may lead to soil degradation. Three main groups are identified: i) agriculture, pastoral and forestry activities, ii) industrial activities, and iii) urbanization. The above-mentioned factors trigger physical, chemical, and biological soil degradation processes. These processes are mostly intimately linked and interact among themselves. This situation is created by a generalized lack of knowledge on the soil, its ecological value, its several functions, also as a consequence of the subject not being sufficiently addressed in education programmes at all levels. Therefore, land planning at different levels is considered to be the key issue in the prevention and mitigation of soil degradation on the island of Sardinia. For this purpose, the planning process must be based on an accurate inventory of the natural resources, including soil, land evaluation and definition of alternative and suitable uses.

THEME: S39 : LAND DEGRADATION AND HAZARDS IN A CHANGING ENVIRONMENT

ABSTRACT NUMBER: 63

## ESTIMATION OF VOLUME OF SEDIMENTS PRODUCED BY LANDSLIDES AND SOIL EROSION AND THEIR IMPACT ON THE HYDRO-MORPHOLOGICAL CHARACTERISTICS ON THE LACHUNG RIVER

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Landslide and soil erosion are the most hazardous phenomena in the Lachung River Basin of North Sikkim district of India. All the eroded soil and debris are carried down the river and deposited in the lower reach of the Lachung River and thereby affecting the hydro-morphological characteristics of the Lachung River. The present study is emphasising on quantification of the volume of eroded soil and landslide produced debris-materials separately. For estimating the actual amount of soil loss of the Lachung River Basin, RUSLE model is used. Individual landslide affected areas are marked and volume of the produced materials by those slides are calculated to understand the changed morphology of the river due to the formation of landslide dams. The landslide dams are formed due to accumulation of the debris-materials in the lower reach of the river where the slope is relatively gentle. Subtracted value of landslide produced debris-materials from actual soil loss amount of the whole Lachung River Basin has been calculated in order to determine the amount of soil loss that is affecting the river morphology directly. As a result depth of the river bed is decreasing and creating further fluvial hazards.

**Keywords:** Landslide; soil erosion; RUSLE model; Hydro-morphological character

THEME: S39 : LAND DEGRADATION AND HAZARDS IN A CHANGING ENVIRONMENT

ABSTRACT NUMBER: 94

## AGRICULTURAL LAND DEGRADATION IN SOUTHERN SIBERIA

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Territorial distribution of erosion on agricultural lands in Siberia are considered. To ensure environmental safety in the south of



Siberia, a network of complex geographic research stations has been established more than 50 years ago, where soil erosion within the economically developed land has been studied. We established that soil erosion is the main process of natural denudation on 70% of the territory in the semiarid regions of Siberia. At the same time, the average denudation rate is 0.01-0.7 mm/year; at local sites it reaches 2.8 mm/year. Active agricultural land use during the 17-20th centuries produced soil degradation, especially intensive during the virgin land development in 1954-1957. Agricultural lands occupy more than 52 million hectares, and about half of them are plowed. 9 million hectares are subject to flushing and deflation. Degradation mechanism changes from west to east. In the mountain relief agricultural enclaves are confined to intermontane basins, where the concentric zoning of mechanisms and the rate of land degradation are observed. Aeolian processes prevail in the center of basins. In the foothills - water denudation and gully formation. Currently, 15 million hectares of agricultural land are vulnerable to erosion. Long-term changes in erosion intensity were estimated according to the runoff of suspended sediments for the main river basins. The average modulus of suspended sediments runoff varies from 2.7 to 59 t/km<sup>2</sup> per year. There is a period of sharp decrease in the intensity of soil erosion in the Lake Baikal basin, associated with the conservation of economic activity since 1990. A predictive estimate of soil losses from erosion using quantitative empirical process models is performed. Zoning of southern Siberia was carried out in accordance with the erosive danger of lands.

**Keywords:** land degradation; wind erosion; soil losses and splash; Siberia

THEME: S39 : LAND DEGRADATION AND HAZARDS IN A CHANGING ENVIRONMENT

ABSTRACT NUMBER: 100

## ROLE OF TOPOGRAPHY AND CULTIVATION IN SOIL DEGRADATION OF THE MEGHALAYA PLATEAU IN NORTH-EAST INDIA

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Land use type and topography are important factors that influence soil properties, agricultural development and potential degradation processes. A hilly catchment (4 km<sup>2</sup>) was selected for the investigation of landform and sedentary slash and burn cultivation impact on soils in the central part of the Meghalaya Plateau. Selected physical and chemical soil properties were analysed such as texture, bulk density, colour, pH, C, N, P, K, exchangeable K, Ca, Mg, Na and Al. Data were examined for normal distribution using the Shapiro-Wilk test. One-way analysis of variance (ANOVA) and parametric t-tests were then performed. Soil Evaluation Factor and Soil Deterioration Index were calculated to quantify the degree of soil fertility and degradation.

It was assumed that monsoonal climate, deep weathered granites and time are relatively uniform over the catchment, and differentiation of soil properties can therefore be attributed to two landforms (flat ridges and steep slopes) and three land use types within each of them (natural deciduous forest, sedentary slash and burn cultivation of potatoes, and secondary pine forest).

Analyses revealed that agricultural activity increases heterogeneity of the soils at different spatial scales. At a local scale, slash and burn cultivation increases the fertility of soils on flat terrain and at the same time causes soil deterioration on steep slopes, both in reference to the soil under natural forest. At a regional scale, the low yield of potato increases the risk of soil degradation by the tendency to increase production through encroachment on steep slopes, in combination with shortening of the fallow period. Nevertheless, slash and burn cultivation on deeply weathered granites can be continued for a much longer time than on shallower soils developed on neighbouring metamorphic rocks.

**Keywords:** slash and burn cultivation, potatoes monocrop, landform, granites, erosion

THEME: S39 : LAND DEGRADATION AND HAZARDS IN A CHANGING ENVIRONMENT

ABSTRACT NUMBER: 101

## LAND DEGRADATION IN THE TSITSA CATCHMENT, SOUTH AFRICA: A COMPLEX WEB OF HAZARD, HISTORY AND HOPE.

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This paper examines how environmental hazards and political forces have combined to create a highly degraded landscape in the Tsitsa catchment of South Africa and reflects on future prospects for restoring landscape function. Environmental hazards derive from the soil, topography and climate. Soils derived from mudstone rocks are highly dispersive and prone to tunnel erosion and gully, a process exacerbated by steep slopes and a variable climate that swings between drought and flood. Socio-economic hazards derive from the political history that has driven land utilisation in the area. Straddling the border between the commercial farmland of the Republic of South Africa and the communal lands of the former homeland of the Transkei, the catchment has been subject to political forces over the last 100 years that have been a major disturbance to the socio-economic system. A new political ecology driven by the agenda of the present government is now being developed in the catchment through the implementation of catchment-wide rehabilitation that ascribes to a vision of restoring a functioning ecological infrastructure that support livelihoods. The opportunities and hazards, both natural and social, enabling and constraining the successful implementation of the programme will be assessed.

**Keywords:** Land degradation; hazards; political ecology; rehabilitation; ecological infrastructure; South Africa

THEME: S39 : LAND DEGRADATION AND HAZARDS IN A CHANGING ENVIRONMENT

ABSTRACT NUMBER: 130

## GEOMORPHOLOGICAL AND SEDIMENTOLOGICAL INDICATORS OF LAND DEGRADATION (MEGHALAYA PLATEAU, NE INDIA)

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Replacement of forests by cultivation in hilly regions can lead to a dramatic increase in overland flow and soil erosion, resulting frequently in land degradation. This study aims to determine the impact of long-term human activity and natural geomorphic processes in land degradation of two catchments located in the Meghalaya Plateau in NE India. Both catchments are built by deep weathered granites with hilly topography, but have contrasting land use. Forested catchment (1.5 ha) is covered by natural deciduous forest, while deforested catchment (3.5 ha) is affected by intensive cultivation and boulders extraction.

Detailed geomorphological mapping and sediment pattern analysis revealed a complex role of man in land degradation. Human activity contributes directly to the creation of new landforms in the deforested catchment and indirectly through influencing the course and intensity of geomorphological processes masks already existing the natural relief.

Slope degradation (retreat) and erosion under impact of high rainfall could not be effectively reduced through terracing. However, accelerated erosion on slopes and sediment transfer to the valley bottom converted the uneven valley bottom with incised channel to an accumulation plain and enlarged alluvial fan. This increased proportion of flat landforms is favourable for cultivating the deforested catchment.

Differences in sediment pattern show enrichment of topsoil in fine sediment because of tillage in the whole deforested catchment. Selective granite boulders extraction for construction and ornamental purposes leads to decrease their area by 73% in deforested catchment, which gained new land to agriculture.

**Keywords:** landform; land use; geomorphological mapping; sediment pattern; subtropical upland

THEME: S39 : LAND DEGRADATION AND HAZARDS IN A CHANGING ENVIRONMENT

ABSTRACT NUMBER: 238

## IN-FILLED RESERVOIRS SERVING AS SEDIMENT ARCHIVES TO ANALYSE SOIL ORGANIC CARBON EROSION – A CASE STUDY FROM THE KAROO RANGELANDS

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The semi-arid rangelands of the Great Karoo region in South Africa have experienced various environmental changes. After European farmers settled in the late 18th century agricultural activities increased, leading to overgrazing and probably triggering land degradation.

As a consequence of a higher water demand and shifting rainfall patterns many dams and reservoirs have been constructed to provide drinking water for cattle or to facilitate irrigation during dry periods. High erosion rates lead to a fast filling-up of reservoirs and thereby reduced their storage capacities. Thus, most of the dams are nowadays dry (filled with sediment) or even breached and the landscape is characterized by badlands and complex gully systems.

In this ongoing project, a combination of analytical methods, including drone imagery, landscape mapping, erosion modelling and sediment analysis, have been employed to determine whether land degradation in the Karoo has resulted in the reversion from a net carbon sink to a net carbon source. Sediment deposits from silted-up reservoirs were analysed for varying physicochemical parameters, in order to analyse and reconstruct erosional/depositional patterns. A sharp decrease in total carbon content with decreasing depth suggests that land degradation during and after the post-European settlement most likely triggered erosion of the relatively fertile surface soils, which presumably in-filled the reservoirs. It is assumed that the carbon-rich bottom layers of the dam deposits originate from these eroded surface soils. Low organic carbon content in top layers of the reservoir in-fill, and in the eroded source areas, supports the assumption that eroded material was transported from degraded areas down into the reservoir, where it settled. This raises a crucial question of whether the decline of carbon sinks in degraded rangelands due to exacerbated soil erosion may have had a greater attenuating effect on GHG emissions than modelled scenarios of present emissions suggest.

THEME: S39 : LAND DEGRADATION AND HAZARDS IN A CHANGING ENVIRONMENT

ABSTRACT NUMBER: 347

## DYNAMICS AND PATTERNS OF LAND-LEVELLING FOR AGRICULTURAL RECLAMATION OF EROSIONAL BADLANDS IN CHAMBAL VALLEY (MADHYA PRADESH, INDIA)

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Gully and badland erosion constitute important land-degradation processes with severe on-site and off-site effects above all in sedimentary deposits and alluvial soils of the arid and semi-arid regions. Agricultural use of the affected land is impeded both by the irreversible loss of topsoil and the morphological dissection of the terrain, a solution to which is attempted by infilling of gullies and levelling of badland topography in order restore a morphology suitable for cultivation.

Gully and badland levelling for agricultural reclamation has been conducted for decades in the large ravine lands of India. This study aims at analysing the distribution and dynamics of land-levelling within the Chambal badlands in Morena district, Madhya Pradesh, between 1971 and 2015. Using high to medium resolution satellite images from the Corona, Landsat, Aster and RapidEye missions and a multi-temporal classification approach, we have mapped and quantified areas that were newly levelled within eight observation periods. We analysed the spatial relation of levelled land to several physical and socio-economic factors that potentially influence the choice of reclamation site by employing GIS analysis methods and results from focus-group discussions in selected villages.

Results show that nearly 38 km<sup>2</sup> or 23% of the badlands in the study area have been levelled within 45 years. The levelling rate generally increases during the observation period with high annual variability. We have found spatial relationships to badland morphology, vicinity of existing cropland and proximity to villages and drainage lines. From a socio-economic point of view, availability of financial and technical means, access rights to the badland and ownership issues play an important role. Considering studies on soil degradation caused by levelling of badlands in other regions, the sustainability of the newly reclaimed fields in the Chambal badlands is questionable.

**Keywords:** land levelling; land-use change; agriculture; badlands; remote sensing; change analysis

THEME: S39 : LAND DEGRADATION AND HAZARDS IN A CHANGING ENVIRONMENT

ABSTRACT NUMBER: 369

## EFFECTS OF POST-FIRE MANAGEMENT PRACTICES ON EROSION RESPONSE AND VEGETATION RECOVERY – MT. CARMEL, ISRAEL

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The largest forest fire ever recorded in Israel, burning from 2 to 6 December 2010, destroyed more than 2,500 ha of natural and planted vegetation on Mt. Carmel. Removal and clear-cutting of the burnt stands close to roads and recreation sites was started soon after the wildfire.

The study area is located at Mt. Carmel, Israel. Given the severity of the wildfire and the size of the burnt area, this study analyzes the effect of the post-fire management practices on soil-vegetation dynamics and erosion processes.

The study plots were set during the third winter after the wildfire following a massive cutting and removal of burnt logs. Eight silt fences, four at the south (SFS) and four at the north aspects (NFS) were placed on steep slopes (> 30%) of the Rakit stream. Sediment yield was sampled following 12 effective rainfalls.

During the first research season, the NFS clear-cutting plots contributed 3.1 kg vs. 31.2 kg collected in the SFS. In an adjacent watershed, the SFS received 390 mm compared to 361 mm in the NFS, meaning, addition of 29 L/m<sup>2</sup> on the SFS. Consequently, given the nature of the shallow eroded soils and higher rainfall amounts, the erosion potential of the SFS was much higher; evidently, sediment yields following management practices are elevated. On both aspects, vegetation was sampled for relative coverage along four line-transects of 30 m each. The plots were mapped and pictured using drone to detect changes in vegetation cover and flow pattern.

The results indicated a distinctive rill-patterned development following the clear cutting, even in places where total vegetation coverage exceeded 97%. The transition from sheet flow immediately after the wildfire, when the slopes were denuded of vegetation, towards rills developed between the emerging shrubs, altered the timing, quantity and texture of the eroded sediments.

*THEME: S39 : LAND DEGRADATION AND HAZARDS IN A CHANGING ENVIRONMENT*

**ABSTRACT NUMBER: 384**

## **SOIL EROSION ON AGRICULTURAL LAND ASSOCIATED TO EXTREME BLIZZARD CONDITIONS WITHIN NORTH-EASTERN ROMANIA**

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The meteorological background of the remarkable event of wind soil erosion from 6 to 8 of January 2017 in North-East Romania is represented both by prior weather conditions of the winter season and also by the blizzard manifestation during the episode. Both aspects are analyzed from synoptical point of view for better understanding the role of weather conditions on the wind erosion event.

To assess the erosional effect on soil cover of this extreme meteorological event, several field campaigns have been conducted within 12 representative sites all over the Moldavian Plateau. The selected areas presented different geographic conditions in terms of soils, landforms, land cover & land use features. Thus, over 64 snow core samples have been collected in order to indirectly estimate the wind erosion rates by measuring the sediments deposited during the event on the pre-existing snow cover. Moreover, based on the solid samples obtained in this way, a series of laboratory analyzes have been accomplished such as granulometry, humus content, macroelements content (N, P, K), conductivity, pH.

The preliminary results show that the mean sediment content of the sampled snow varies between 0.56 - 43.40 g/dm<sup>3</sup>, resulting 334.67 - 2933.45 g/m<sup>2</sup>. The maximal values are specific to the cropland and arrive up to 108.25 g/dm<sup>3</sup>, respectively 88508.87 g/m<sup>2</sup>.

By correlating the sediment accumulation rates with the weather conditions of that moment and the pre-existing natural patterns it is possible to evaluate the erosional potential of such exceptional event.

*THEME: S39 : LAND DEGRADATION AND HAZARDS IN A CHANGING ENVIRONMENT*

**ABSTRACT NUMBER: 561**

## **BOULDER MOBILITY IN EXTREME FLASH FLOODS- CASE STUDIES IN THE JORDAN RIVER (ISRAEL) AND AMBATO RIVER (CATAMARCA, ARGENTINA)**

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Megaboulders mantle the steep channels of mountainous rivers, and they moderate the incision rates by increasing the channel roughness. Because direct measurement of boulder transport in natural rivers is difficult, there are few field studies on the subject. Megaboulders transported in catastrophic floods in urban environments have destructive power rushing downslope. Two case studies

are analysed: The 1969 Jordan river catastrophic flood in Israel with a recurrence interval of 1:200 years and the January 2014 Ambato river flood in Argentina with an assumed recurrence interval of 1:100 years.

The Jordan channel is composed of gravel and boulders and therefore a high shear threshold is needed for bedload transport. The large boulders are 1500 mm b-axis and even reach 2000 mm among the biggest sizes known in fluvial bed material. Shear stress and stream power are maximized where the depth-slope product is maximized, hence in the narrower section there is no deposition of boulders. All sizes of material move with a recurrence interval of 1:10 years.

The Ambato river forms a boulder delta drained by episodic floods. The 2014 flood caused victims and economic losses in the El Rodeo village in the province of Catamarca. The village developed on the alluvial river fan and the catastrophic flood caused victims, destroyed several houses, a bridge and carried vehicles caught by the flood. All sizes- including 2000 mm b-axis- of bed material were transported.

The assessment of boulder mobility is needed for the mitigation of flow hazards in mountainous urban areas.

**Keywords:** Flash floods; Boulder transport; Stream power; Ambato river; Jordan river

*THEME: S39 : LAND DEGRADATION AND HAZARDS IN A CHANGING ENVIRONMENT*

**ABSTRACT NUMBER: 591**

## **A MODEL FOR DEGRADATION OF KOBRESIA PYGMAEA TURFS ON HILLSLOPES**

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Kobresia pygmaea meadows are typical of Tibetan Plateau landscapes in the 3000 to 5500 m elevation range, and constitute the most extensive alpine ecosystem in the world. K. pygmaea forms turf mats that stabilize the surface and shelter the underlying soils from water erosion. Large tracts of the Plateau, however, exhibit signs of ongoing degradation of the turf and erosion of the underlying soil. Despite the crucial role played by K. pygmaea turf mats in the stabilization of the headwaters of major Asian rivers, the mechanisms responsible for their degradation remain poorly investigated. Here we develop a process-based model of land degradation of Tibetan Plateau slopes, which accounts for (i) turf cracking; (ii) water flow concentration in the cracks; (iii) crack widening by scouring; and (iv) sheet-flow erosion. As expected, soil erosion increases with the slope and drainage area (hence the observation of stronger erosion in relatively steep downhill sites). Model simulations indicate that, with a sensible set of parameters representative of soil and hydrologic conditions in the region, Tibetan Plateau landscapes are extremely vulnerable to turf mat defoliation and soil erosion. As soon as polygonal cracks develop, water flow widens them until the landscape is completely barren. At this point sheet-flow eventually erodes the mineral soil leaving behind a highly degraded landscape.

*THEME: S39 : LAND DEGRADATION AND HAZARDS IN A CHANGING ENVIRONMENT*

**ABSTRACT NUMBER: 642**

## **APPLICATION OF SAR INTERFEROMETRY IN MONITORING MINING SUBSIDENCE IN AN AROUND RANIGANJ COAL MINE, WEST BENGAL, INDIA**

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High-intensity coal mining frequently causes large-scale ground damage within a short period of time. Understanding subsidence under high-intensity mining can provide a basis for damage assessment, land remediation and ecological restorations in an actively subsiding area. SAR interferometry is a well-documented modern technique for the characterization of ground motion over large spatial areas. In this present study, a comprehensive attempt has been made to monitor the subsidence scenario at Raniganj (India) coal field, using differential interferometric synthetic aperture radar (DInSAR) technique. A time series of ALOS PALSAR-1 (L-band) and SENTINEL-1 (C-band) data have been used to monitor the mining induced land subsidence. DInSAR utilizes the phase contained within the image data. The SAR images are needed to form interferometric pairs and each pair has to be precisely co-registered, so that the phase difference, or so-called interferogram, can be calculated on a pixel-by-pixel basis between the two images. As curvature of the Earth and topography has a potential influence on the phase information received by satellite, flattening and topographic phase removal using an external DEM should be applied to the interferogram to eliminate those errors. Time series of ground deformation map provides detailed pattern and nature of subsidence. As mining environment is dynamic in nature, active query areas should be mask out from displacement maps to avoid the false alarm. Results indicate that coal mining-induced land subsidence can be feasibly

monitored with the DInSAR technique. Overall findings suggest that a vast stretch of land is suffering from land subsidence due to different modes of mining. The knowledge base on subsidence in the form of time series of displacement maps will be useful to take management initiatives for overcoming the land subsidence and related environmental problems.

**Keywords:** Mine, Subsidence, SAR, Interferometry, Raniganj

THEME: S39 : LAND DEGRADATION AND HAZARDS IN A CHANGING ENVIRONMENT

ABSTRACT NUMBER: 723

## NEW GEOMORPHOLOGY OF INDIA CAUSED BY HYPER URBANIZATION

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Industrialization resonated the economic growth along with unmatched urban population growth and natural resource depletion, as never occurred previously in the human history. This rapid mass transformation of anthropogenic geomorphic process hampering both surface and ground ecosystems, surpassing the tipping points enhancing inextricable domino effects. India accounts 2.4 percent of world land area sheltering about 18 percent of the world's population but concurrently, it's around half of land area is degraded. So, big challenge before planners of poverty eradication, food security and sustainable land management need an exigent and systematic approach, rooting deeply the new alchemy which drags the country's development towards sustainability.

The study aims in enlighten the awareness of the effects of urbanization on climate change, landforms and country's valuable GDP. Then finding out the trends analysis of land degradation economics of India. And finally giving the shape to new paradigm by conceptualizing the integrated land management and spatial planning tools through macro-micro-macro approach.

**Keywords:** Urbanization; Climate change and domino effects; Land degradation; Rational choice theory; Integrated land management and spatial planning tools

THEME: S39 : LAND DEGRADATION AND HAZARDS IN A CHANGING ENVIRONMENT

ABSTRACT NUMBER: 725

## ENVIRONMENTAL IMPACTS AND ECOLOGICAL IMBALANCES IN ALLUVIAL GEOMORPHOLOGY OF GREAT GANGETIC PLAINS: A CASE STUDY OF BRICK KILNS

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At present environmental problems and ecological imbalances due to brick kilns enjoy the limelight of public and scholarly attention. The scenario of alluvial Gangetic plain is changing. Thousands and thousands of small rural alluvial localities are turning into big rural growth centers. These big rural growth centers are concentrations of buildings, agricultural production, consumption and transportation. They need capital, labor, technology and resources as inputs for working and living. Expanding rural growth centers and increasing population implies an increasing demand of resources. It is the nature of the system that more expansive and lighter commodities may be drawn from the cities away from the rural growth centers while the more bulky, low-value materials are drawn from close by areas.

The growing physical structure of the rural growth centers requires large quantities of building construction materials like bricks, sand, gravel etc. The impact of these demands may be seen in the form of number of brick kilns, soil quarrying pits, located around most of the rural growth centers of alluvial Gangetic plains. All these have environmental impacts.

The land which was previously under healthy agriculture, now due to soil quarrying for brick kilns, has been converted into ditches, burrow pits and low lying areas. In these lands, the problem of water logging and deforestation has become acute. The waste generated by brick kilns is also creating problem. The mango gardens are also highly affected resulting into the degradation of the quality and quantity of fruits. Besides, there is emission from the brick kilns which has affected not only the surrounding crops and vegetation but also the health of the workers and rural dwellers. Conditions are in fact, moving from bad to worse and more and more new problems are coming up every day.

**Keywords:** Alluvial; Resource; Brick Kilns; Degradation

ABSTRACT NUMBER: 748

## GEOSPATIAL APPROACH FOR LANDSLIDE INVENTORY AND SUSCEPTIBILITY MAPPING ALONG TONS VALLEY, GARHWAL HIMALAYA, UTTARAKHAND, INDIA

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The present study brings out an integrated approach concerning landslide which were carried out along the Haripur to Sankri track via. Haripur-Minus road in Tons valley. The area is traversed by main Boundary thrust in the South and Tons thrust, Krol thrust and many other thrust, faults and lineaments. During the field study along the road side 200 km, 100 landslides were identified. A landslide inventory is being prepared on basis of pre and post Uttarakhand disaster of 2013 using high resolution satellite data (LISS-IV). A total of 686 landslides were identified in pre-disaster situation through (2011) and 1160 were identified in post-disaster (2014). Total of 1828 locations were identified and recorded. In this study, landslide susceptibility mapping was done using an integrated geospatial technology and ground based observation. Susceptibility mapping twenty one thematic layers viz Lithology and Structure, lineament Density, Geomorphology, Slope, Slope Aspect, Absolute relief, Relative relief, Dissection, Index Roughness Index, Topographic Index, Curvature, Population Density, Seismic Zone, Drainage Density, Drainage Frequency, Drainage Texture, Soil erosion and Soil depth, Hydrological Condition, rainfall, Vegetation (NDVI) and LULC were created mostly by visual interpretation with the help of published maps and literature survey. Outcome was confirmed by relating with the landslide occurrences in different classes. The landslide susceptibility map classifies five classes i.e., very high, high, moderate, low and very low. An attempt was also made to validate the map with the existing landslides of the area. The final risk was obtained by multiplying the susceptibility map and vulnerability map in raster calculator of ArcGIS. There are four risk zones as identified from the map namely very low (20%), low (21%), Moderate (32%), high (15%) and very high (12%). Landslide susceptibility zonation (LSZ), vulnerability and Risk mapping are important for disaster management and planning development activities in the Himalayan regions.

**Keywords:** Garhwal Himalaya, Tons Valley, Landslide Inventory, Susceptibility Mapping, Geomorphology, NDVI

ABSTRACT NUMBER: 19

## QUANTITATIVE ROCKFALL RISK ANALYSIS BASED ON LANDFORM CLASSIFICATION

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Rockfall risk map subdivides the terrain into zones with differing magnitude, likelihoods, and consequences of potential rockfall occurrences. The analysis should be based on the homogeneous area according to degrees of actual or potential rockfall risk. Landform classification considering surface form and process in a rockfall-prone area exhibits scale-specificity. The magnitude (volume) and frequency of boulder deposits may have a specific scale related to each generic landform. Different values of the scaling exponents in each landform reflects that landform influences the rockfall risk. Landform classes can pose important zones of rockfall process where magnitude, likelihoods, and consequences of rockfall are diverse in places. The author proposes a comprehensive risk approach integrating relevant stage of quantitative rockfall risk analysis and geomorphological analysis in a scarce data environment area. Landform class is used as a mapping unit to evaluate the occurrence probability, the colliding probability and the physical vulnerability with particular boulder size in space and time. The risk to building and the risk to person inside the building are calculated based on the chance of loss (in monetary term) during a specified time.

**Keywords:** rockfall; risk; landform; quantitative

THEME: S40 : YOUNG GEOMORPHOLOGISTS' SESSION

ABSTRACT NUMBER: 33

## LANDSLIDE DISASTER RISK IN THE URBAN AREA OF TEZIUTLÁN, PUEBLA, MÉXICO: BUILDING EXPOSURE THROUGH TIME

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Significant landslide disasters have occurred in Mexico during the last decades. In 1999 the municipality of Teziutlán was severely affected by rainfall induced landslides and consequences included human, economic and environmental losses.

Owing to the large spatial extent of a non-welded pyroclastic deposit of ignimbrite type, Teziutlán is highly susceptible to landslides. However, one of the major drivers of disaster risk is exposure. Population of the whole municipality has increased from 63,245 inhabitants in 1990 to 92,246 people in 2015. Derived from such population growth, the consequent land-use changes and urbanization have led to the development of human settlements on unstable ravines. Quite commonly, vulnerability levels of population living under such conditions of exposure are also high.

This papers aimed at analyzing the development of exposure in the urban area of the municipality by comparing multi-temporal high resolution orthophotos, satellite and drone images during the period 1954-2016. Urban development was analyzed and correlated with a landslide inventory and a susceptible map available for the area.

Patterns of development of human settlements were identified and characterized according to exposure indicators. The latter included both the exposure of people and dwellings. Critical urban areas at local level were categorized in terms of landslide disaster risk based on exposure indicators and landslide susceptibility.

**Keywords:** landslides, disaster risk, exposure, land-use, urbanization

THEME: S40 : YOUNG GEOMORPHOLOGISTS' SESSION

ABSTRACT NUMBER: 34

## PROGRESS OF GEOMORPHOLOGICAL RESEARCH IN INDIA IN 21ST CENTURY

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The objective of the present paper is to analyze the recent trends of progress of geomorphological research in India in 21st Century. This is a theoretical paper which also introspect major lacunas to enhance the better research quality and to establish Geomorphology as an independent subject at Postgraduate level. To give a full sketch of aforesaid topics researcher go throw the published research papers in standard refereed journals. The Earlier available and published literatures are limited to the researches going in the departments of Universities only. Apart from Universities very interesting and world class researches are continue in the engineering and pure research institutes e.g. IIT Kanpur, IIT Roorkee, PRL, CAZARI, DTRL, WIHG, IIRS, IISC and IISEAR also. Process geomorphology is major thrust area in universities while engineering institutes are highly involved in paleoclimatic studies, planetary geomorphology and interpretation of structural and sedimentary control over landforms.

The historical development of Geomorphological research is classified in three different time span : Pre Independence( Before 1950 A.D. ), after independence ( 1951 A.D -2000 A.D ), Recent age ( 2001 A.D onward). In first half of twentieth century geomorphological researches were confined to the description of the origin and structure of the major physiographic divisions of India while second half was focused over regional geomorphology and quantitative geomorphology. Application of remote sensing images is highly incorporated with end of last century which is flooded now. Field geomorphology is under threat due to over dependence on this technology. Applied geomorphology, urban geomorphology, environmental geomorphology, river dynamics and micro landforms are major focused topics of geomorphological research in 21st Century.

There is a great need of high interaction and integration of geomorphological researches continues in universities as well as engineering and research institutes.

Keywords: Regional Geomorphology, Paleoclimatic Studies, River Dynamics, Time span



THEME: S40 : YOUNG GEOMORPHOLOGISTS' SESSION

ABSTRACT NUMBER: 176

## FORMATION OF LANDSLIDE DAMED LAKE IN THE KANAKA RIVER, SIKKIM HIMALAYA, INDIA

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On 13th August 2016, a massive landslide (N 27° 32' 31.75", E 88° 30' 4.07") occurred near Zongshu in the Sikkim Himalayas, India and created a landslide dam lake of 3 km long, 200 m wide, 65-75 m high. This landslide blocked flow of the River Kanaka for about 12 hrs, after that water started overflow through a narrow channel over debris and boulders. A detailed field survey is carried out at landslide-dam lake site and the affected area. Very high-resolution Cartosat-2 (1 m) images are used for geomorphic investigation and monitoring the landslide-dammed lake. River discharge data are collected for analyzing the variation of discharge. It is found that a total of 29 houses were affected by the landslide. Out of the 29 houses, 14 were submerged by the lake, 15 houses belonging to the local people and the department of Roads and Bridges were completely damaged. River discharge data shows that amount of discharge gradually reached to near normal i.e. 105 cusec and the river has formed its normal course and flowing naturally through such landslide dam. Field investigation revealed that the region is composed with high grade central Himalayan crystalline rocks with large number of cracks and joints. Groundwater seepages from the exposed joint planes are observed during field survey. Therefore, the aquifer induced pore pressure along with adverse geological formation could be the probable causative factors for occurrence of the landslide.

THEME: S40 : YOUNG GEOMORPHOLOGISTS' SESSION

ABSTRACT NUMBER: 180

## MORPHODYNAMICS AND ANABRANCHING PATTERN OF BRANCO RIVER, NORTHERN AMAZONIA

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There are no previous works focusing the Branco River morphodynamics, despite the fact that this is one of the most important northern tributaries of the Amazon basin. This work aimed to fill up this gap, analyzing the Branco River morphodynamics and discussing its channel pattern with basis on TM/Landsat-5 multi-temporal imagery and digital elevation model, integrated with sedimentological and chronological data. The results revealed that the Branco River is predominantly straight upstream, but turns into slightly sinuous downstream with average slope of 0.008. The lower course of this river presents an upper and lower alluvial plain formed between 18.7 ky - 7.5 ky cal BP and 5 ky cal BP - current, respectively. There are also many fluvial bars and islands in this river, a characteristic commonly related to anabranching sand-bed rivers. We calculated that the migration rate of the Branco River is lower (1 m/yr) than other Amazonian rivers. This is a typical of semi-controlled channels, which is consistent with the fact that the Branco River is incised on Mid-Late Pleistocene deposits. In addition, this river has many local avulsions along its entire course, a characteristic commonly related to anabranching rivers. The temporal analysis of TM/Landsat-5 images between 1985 and 2014 revealed that the anabranching appearance results from the fragmentation of alluvial plains by local river avulsions, forming islands. Bar deposits can also coalesce into both fluvial islands and the modern alluvial plain, being completely covered by vegetation within this time-frame. Erosion and accretion rates revealed a non-uniform distribution of values tending to a modest depositional balance. Such characteristic is related to the fact that this river occurs in a sedimentary basin with late Quaternary tectonic subsidence, as also verified in the largest anabranching river systems worldwide.

ABSTRACT NUMBER: 338

## ESTIMATING SUSPENDED SEDIMENT CONCENTRATION BY USING HISTORICAL LANDSAT 5 DATASET: EXPERIENCES BASED ON TWO SOUTH AMERICAN LARGE RIVER BASINS, AMAZON AND PARANÁ

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One promising tool for retrieving suspended sediment concentration (SSC) datasets is by means of estimating it from historical remote sensing images. By using this technology, the sediment transport and dynamics of many poor-monitored rivers can be better evaluated. In the past two decades several datasets became free, and the historical archive has been increasing. A great example is the Landsat program database, in particular the Landsat 5, which was the longest-operating Earth-observing satellite in history. In the present work, we present applications of the Landsat 5 database for retrieving SSC in rivers from two South America basins: Amazon and Paraná. The Paraná basin is within the La Plata river basin, the second largest basin of the South America (about 3,000,000 km<sup>2</sup>), and it represents approximately 86% of the La Plata basin. The Amazon basin is the largest basin of the world (about 6,100,000 km<sup>2</sup>), comprising the majority of the Amazonian rainforest. Models for estimating SSC were developed by means empirical approach, including the regression of in situ and spectral reflectance data, selection of the better estimators (bands and band ratios) and residual analysis. Nine stations, in seven great rivers of the Amazon basin, and one station in the Paraná river were analyzed. In the total, 5544 Landsat 5 images were processed, 5409 in the Amazonian rivers and 135 in the Paraná river. This database covers the period from 1984 to 2011, which was used in conjunction with in situ data for understanding temporal trends and general responses to precipitation fluctuations and soil coverage changes. As example of findings, an important reduction in the SSC was documented in the Upper Paraná River (UPR), from 24.52 mg l<sup>-1</sup> to 4.91 mg l<sup>-1</sup>, respectively before and after the damming of the Porto Primavera (in 1998).

ABSTRACT NUMBER: 441

## FLUVIAL DISCONTINUITY AND ITS IMPLICATIONS TO GEODIVERSITY IN AN ALLUVIAL MEANDERING RIVER: THE PEIXE RIVER, BRAZIL

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Morphometric variations in floodplains may reveal landscape aspects that control geodiversity. The aim of this study was to evaluate the distribution of geomorphic units to explain the factors that control the landscape in a meandering alluvial valley. The study area is an alluvial segment of lower Peixe River, in southern Brazil, where geomorphic units were mapped and, then, floodplain width and channel direction were assessed to delimit the geomorphological zonation. The measure of floodplain width was performed in a geographic information system and its results demonstrated to be efficient. Geomorphic unit assemblages along the alluvial valley indicate three landscape units. A remarkable floodplain variation width associated with channel change direction caused a fluvial discontinuity which is vital to geodiversity understanding. These features influence the occurrence of fluvial processes and forms, i.e. avulsions and backswamp. Investigations on slope tributaries suggest the role of neotectonic events which are evidenced by faults, paleomorphologies and drainage capture. This finding is also supported by asymmetry in terraces and the alluvial fan formation at floodplain-terrace contact. Paleochannels ages in the lower terrace suggest that the fluvial discontinuity took place in late Holocene.

THEME: [No Theme]

ABSTRACT NUMBER: 297

## RESEARCH ON IMPACT OF TOURISM ACTIVITIES FOR DUNE LANDSCAPE ON DESERT TOURISM AREA——SHAPOTOU SLIDING SAND IN NINGXIA AS AN EXAMPLE

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China desert tourism area developed rapidly, and give the scenic spot of passengers bring substantial benefits as well as the damaging effect of dune landscape. Research using real-time dynamic positioning technology (RTK) on the micro scale of descending in October, April I, August of 2014 and in March of 2015, get the scenic spot slippery slope four times of the topographic map, and with the aid of GIS software will topographic map generation model, on the slope, slope variability and cross section analysis; Then obtain topographic map in 1995, 2003, 2009 and 2013 remote sensing film such as basic data, based on the GIS software on macro scale analysis of the study area, and then adopt the method of superposition of contrast in different periods of the image, to look at the sliding sand slope change in recent 10 years. By total station measuring technology for sand slope bottom tree height measurement, and in different functional areas to select samples of trees, and trees are slope buried node set scale, so as to verify the study area sand slope bottom depth value of the trees buried by sand dunes. Finally combining with descending weather stations rainfall and wind direction data and characteristics of tourists and visitors to correlation research of sliding sand slope, finally come to the conclusion that factors on slope change respectively. Study found that descending slide in sandy slope steep fall trend in recent years, tourists influence and scenic natural recovery cannot reach the balance, the slope gradually slow, the upper edge of slope after the shift, shapo tail extends, effecting the landscape and tourist scenic sand skiing experience largely. If don't take feasible measures, will seriously affect the capacity of the scenic spot and tourist experience.

**Keywords:** dune landscape; desert tourism; tourism activities; GIS

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ABSTRACTS FOR POSTER  
PRESENTATION



THEME: S1 : THEORETICAL GEOMORPHOLOGY

ABSTRACT NUMBER: 227

## THE ROOTS OF FUNDAMENTAL CONCEPTS OF GEOMORPHOLOGY IN THE AL-BIRUNI'S THOUGHTS

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Although many of the geomorphologists link the flourishing of Science geomorphology to William Morris Davis, but the beginning of this modern science rests elsewhere. The philosophers and geographers of ancient Greece and Rome such as Herodotus, Aristotle, Theophrastus, Xenophon, and many others theorized about flood, Erosion of rivers, changes in sea level In the centuries BC. Moreover, scientists such as Venerable Bede and Edrisi presented their theories on erosion and topographical features in the centuries AD. Whereas, the views of Al-Biruni regarding geomorphology and earth sciences have remained relatively unknown, and could change the history of science geomorphology. Al-Biruni is regarded as the greatest Muslim and Iranian scientist of all ages. Encyclopedia of Sciences, Moscow edition, introduces him as the scientist of all times. Al-Biruni was a mathematician, astronomer, chemist, geologist, geographer, tourist and father of Indology. Moreover, Avicenna, his contemporary scientist, theorized about differential erosion, palimpsest, and uniformitarianism, which are connected to the modern scientific revolution.

This study aims to examine ancient books, including The Remaining Signs of Past Centuries, The Mas'udi Canon, Understanding Astrology, Demarcation of the Coordinates of Cities, from the viewpoint of geomorphology, through a descriptive-analytical method; and to compare his views with modern theories. The results of this study show the remarkable service Al-Biruni in different fields of earth sciences and geomorphology. He theorized about the creation of natural springs and artesian wells, diagenesis and stratigraphy of sedimentary rocks, wind and water erosion, Isostasy, gradual changes to earth's surface, and riverbed erosion cycles. The most controversial of his geomorphology subject is the gradual changes to the earth's surface, which be known as uniformitarianism in the 19th century. Interestingly, he fully delineated the erosion cycle of earth and riverbeds before Davis (20th century), and theorized about the biological theory of evolution.

**Keywords:** Al-Biruni; Davis; The erosion cycle; Uniformitarianism

THEME: S1 : THEORETICAL GEOMORPHOLOGY

ABSTRACT NUMBER: 499

## TECTONIC PROCESSES - SEISMICITY INDEX $T\delta$ : A NEW INDEX FOR EVALUATING THE DEGREE OF TECTONIC ACTIVITY AND ASSESSING SEISMIC HAZARD

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Geomorphic indices, computed using GIS, are considered suitable for evaluating the effects of active tectonics, over a wide area. This paper proposes a new Index, which is named Tectonic processes - Seismicity index ( $T\delta$ ) and defined as the ratio of the hypsometric integral (HI) to a lithology - hydrolithology coefficient ( $\delta$ ). This coefficient describes the lithology and hydrolithology behaviour of geological formations in a drainage basin and directly depends on erosion conditions. The  $T\delta$  Index eliminates the influence of lithological structures and erosion and highlights the role of tectonic processes (recent and active) in the configuration of the terrain of a drainage basin. Its values range between 0.00 and 1.00 and are distinguished into three classes, depending on the degree of tectonic activity: 1st Class ( $0.60 < T\delta \leq 1.00$ ; high), 2nd Class ( $0.30 < T\delta \leq 0.60$ ; moderate), and 3rd Class ( $0.00 < T\delta \leq 0.30$ ; low). The low values correspond to reduced tectonic activity or relatively inactive areas, while the high values correspond to basins which were affected or are still affected by tectonic structures and processes. At first, this Index was applied to the drainage basins of five main rivers in Greece, producing highly satisfactory results, regarding the influence of tectonics on these basins. In addition, its high values coincide with areas where active faults are located and recent seismic events have been recorded. Therefore, the  $T\delta$  Index constitutes a useful tool of morphotectonic analysis, for the assessment of active tectonic activity and seismic hazard in an area.



THEME: S2 : APPLIED GEOMORPHOLOGY

ABSTRACT NUMBER: 177

## GEOMORPHOLOGICAL DYNAMICS OF THE CAMAQUÃ RIVER DELTA (BRAZIL).

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The Camaquã river delta (Rio Grande do Sul State – Brazil), is located inside the Camaquã State Park, which is a nature conservation unit created in 1975 and still does not have a management plan. In face of this, it is common to find agricultural activities that have caused changes in the morphodynamics of this environment despite the legislation that protects it. This work was developed with the objective of identifying and analyzing the geomorphological dynamics of the Camaquã river delta, in order to subsidize the elaboration of the area management plan. Two geomorphological maps (1964 and 2012) of detail (1: 25.000) were elaborated. The main features of the relief and hydrography identified were: lacustrine-fluvial plains, lacustrine-fluvial terraces, sandy cords, sandy strips, sandy paleo cords, abandoned channels, abandoned meanders, meanders, meander bars and rectilinear channels (actives and inactives) built to supply irrigated rice crops. The geomorphological dynamics is marked by the increase in the extent of rectilinear channels in areas of irrigated rice that are located on surfaces of fluvial-lacustrine plains and terraces, promoting their decharacterization. It was also verified the ramification of the Camaquã river mouth, besides the formation and consolidation of islands on the delta front with changes in the riverbanks of the fluvial channels adjacent to the delta. There was an increase in the extent of abandoned channels due to river migration processes. The understanding of the geomorphological dynamics of the Camaquã river delta should support the proposition of the environmental zoning units of the state park, indicating the recovery zones, the restricted use zones, the primitive zones and the intangible zones, based on the areas that presented the largest and the smallest changes according to the mappings.

**Keywords:** Delta Systems; Geomorphological Mapping; Protected Areas

THEME: S2 : APPLIED GEOMORPHOLOGY

ABSTRACT NUMBER: 320

## MASS MOVEMENTS OF DIFFERING MAGNITUDE AND FREQUENCY IN A DEVELOPING HIGH-MOUNTAIN AREA OF THE MOXI BASIN, HENGDUAN MTS, CHINA – A TREE-RING BASED HAZARD ASSESSMENT

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Assessment and management of mass-movement hazard in developing mountain areas is a significant human problem. It can only be resolved through identifying the background behind the processes, including their magnitude and frequency. Dendrochronology is one of the most precise methods for dating past mass-movement events. Our study aims to provide a tree-ring based discussion of geomorphic hazards and to estimate the frequencies and magnitudes of mass movements of differing origin and scale: large and smaller debris flows, and rockfalls, typically endangering the population of the Moxi basin (1123-7556 m a.s.l., Sichuan, China). In the Xiaohezi gully the ages of 30 spruce trees were determined indicating the date of the last large debris flow moulding terrace levels. On the Daozhao debris cone we determined the dates of the events of smaller debris flows wounding the stems of 43 alder trees. On the Nimatuo Study Site the dates of rockfalls injuring the stems of a sample of 15 alder trees were determined. The results allowed the recurrence intervals of the mass movements to be calculated. During the last 55 years large debris flows originating in the vast, high-elevation and glaciated Xiaohezi catchment occurred every 18 years. During the last 20 years smaller debris flows fed from the mid-sized and medium elevation Daozhao catchment occurred every 7 years. Rockfalls, with a very small and steep source area (Nimatuo Site) occurred every 2.85 years. Based on the results from three study sites representing the densely inhabited main valley of the Moxi basin is affected by 40 large debris flows, hundreds of smaller debris flows and thousands of single rockfalls per century. They affect as much as 27.07% of developed area of the Moxi basin. However, thanks to sustainable land use, the majority is affected by manageable, high frequency, but middle- to low-magnitude phenomena.



THEME: S2 : APPLIED GEOMORPHOLOGY

ABSTRACT NUMBER: 606

## THE ROLE OF GEOINDICATORS IN ASSESSING GEOMORPHOLOGICAL IMPACTS OF HIGHWAYS – A CASE STUDY IN SÃO PAULO, BRAZIL

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Highway construction and operation usually generates great impacts on geomorphological systems, and geoinicators have been considered as an important approach to measure the short term environmental changes related to such structures in different geomorphological systems. This study utilised that approach in a study area of “Rodoanel”, a freeway of São Paulo – Brazil, in a humid tropical environment. A total of 29 geoinicators were applied in six historical scenarios of this highway construction (1962, 2007, 05 e 12/2009, 2010, 2012), regarding the preintervention, active intervention and post intervention phases. To obtain the geoinicators, EIS Environmental Impact Studies reports and data were utilised, as well as geomorphological mapping and fieldwork techniques, geoprocessing tools, GIS, aerial photos (1962, 2007, 2010) and satellite imagery (2009 and 2012), producing geomorphological and land-use maps. The utilization of those tools and geoinicators, allowed to identify and estimate the high magnitude of most of this road impacts and their general distribution in different geomorphological systems. As examples, changes in 30% of stream network and 23% on floodplains were found, associated with interventions on stream channels, by culverts and ditches, and earth moving. The application of geoinicators highlighted the urgency in detailing important phases of engineering interventions and in changing some protocols of EIS of roads in Brazil, particularly to humid tropical environments, due to the very short scales that occur regarding both the most significant direct interventions as well as their geomorphological effects, such as: water turbidity, suspended load transport rates, fluvial-lacustrine deposition rates, among others. Those processes have durations of minutes, hours or days, and can be triggered immediately after the occurrence of direct interventions such as road cuts or landfills.

**Keywords:** Geoinicators, Environmental Impact, Highways, Sao Paulo

THEME: S2 : APPLIED GEOMORPHOLOGY

ABSTRACT NUMBER: 758

## EVALUATING THE LIQUEFACTION HAZARD IN AXIOS BASIN, THESSALONIKI BASED ON DETAILED GEOMORPHOLOGICAL MAPPING

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The delineation of areas prone to liquefaction, the evaluation of their liquefaction potential and their detailed mapping represent crucial issues for mitigating the liquefaction risk and especially for minimizing or even avoiding the occurrence of structural damages at buildings. The recently earthquake sequences occurred in New Zealand (2010-2011) and Italy (2012) confirmed the strong influence of depositional environment of the sediments with the liquefaction occurrences. In particular, it was pointed out that the most highly susceptible to liquefaction sediments are present and former fluvial landforms; alluvial ridges, levee ridges, crevasse splays and abandoned riverbeds and reclaimed land. Thus, it is evident that liquefaction phenomena and the relevant liquefaction-induced failures were not sparsely and randomly distributed on the qualitatively classified as susceptible to liquefaction geological units but they were mainly concentrated within specific zones. Therefore, a further discrimination of the Holocene age sediments following a geomorphological approach could initially provide information regarding the type of sediments e.g. depositional environment and resulted to a more reliable map regarding the susceptibility to liquefaction of the sediments. The goal of this study is the compilation of a geomorphological-based liquefaction susceptibility map of the area of Axios river, Thessaloniki (Greece) based on a detailed geomorphological mapping. In addition, the liquefaction hazard within this area is evaluated by applying a probabilistic approach, enabling surficial geologic maps to be transformed into liquefaction hazard maps. The earthquake scenario that was taken into account is the one occurred on 1759 and is considered as the one of the most catastrophic events in the area.



THEME: S3 : GEOMORPHIC PROCESSES IN COUPLED HUMAN AND NATURAL SYSTEMS

ABSTRACT NUMBER: 99

## IMPACT OF THE LARGE TEA PLANTATIONS DEVELOPMENT ON LANDSCAPE OF THE EASTERN HIMALAYAN PIEDMONT

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The impact of the large tea plantation system on landscape was studied in the 2105.9 km<sup>2</sup> of the Jalpaiguri District of the West Bengal state in India from the mid of the 19th century, i.e. the first settled agriculture to present day. Close relationships occur between landform, soil type, hydrology and LULC in the study area. Terraces with deep, permeable and acidic soils are elevated 6-30 m above floodplains. They are occupied by reserved tropical moist deciduous forest, tea plantations and settlement with domestic gardens. All these land use types are under various forms of Government management. Floodplains with shallow, imperfectly drained and neutral soils are occupied mainly by river channels, remnants of riparian forest and rice cultivation. Due to frequent floods area of floodplains is treated as wasteland.

Analysis of historical reports, cadastral maps and satellite images as well as census data revealed forest area decrease by 69.5%, and land under tea cultivation growth up to 30.7% in 1874-2010. The population density increased from 9 to 470 people/km<sup>2</sup> between 1872 and 2011. Piedmont development showed a period of new land use structure formation with rapid deforestation at the expense of tea cultivation (up to 1930) and its further stabilization with slight deforestation and gradual increase of land under tea (1930-2010). As a consequence, a gradual extension of tea plantation and forestry development helped in stabilizing the land use of the terraces, while the parallel deforestation of floodplains for rice cultivation intensified fluvial activity and river bank erosion. Natural environment features and land use policy cause that tea plantation system is approaching maximum expansion. In contrast, floodplains are under the dynamic equilibrium between fluvial and human activity.

**Keywords:** land use, tea cultivation, landform, fluvial activity, bank erosion

THEME: S3 : GEOMORPHIC PROCESSES IN COUPLED HUMAN AND NATURAL SYSTEMS

ABSTRACT NUMBER: 228

## PRELIMINARY RESEARCH DATA OF FLUVIAL EVOLUTION AND HUMAN IMPACT. A GEOMORPHOLOGICAL AND NEOTECTONIC APPROACH ON PEIROS RIVER, NORTHWESTERN PELOPONNESE, GREECE.

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Fluvial environments can be influenced by changes of the valley floor and therefore by active tectonics that alter the shape of the river channel. The effects of human intervention can also have high impact as it can alter the morphology of the area.

Peiros, the longest river in Achaia, along with its tributaries, emanates from the NE part of Erymanthos mountains, discharging into the gulf of Patras. This study examines the various stages of fluvial evolution of the low part of Peiros's river channel and enables us to trace the links between tectonics, human intervention and fluvial dynamics.

The spatial and temporal variability of sediment transport is controlled by a combination of different variables, including the natural features of the catchment and human activities.

The study area belongs to the geotectonic unit of Gavrovo-Tripoli, consisting mainly of medium-bedded fine-grained sandstones and mudstones and mainly influenced by ENE and WNW trending faults aligned with the river flow and a, recently mapped, dextral strike-slip fault. The river is confined by local tectonics and sets of normal faults, mainly of listric geometry, which control its flow and especially the lower flow part of Peiros.

A significant factor is also human activity, which in this case is being expressed with the construction of a dam and transversal bars to limit the water's speed and stabilize the bottom of the river. Both restrict the river's sediment supply to the lower part and its delta.

The study revealed major lateral erosion of the river's bank of over 15 m. at places, a shrinkage of the river's mouth of 14 m. and a general



channel movement which is attributed to the aforementioned factors and have as a result to drastically change the morphology of the river and surrounding area.

**Keywords:** Fluvial evolution; Tectonics; Geomorphology; Peloponnese; Peiros river

*THEME: S3 : GEOMORPHIC PROCESSES IN COUPLED HUMAN AND NATURAL SYSTEMS*

**ABSTRACT NUMBER: 303**

## **NATURAL HAZARDS AND THE NORMATIVE SIGNIFICANCE OF EXPECTATIONS IN PROTECTING ALPINE COMMUNITIES**

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Protecting alpine communities from natural hazard events is costly. As climate change has led and will increasingly lead to a higher frequency and intensity of such events, at some point in the future states may consider planned relocations of some of these communities.

In this study we investigate the theoretical option of relocations with regard to three alpine areas in Austria that have experienced natural hazard events in the past. More specifically, we focus on residents' expectations about being protected from such events: (1) What do these expectations look like? (2) How morally significant are these expectations?

First, we report approx. 300 questionnaire surveys and 25 qualitative interviews. These surveys and interviews suggest that residents of the research areas widely share the following expectation, henceforth referred to as "E": "In the foreseeable future the state of Austria will provide us with a level of protection from natural hazards that allows us to continue to live in these areas".

Second, we investigate E's moral significance, i.e., to what extent it ought to be considered in assessing the moral rightness or justness of relocation policies. We propose several general conditions for the moral significance of expectations, both epistemic and justice-related ones. Then we argue that E fulfills these conditions to a significant extent.

The findings that residents in the research areas share E and that E is morally significant mean that the option of relocation may be more difficult to justify than previously thought; and that if the implementation of this option frustrates residents' legitimate expectations, they should be owed more compensation.

*THEME: S3 : GEOMORPHIC PROCESSES IN COUPLED HUMAN AND NATURAL SYSTEMS*

**ABSTRACT NUMBER: 403**

## **SELF-ORGANIZATION OF ANTHROPIC OCCUPATION IN THE BRAZILIAN CERRADO LANDSCAPE**

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In the systemic approach, the landscape should be understood as the structure-function duality. This means that the structural factor should be the natural boundaries to the efficiency assessment of the anthropic systems. In the Tropical region, this question is even more relevant due to its productivity in terms of natural resources availability and food security. The Brazilian Cerrado stands out as biodiversity hotspot owing to the high anthropic activities and high biological diversity and landscape heterogeneity among the tropical savannas. In this context, this work evaluated the self-organization of the anthropic systems regarding the natural ecosystems within the geomorphological unities of the Central Plateau of Brazilian Cerrado landscape. The geomorphological unities were mapped with Shuttle Radar Topography Mission (SRTM) data in RGB composition, using elevation, slope, and minimum curvature, respectively. Inside the geomorphological unities were identified the natural reference temporal pattern of Normalized Difference Vegetation Index (NDVI) from Moderate Resolution Imaging Spectroradiometer (MODIS) 10 years time series. The evaluation of the anthropic systems has regarded the natural systems with raster math. The results evidenced two planation surfaces: 1) flat plateau; 2) hilly depression. On the plateau, the annual crops were predominant with the higher amplitude NDVI temporal pattern regarding the savanna vegetation as a natural reference within this unity. The NDVI temporal profile of the depression has followed the natural reference sigmoid seasonal pattern, however with lower mean values, due to pasturelands dominance. The savanna formation characterized by trees and shrub mixture was found predominantly in steep areas and representative patches inside conservation unities. This work highlighted the

Cerrado archetypic landscape and the self-organization of the anthropic systems in each geomorphological unity. This approach can boost multifunctional landscape in tropical savannas considering natural reference and improving agroecosystems design.

**Keywords:** Structural factor, relief, functional factor, vegetation index, systemic landscape.

THEME: S3 : GEOMORPHIC PROCESSES IN COUPLED HUMAN AND NATURAL SYSTEMS

ABSTRACT NUMBER: 411

## INTERVENTION ON ESTUARINE PROCESS AND ITS IMPACTS IN INDIAN SUNDARBANS

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Since 1770, fifty four islands, covering an area of 5370 sq. km of Indian Sundarbans were reclaimed by clearing of mangrove forest facilitated by construction of 3500 km embankments. Hourly day-time tidal data were collected for eighteen months from two temporary gauge stations, Bhanderkhali & Sandeshkhali, located respectively at Hingalganj and Sandeshkhali Blocks of North 24 Parganas Districts, West Bengal. It was observed that tide takes 5 hours 30 minutes to attenuate and 7 hours 10 minute to fall indicating an asymmetrical tidal curve leading to flood domination. Unaltered natural system, however, was ebb dominated. In reclaimed situation, by exclusion of inter-tidal area with embankments, high tide becomes faster. Huge sediment is transferred landward by flood tide but that are not drained downstream by incapacitated sluggish flow of ebb tide, leading to deposition of sediment inside the channel and resultant drainage decay. Local people occupied land from channel beds by constructing series of long and cross embankment taking the advantage of drainage decay. Estimate shows that drainage lines of more than 2500km have been completely occupied and thus separated from the entire drainage system of Indian Sundarbans causing a considerable loss of water holding capacity. This, in turn, leads to the concentration of additional volume of water along main streams resulting to the potentiality of overtopping and embankment breaching, that was experienced on 25th May, 2009 ( Aila, the severe cyclonic storm).

**Keywords:** Reclamation, Tidal Asymmetry, Drainage Decay, Water-holding Capacity, Overtopping Breaching.

THEME: S3 : GEOMORPHIC PROCESSES IN COUPLED HUMAN AND NATURAL SYSTEMS

ABSTRACT NUMBER: 528

## A CONCEPTUAL CONNECTIVITY FRAMEWORK FOR UNDERSTANDING GEOMORPHIC CHANGE IN COUPLED HUMAN-GEOMORPHIC SYSTEMS

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Human-induced landscape change is difficult to predict due to the complexity inherent in both geomorphic and social systems as well as due to the coupling relationships between them. To better understand system complexity and system response to changing inputs, "connectivity thinking" has become an important recent paradigm within various disciplines including ecology, hydrology and geomorphology. In the presented conceptual connectivity framework on geomorphic change in coupled human-geomorphic systems we (i) include and systematically conceptualise the role of different types of human agency in altering connectivity relationships in geomorphic systems and (ii) integrate notions of human-environment interactions to connectivity concepts in geomorphology to better explain causes and trajectories of landscape change.

Geomorphic response of geomorphic systems to human disturbance is demonstrated to be determined by system-specific boundary conditions (incl. system history, related legacy effects and lag times), vegetation dynamics and human-induced feedback mechanisms between the different spatial dimensions of connectivity. It is further shown how changes in social systems can trigger a process response feedback loop between geomorphic and social systems that further governs the trajectory of landscape change in coupled human-geomorphic systems.

**Keywords:** Complexity, resilience, coupling, human-landscape systems, river management

THEME: S3 : GEOMORPHIC PROCESSES IN COUPLED HUMAN AND NATURAL SYSTEMS

ABSTRACT NUMBER: 547

## LAND SYSTEM ANALYSIS AND LAND MANAGEMENT PLAN FOR KABANI RIVER BASIN, WAYANAD DISTRICT, KERALA, INDIA

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Land is a finite resource. However, it is under stress due to multiple and competing usability, decreasing land man ratio, and demand for socio-economic development. Scientific analysis of land system is warranted to devise proper land management plan. This case study for Kabani river basin is one such attempt. The study area falls in the Wayanad district of Kerala State, which is economically backward district and dominated by indigenous population. The study covers analysis of geomorphic process, identification of land system units and their characterization and finally preparation of land management plan for all land systems units. Data have been generated using maps, satellite images, air photos and detailed field measurements. There are seven land system units recognizable in the study area under the processes of fluvial and denudational. These are: Flood plain, valley fill and alluvial basin (F1), Low rolling terrain (D1), Moderately undulating terrain (D2), Highly undulating terrain (D3), Isolated hills (D4), Scarp slope (D5), and Hummocky terrain (H1). Denudational process dominates the land systems in this basin by covering 60 % of total area of the basin. River shows signs of rejuvenation and structural control. The sinuosity index of the Kabani river basin is generally low (1.03-1.4) in upstream but it increases in the downstream from 1.1 to 2.24. The flat bottomed valleys bear imprints of past climate change. Each of these units is ecologically unique and differs in their production potential. This study stresses that a sustainable land management plan can be devised through detailed scientific analysis of land system units within the frame work of a river basin.

THEME: S3 : GEOMORPHIC PROCESSES IN COUPLED HUMAN AND NATURAL SYSTEMS

ABSTRACT NUMBER: 577

## INVESTIGATING THE BUFFERING CAPACITY OF MOUNTAIN COMMUNITIES TO SOCIO-ECONOMIC AND NATURAL HAZARD SHOCKS

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Recent extreme natural disasters have focused the attention of the global community to society's vulnerability to these events. Simultaneously these natural disasters occur within a broader social and physical context that is interconnected and may include climate change and economic crises. While progress has been made to mitigate and adapt to natural hazards, much of the existing research lacks interdisciplinary approaches that equally consider both natural and social processes. More importantly, this lack of integration between approaches remains a major challenge in developing disaster risk management plans for communities. In this study we focus on European Alpine communities that face numerous human and environmental risks and differ regarding their ability to cope with these risks and develop resilience. To shed light on this topic we have developed a coupled human-landscape model (MC-CHLS, Mountain Community Coupled Human Landscape System) for mountain communities exposed to socio-economic and physical "shocks". MC-CHLS contains a system dynamics component to reproduce socio-economic developments at the community level and socio-economic shocks that include economic crises. Additionally MC-CHLS contains a landscape evolution component (CAESAR-Lisflood) that replicates physical shocks on the community that include floods and landslides. Over decadal time scales we use MC-CHLS to investigate which shocks overcome the buffering capacity of mountain communities. Socioeconomic, climate, and hazard shock scenarios have been developed for three different community types: growing, stagnating and declining in terms of population and economic welfare. Guided by the model and scenarios we discuss the behavior of coupled human-landscape system and the potential outcomes regarding community adaptation and resilience.

ABSTRACT NUMBER: 579

## GEOMORFOMETRY AND URBAN PLANNING: CORRELATION BETWEEN FORMS OF RELIEF AND EROSION IN THE FEDERAL DISTRICT – BRAZIL

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The objective of this research was to correlate in the GIS environment the occurrence of linear erosions identified in the Federal District - Brazil with the types of relief form. Erosion records were made from satellite image analysis (Quickbird), aerial photos and field validation. 843 erosions were identified and registered, being 343 of the Rill type, 471 of the Ravines type and 22 of the Gullys type. The relief forms were obtained in a GIS environment, using 5-meter equidistance level curves as basis and overlap analysis using the horizontal and vertical relief curves. The curvatures of the area were obtained from a matrix of altitude. They were calculated cell by cell, and for each cell a fourth degree polynomial of form was determined. In order to integrate the horizontal and vertical curvature, 9 forms of relief were obtained (Concave-convergent; Concave- planar; Concave-divergent; Rectilinear-convergent; Rectilinear-planar; Rectilinear- divergent; Convex-convergent; Convex-planar and Convex-divergent). The results indicate that the highest concentration of erosions (26.8%) are on relief in a rectilinear-planar manner. More advanced Erosions of the Gullys type are concentrated in a concave-divergent shape. This favors flow concentration and erosion development, which may indicate a greater need for the conservation of areas with this type of relief.

**Keywords:** Geomorphometry; Erosion; Forms of Relief

ABSTRACT NUMBER: 674

## RAIN-TRIGGERED LAHARS ASSESSMENT OF THE 2014 KELUD VOLCANO ERUPTION, EAST JAVA (INDONESIA)

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The Kelud eruption in 2014 had impact on human environment in the area surrounding. Large agriculture areas and infrastructure facilities were covered by lahars, thus decreasing its productivity and services significantly. Despite suffering from this devastating impact of the volcano, the people in the Kelud region in particular farmers and sand manners decided to live and adapt to the phenomenon. Identification and assessment of hazard areas due to lahar in the Kelud region is a necessary to design proper disaster risk management.

This paper aims at identifying areas vulnerable to lahar and its impact. The combination of GIS techniques, geomorphological field survey as well as in-depth-interview was applied to assess the vulnerability of study area. Factors such as landform, rain fall data, river morphometry, river flow velocity, rock material distribution, and socio-economic data were considered for the identification of hazard-impact processes.

The results show that highest occurrences of rain-triggered lahars were located in the DAM 2 with the flow of rate 917, 8 m<sup>3</sup>/s and dominated by andesite, tuff and pumice material with the diameter 7-12 cm. This area is characterized by intensive mass movements of the volcanic deposits, especially during the rainy season. In addition, the geomorphic characteristic has been change due to intensive manning activities. Our socio-economic survey showed that lahars not only give negative effects for community life but also positive effects. Hence, the disaster risk management within Kelud region should considered not only negative risk reduction but also include positive outcomes of volcanic processes.

**Keywords:** Kelud volcano; lahars; disaster risk reduction

ABSTRACT NUMBER: 731

## EMERGING WASTELANDING PROCESSES IN ALLUVIAL GEOMORPHOLOGY OF TONS BASIN, INDIA

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Tons basin is solid geomorphic unit of 'Vindhyanal-Baghelkhand North Region' of 'Peninsular India'. As an amalgam of valleys and ridges, sheltered alluvial basins and bare rock expanses, forest cover and agricultural lands, the region naturally presents a transitional zone incorporating highlands, plateaus, ridges and valleys. The area has been under the age old operations of the morphogenetic processes since Archaean punctuated by the tectonics of varied nature and intensity. All these processes have carved out varieties of morphological facets of different orders where in 'wastelanding processes' have been emerged most destructive.

In entire Tons basin, the hectares and hectares of land have been emerged as wasteland. The study reveals that three types of wastelands have come up. The largest category is underutilized degraded notified forestland, while the second is devoted to steep sloping areas. The third is of gullies and ravines in riparian zones of alluvial rivers. Gully and ravine erosion is at its worst stage. Alluvial streams in lower parts of the region have scoured their channels more than 35 meters into the alluvium.

The factors of destruction in play are mostly ecological but there are ample evidences of recent down-cutting and erosion suggesting that this part of the Tons basin has been rising even during recent times. It may also be added that anthropogenic factors have also wasted the land powerfully by removal of green carpet from the floor of the Tons basin.

In short, it is the need of hour to check the increasing wastelanding processes. Author is of opinion that without quantifying the potential productivity of wastelands both in terms of their socio-economic and biological potential, the measures taken to prevent further wastelanding may increase the diminishing resource base.

**Keywords:** Wasteland; Alluvium; Gully; Ravine; Resource

ABSTRACT NUMBER: 750

## GEOMORPHIC CONSTRAINTS TO URBAN DEVELOPMENT IN NATIONAL CAPITAL TERRITORY OF DELHI (INDIA)

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Geomorphic setting, which plays a vital role in urban planning and development, is regrettably ignored in planning of most of the Indian cities. Town planners and policy maker are sufficiently unaware whether the land, which has been chosen for urban development, is geomorphologically suitable or unsuitable. Consequently some of the urban land shows a mismatch between adopted land use and geomorphic setting. The proper realization of the effects of geomorphic setting and surface processes may be helpful in classification of suitability of land for different urban uses. Delhi, which has an ancient origin, has been destroyed and built several times. Rapid population growth especially during last six decades has led to physical expansion of the city. Despite physiographical, topographical, hydrological and seismic constraints, Delhi continues to expand towards its periphery and much of the suburban area has been added into its urban limit. These constraints have become even more critical as the rate of urbanization increases. Therefore it becomes essential to analyze the geomorphic constraints to urban development of Delhi in order to measure the geomorphic capability of the area. The present paper attempts to find out topographical, physiographical, geological and hydrological constraints to urban development of Delhi by applying geomorphic information. This study finds a number of geomorphological consequences to urban development of our capital city. Due to rapid urbanization, city growth (horizontal expansion) is taking place in geomorphologically unsuitable areas and seismically sensitive platform of the city does not allow the vertical expansion. With the ever-growing population and limited land resources along with some other issues, the situation of Delhi is becoming more critical with the passage of time.

**Keywords:** Geomorphic process; Geomorphic capability; Urban development

THEME: S5 : VOLCANIC GEOMORPHOLOGY

ABSTRACT NUMBER: 559

## INITIATION AND RESSION OF THE FLUVIAL KNICKPOINTS: A CASE STUDY FROM THE YALU RIVER–WANGTIAN'E VOLCANIC REGION, NORTHEASTERN CHINA

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Initiation and recession of the knickpoints are significant boundary condition for processes of fluvial system. In the Yalu River–Wangtianè volcanic region of northeastern China, broadly distributed flat lava terrain provides an ideal site to study the recession of fluvial knickpoints because knickpoints and waterfalls are well preserved here. Here we describe the distribution of knickpoints in the Yalu River–Wangtianè volcanic region by combining DEM analysis and numerical modeling. Furthermore, we present a knickpoint celerity model, derived from stream–power incision model, to relate knickpoint recession rate to drainage area. We calibrate important empirical coefficients with our knickpoint celerity model; the best fit erosion coefficient (K) is  $1.32 \times 10^{-8}$ , and the best fit drainage area exponent (m) is 0.69. Error analysis indicates a close correspondence between synthetic and real knickpoints. Finally, we show that knickpoint recession rates in the Yalu River–Wangtianè volcanic region between  $\sim 1$ – $10$  mm/a during the early stages of transient incision, and that the present rates are  $\sim 1$ – $6$  mm/a. Our results are in good agreement with previous findings from the Aso Volcano and volcanoes near Boso Peninsula (Japan), providing new insight into landscape evolution in the Yalu River–Wangtianè volcanic region in northeastern China.

THEME: S5 : VOLCANIC GEOMORPHOLOGY

ABSTRACT NUMBER: 689

## METHOD APPROACHES ABOUT VOLCANIC GAS RISK ANALYSIS AND RISK MODELLING STUDIES

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Risk analysis is determining the potential for harm from hazardous with proportional or numerical values. In risk analysis studies, the aim is to determine the extent or amount of damage in different future possibilities. In the process of risk analysis some factors are interpreted; how danger interpreted by people, efforts to reduce the danger, human factors, which phases are being carried out, which are overlooked, the scope of losses in future disasters.

The essence of this work is to develop awareness of the baseline data and methods for volcanic and volcanic gases risk analysis and modeling. For this some works which about volcanic and volcanic gas outflows for different volcanic regions have been assessed by comparing risk analysis and risk modeling. The main objective was to make advance on the expression methods, dimension of the danger and the consequences of the risk and natural disaster. In risk analysis numerous data inputs such as the probability of volcanic activity, volcanic gas emissions and gas properties, climatic characteristics, geomorphological characteristics, population, human and economic characteristics have been tried to be evaluated.

One example of risk analysis studies have done within the scope of the study, risk analysis and modeling studies were carried out by taking advantage of the measurement of gas well located 3 km north of Gölcük Volcano in Isparta-Turkey. Gas risk analysis and dispersion modelling have done by taken into consideration on gas chemical analyzes, topographic and meteorological effects. Other examples have been done by other researchers, risk analysis and modeling studies for the Vesuvius Volcano Naples in Italy, Nevado Del Ruiz volcano which led to the death of more than 10 000 people with volcanic activity in 1985 in Colombia, El Misti, Arequipa volcanic regions in southwestern Peru.

**Keywords:** Volcanism, Volcanic Risk, Risk Modelling, Gas Risk Analysis.

THEME: S6 : KARST GEOMORPHOLOGY

ABSTRACT NUMBER: 50

## SINKHOLES IN A HYPOGENE GYPSUM KARST. THE CASE OF SANT MIQUEL VALLEY, NE SPAIN

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Recently, cave studies in hypogene karst systems have received large attention. However, sinkhole investigations in this type of hydrogeological settings are relatively scarce and the specific features of sinkholes in hypogenic systems remain poorly explored, despite the important practical implications. This work analyses sinkholes developed in the hypogene gypsum karst of the Sant Miquel Valley, NE Spain, located in the northern sector of the Ebro Cenozoic Basin, just south of the Pyrenean orogene. Here, the Eocene succession comprises the following hydrostratigraphic units relevant to our study, from base to top: (1) a regional limestone aquifer; (2) a gypsum unit up to 290 m thick (Beuda Gypsum); and (3) a confining marl unit up to 425 m thick (Banyoles Marls). The interstratal karstification of the Beuda Gypsum is mainly related to rising groundwater coming from the underlying aquifer. The Sant Miquel Valley is drained by a N-flowing stream and shows a relatively flat floor bounded by steep slopes. A cartographic inventory including 93 sinkholes, mostly of caprock-collapse type, has been constructed using remote-sensed data and conducting detailed field surveys, covering 32 km<sup>2</sup>. This is the area within the evaporite karst of La Garrotxa with the highest density of sinkholes; 2.9 sinkholes/km<sup>2</sup> and 2.13% of sinkhole percentage area. Caprock collapse sinkholes reach 400 m in diameter and may affect marl successions hundreds of meters thick, revealing the development of large deeply-rooted cavities and collapse structures. Sinkholes in the slopes area typically old and degraded, whereas in the bottom are younger and may host lakes. A number of features related to the spatial and temporal distribution of the sinkholes with practical implications are analyzed: spatial variability of sinkhole density and contribution of controlling factors, clustering, magnitude and frequency relationships, probability of occurrence, temporal relationships with the hydrological regime.

THEME: S6 : KARST GEOMORPHOLOGY

ABSTRACT NUMBER: 223

## THE SITUATION AND CHARACTERISTIC OF KARST LANDFORM AND WATER AND SOIL LOSS IN NORTHERN GUANGDONG

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Karst landform is developed and distributes widely in northern Guangdong, China. This region is of fragile ecological environment and severe water and soil loss. The soil and rocky desertification have become the prominent problems in karst area. The typical karst areas were investigated by field survey in the northern Guangdong, and using GIS techniques. The situation and characteristic of Karst landform and soil erosion are studied and the comprehensive treatments were properly proposed. The following conclusions are obtained: (1) The karst landform consists of mountains, hills and plains with karst in northern Guangdong. The regions are mainly distributed in Lianyang plateau mountain, the larger Karst landscape acreage is over 72%. The occurrences of soil erosion are mainly located in the mountains above altitude 500 m. (2) Karst process is very strong in karst areas and its development is accelerated by the high temperature and rainy weather. (3) Because of specific rock and soil composition, soil erosion is various in the karst area. The soil erosion is characterized by the superimposition of soil loss on the ground surface and under the ground. (4) The occurrence of karst rocky desertification with the erosion was explained from natural factors. The spatial difference of Karst landform affected soil, vegetation, topography, geology and other soil erosion factors, leading to the spatial differentiation of soil erosion mechanism. (5) Comprehensive treatments are the key to combat karst rocky desertification. Forests should be closed to human interference and deforestation must be stopped. Plants should be planted to increase vegetation cover. Small on-slope water conservation structures for Effective utilization of water resources should be constructed. Results have important values in the protection of the ecological environment and the control of rocky desertification in karst regions.

**Keywords:** the northern Guangdong; karst landform; soil and water loss; rocky desertification; comprehensive treatments

THEME: S6 : KARST GEOMORPHOLOGY

ABSTRACT NUMBER: 643

## THE EFFECT OF CARBONATE FORMATION ON SINKHOLES AROUND THE LAR DAM, NORTHWEST OF TEHRAN

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The lar dam has been constructed to supply drinkable water for Tehran, capital city of Iran.

During the years it has been exploited, various unconventional phenomena including formation of several large sinkhole around the lake have occurred.

The water leakage at the Lar Dam is mostly due to the abundance of caves and conduits in the underlying limestone beds. Although many efforts have been made to prevent the leakage (mainly by grouting), none of them have been successful. In this regard, existence of old sinkholes and development of new ones in the area, especially on the upstream side and in the vicinity of the dam wall, rise uncertainties around the dam's stability.

According to the geology map and aerial photos, tree major active faults were distinguished in the study area under the Lar dam structure. Mainly, the region is made of series of karstic limestone. The geological observations imply the alluvial extends down to 300m deep and thereafter a limestone formation made of limestone is present that indicates a karstification process and sinkhole formation.

In this study, to determine activity level of the sinkholes, the SAR method was employed.

We evaluated the effectiveness of our ESBAS method in monitoring of a significant sinkhole-related subsidence around the LAR dam. In this regard, ten sinkholes were observed in the area and within few kilometers away from the dam's location on the upstream side. The outcome of the analysis demonstrated that there is a water leakage as much as 28-34 mm/year from the sinkholes available around the lake.

THEME: S6 : KARST GEOMORPHOLOGY

ABSTRACT NUMBER: 702

## AN EXAMPLE OF POLYGENETIC GEOMORPHOLOGIC DEVELOPMENT (KARST-GLACIAL-TECTONICS) ON MUNZUR MOUNTAINS: KEPİR CAVE-ELBABA SPRING KARSTIC SYSTEM.

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Munzur mountains located between Erzincan and Ovacık Plains extend west-east directions along 100 km and formed from limestones on a large scale. The mountains is also an elevated karstic massive having an altitude of 3443 m. This karstic massive along with being glaciated in Pleistocene, it has plenty of karstic depressions. The study area comprises Kepir Cave, as a swallow hole cave and the Elbaba karstic spring which is located in the middle of the southern slope of the Munzur Mountains. The southern slope of the Munzur Mountains is bordered by the Ovacık fault and numerous springs demarcate this fault. These springs have been fed with water sources and sometimes with insurgence in the glacio-karstic basins located at the elevations of 2500-2700 m. The surface water infiltrates through the karstic basins and enters the underground system via dolines, sinkholes and vertically developed swallow hole caves. Later most of this water resurge at elevation of 1300-1350 m near the Ovacık Fault. The thick limestone provides the geologic structure for underground drainage and the formation of what may be a significant and deep cave system. The cave system appears to be developing vertically along a prominent fault that is visible just inside the swallow hole entrance. This karstic system continues to develop as an active system fed by significant snow and rain waters. In this study, we have attempted to explain the geomorphologic evolution of the karstic spring, Elbaba. We theorize this resurgence is the result of polygenetic geomorphology whose processes include glaciations, karst, fluvial and tectonics. The data sources of this study are comprised of 1:25000 scaled topo-maps; 1:100000 scaled geological maps; DEM, GPS measurements, satellite images and maps produced following field studies carried out in 2011,2012,2013. 3D and spatial analyses have been applied to create a database using GIS.



THEME: S7 : ANTHROPOCENE GEOMORPHOLOGY

ABSTRACT NUMBER: 593

## LANDSCAPE ANALYSIS AND MILK PRODUCTION IN BRAZIL

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Brazil is a world leader in milk production. Holstein animals have developed in Brazilian territory since the colonial period. The Holstein breed, as well as the breeds of its cross, are responsible for the high production of milk in the national territory. In order to increase and improve production a number of scientific studies have been developed in genetics landscape. This area of knowledge analyses the relationship between economic, social and geomorphological factors and the development of the animals in the places that are inserted. Thus, this work has aim to analyze the interference of the geomorphological aspects (altitude, relief and humidity), vegetation cover, precipitation, temperature, socioeconomic data in the milk production of the Holstein breed in Brazil. The genetic values of 65,383 animals of the Brazilian Holstein Breeders Association (ABCGH) were analyzed. The methodology was developed based on identification of clusters using the PROC FASTCLUS procedure of SAS (Statistical Analysis System, v.9.3, Cary, NC), canonical (CANDISC) and discriminant (DISCRIM) analyzes from milk production and dairy form data. The results confirm that the characteristics of the milk-producing animals have changed with the environmental factors of precipitation and temperature. In relation to the dairy form the most important variables in the determination of clusters were thermal amplitude, altitude variation and precipitation. This result attests that the environmental factors has a great influence of the milk production in Holstein breed in Brazil.

**Keywords:** Milk production; Genetics landscape; Geomorphological.

THEME: S7 : ANTHROPOCENE GEOMORPHOLOGY

ABSTRACT NUMBER: 724

## WATER IN THE URBAN & RURAL AREAS: AN OVERVIEW OF NEW LANDFORMS WITH INTEGRATED WATER MANAGEMENT

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Rapid urbanization growth with ever increasing concrete dominated spaces stemming firmly the ineffectiveness of water management in the cities along with inextricable domino effects. Concurrently, along with tackling the urbanization effectively another facet of 21st century is demand for sustainable development which helps in galvanizing the tipping points of various after effects of urbanization. But in vain, the century is canopied under higher rate of exploitation of environmental resources surpassing the biosphere's regenerative capacity where cities are main engines or forces of polluters. Water is considered as one of the basic prerequisite for sustenance of life and acts as the spine of quality of life of future cities, so need of the hour is exigent and evolutionary approach based on macro-micro-macro strategies which solidify in conserving the water resource efficiently and effectively.

Initially, paper reviews urbanization trends with various multiple effects on climate change and natural capital, shaping the new landforms. The current scenario of degradation of water resources along with impact on water cycle in both urban and rural areas separately. Finally, the paper concludes with the integrated water resources management techniques and strategies with a conceptual framework showing the tools required for spatial planning and water management.

**Keywords:** Urbanization; Climate Change and Domino Effects; Tragedy of Commons; New Geomorphology; Integrated Water Resource Management

THEME: S9 : BIO-GEOMORPHOLOGY

ABSTRACT NUMBER: 55

## WHAT DO MICROBES 'DO' ON ROCKS? INITIAL APPLICATION OF COMMUNITY LEVEL PHYSIOLOGICAL PROFILING (CLPP) IN BIOGEOMORPHOLOGY

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Research and understanding of the nature and roles of microbes in geomorphology is limited in comparison to plants and animals. However, the availability of new techniques from allied disciplines offers much opportunity for biogeomorphologists. Environmental metagenomics – the rapid, community-level identification of microbes using genetic material – can be used to identify which species are present on rocky substrates, their taxonomic diversity, and their compositional variability in time and space. Whilst this is a good starting point, a further and fundamental question for biogeomorphologists to address is ‘what are these communities doing?’ What are the functional roles of rock surface microbes? What are they metabolising and how does this impact the substrates they grow on and their susceptibility to weathering and erosion? Is taxonomic diversity commensurate with functional diversity?

To start addressing these questions, a culture-based technique developed in the soil sciences (Community Level Physiological Profiling, CLPP) was applied to epilithic microbes for the first time. The Biolog EcoPlate(TM) system allows the characterisation of whole bacterial community physiological function, measured colourimetrically as the richness, intensity and rate of carbon substrate utilisation. Here, metabolic fingerprints were obtained from different micro-sites at Great Asby Scar limestone pavement, northern England, UK. Initial tests show that the technique can be successfully applied to lithic communities, and can reveal spatial variability in bacterial metabolic function associated with different geomorphological features (clint surfaces, gryke walls, solution hollows and surrounding soils) and environmental conditions such as aspect and microclimate. Whilst there are important limitations to the technique that must be considered, initial tests show significant promise, particularly if coupled with genetic-based taxonomic identification.

**Keywords:** microbial geomorphology; biogeomorphology; karst; microbiology; CLPP

THEME: S9 : BIO-GEOMORPHOLOGY

ABSTRACT NUMBER: 388

## DISTRIBUTION OF THE UPPER LIMIT OF POSIDONIA OCEANICA MEADOW IN RELATION WITH WAVE INDUCED HYDRODYNAMICS IN MEDITERRANEAN BEACHES

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The interaction between underwater vegetation and waves, coastal hydrodynamics and sediment transport has been the subject of recent coastal biogeomorphological studies. Particularly in the Mediterranean coastal systems the phanerogame *Posidonia oceanica* is considered to play an important role in the coastal morphodynamics, protecting the coastline from erosion. Therefore *P. oceanica* meadow is protected by EU legislation including the Habitat Directive and the Water Framework Directive. Light availability determines the location of the deepest limit of *P. oceanica* meadow while the reasons which determine the upper limit position are still uncertain. This work aims at extending the previous works on the connection between the growth of *P. oceanica*, coastal hydrodynamics and sea bottom types. In particular we investigate in detail the influence of hydrodynamic parameters (e.g., wave-induced main currents, wave orbital velocity, total currents) on the position of the meadow upper limit. This study is based on wave hydrodynamics reconstruction by running numerical simulations. The bathymetry and meadow distribution of the Mediterranean beach systems, located in Sardinia, were acquired by field surveys (side scan sonar and single beam echosounder) and aerial photo analysis. Preliminary results show that the *P. oceanica* upper limit is usually found in water depth ranging between 6 and 12 meters depending on incident wave conditions and substratum characteristics. In particular, on sandy beaches the upper limit lies offshore of the most dynamic region of the nearshore suggesting that wave induced flows are the limiting factor for the meadow extension. However, on rocky substrata, the upper limit of the meadow is likely to reach shallower depths, a result probably related to the increased anchoring ability offered by the hard seabottom. In conclusion, this approach allows the identification and the role played by the main factors influencing the *P. oceanica* upper limit.

THEME: S9 : BIO-GEOMORPHOLOGY

ABSTRACT NUMBER: 501

## TREE-RING BASED DATING OF LANDSLIDES: THE NOISE/SIGNAL RATIO

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Dendrogeomorphic chronologies of landslide movements are frequently used to investigate past landslide activity. Slide areas are often affected by other slope movements (e.g., creep) simultaneously. Trees growing on landslides record all types of ground movements, which potentially creates significant noise in tree ring based chronologies of landslide movements. The effect of creep movements on dendrogeomorphic landslide chronologies was evaluated in a block-type landslide in the south-western foreland of the Orlické hory

Mts. In total, 272 trees (*P. abies* and *F. sylvatica*) were sampled (1088 increment cores) on the sub-horizontal surfaces of rotated slide blocks, which were presumably created only by slide movements, and on the steep internal scarps separating landslide blocks, which were presumably created and affected by a combination of slide and creep movements. Ground movements were dated based on growth disturbances identified in an analysis of eccentric tree growth. The trees growing on the internal landslide scarps separating the rotated blocks exhibited a significantly higher number and frequency of growth disturbances than those growing on the sub-horizontal block surfaces. All eight dated block surface movements were also identified on the internal scarps. Creep-based events represented as many as 70 % of the dated movement events on the internal scarps. Varying the  $\Delta t$  thresholds did not filter out more than 40 % of the noise without significantly reducing the number of true dated slide events. A significant difference was observed between the ability of *P. abies* and *F. sylvatica* to record ground movements by eccentric growth. Probably due its shallower roots (and weaker anchoring of the tree to landslide blocks), *P. abies* appears to be more sensitive to surficial ground movement, which potentially increases the proportion of dated creep events (noise).

**Keywords:** dendrogeomorphology; landslides; creep; chronology; noise/signal

THEME: S9 : BIO-GEOMORPHOLOGY

ABSTRACT NUMBER: 584

## GEOMORPHOLOGICAL AND BIOLOGICAL INFLUENCE ON SOIL $\Delta^{13}C$ AND $\Delta^{15}N$ ALONG A CATENA IN THE CENTRAL BRAZILIAN PLATEAU

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We explored the influence of topography, soil type, and plant community composition on the storage and dynamics of soil carbon and nitrogen along a catena in the Central Brazilian Plateau. We measured changes in total soil carbon, nitrogen, soil carbon isotope ratios ( $\delta^{13}C$ ) and soil nitrogen isotope ratios ( $\delta^{15}N$ ) along sampled soils (to a depth of 100 cm) with a factorial combination of three different soil types, two savanna formations and two forest types and three topographic positions along a catena at the Sarandi basin: I - cerrado sensu stricto on Rhodic Hapludox in upland, II - cerrado sensu stricto on Typic Hapludox in Plateau board, III - cerradão on Rhodic Hapludox in the lowland, and IV - gallery forest in Aqualf in the lowland. Carbon stock ranged from 141.9 Mg.ha<sup>-1</sup> in area II to 237.7 Mg.ha<sup>-1</sup> in area IV, while nitrogen stock ranged from 7.1 Mg.ha<sup>-1</sup> in area II to 13.2 Mg.ha<sup>-1</sup> in area IV up to 100 cm.  $\delta^{13}C$  ranged from -27.5‰ in the area III to -18.0‰ in I area. I and II areas are higher in  $\delta^{13}C$  than soils III and IV areas up to 80 cm.  $\delta^{15}N$  ranged from 2.0‰ to 11.1‰, with the most enriched  $\delta^{15}N$  soils being in the lower areas of IV area. In all soils, however, there is an increase in values from  $\delta^{15}N$  to 40 cm depth. For I and II areas, there weren't relationship between  $\delta^{15}N$  and soil C/N ratio, while areas III and IV had a negative relationship. The differences in the storage and dynamics of C and N along the catena showed that both geological and biological controls are relevant at the Brazilian savanna, and this dynamic can be evaluated using the soil carbon and nitrogen stable isotope ratios.

**Keywords:** Brazilian savannas, Oxisol, Relief, stable isotopes

THEME: S9 : BIO-GEOMORPHOLOGY

ABSTRACT NUMBER: 592

## POTENTIAL INFLUENCE OF RELIEF DISSECTION IN SOIL $\delta^{15}N$ VALUES OF WESTERN PAULISTA PLATEAU, SOUTHEASTERN BRAZIL

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The stable isotopes ratio of nitrogen ( $\delta^{15}N$ ) has been used to track soil organic matter dynamics in different landscape contexts. Some studies have shown clay content as stabilizing factor of higher soil  $\delta^{15}N$  values, corroborating the influence of clay in soil organic matter decomposition process. Vegetation and land use are well-known factors to influence  $\delta^{15}N$  in ecosystems, however, state factors like geomorphology influences  $\delta^{15}N$  values are still unclear. Since magnetic susceptibility has the potential to identify variation in soil formation processes, the objective of this work was to investigate the relationship of soil  $\delta^{15}N$ , clay content and magnetic susceptibility

in different stages of dissection relief, in Western Paulista Plateau, southeastern Brazil. Sampling planning was based on the geologic map of São Paulo state, relief dissection map obtained from landform classification and variability of soil attributes (granulometry, soil fertility, mineralogy, and magnetism). Thus, were selected representative sampling points. We analyzed soil  $\delta^{15}\text{N}$ , clay content and magnetic susceptibility (0-20cm depth), and compared mean values considering the stage of relief dissection (low and intermediary dissection). Low dissected relief tended to have higher mean values of  $\delta^{15}\text{N}$ , clay content and magnetic susceptibility in comparison than intermediary dissected relief. These results corroborated the correlation between clay and  $\delta^{15}\text{N}$  but also showed a possible relationship between  $\delta^{15}\text{N}$  and magnetic susceptibility. These results show the potential influence of relief dissection over soil  $\delta^{15}\text{N}$  values highlighting the importance of ecological-geomorphological approaches to study soil organic matter and their interactions in dynamic landscapes.

**Keywords:** isotopic signature, magnetic signature, geovariability, soil biogeochemistry, landscape compartments

THEME: S9 : BIO-GEOMORPHOLOGY

ABSTRACT NUMBER: 739

## BIOCHEMICAL WEATHERING AND DUST ACCRETION DETECTED IN COMPLEX ROCK VARNISH FROM THE DRY VALLEYS (ANTARCTICA)

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Rock varnish is a glossy, yellowish to dark brown coating that covers geomorphically stable, aeri ally exposed rock surfaces and landforms in arid lands. In warm deserts, rock varnish consists of clay minerals and Mn-Fe oxides/hydroxides, occasionally containing sulphates, phosphates and organics. In Antarctica, rock varnish has been described being mostly formed of Si, Al, Fe, sulphates. We investigated rock coatings developed on sandstones outcropping in the Dry Valleys of Antarctica and we noticed that the most of rock varnishes is extremely complex. Optical microscope evidenced the occurrence of highly birefringent material, occasionally thinly laminated (corresponding to Si and Al) interlayered by few micron-thick dark lenses and layers. The latter are well evident under the SEM and chemical analysis confirmed that they consist of different kinds of sulphates (jarosite), but gypsum crystals were also found. Fe-rich crusts and coatings were also detected, sometimes preserving the shape of the hyphae they have replaced. Samples collected from small weathering pits are rather different and rarely display a very thin Si/Al-bearing rock varnish. These samples show a yellowish brown rind around the external quartz grains, which are often coated by an amorphous, dark Mn/Fe-rich rock varnish. The formation of rock varnish in the Dry Valleys is a complex process, which required the accretion of airborne dust of variable composition and subsequent recrystallization of some constituent, possibly promoted by microorganisms. On the contrary, the formation of Mn-rich varnish should be in relation with the occurrence of higher environmental humidity within weathering pits. Rock varnish in the Dry Valleys represents a potential tool to reconstruct past water availability and changes in the aeolian fallout.

**Keywords:** Rock varnish; Antarctica; Sandstone; Sulphates.

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 117

## ENORMOUS DEEP-SEATED GRAVITATIONAL SLOPE DEFORMATION OF FLYSCH MONOCLINAL RIDGE: LARGE-SCALE SACKUNG AND GRAVITATIONAL TRANSPRESSION IN OUTER WESTERN CARPATHIANS

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Recently emerged concept of "slope tectonic" suggests that gravitational mass movement might produce structures similar to extensional, strike-slip and compressional tectonic deformations. However, only some of these slope tectonic features were hitherto identified in the field and there is still lack of field evidence of specific structures, like those related to gravitational transpression. Here we present an example of large-scale sackung-type deep-seated gravitational slope deformation (DSGSD) of monoclin al ridge in the flysch Czech Outer Western Carpathians (Smrk Mt.). Sackung landforms involving synthetic and antithetic scarps are strongly related to transverse (NNW and NNE trending) inherited normal and strike-slip faults and mainly cross-cut general topography of

the mountain ridge. Geomorphic mapping using high resolution LiDAR-derived topography supported by geophysical sounding (ERT and GPR) enabled identification of subtle landforms characteristic of slope tectonics, such as various types of scarps and gravitational folds. Although some of these folds originated as a product of buckling or compression in the distal parts of secondary landslides, pronounced concentration of folds along bended sacking lineaments suggests their transpressive origin. More specifically, we attribute genesis of these folds to the gravitational transpression originated due to the localized contraction between southward gravitationally sliding slab of sandstone flysch and bended sacking faults. It is for the first time, when field evidence suggests connection between DSGSDs kinematics and origin of transpressive structures excellently reflected in the topography. Our results suggest that geomorphic mapping based on LiDAR-derived topography could be useful tool for interpretation of slope tectonic features and inferring of DSGSDs kinematics, especially in soil-mantled forested mountain ranges with lack of outcrops.

**Keywords:** Slope tectonics; transpression; DSGSDs; LiDAR; near-surface geophysics; monoclinical ridge; Flysch Carpathians

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 183

## EFFECT OF INJECTED SEDIMENT CONCENTRATION ON RED SOIL EROSION AND FLOW HYDRAULICS

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The injected sediment concentration which was added at the beginning of experiments could be severe impact on soil erosion process and flow hydraulics. Little attention was paid on such effect using mud-water, most using clear-water. The objectives of this study were to determine the effect of injected sediment concentration on red soil erosion and flow hydraulics, and to try providing an insight into whether the suitable flow hydraulic for erosion can be influenced by injected sediment. Controlled Laboratory flume experiments with five injected initial sediment concentrations were conducted to evaluate its effect on soil erosion and flow hydraulic. Results indicated that there are three stages of beginning stage, rising stage, and stable stage for runoff generation process when added injected sediment load from 30kg/m<sup>3</sup> to 150kg/m<sup>3</sup>. They are. Injected sediment load mainly marked influenced on runoff volume at rising stage and stable stage. The injected soil increased the detaching capacity of the flowing water thus accelerating the erosion. Cumulative sediment mass has well lineally relationship with cumulative runoff volume under different injected sediment load.

The injected sediment load also significant influence on erosion flow hydraulics as runoff and sediment. Injected sediment load give significant impact on hydraulics of Re, f, and n/h. Re and f increased, and n/h decreased as injected sediment concentration increased. The relationship between Darcy-Weisbach friction coefficient and sediment load can be expressed in linearly function as:  $y=0.021x+0.0498$  ( $R^2=0.536$ ). Darcy-Weisbach friction coefficient is more suitable for indicating soil erosion than Re and n/h under this controlled condition.

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 315

## APPLICATION OF PAP/RAC FOR MAPPING FORMS OF SOIL EROSION IN THE CATCHMENT OF ASSIF GHZAF CENTRAL HIGH ATLAS, MOROCCO.

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The catchment of the Oued Assif Ghzaf is an environment favorable to the development of the phenomena of water erosion. Assif Ghzaf is the main tributary of Oued El Khdar, bounded on the north-east side by the Oued Lkhdar, on the south by Oued Tsaawt and Oued Mhacer from the west. Administratively belongs to the region of Beni Mellal-Khnifra extends over an area of 577 km<sup>2</sup>.

The catchment is characterized by concentration of precipitation in time and an absence of vegetation cover, absence of soil conservation, improper handling towards the environment, and that activate the soil erosion.

To determine the forms of soil erosion choosing the PAP /RAC (Priority Actions Programme /Regional Activity Centre), This method is based on two approaches: predictive and descriptive approaches, those two approaches give a consolidated map PAP/RAC whose analysis shows that soil loss throughout the catchment, is proportional to the increase of the major factors of water erosion according to the level of importance. In this paper adopting the second approach to obtain a Descriptive mapping of the various forms of erosion.

*THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS*

**ABSTRACT NUMBER: 319**

## **RELIEF EVOLUTION OF LANDSLIDE SLOPES RECONSTRUCTED FROM DEM BASED ON AIRBORNE LIDAR DATA (SUDETEN MTS, POLAND)**

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The aim of our study was to reconstruct the evolution of relief of the Kamiennie Mts (Central Sudeten Mts, Poland) with the use of DEM from airborne LiDAR data. Bedrock of the study area consists of volcanic rocks covering clastic sedimentary rocks of late Carboniferous and early Permian age. This type of lithological sequence favours slope instability and landsliding. Detailed analyses of DEM images combined with geological maps and slope cross sections were performed in ArcMap 10.5 and Surfer 13 to outline specific types of relief and to establish consecutive stages of relief development. DEM analysis confirmed widespread occurrence of landslides in the area under study. Results show that there are two main schemes of relief evolution of landslide slopes in the Kamiennie Mts. Landsliding tends to begin near the boundary between volcanic and sedimentary rocks and next can spread downslope or upslope. In the first scheme lithological boundary is located high on a slope and landsliding starts with a graben located on a mountain ridge. In the second scheme, sedimentary-volcanic boundary is located lower. Mass movements start as a small landslide in the lowest part of slope. Once landsliding is initiated it accelerates and develops upslope. Appearance of steep, almost vertical landslide scarps in the lower/middle section of a slope undermines bedrock located above. Successive generations of landsliding with secondary rockfalls can lead to the development of a vast landslide slope with main scarp reaching topographic culmination of a mountain ridge. In the final stage of relief evolution landslide activity results in complete disintegration of a mountain ridge. All consecutive stages of relief development were found in the present relief as different landslide slopes are probably of different age or develop with diverse speed.

*THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS*

**ABSTRACT NUMBER: 368**

## **TUFA DEPOSITS SHELTERED BY INLAND NOTCHES AS INDICATORS OF QUATERNARY DENUDATION RATES**

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As denudation of carbonate terrains in the Mediterranean zone involves mainly karstic dissolution, Israel is a natural laboratory for the study of denudation rates because of its carbonate terrain and steep precipitation gradient, ranging from >1000 mm in the north to less than 100 mm in the south.

"Inland notches" are elongated concave-shape indentations that develop on the carbonate rocky cliffs of mountainous zones in Mediterranean climates, as a result of differential weathering rates: the most porous cavity bed retreats at a faster rate compared to the slower subaerial dissolution of the visor bed, until a critical point is reached where the visor collapses. "Inland notches" are most common mainly in areas with annual rainfall of between 400 mm and 850 mm. Our study area is located on Mt. Carmel (Israel), that receives annual precipitation rates of 650-700 mm.

To determine the relative slope denudation rates, we calculated minimal ages of formation of notches using U-Th dating of tufa deposits developed under the notches' visors, or covering notches' cavity beds.

The tufa deposits were dated by U-Th at the Geological Survey of Israel using ion exchange column chemistry and MC-ICP-MS techniques modified after Vaks et al 2006. In each notch the oldest tufa layer was dated giving the minimum age of the surface formation. Six layers from four tufa samples were dated giving ages spanning from  $13,636 \pm 834$  ky to  $37,562 \pm 2,397$  ky, implying that the minimal age of these notches is last glacial period, or last deglaciation.

**Keywords:** Inland notches; Tufa; U-Th dating; Weathering; Denudation

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 444

## REGIONAL SOIL PARAMETERS ANALYSIS IN THE SHALLOW LANDSLIDE MODEL: APPLICATION IN THE SERRA DO MAR (BRAZIL)

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Landslides is one of the most dangerous natural disasters in the world and an important evolution hillslope process. Different physically-based models for predict landslide have been proposed. Thus, one of the most important discussion on the implementation of these physical models are: What are the values of soil parameters should we use? How to parameterize soil properties in basin or any area? This paper aims to apply Shalstab model to analyze the performance of model results in comparison with parameterization of soil properties using previous landslides location. The study area is located in Serra das Araras region (subdivision of the Serra do Mar) in the west of Rio de Janeiro state (Brazil). We constructed a 5-m grid Digital Terrain Model (DTM) using digital stereoscopic from aerial photographs with 1-m spatial resolution. Slope and contributing area were calculated from the resulting DTM. Landslide scars were mapped from digital stereoscopic interpretation. We used a range values based on field survey with similar geological and geomorphological conditions for the cohesion, friction angle and bulk density. We determined the best model from the fit index (FI) that is the percentage of total pixel of landslide scars, which is properly predicted as unstable. The two best models were the same FI index (friction angle = 40o and 45o, bulk density = 1.5 g/cm<sup>3</sup> and Coehsion = 2kPa). This result is similar as presented by Guimarães et al. (2003) for the tenth best models. The worst models have the highest cohesion (e. g. Coehsion = 8 kPa) and bulk density values of 1.5 g/cm<sup>3</sup> and Coehsion = 2 kPa are most frequent in the 10th best models. The highest unstable class occur in the northwest area. The results suggest the landslide retains a strong topographic control in the Serra do Mar region the Brazil.

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 446

## THE INFLUENCE OF GEOLOGICAL AND MORPHOLOGICAL SETTINGS ON SHALLOW LANDSLIDES, SERRA DO MAR, BRAZIL.

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In Serra do Mar, a mountain range that extends the southeast and south of Brazil's coast, shallow landslides are recurrent, due to climate and relief characteristics, such as altitudes, which vary from 800 m to 1.200 m. In 1967, a rainfall event (~ 600 mm/48h) occurred in Caraguatuba, severe housing, and infrastructure damages and many deaths. Therefore, studies aiming to identify susceptible areas and the major characteristics regarding landslides occurrence are necessary. Thus, the objective of the present study was to determine the influence of morphological (slope, aspect, curvature, elevation) and geological (lithology and structures) parameters on the occurrence of shallow landslides. The methods were: (i) Selection of two basins affected by the event with different magnitudes; (ii) Production of morphological and geological maps based on a high-resolution (5 m) digital elevation model (DEM), and a detailed geological map of Mineral Resources Research; (iii) Evaluation based on analysis of an agreement between predicted susceptibility and the landslide scar's map, using two indexes -Landslide Potential (LP) and Scars Concentration (SC).

The results showed that shallow landslides have occurred mostly on concave curvature in slopes of >30°, south orientation and 200-600 m of altitude. Such characteristics enable slope instability, flows concentration and soil saturation in both basins. The difference of magnitude in selected basins, considering the 1967 event, result from structural control. The influence of structure features in Santo Antônio basin, one of the most affected by landslides, is high, showing an important role of faults and fractures to landslide occurrences, which demonstrates that morphological parameters are not independent and must be analysed in a geological context.

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 448

## MORPHOMETRIC PARAMETERS ASSESSMENT AND DEBRIS FLOW MAGNITUDE IN BRAZIL.

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In Brazil, debris flow is a recurrent process, especially in Serra do Mar, a mountain range that extends about 1,500 km along south and southwest regions, due to its climate and geomorphologic characteristics. In last 50 years, several catastrophic events related to debris flow occurred, detaching the one of 2011, in Rio de Janeiro (> 1.000 deaths). Between March 17th and 18th 1967, next to Caraguatatuba municipality, northeast of Serra do Mar in São Paulo's State, hundreds of landslides and major debris flows were generated during heavy rainfall (580mm in 2 days), approximately 35% of the total annual rainfall for that region. Thus, the goal of this research was to analysis the relationship between morphometric parameters and the magnitude of debris flow in Caraguatatuba/SP. The methods were: a) selection of basins with debris flow deposits; b) definition and mapping of morphometric parameters; and c) definition of the debris flow magnitude. The results showed that in basins with high magnitude some parameters have got more evidence, such as > 25° area, the longitudinal profile of the main channel, drainage hierarchy, drainage density and relief ratio. With those data, susceptible basins can be identified just as its magnitude potential, preventing the occupation of those areas by the population and avoiding new catastrophic events related to debris flow.

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 534

## EVALUATION OF LANDSLIDE ACTIVITY USING TERRESTRIAL LASER SCANNING

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Landslides are one of the most important in relief development of the Polish flysch Carpathians. More than 65,000 landslides was found there, and their density is 3 forms per 1 km<sup>2</sup>. Landslides fronts often enter to mountain streams, and lateral erosion causes landslides triggering or re-activation of existing landslides. The aim of studies is to evaluate the role of gravitational processes and fluvial processes in landslide activity.

Small landslide (110 m long) formed in 2010 was selected for detailed analysis. Landslide is located at the Rożnowskie Foothill. It is developed within less resistant flysch of the Skole unit. In order to determine the spatial and volume changes within the landslide 8 series of measurements were made between April 2014 and April 2017, using Terrestrial Laser Scanning (TLS). Detailed analysis of the high resolution Digital Elevation Models (DEM) obtained by TLS have revealed the most active fragments of the studied landslide. Comparative analysis of DEM for different time periods allowed to determine the magnitude of changes occurring in particular periods. There are two main types of changes in surface of the landslide: (1) a removal of colluvia from the landslide by a lateral erosion during floods induced by the high totals precipitation; (2) a retreat of the main landslide scarp in the period of small amounts of precipitation, which results in increasing the surface of the landslide.

**Keywords:** landslide; stream erosion; Digital Elevation Models; Terrestrial Laser Scanning; Polish flysch Carpathians

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 535

## RECONSTRUCTION OF LARGE LANDSLIDES MOVEMENTS BASED ON DENDROGEOMORPHOLOGICAL METHOD (SAWICKI LANDSLIDE EXAMPLE IN THE BESKID NISKI Mts).

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Sawicki Landslide is one of the most famous landslides in the Polish Carpathians, because of landslide disaster in 1913 described by Ludomir Sawicki. Landslide is situated in the Beskid Niski Mts. It has more than 1.6 km<sup>2</sup> and is 2.5 km long. It is a detrusive landslide of complex type, formed probably in middle Holocene and rejuvenated, inter alia, in 1784 and 1913. Total amount of displaced mass was estimated at 25 million cubic meters. About 70% of the landslide area is covered with forest.

The aim of this study was to reconstruct the pattern of mass movement within the Sawicki Landslide. The dendrogeomorphological method has been applied. The cores of Scots pine (*Pinus sylvestris*) and Silver fir (*Abies alba*) were collected using an increment borer in the years 2013-2014, in the lower part of the landslide. Widths of annual tree rings were measured for each tree (on upslope and downslope sides of stump). The indicators of eccentricity, eccentricity index and yearly variation of eccentricity index were calculated on the basis of Malik and Wistuba equations.

Periods of high numbers of received landslide signals was considered for moments of activation of the tested landslide parts. These are the years: 1899, 1901, 1905, 1910, 1913-1914, 1920-1921, 1929, 1931, 1935, 1937, 1945, 1977, 1979, 1981, 1984-1985, 1990, 1992-1993, 1997, 2003-2004, 2006, 2010-2012. A large part of the results shows correlation with high values of precipitation, although some of landslide movements took place in dry years. In the most periods of landslides was activated by heavy rain during the warm half-year. It was also noted annual delay of landslide signals in the tree rings in relation to the years with high precipitation.

**Keywords:** landslide; dendrogeomorphology; eccentricity index; Polish Carpathians

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 546

## MORPHOMETRIC ANALYSIS AND EVOLUTION OF BADLANDS IN THE EMILIA APENNINES (NORTHERN ITALY)

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This paper shows the results of a pilot study conducted in the Emilia Apennines in the frame of a larger scale research programme promoted by the Italian Association of Physical Geography and Geomorphology (AIGeo) and aiming at implementing a national database on badlands and their evolution.

This study focused on the morphometric analysis of badland areas in the Province of Modena (Northern Apennines, Italy) - where clayey terrains largely outcrop - with the aim of understanding the role of the different factors that contributed to badland development and of outlining the evolution of badland landscape since 1950s. The research was based on the inventory of badland features in a larger area and then focused on selected sites. Multitemporal aerial photointerpretation and detailed morphometric analysis, coupled with meteorological data analysis and appraisal of landuse changes, enabled to outline the evolution badlands in a number of hydrographic basins. The preliminary outputs of the research show a progressive reduction of active badland areas and related progressive stabilization of gully features. It is likely that landuse change played a major role in this landscape evolution.

**Keywords:** Morphometric analysis; Badlands; Northern Apennines Italy

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 551

## THERMOMECHANICAL CONTROLS ON ROCKFALL FREQUENCY AND MAGNITUDE (SWISS ALPS) – INTEGRATING DEDUCTIVE ROCKWALL SURVEYS INTO ABDUCTIVE TALUS APPROACHES

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At instable mountain rockwalls, rockfall events are major drivers of rockwall erosion and sediment deposition. Both from a systemic

and natural hazard perspective, it is therefore essential to understand the causes and frequencies of rockfalls as well as to predict the block sizes deposited at specific downslope locations. However, contrary to large catastrophic landslides, small-size rockfalls (<104 m<sup>3</sup>) have received scant scientific attention. Here, we aim to improve our understanding of rockfalls at the lower magnitude spectrum with respect to their return periods and controlling factors. We present a holistic study of two rockwall-talus systems at the Hungerli Peak in the Swiss Alps, where we integrate deductive geotechnical and thermal investigations of the source rockwalls with abductive talus-based explanations of rockfall volume and frequency.

Our integrative approach reveals that decadal, large planar slides (~ every 250 years) overlain by smaller, annual wedge and toppling failures (~ every 17-50 years) as well as high-frequency flake-like clasts (3-6 events/year) characterise the rockfall frequency-magnitude pattern at Hungerli Peak. The rockwalls' 3D joint pattern indicates that 75% of rockfalls may occur as debris fall (< 14 m<sup>3</sup>) and boulder falls (14-61 m<sup>3</sup>), which is mirrored in the corresponding talus material. Seasonal ice segregation is likely the key destabilising process. Using 2-years records of near-surface rockwall temperatures as input for a numerical frost cracking model underlines that deepest cracking of 300 cm occurs on the NNE-exposed, snow-rich rockwall, peaking at the outermost surface.

Here, we argue that small-size rockfalls from instable rockwalls need more scientific attention and that future frequency-magnitude analyses should ideally incorporate site-specific structural and thermal properties. To proceed to this research agenda, the integration of deductive small-scale surveys of rockwall instability into multi-causal explanations from abductive assessments of talus archives may provide a valid basis.

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 729

## THE ROLE OF SOIL GRANULOMETRY IN THE DEVELOPMENT OF SHALLOW LANDSLIDES IN THE SERRA DO MAR STATE OF SÃO PAULO

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Mass movements are natural processes of relief evolution, with occurrence associated, particularly, to mountainous regions. The deflagration of those processes is related to a variety of geological, pedological and geomorphological factors, among them the physical-mechanical properties of the soil.

In Brazil, shallow landslides are recurrent, mainly in the Serra do Mar region, being the most common mass movement in this area, especially in high and medium stretches. The ruptures occur largely in the contact between the residual soil/saprolite soil, in which there are significant pedological differences.

Thus, this work aimed to identify a possible relationship between the soil granulometry and the development of shallow landslides, at the Guaxinduba river basin, located in the city of Caraguatatuba (SP). The area was strongly affected by landslides during the intense precipitation (~ 500mm / 48hs) in March 1967.

To achieve this, the following steps were performed: I) Sampling and sample collection at two points: P1 (stable, without scars) and P2 (unstable, area close to the scar); II) Granulometric tests. P1 and P2 are located under the same lithology, as well as a similar topographic and altimetric conditions.

The granulometric distribution of P1 presented, with more depth, an increase of the sand fraction and decrease of the silt and clay fractions, without abrupt texture changes. The results showed that P2, an area close to the scar, may be more prone to be unstable, associated with intense rainfall events, due to the presence of abrupt texture discontinuities and to be found in a concave area.

**Keywords:** Soil physical properties; Guaxinduba river basin; Caraguatatuba

THEME: S11 : HILLSLOPE PROCESSES AND MASS MOVEMENTS

ABSTRACT NUMBER: 785

## CHARACTERIZATION AND MAPPING OF MASS MOVEMENT HAZARDS IN THE BAMBOUTO CALDERA (CAMEROUN VOLCANIC LINE): A CONTRIBUTION FOR THE MITIGATION OF ASSOCIATED RISKS

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Bambouto volcano is one of the voluminous volcanic apparatus along the Cameroon Volcanic Line. The history of this volcano has been dominated by a piecemeal collapse type of its crater that gave rise to the formation of a large sub-elliptical (16x8 km) caldera at the summit (2,740 m). The process of the caldera formation have been ruled by important volcanic and tectonic events. The topography of the caldera appears uneven. The overlaying materials are loose in some areas of the caldera. The vegetal cover is made up of meadow that dominated significant areas. These features combined to human activities (farming, breeding, opening of roads, building) and heavy precipitations, triggered several mass movement hazards in the caldera. The most frequent are landslides, rocks falls and debris flows. They are sometimes associated to gully erosions. These hazards have an impact on human beings, infrastructures (house and roads), cultures and cattle. Through field and laboratory works, predisposing and triggering factors of mass movements have been identified and mapped. These maps have been combined to realizing the mass movement hazards map. It emerges that villages located in the western part of the caldera are less exposed to mass movement hazards. In the contrary, villages situated close to northern, eastern and southern rims and on external slopes are more exposed to these hazards. Hence, recommendations are provided: populations must be sensitized about mass movement hazards that they are facing; they must avoid construction on steepest slopes, deforestation and bushfires; moreover, they must create stock farms to avoid overpasturing... This works aims at bringing out a significant contribution in the sustainable management policy of the Mount Bambouto caldera whose inhabitants are assessed at around 4,000 nowadays. It will be helpful for decision makers to mitigate the risks associated to the mass movement hazards.

*THEME: S12 : PALAEOHYDROLOGY AND FLUVIAL ARCHIVES - HYDROLOGICAL  
EXTREME AND CRITICAL EVENTS (HEX)*

**ABSTRACT NUMBER: 414**

## **POSTGLACIAL CHANGES IN FLUVIAL MORPHOLOGIES OF THE UPSTREAM LOIRE CATCHMENT AND THE MIDDLE CHER RIVER VALLEY**

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The present study aims to provide new insights of fluvial metamorphosis associated with postglacial environmental changes. Investigations were conducted on different points upstream to downstream of the Loire catchment (Loire itself, Dore river and Cher river). This work allows the role of catchment size to be discussed regarding sensitivity of fluvial environments to climate changes.

Topography of the alluvial plain was analyzed using LiDAR DEM. Such datasets show topographic variations highlighting postglacial fluvial patterns and their relative chronology. Boreholes and electrical imaging survey help to estimate the geometry of former channels. Cores collected in palaeochannels provide organic materials suitable for radiocarbon dating and multiproxy analyses.

In Dore valley, incision of Pleniglacial deposits and the building of the Holocene floodplain occur after 23136-23958 Cal. BP, the youngest date obtained from organic filling sampled in palaeochannels. The oldest dates obtained in the Holocene deposits take place around 8000 Cal. BP.

On Burgundian Loire, Pleniglacial deposits are incised around 17 000 Cal. B.P. The fluvial pattern is then characterized by a braided system evolving to a meandering pattern probably active until 14 0000 Cal. B.P., when a new incision occurs and another braided system reworks previous deposits until 12 000 Cal. B.P.

In the Cher river valley, some inherited landforms correspond to wide and straight palaeochannels interpreted as transitional multichannel system following a braided fluvial pattern. They might be associated with an incision of the Pleniglacial floodplain and their cutoff are dated from 15 000 to 13 500 Cal. BP.

The beginning of the Lateglacial period is characterized by a significant incision occurring at different times. If this phenomenon is not unknown within postglacial alluvial deposits, such results can lead to a better knowledge of diversity and complexity of fluvial responses observed during the Lateglacial period on key positions of a fluvial network.

THEME: S12 : PALAEOHYDROLOGY AND FLUVIAL ARCHIVES - HYDROLOGICAL  
EXTREME AND CRITICAL EVENTS (HEX)

ABSTRACT NUMBER: 440

## LATE HOLOCENE EVOLUTION OF FLUVIAL SYSTEM IN SOUTHERN INDIA, TAMIL NADU: AN APPROACH FOR PALAEOFLOOD RECONSTRUCTION.

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Fluvial deposits are the geomorphic archives which serve as continental proxies for climate and tectonic studies. A general perception is that being a craton this region is tectonically stable but recent studies by many geologists has shown that region was tectonically active in recent past. The region is important to study because of two reasons (1) transgression of sea in Punducherry due to tectonics and (2) dominance of north-east monsoon, which lead to events such as recent Chennai floods. The Vellar River, the Then-Pennai, the Gingee River, the Palar River and associated palaeo-channels that formed due to migration of rivers in Tamil Nadu have been studied. The objective of this work is to (1) reconstruct the Late Holocene palaeoflood record from southern India, (2) to establish precise chronology of channel avulsion and look into the causes of these avulsions. A multi-dimensional approach using remote sensing, luminescence dating and sedimentary record is applied to address the problem. The palaeo-channels were identified using satellite images, the palaeoflood record was reconstructed using the sedimentary facies and these events were dated using optically stimulated luminescence (OSL) dating. The events such as Medieval Warming Period (MWP) and Little Ice Age (LIA) were identified. The rough boundary for MWP can be established between 1.2 to 0.7 ka, this period experienced heavy rainfall and rapid sedimentation on rivers. The boundary for LIA can be well established from 1250 AD to 1730 AD, LIA was a very dry phase. After LIA several flooding events have been identified using OSL dating which match well with the historical flood records such as in 1924 and 1961. The data also suggests that the region was tectonically active in recent past with one such activity between 1.2 to 0.7 ka.

**Keywords:** LIA; MWP; OSL; Palaeoflood.

THEME: S12 : PALAEOHYDROLOGY AND FLUVIAL ARCHIVES - HYDROLOGICAL  
EXTREME AND CRITICAL EVENTS (HEX)

ABSTRACT NUMBER: 468

## LUMINESCENCE CHRONOLOGY OF PALAEOFLOODS IN UPPER CAUVERY BASIN: IMPLICATIONS TO HOLOCENE CLIMATE RECONSTRUCTION

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Floods are naturally recurrent phenomenon caused majorly by high rainfall and snowmelt. The flood deposits are well preserved in overbank discharges as slack water deposit and also can be found in levees deposits for low discharge rivers. Downstream parts of rivers are more flood prone owing to high discharges; however only major flood events leave impacts on the upstream reaches of river basins. Such sedimentological records along with robust chronological structure help to predict duration, intensity and timings of palaeoflood events that are directly related to the climatic variations. We have attempted to identify paleoflood deposits from the upper reaches of Cauvery river and give them time framework using Optically Stimulated Luminescence (OSL) dating technique. OSL dates the last daylight exposure of sediment before burial. It erases geological signal from previous deposition resetting the clock to zero. Cauvery flows mostly through rocky terrain in the study area, carrying locally weathered sediments and sediments brought in by the adjoining tributaries. Daylight bleaching in high energy fluvial settings due to very short transport distance might be heterogeneous and incomplete in erasing geological signal. It will be interesting to see the extent of bleaching, thus feasibility of OSL dating in such geological environments, also in very young sediments dating back to few tens of hundreds of years only.

Heterogeneous bleaching was observed in the sediments from the upper parts of Cauvery. Proper age estimates were made only after application of various age models. The area has witnessed several major flood events in response to the medieval warm and humid phases during ~2 ka, ~160-220 years and ~60-50 years BP. The study throws light on luminescence characteristics, bleaching status and helps to reconstruct past fluvial history of upper Cauvery river, generally associated with change of climate and wet phases.

**Keywords:** Paleoflood; Cauvery; OSL

## ARTIFICIAL OPEN CHANNELS AS TOPOGRAPHICAL SIGNATURES AND THEIR IMPLICATIONS ON THE HYDROGEOMORPHOLOGICAL DYNAMICS OF RIVER BASINS

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In basin focused on traditional activities, the presence of artificial open channels that perform various environmental services are common. Because they are topographical signatures that interact with the surface runoff in the slopes, it is intended to evaluate if these channels cause changes in the hydrogeomorphological dynamics. A basin in the Brazilian tropical region of 48km<sup>2</sup> was considered for study, with 11 natural and 16 artificial channels, evaluated through fieldwork and the application of GIS tools to define flow directions (slope orientation) and the spatialization of these topographical signatures. The field survey revealed that the artificial channels are mainly in the average slope, following the contour lines and total length of 32 kilometers. As for the flow, about 57% is diverted from the natural channels to the artificial ones, in these the slow flow velocity (less than 0.5m / s) generates sedimentation in the artificial, which demands periodic cleaning. The cleaning activities of the material accommodated in the canal generate marginal deposits, such as artificial dikes, that can exceed 1 meter in channels with only 50cm of width and 20cm of depth, intercepting the superficial flow that moves of the topographic divider in direction to the valley bottom. Therefore, part of the sedimentary material in circulation in the basin can be retained, or in the sectors coming from the natural course or in the slope near the retention dykes. This evaluation suggests that the construction and maintenance of these channels modify the hydrosedymetological response in the basin, making it necessary to demonstrate this fact when presenting the exudation measurements of these basins, because next to the artificial channels a progressive accumulation of material responds by the elevation of the surface and changes the Dynamics of the hydrological circulation, a example of a modified hydrogeomorphological system.

**Keywords:** flow derivation; connectivity; Antropogeomorphology

## GEOMORPHIC HAZARDS ASSOCIATED WITH RIVER CHANNEL PROCESSES - MANIFESTATION, FREQUENCY, MAGNITUDE

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River channel lateral deformations associated with changes of their planform can impose serious threats to humans. Major hazards are associated with bank erosion and alluvial bedform migration. Constructions and communications located within channel or on its banks can be damaged or destroyed. In extreme cases buildings of towns can be washed away by a river. Migration of alluvial bedforms can result in blocking water intakes, fairways, ports and marinas. In other cases, alluvium can be eroded from bases of different constructions, and such objects lose integrity or totally collapse.

Rates of bank erosion and bedform migration depend on river sizes. Banks of medium and large rivers are eroded at rates up to 5-10 m/year. Sandy dune bedforms can shift up to hundreds of meters over the warm season. On small rivers bank erosion is about 0.3-0.7 m/year, while bedform migration for those is not important. Bank erosion occurs only during spring snowmelt floods and rainfall-induced high-water periods. At the peak stage of rising water level and discharge banks collapse at the maximum possible rates.

Assessment of geographic distribution of geomorphic hazards associated with river channel processes in Russia we used mapping method at the scales of the entire country and in separate river basins. These maps show the regions with increased, moderate and low levels of hazard with regard to bank erosion alluvial bedforms migration. Detailed characteristics of the hazard, the magnitude of its manifestations and potential consequences for bank and within-channel constructions are included in legends of such maps. Combination of the potential hazards of channel processes at various scales with information on existing or planned development within river or the riparian zone allows to evaluate risks of implementation of various land use types in river valleys.

**Keywords:** river, channel processes, geomorphic hazards, bank erosion, bedforms migration, risk assessment.

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 122

## ASSESSING THE GEOMORPHIC AND ECOLOGIC RESPONSE OF A RESTORED STREAM IN A COMPENSATORY MITIGATION BANK PROJECT, NORTH-CENTRAL TEXAS, USA

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Mitigation banks are aquatic resources that have undergone restoration and/or preservation for the purpose of providing compensatory mitigation for unavoidable losses of wetland acreage and function as a result of development activities. Mitigation banks in Texas are assessed according to three sets of standards: (1) stream performance standards; (2) riparian performance standards; and (3) Texas Rapid Assessment method (TXRAM) scores. In this paper, we provide an overview of the geomorphic and ecologic response of 6,950 meters and 35.6 hectares of restored stream and riparian habitat, respectively, in the Mill Branch Mitigation Bank in north-central Texas. Restoration efforts were focused on stabilizing failing banks, constructing flood-prone benches, increasing sinuosity (reducing slope), reconnecting disjointed channel segments, and establishing proper riffle-pool sequences and appropriate channel hydraulic geometry to convey channel-forming inputs of water and sediment. We conducted storm-based monitoring of slope runoff, channel flow and sediment loads as well as monthly scanning of the channel using 3D laser techniques to assess channel and overall stability.

**Keywords:** stream restoration; ecologic assessment; mitigation bank; geomorphic stability

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 137

## LATE GLACIAL TO HOLOCENE MORPHOSEDIMENTARY EVOLUTION IN THE LOWER VALLEY OF THE HÉRAULT RIVER, NORTHWESTERN MEDITERRANEAN

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The main steps of the sedimentary filling and geomorphic evolution in the Northwestern Mediterranean ria of the Hérault River during the last Holocene sea-level rise were reconstructed from a stratigraphic database composed of 483 drilling sites. Geostatistical analyses were undertaken to evidence three diachronic palaeosurfaces as well as the geometry and volume of the sedimentary units burying the palaeosurfaces. These concern the last Pleniglacial channel of the Hérault River, the maximum flooding surface associated with the marine transgression in the lower valley, and the surface buried under the fluviodeltaic progradational sequence. The first results show that coarse alluvium composed of gravel, pebble and sand deposited in the Pleniglacial channel during the Late Glacial. The coastal valley of the Hérault River was then flooded by the sea during the early Holocene, leading to the deposition of a retrogradational sequence composed of dark greyish to black muddy estuarine sediments. This transgressive systems tract (TST) reaches up to 25 m-thick at the modern shoreline and extends to 10 km inland. The TST is superimposed in the coastal area by a ca. 10 m-thick high-stand systems tract (HST) composed of grey to blue grey sand and gravel. From ca. 7000 cal yr BP, a fluviodeltaic progradational/aggradational sequence up to 10 m-thick deposited on the TST/HST. Ongoing studies will establish onshore/offshore stratigraphic correlations of the TST/HST sequences across the continental shelf of the Gulf of Lions, as well as rates of submerged area by the sea and the impact on archaeological settlements in the valley of the Hérault River.

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 155

## CHANNEL HEAD LOCATION IN SMALL CATCHMENT IN MONSOON CLIMATE

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The aim of the study is to determine the location and evolution of channel heads in small catchment in monsoon climate based on

the analysis of the morphometric characteristics of the channel heads and their contributing areas. A 0.21 km<sup>2</sup> catchment located in the Cherrapunji area in NE India was selected for the study. The area is characterized by horizontally bedded sedimentary rocks lying on the crystalline rocks of Indian Shield. It is the area with the highest precipitation rates in the world up to 12,000 mm per year. Morphometric measurements using a GPS and a laser rangefinder were made in the field: length and width of channel head, gradient of channel head, gradient of slope below and above channel head. The statistical distributions of morphometric parameters of channel heads are close to normal with a significance level of  $p = 0.05$ . The channel heads were divided into two groups according to the slope aspect. Then, to test the significance of differences in morphometric parameters between groups, the t-test for independent variables was used, for  $p = 0.05$ . The 29 channel heads were found with the contributing area of 9–1000 m<sup>2</sup>. On the E-slopes, the contributing areas, depths, widths and gradients of channel head and slope below channel head are greater than on the W-slopes. A statistically significant positive correlation occurs between the size of contributing area and the gradient of the channel head. The presence of positive correlation between these parameters distinguishes this catchment against other areas of the world in a humid climate, where this dependence is reversed. It can be concluded, therefore, that, despite the high precipitation, the development of the beginning of the trough is similar to the semi-arid areas, where overland flow dominates.

**Keywords:** channel head; monsoon climate; morphometric parameters; NE India

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 156

## CONTEMPORARY EVOLUTION OF HEADWATER VALLEYS IN A MOUNTAIN ENVIRONMENT (WESTERN TATRAS, POLAND)

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The main purpose of this research is to describe the contemporary evolution of headwater valleys in a mountain environment on the example of the Chochołowska Valley in the Western Tatras in Poland. The study attempts to answer the questions: Where is the boundary between the slope subsystem and the fluvial subsystem? and What are the morphometric and morphodynamic characteristics of the headwater section of a valley? The study area consists of the Potok Chochołowski catchment in Tatra National Park and includes 50 subcatchments ranging from first order to third order based on the Horton-Strahler classification system. The studied subcatchments are located within two distinct zones based on morphogenetic process type and level of activity: high-mountain zone (22 subcatchments) and mid-mountain zone (28 subcatchments). The first stage of the research study consisted of catchment morphometric analysis using a digital terrain model. Trend line patterns and gradients were analyzed for the catchment gradient-to-catchment area relationship in order to identify the boundary between a slope system and a fluvial system. Mountain stream channels in the Western Tatras found in catchments with an area of 0.2 km<sup>2</sup> or less and with a gradient above 0.49 m m<sup>-1</sup> are classified as part of slope system. The boundary between a slope system and a fluvial system is somewhat fuzzy. The transition from one predominant morphogenetic process to another occurs gradually via a transitional stream channel section. The next stage consisted of geomorphologic mapping of seven sub-catchments, monitoring of hydrologic and geomorphologic processes. The bedload transport models for this particular mountain range were created. These models explain the bedload transport mechanism in the longitudinal profile of a slope-fluvial system, with a particular focus on the transitional stream section.

**Keywords:** headwater valleys; slope and fluvial system; morphometric parameters; the Western Tatras

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 167

## ABOUT THE RESULTS LONG-TERM MONITORING OF GULLY EROSION IN UDMURT REPUBLIC, RUSSIA

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Gully erosion is an important soil degradation process in the southern half of the Russian plain. The territory of Udmurt Republic is located in the east of the Russian Plain in the southern part of the Vyatsko-Kamskoe interfluvium. It's characterized by the spread of the southern taiga landscapes and the zone of mixed coniferous and broad-leaf forests, transformed greatly by anthropogenic activity.

Two approaches were used for evaluation of gully head retreat rates. High resolution aerial photographs (flights of 1959, 1970 and 1980) were used for evaluation mean annual gully head retreat for periods 1959–1970 and 1970–1980. Field monitoring of 168 gully heads located in 28 locations within the different parts of the study area was organized since 1978 and it is continued until now. Measurements of gully head retreat are made once per year for the most part of sites. But retreat of 40-42 gully heads located in the Eastern part of the study area with high proportion of the arable lands are measured twice per year (after snow-melting in May and after rain-storm season in October).

The main reason of the serious reduction of the gulling since 1997 is increasing of winter air temperatures as a consequence of global warming. In the result serious reduction of surface runoff from the slope occurred during snow-melting in the years with frozen soil depth below 40-50 cm. It is confirmed by reduction of snow-melting in annual gully head retreat to 53% with relatively high variation from year to year. It is necessary to underline that during warm part of the year serious gully head retreat is observed after intensive rain-storms with layer of precipitation > 40 mm. Maximum of such rain-storms is observed within Vyatsko-Kamskoe interfluvium during 1990–1994.

**Keywords:** gully erosion; monitoring; Udmurt Republic

*THEME: S13 : FLUVIAL PROCESS AND LANDFORMS*

**ABSTRACT NUMBER: 168**

## **TRENDS IN THE DEVELOPMENT OF GULLY EROSION ON THE RUSSIAN PLAIN**

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The Russian Plain is area with intensive agricultural activity with high percentage of cultivated lands in the southern half. Climate changes and transformation in agricultural activity during last 25 years led to reduction of gully erosion rates and the length of the active gully.

An electronic vector maps of active gully density were composed for different river basins, located in forest, forest-steppe and steppe landscape zones of the Russian Plain. Results of interpretation of aerial photos and satellite images for the 2-3 time intervals (1956-60, 1986-1991 and 2010-2015) undertaken for the individual small catchments within the each river basin were used for the gully density mapping. It is allowed to identify trends of changes of the active gully network since the second half of the 20th century. It was found, that gully density were relatively stable until the end of 1980th due to low variability climatic conditions and a unchangeable area of arable land. However, results of the gully density evaluation conducted over the period 2010-2015 indicates a reduction of the active gully length on one order of magnitude and the decrease in the rate of gully erosion in 3-4 times for the period since the end of 1980th.

The main reason for the sharp reduction in the gully erosion rate is climate changes, which contributed to a significant reduction in coefficient of surface runoff from the slopes during spring snowmelt. A reduction in the depth of soil freezing is occurred due to increased air temperatures in the winter months, especially after 1997. In addition, reduction of cultivated land areas since the 1991 in particular in the forest zone and constant reduction of gully catchment area due to gully head retreat are the other reason of decreasing of active gully density.

**Keywords:** gully density; trends; Russian Plain

*THEME: S13 : FLUVIAL PROCESS AND LANDFORMS*

**ABSTRACT NUMBER: 190**

## **THE EROSION'S BELTS ON THE PLOWED SLOPES OF THE RIVER BASINS (BASED ON THE EXAMPLE OF THE RUSSIAN PLAIN)**

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Question Geomorphological conditions and agricultural activity define the surface runoff flow and erosion on the slope of the river



basins. In case there is more than 50% of the tillage square in the river basins, the special spatial structure of a basin's erosion in the forest and forest-steppe landscapes of the Russian Plain could be formed out.

Methodology Investigations of spatial and territorial regularities of erosion were conducted in the Middle Volga basin of the Russian Plain. Erosion structure studies have been conducted in more than 300 basins with the methods of remote sensing and the field research.

Results Within the regions of the basin erosion development there are different belts or areas might be distinguished according to the intensity of the erosion processes: 1) the areas absence of erosion; 2) raindrop destructing; 3) sheet (interill) and rill erosion; 4) ephemeral gully; 5) gully erosion; 6) dominated accumulation.

Erosion belts: the raindrop destructing and gully erosion on the slopes have the discrete location. The areas of the forest location could be distinguished with the absence of erosion. Dominated accumulation is related to the river floodplains. The continuous distribution on the slopes of river basins has only two levels: sheet (interill) and rill erosion which occupy around 25% of location) and ephemeral gully (occupies around 60% of location).

The width and the area of the belts are the functions of the slope declivity and length and permeable of the rocks and soils the volume and intensity of the runoff. The indicator of the basins' timberland is considered to be the core value in the process of forming erosion's belt structure. In the forest zone, its critical score should be less than 25%.

**Keywords:** erosion's belts; river basins

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 191

## TRENDS IN THE DEVELOPMENT OF GULLY EROSION ON THE RUSSIAN PLAIN

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**Keywords:** gully density; trends

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 215

## QUANTITATIVE AND QUALITATIVE ANALYSIS OF RELATIVE TECTONIC ACTIVITY OF NORTHWESTERN GREECE

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Since 1984, scientists have been trying to find a way to formulate model-based methods around the processes taking place on the surface of the earth and decode the relation between Tectonics and Geomorphology, in order to determine an area's relative degree of tectonic activity in a more accurate manner. The aim of this study is to improve the method of developing a quantitative geomorphic analysis of tectonic activity, by combining its results with the conclusions deriving from the fieldwork data of the Qualitative Analysis. For the quantitative geomorphic analysis, three significant morphometric indices are used. These indices include: the basin elongation ratio E, the basin asymmetry factor AF and the erosion - tectonic uplift ratio  $\epsilon$ . The combined analyzed indices using Geographic Information Systems - GIS, represent the relative active tectonics, reflected by the Tectonic Geomorphology Index ITG. The proposed methodology is applied in 209 basins in Northwestern Greece. The study area was divided into four regions, according to the values of ITG. These classes include class 1 (very high activity; 10% in area), class 2 (high; 26% in area), class 3 (moderate; 53% in area), and class 4 (low; 11% in area). The regions with high relative tectonic activity mostly coincide with the active structures in the basin. The study area features various degrees of active tectonics, resulting from the collision of the African with the Eurasian Plate and its location between the Adriatic collision and the subduction along the Hellenic Arc. By the hypothesis, relatively high degrees of active tectonics are associated with indicative values of ITG and are consistent with field observations on landforms and tectonic structures.

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 249

## FORMATION STAGES OF THE TARBAGATAYKA RIVER VALLEY (WESTERN TRANSBAIKALIA) IN THE LATE GLACIAL AND HOLOCENE

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One of the most important issues in the development of river systems is the establishment of a chronology of the formation of river terraces and the reaction of river systems to landscape-climatic changes on the basis of a detailed study of the structure of the terraces, the genesis and age of the constituent deposits and soils. This problem is relevant for the Western Transbaikalia. Here we presents the results of paleoecological changes in the small catchment basin of the Western Transbaikalia for the last 14 kyr BP, recorded in the sediments of the first and second terraces of Tarbagatayka river located in central part of Selenga middle mountains.

The time of the terraces formation is determined. For the second terrace, the transition from the floodplain sedimentation regime occurred 8.0 kyr BP, the first terrace - 3.4 kyr BP. Six stages of deposits accumulation were identified: Late Glacial (14-11.7 kyr BP), Early Holocene (11.7-11 kyr BP), Early and Middle Holocene (11-8.0 kyr BP), Middle Holocene (8.0-6.6 kyr BP), medium and late Holocene (6.6-0.5 kyr BP), and modern (<0.5 kyr BP). The obtained results are in good agreement with the data on the reconstruction of river flow in the Lake Baikal and information on its paleolevels obtained from geoarcheological data.

Most stages of pedogenesis recorded in studied sections are reflected in the Selenga and Orkhon terraces and floodplains, the rivers of the South-Eastern Transbaikalia and are in chronological agreement very well. This fact allows talking about regional climatic changes that have caused stable phases of landscape development.

**Keywords:** river terrace, stage of deposits, Late Glacial, Holocene.

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 289

## PHYSICAL CHARACTERISTICS AND FLOW MEASUREMENT IN SPRINGS OF THE SÃO FRANCISCO RIVER IN SERRA DA CANASTRA, MINAS GERAIS-BRAZIL

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Geological events made possible a structural rearrangement in the southwest of the state of Minas Gerais, originating the Serra da Canastra, a divide of the São Francisco and Paraná River basins. Considering the springs as important elements for the hydrogeomorphological dynamics, both in the water production and in the relief sculpture, it is sought to understand these natural and anthropogenic water outcrops, especially those that are part of the springs system of the São Francisco River. Thus, four springs were selected, called: GP1, GP2, GP3 and GP4. Fieldwork was carried out in January 2017, and a empirical analysis of the morphology and conditions of the

elements of the physical environment (rocks and regolith, depth, outcrops situations, texture and presence of water), taking aerial and surface photos and flow measurement. The biological activities, especially the action of termites, increase the porosity of the covering materials, consequently, tend to increase the infiltration, in contrast, in these same superficial materials, cementation levels, mainly ferricrete turn difficult the infiltration of the water for deeper layers, favoring the exfiltration of water. There are also layers of very thin unconsolidated materials, usually with outcrops of quartzite rocks, a characteristic that contributes to the emergence of springs. The source GP1 presented a flow of 22,2 liters/hour, occurs on the road, with multiple flows. The nascent GP2 has its morphology linked to soil sinks by retraction of a gully head walls, with output of 199,2 liters/hour. The nascent GP3 has its flow initiated by the outcropping on quartzite rocks, whose flow is 104,4 liters/hour. The source GP4 presented flow values of 142,2 liters/hour in the head of a ravine system. It is noted that the physical characteristics of Serra da Canastra are fundamental to guarantee the water productivity for the entire drainage system, which impacts directly downstream.

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 442

## SURVEY AND SYSTEMATIZATION OF HYDROMORPHOLOGICAL PARAMETERS FOR CHARACTERIZATION AND EVALUATION OF THE DIVERSITY OF RIVER CHANNEL PATTERNS IN THE XINGU RIVER BASIN

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The present study aimed to identify, characterize and evaluate the diversity of river channel patterns in the Xingu Drainage Basin as well as to propose procedures and parameters for this characterization and evaluation. The choice of the study area was justified by the potential of the existence of a great diversity of river channel patterns. This diversity occurs from the headwaters in the state of Mato Grosso to its mouth in the Amazon River, State of Pará/Brazil. This potentiality is due to the heterogeneity of geological/geomorphological environments along the longitudinal river profile, allied to its hydrological peculiarities. It was also justified by the importance of the protection of this element of the natural heritage that has been drastically impacted by the construction of the Belo Monte Power Plant in the region called "Volta Grande do Xingu". 23 reaches were selected to represent different river channel patterns along with the drainage network of the Xingu River and its main tributaries. We studied the dynamics of each of these reaches by the survey, correlation, and analysis of the hydrological data and morphological interpretation of satellite images and pre-existing mappings beyond fieldwork recognition. Among the main results, it was verified that the Xingu Drainage Basin is, in fact, highly diverse in relation to fluvial morphology patterns, since it presents almost all the channel patterns highlighted as the most important ones in the literature in a single drainage basin. Another methodological result was the systematization of parameters to evaluate geodiversity in hydrographic basins, particularly in the Amazon region.

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 464

## RATIO OF BED LOAD TO TOTAL SEDIMENT LOAD IN RIVERS

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The sediment transport rate is important to solve many engineering problems related to channel change in rivers. There are few of available bedload data because measuring bedload is very difficult and burdensome compared to suspended load in rivers. In flood seasons the total sediment load has been frequently estimated at the sum of the suspended load measured in field and the bed load calculated by many bedload equations. This paper is to investigate the ratio of bed load to total sediment load in the gravel bed river. The bed load ratio equation derived from Bagnold's approach for sediment transport rate may be suggested as a function of the dimensionless effective tractive force and the relative bed-load layer height. The coefficient in the bed load ratio equation has been dependent on the particle shear velocity Reynolds number. The bed load ratio increases with increasing the discharge per unit width of channel. The ratio is greater in rivers with the gravel bed than the sand bed.

**Keywords:** Bed load; Total sediment load; Dimensionless effective tractive force; Gravel bed river

ABSTRACT NUMBER: 507

## PLANFORM CHARACTERISTICS AND DEVELOPING LEVEL OF INTERCHANNEL WETLANDS IN A GRAVEL-BED ANASTOMOSING RIVER, MAQU REACH OF THE UPPER YELLOW RIVER

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Interchannel wetlands as well as multiple channels are crucial geomorphologic units in an anastomosing river system. Planform characteristics and developing level of interchannel wetlands and multiple channels control the characteristics of anastomosing rivers. Intending to understand the role interchannel wetlands play in the development of anastomosing river, a study was carried out at the Maqu reach of the Yellow River, a gravel-bed anastomosing river. Geomorphologic units in the study reach were extracted from high resolution satellite imagery in Google Earth, size distribution of interchannel wetlands and interchannel wetland clusters (special combination of interchannel wetlands and anabranches) were investigated, and geomorphologic parameters including ratio of interchannel wetland area to interchannel wetland cluster area (P), shoreline density (Dl) and node density (Dn) were used to analyze planform characteristics of interchannel wetland clusters and the development level of multiple channels in study reach. The results suggest that interchannel wetlands with small or middle sizes and interchannel wetland clusters with large or mega size are more common in study reach. The area of interchannel wetland cluster (Su) is highly related to other geomorphologic parameters, P increases with the increasing of Su, 80% is basically the upper limit value of P, which indicated that the development of interchannel wetlands and anabranches in an interchannel wetland cluster entry the equilibrium stage. In contrast, Dl and Dn shows a tendency to decrease with the increasing of Su due to evolution processes diversity in interchannel wetland clusters with different sizes. There are three main reasons leading to the formation of interchannel wetland clusters: stream power diversity caused by the meandering principal channel; development of river corridor due to the weakening of geologic structure control; and high stability of interchannel wetlands due to conservation by shoreline vegetation.

**Keywords:** channel planform; gravel-bed anastomosing river; interchannel wetland; geomorphologic parameter; Yellow River

ABSTRACT NUMBER: 522

## RESPONSE OF BHUKI BASIN TO CLIMATE DURING THE MID-PLEISTOCENE PERIOD WITHIN THE KACHCHH MAINLAND, WESTERN INDIA

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The arid and semi-arid western India has preserved the alluvial record of past. The present study is to improve our understanding of the river response to Indian Summer Monsoon (ISM) variability and related landforms. Towards this; we investigated a north flowing Bhuki river of the Kachchh peninsula. Geomorphologically the river flows through four distinct landforms: northern rocky upland, pediment zone, alluvial plain and lower most alluvial fan at the fringe of the Banni plain.

The incised alluvial succession is exposed at multiple locations in the alluvial plain. Based on sediment texture and structures, six lithofacies are discerned. Overall the facies architecture indicates that the deposition occurred under highly fluctuating hydrological condition. The lowermost gravel horizon suggests flashy condition probably associated with stormy phase. The fine sand with calcareous nodules (unit-II) indicates hydrological stability and consistency of the flow condition associated with strengthened ISM. The laminated gravelly bed containing platy lithoclast (unit-III) indicates reversal towards weaker ISM. The deposition of the massive sand containing dispersed gravels (unit-IV) indicates moderate stability in the fluvial discharge with less frequent flashy condition (moderate ISM). The overlying fine sand with calcareous nodules showing evidence of pedogenesis (unit-V and VI) indicates relatively strengthened and stable ISM condition. However, considering the proximity of the tectonically active Katrol Hill Fault (KHF), the mobilization of the gravelly horizons and or the platy lithoclast could have been ascribed to the tectonically induced contribution into the fluvial system.

The above observations are further supported by the geochemical studies and optical chronology. Chemical Index of Weathering suggests not much effective climatic weathering situation. Optically Stimulated Luminescence ages showing the age within 66.2+/-6.6ka to 62.2+/-4.9ka. Overall it can be suggested that the area witnessed weak/ episodic monsoonal activity during middle Pleistocene period.

**Keywords:** Kachchh; Fluvial Archives; Middle Pleistocene

ABSTRACT NUMBER: 557

## THE HYDROGEOCHEMICAL STUDY OF VARZAGAN PLAIN

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Varzagan plain's aquifer with its 29.11 square kilometer area is located in northwestern Iran, in the western side of Sabalan Mountain between the 46°30' to 47°E and 38°30' to 39°N in the East Azarbaijan province and is part of the Caspian Sea catchment.

Geophysical data show that the thickness part of the alluvium of the plain is in the western half of Varzagan and is about 30 meters. This thickness reduces, as we get closer to the east and at the Goijeh soltan, it becomes 20 meters thick. The rock at the bottom of the aquifer is clay and marl in general.

It is estimated that the maximum capacity of the aquifer in the east bank of Aharchai and in its middle part ( Karvig valley) is about 150 m<sup>2</sup> daily.

Ahar plain's water sources include 7 deep wells and 157 active semi-deep wells, with a yearly outlet of 2.64 million m<sup>3</sup> , 187 springs with a yearly outlet of 19.38 million m<sup>3</sup> and 23 aqueducts with a yearly outlet of 2.04 million m<sup>3</sup>.

Electricity conductivity of the water in the feeding regions of the aquifer is about 400 to 700 microsiemens per centimeter (minimum) and in the east, it reaches 1400 microsiemens per centimeter (maximum). Aggregate amount of solvent salts in the water of the aquifer is about 300 milligrams per liter in the feeding regions and it reaches up to 950 milligrams per liter in the outlets. Drinking water quality moves from good to acceptably as we go from the feeding regions to the outlets. From the agriculture point of view, the quality of the water goes from C3-S1 (good for agriculture) in the feeding region to C3-S2, in the middle and outlet parts.

**Keywords:** Aquifer; Conductivity; Ground Water; Aquifer Water Quality; Varzagan Plain.

ABSTRACT NUMBER: 583

## ANALYSIS OF CHANNEL PATTERN CHANGES IN THE COASTAL PLAIN OF GILAN, IRAN

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The coastal plain of Gilan is located between the Alborz Mountains and the Caspian Sea in the North of Iran. There are many rivers pass through the Gilan Plain and reach to the Caspian Sea. Since the geometrical parameters and channel pattern are the main properties of each river which are used for river engineering and management projects. This paper evaluated differences in channel patterns of 11 rivers (Sefidrood, Shalmanrood, Shafarood, Polrood, Shakhrz Anzali, Chubar, lamir, Chelvand, Essar, Karganrood, Navrood) in the coastal plain of Gilan. For this reason, all of 11 rivers were divided to several reaches and some parameters (e.g. stream power, unit stream power, discharge, channel slope, channel width and curvature coefficient) and channel patterns were calculated in 69 cross-sections using topographic maps, Google Earth images, GIS analysis and field observations. Finally relation between main parameters and channel patterns were evaluated by statistical analysis. Results showed that there are two types of channel patterns (single thread and multi-thread) but 49 cross-sections have single thread and among these, 28 cross-sections have sinuous pattern also 20 cross-sections have multi-thread pattern. Statistical analysis showed that there is a significant difference in stream power, discharge, slope and width between single and multi-thread patterns but there isn't any significant difference in unit stream power between these two types of patterns. Also there is a significant difference in stream power between three types of single thread (straight, sinuous and meandering) and there isn't any significant difference in stream power, discharge, slope, width between three types of single thread pattern. Therefore the stream power has a key role affected on channel patterns in Gilan Rivers.

**Keywords:** Channel patterns; stream power; coastal plain; Gilan

ABSTRACT NUMBER: 616

## ROLE OF GEOMORPHIC PROCESSES ON EVOLUTION OF VALLEY-FILL DEPOSITS IN DIFFERENT REACHES OF THE ALAKNANDA RIVER BASIN

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The valley-fill deposits in mountainous terrain records response of various geomorphic processes i.e., glacial, fluvial and hillslope, that are influenced by climatic and tectonic events. The Alaknanda River basin, a headwater tributary of the Ganga River, in NW Himalaya stores enormous amount of such valley-fill deposits characterised by complex assemblage of varied landforms. Recent studies suggested vital role of climate in the aggradation and incision phases of the Alakananda River. Variation in the geological and geomorphic characteristics along the Alaknanda River has guided the development of the valley-fill deposits in its different river reaches.

Present study is carried out to understand the role of various geomorphic processes in the evolution of valley-fill deposits in specific reaches of the Alaknanda River basin. Two reaches of the Alaknanda River viz., Pipalkoti and Srinagar valley were selected for comprehensive geomorphological and sedimentological investigations of the valley-fill deposits. Geomorphological classification of valley-fill deposits shows presence of landforms like fluvial terraces (both - cut & fill and strath terraces), debris flow surfaces, debris covered hillslopes, and vegetated/bedrock hillslopes. Valley-fill sedimentation in the studied reaches is controlled by sediments from the Alaknanda River (axial river) - qi, local stream/tributary deposits - qt and mass movement deposits - qh.

The results suggest that evolution of Pipalkoti's valley-fill deposits are developed due to interaction between fluvial and hillslope processes. Whereas, valley-fill deposits of Srinagar valley evolved due to coupling of the Alaknanda River, its tributaries and hillslope processes. The study also concludes that a river shows variable response along its length to any climatic and tectonic event as the lithology and geomorphic processes vary in different reaches.

**Keywords:** Valley-fill deposits; Main channel - Tributary coupling; Debris flow; Alaknanda River; Himalaya

ABSTRACT NUMBER: 617

## PREDOMINANT LITHOLOGICAL OVER CLIMATIC CONTROL ON THE VARIABILITY OF LANDSCAPE CHARACTERISTICS IN TECTONICALLY PASSIVE WESTERN GHAT

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Landscape patterns in the passive tectonic margins are shaped by either geological or climatic parameters or both. The 1500 km-long Western Ghat is an excellent example of passive margin escarpment in the west coast of India, which has an average elevation of ~1 km. Here, we use fluvial geomorphological attributes, climatic proxies, and lithologic heterogeneity to gauge the geomorphic variability and to ascertain its primary driver.

A regional scale geomorphic analysis is undertaken using SRTM 90m DEM. 45 drainage basins have been delineated along-strike of the Ghat, for relief and channel profile analyses. Although local relief and clusters of gridded hypsometric integral depicts consistent higher erosivity all along the escarpment fringe, there are several patches of high potential erosion zones that are identified in northern coastal regions, anomalous steep zone in the central part along the margin and southern highlands. Swath-averaged topographic profiles indicate a significant variability in relief in southern basins in comparison to northern ones. River basins overlain by Cenozoic Basalt in the northern part portrays relatively less concavity in comparison to basins overlain by Archean-Precambrian lithology in the southern counterpart. Rainfall distribution is comparable along the Ghat; however, peak runoff is higher for northern rivers than southern ones. Sediment rating curves also show higher erosion and sediment supply in northern rivers. Higher weathering and erosion promotes less relief in northern basins. We have found that the bivariate correlation between concavity and mean monsoon discharge and mean peak monsoon discharge is negligible. Whereas, lithology and their erodibility explains the breaks in longitudinal profiles and its shape for most of the rivers. Overall analyses suggests that lithology acts as a primary driver of the concavity and steepness of river profiles and subsequently is dominated by the hydrological responses of the drainage basins.

**Keywords:** Passive margin; longitudinal profiles; hypsometry; relief.

ABSTRACT NUMBER: 655

## SLOPE-AREA AND SLOPE-DISTANCE CHANNEL STEEPNESS INDICES YIELD ANALOGOUS RESULTS FOR A HIGH-RELIEF POST-OROGENIC LANDSCAPE

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Channel steepness indices have been widely used to investigate the pattern and style of landscape evolution in erosional landscapes. It relies on the assumption that local slope and discharge characteristics control the nature and efficiency of erosional processes as described by the stream power model. However, as discharge data with adequate resolution is regularly unavailable, a proxy to discharge – either (1) downstream distance or (2) drainage area, is traditionally used. Plotting channel slope as a function of 1 or 2 should yield a straight line – or series of straight lines, where the angular coefficient in case of using 1 or the b-intercept – using 2 on a log-log space, represent a measure of the relative steepness of a river channel and, more importantly, an index of stream power. These indices are referred as the stream length-gradient index (SL index) and the normalized steepness index (Ksn). The Ksn is presumed to be more robust than the SL index because (i) the correlation between discharge and drainage area is assumed to be stronger than the relationship with downstream distance; (ii) Ksn has been demonstrated to be closely related to erosion rates; (iii) the Ksn is allegedly theory-driven while the SL index was empirically established. We test the hypothesis that the Ksn approach yields better results for quantitative geomorphic analysis than the SL index method. Hence, we quantified catchment-averaged Ksn and SL index for 63 basins extending over a range of sizes of a high-relief post-orogenic setting, the Quadrilátero Ferrífero – Brazil. We compare intra-basin variability in steepness indices as well as their correlation with other geomorphic metrics – e.g. mean slope angle, local relief, drainage area. Our results suggest overall consistency between both types of measurements. They correlate similarly with topographic parameters, and there is not significant intra-basin variability.

ABSTRACT NUMBER: 663

## THE ROLE OF INHERENT BASIN CHARACTERISTICS IN DEFINING FLUVIAL RESPONSE TO CHANGED FLUX REGIME IN GLACIATED SUB-BASINS, NORTHWEST HIMALAYAS

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Rise in temperature is poised to increase water and sediment input into fluvial systems of glaciated and permafrost bound river basins of northwest Himalayas due to increased melting and permafrost degradation. In this context, understanding and prognosticating geomorphic response of rivers to the new dispensation of increased fluxes is of utmost importance. An important factor that will determine the resultant change in fluvial processes and equilibration dynamics of fluvial system is the inherent geomorphic characteristics of basins. The present work attempts to quantify and analyze these traits that will facilitate anticipation of river response trajectory by using a combination of topographic parameters like longitudinal stream profile, steepness index, chi plot and excess topography. These parameters provide a measure of resisting force in the channel and will have a bearing on the efficacy of stream power (driving force). Convexity of river longitudinal profile, higher steepness index, chi plot values above the equilibrium line and higher excess topography indicate reaches where more geomorphic work in the form of erosion is required to attain graded profile and more stable topography. The reverse of these conditions holds true where geomorphic work of aggradation is required. Lengths of potential net erosional and potential net depositional reaches have been measured by way of pixel counting above and below the equilibrium line of chi plot respectively. Further, hypsometric integral values show that sub-basins traversing the crest of high Himalaya are especially notable for exhibiting out-of-equilibrium signal which are potential zones of erosion. Sub-basins in the trans-Himalaya and Sub-Himalaya on the other hand has lower hypsometric integral and thus are potential aggradational zones. Such identification of potential reaches of aggradation and erosion will help in predicting and anticipating the future evolving trajectories of these rivers in response to flux variability.

**Keywords:** Temperature rise; fluvial response; chi-plot; excess topography.

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 696

## THE UPPER HOLOCENE IN ITAPICURU RIVER BASIN (BRAZIL): PROPOSITION OF SCENARIO FOR THE LOWER COURSE AND COASTAL PLAIN

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The occurrence of geomorphological processes associated with the Upper Holocene is still unknown in many areas of the Bahia State, however the coastal regions are those with greater availability of information. In the national literature models of coastal evolution and sea level variation curves were developed, while the continental regions need to be better investigated. This thesis problematized the need to establish relations between events occurring in the coastal plain and in the lower Itapicuru course, responsible for the elaboration of low fluvial terraces and marine terraces during the Upper Holocene. With the objective of proposing the evolutionary scenario for this period, particle size analysis and OSL dating were performed at low fluvial terrace, younger alluvium deposits and marine terraces, correlating them with environmental variables and the available literature. It was possible to infer that during the Upper Holocene, coarse depositional cycles predominated, with variations between the sands in the fluvial landforms and recent cycles of deposition in the coastal plain. In the shoreline, the period was marked by eustatic processes and in the valley, climatic processes prevailed. There were alternations between humid and drier climatic pulses that the current climate, a scenario suggested in previous surveys for the Northeast of Brazil.

**Keywords:** Upper Holocene, Itapicuru River, Fluvial Terraces, Coastal Plain.

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 698

## SEMIAUTOMATIC IDENTIFICATION OF ALLUVIAL FORMS ON THE WARTA RIVER FLOODPLAIN, POLAND

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Alluvial forms located on the floodplain of the Warta River were performed by geomorphometric analysis. Geomorphometric features of alluvial forms were determined on the basis of calculated geomorphometric indicators: slope, vertical and planar curvatures, relative height index, topographical index position (TPI), and a multi-resolution valley flattening index (MRVBF). Calculations of the above statistics were made on the basis of a digital elevation model with grid size of 1 m (ALS; cloud of data points with a density of 6 points by square meter) and used to develop three exemplary, semiautomatic methods for detecting various types of floodplain forms. Note, these methods determine the places where potentially different types of forms may exist in the investigated area. Therefore, they should be treated as semiautomated methods requiring expert knowledge in order to confirm the correctness of the detection of a particular type of alluvial landforms. For the analytical purposes, 82 forms were most readable during remote interpretation. It was not possible to determine terrace ribbons, sand shadows and other smaller forms due to the lack of clear boundaries of these forms. Some problem was also the delimitation of the levee boundaries. In this case, the boundary was often carried out at the place of a change from a significant elevated terrain to the flat area. Another problematic location of the boundary was the contact of younger oxbow lakes with the surrounding embankment. Geomorphometric analysis has shown that the DEM constructed on the basis of altitude data from ALS is very well suited for determining the morphometric characteristics of most types of alluvial forms found on a floodplain. The geomorphometric characteristics of most types of forms existing on the studied Warta floodplain were determined.

**Keywords:** alluvial forms; fluvial landforms; floodplain; geomorphometry; the Warta River

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 737

## STRATIGRAPHIC CHARACTERIZATION AND GRANULOMETRIC ANALYSIS OF MARGINAL SEDIMENTS IN THE COASTAL SECTION OF THE TRÊS BARRAS RIVER, SOUTHERN BRAZIL,



## AND RELATIONSHIP WITH FLUVIAL DYNAMICS

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The study aimed to carry out a preliminary stratigraphic characterization and grain size analysis of marginal sediments in two sections of the Três Barras River, located in the humid subtropical environment of northeastern Santa Catarina State, southern Brazil, in order to provide data for understanding the local fluvial dynamics and its interactions with the coastal plain. The 64 km<sup>2</sup> watershed is composed mainly by three different environments: the Atlantic Plateau, the scarps of the Serra do Mar mountain range and the coastal plain, with an altitude variation of 1,360 m along the 23.8 km long Três Barras River. The diversity of structural and morphological features and the annual rain distribution pattern have strong influence on river dynamics and sediment transport and deposition. Samples were collected from every significant stratigraphic layer of two river bank profiles placed 2.5 km apart in the coastal plain section of the river and underwent grain size analysis, both with traditional and laser granulometry in order to test the degree of reliability of the methods employed. Sediments analyzed show the intercalation of different grain size sandy layers with pelitic sediments upstream, while downstream coarser sandy sediments prevails, suggesting alternating of lower and higher energy events as well as possible influence of sea currents. The variation of grain size signature along the Três Barras river bank profiles reveals a possible relationship to cyclic events and to variations in sea level through time as well, factors that have great influence on the fluvial dynamics.

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 752

## IDENTIFYING VULNERABILITY ZONES IN A TECTONICALLY ACTIVE RIVER CATCHMENT: RUAMAHANGA RIVER, WAIRARAPA, NEW ZEALAND

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The dynamics of coarse-bedded rivers of New Zealand's Wairarapa Region are complicated to a high degree by tectonic activity. Multiple, active oblique strike-slip cross-faults compartmentalize fluvial process zones in the Ruamahanga catchment, and include the Wairarapa Fault, which generated the largest documented land-based horizontal displacement (18m) from a single earthquake in 1855. Field visits and analysis of high-resolution terrain models suggest many modern fluvial forms are out-of-phase with current hydrologic regimes. Additionally, multiple contemporary river paths differ from prevailing prehistoric alignments and paleofluvial signatures suggest changes may have been abrupt (i.e. avulsion).

Recent land-use shifts to intensive-agriculture and rural-residential in the region involve significant economic investment in flood-prone areas and elevate potential adverse consequences to human life and property associated with erosion and flooding. Four valley segments have been identified for detailed investigation based on anticipated sensitivities to bed elevation changes and potential consequences for the Wairarapa's population centers. A morphological sediment budgeting approach using repeat high-resolution topographic data sets is being employed to quantify current coarse sediment flux. Combined with catchment-based models, several sediment scenarios will be hydraulically modeled to evaluate reach-scale sensitivity to bed elevation changes and establish magnitude-frequency relationships for break-out flooding and/or avulsion.

THEME: S13 : FLUVIAL PROCESS AND LANDFORMS

ABSTRACT NUMBER: 760

## LATE QUATERNARY EVOLUTION OF FLUVIAL TERRACES IN MIDDLE TISTA VALLEY, DARJEELING-SIKKIM HIMALAYAS: INSIGHT INTO PALAEOCLIMATE AND TECTONICS.

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Fluvial systems are sensitive to climate change and tectonics; and respond promptly to any such change. Fluvial terraces are one of the important geomorphic features archiving the record of past climate and tectonics. The objective of this work is to study Late Quaternary

evolution of the Tista River basin and to understand the role of tectonics and climate in shaping the morphology of the region.

A holistic approach using remote sensing, geochemistry and luminescence chronology has been used for the study. A field work was carried out and sampling from three sites on a stretch of 25 km was done. Preliminary studies show that the T3 (highest level of terrace) formed between 50-30 ka. The geochemical studies indicate that weathering was not intense in this period and relatively dry conditions prevailed. The terrace material is generally sand with few cobbles and pebbles, indicating low energy conditions. Younger sediments of T3 ( $30.7 \pm 3.7$  ka) are at a higher elevation than older sediments ( $36.4 \pm 2.1$  ka) suggestive of a deformation event which uplifted the T3 sediments. The formation of T2 took place between 24-11 ka. The T2 has been uplifted due to a deformation event which occurred after ~11 ka. Similar kind of deformation was also observed in the T1 and T0 terraces suggesting that region in one of the study sites is still tectonically active. Further downstream the older sediments (~80 ka) show the signature of palaeosols overlain by younger sediments (~15 ka). This shows that after 80 ka there was a long dry phase which provided sufficient time for the development of palaeosols.

**Keywords:** Fluvial terrace; Himalayas; OSL; palaeoclimate; tectonics.

THEME: S14 : LARGE RIVERS

ABSTRACT NUMBER: 110

## DETERMINING FLOOD-PRONE REGIONS OF KARAJ BY USE SCS CURVE NUMBER METHOD

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Development of urban zones in the edge of rivers, beds and edges of Flood Prone plains without knowledge and consideration to the hydrological and dynamic conditions of rivers and upper parts of the region which increases the flood risk, cause physical, financial and fundamental damages resulted from that, makes development to be faced without knowledge so, the importance of providing flood zoning plans which have many usages in flood plain management, is specified. In this study, the risk of flood-prone around Karaj City and yielding water regions of Karaj river is considered, by use of curve No.CN. For this reason, first, necessary data and information such as statistics of regional statues, satellite pictures have been gathered and were analyzed in GIS environment. By assimilation of this data and information, based on SCS curve number method plan of zone, the rate of influence and measure of runoff were provided. Finally, by use of weight model and by merger of rate of zone's rain, hydraulic groups of soil, slope, application of land and ... the plan of zone's yearly flood-prone potential zoning was provided which finally by considering final plan flood prone levels with high risk, are located in West-North and west parts of region in zones and levels with low risk are located in East-North, North and East parts of region in zones.

**Keywords:** GIS; curve No.(CN); Runoff; Flood water; karaj

THEME: S14 : LARGE RIVERS

ABSTRACT NUMBER: 184

## DEFORMATION OF THE AMUR RIVER CHANNEL UNDER THE CATASTROPHIC FLOOD OF 2013

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Despite progress in the study of channel processes, many aspects of the dynamics of large rivers channels and their floodplains in conditions of excessive accumulation of sediments are not well studied. Such rivers are typically characterized by multi-arm with complex types of floodplain-channel branching. Heavy floods which occur there significantly transform the channel; that should be considered during different types of economic activity.

Catastrophic floods in the rivers of Amur basin are of a rain genesis. High floods are formed during the second half of the summer. As a result of their passage the morphology and orientation of individual river arms are substantially changing. Heavy floods contribute to the activation of water flow redistribution between the arms, change the dynamics of their development, increase the rate of the banks erosion and lead to the formation of large accumulative landforms in the channels and extensive sandy trails on the floodplain.

In 2013, in the lower reach of the Amur River there was the largest rain flood for the entire period of observations. Expedition research

and analysis of satellite images allowed us to estimate the scale of the channel transformation, to identify areas of the most intense activation of erosion and accumulation processes and patterns of redistribution of runoff water in the branched channel sections.

It was found that the most significant changes in the topography of the riverbed occurred in the areas of secondary sources and mouths of the river arms. Near them vast shoals were formed, which led to an increase in water flow and deepened the channel in the largest branches of the river. In many areas, the coastal erosion, which value amounted to 15-20 meters in places, was intensified.

*THEME: S15 : INTEGRATED RIVER MANAGEMENT*

**ABSTRACT NUMBER: 37**

## **ASSESSMENT OF WATER QUALITY IN PRE MONSOON & POST MONSOON SEASONS OF RANIKHOLA RIVER AND ITS TRIBUTARIES, SIKKIM, INDIA**

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Ranikhola River, rising in the Sikkim Himalaya (the Lesser Himalaya) is one of the multitudes of south-west flowing Himalayan Rivers of rain fed characteristics. The prime objective of the present study is to find out the pollution status in terms of metals and chemicals into the river by jhoras (tributaries). For such study, 6 sample sites have been taken from the lower portion of the Ranikhola river: i) Adampool near STP, ii) under Ranipool bridge, iii) Namli, iv) Martam khola, v) Marchak near dumping yard, vi) Singtham near the confluence of river Tista and Ranikhola. The organic and microbiological status of the river has also been studied along with the jhoras meeting with the river. BOD-COD ratio is an indicator of biodegradability. Natural water bodies will have an ability to purify water and acts as a sink for pollutants. But the ratio of BOD-COD of the above mentioned sample sites are less than 0.2 in pre monsoon time, which is not biodegradable. The highest Most Probable Number (MPN) is found in Martam khola (6/100ml) water, moderate MPN is found in Namli and STP (Adampool) area (2/100ml) water and the lowest MPN is found in Singtham, Marchak and Ranipool area (<2/100ml) water in pre monsoon time. In post monsoon time through Standard Plate Count the number of bacterial colonies is TNTC (Too numerous to count) in Martamkhola, Ranipool and Namli area. Therefore the results clearly show that the water of Martam khola and Namli area is much more pathogenically contaminated in both the seasons than other sites.

**Keywords:** Ranikhola river; BOD-COD; Bacterial colonies; Water quality.

*THEME: S15 : INTEGRATED RIVER MANAGEMENT*

**ABSTRACT NUMBER: 197**

## **IMPACT OF CLIMATE VARIABILITY AND HUMAN INTERFERENCE ON FLUVIAL GEOMORPHOLOGY IN THE DAMODAR VALLEY, INDIA DURING ANTHROPOCENE**

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The Anthropocene is the time when human impacts have become one of the major external forcing on natural processes and even sometime it has crossed the threshold value of balanced man-nature relationship. Keeping in view this concept, present study has been carried out on Damodar River where first multipurpose river valley project of India came into existence. Field mapping, sedimentologic investigations and geomorphological analyses in combination with a series of temporal ancillary data i.e. hydro-meteorological data, sand excavation data and satellite data define a record of Anthropocene landscape change along 282.7 km stretch of the Damodar River in West Bengal, India. During the 20th Century, the Damodar basin was extensively engineered for irrigation and flood control. Since that time up until the present time, the hydrology and morphology of Damodar River has been controlled by dams and embankments, with these, now another intervention i.e. large-scale excavation of river sand has been added. Through historical satellite image, hydro-meteorological data, grain size data and cross sectional surveys, we demonstrate that the influence of the upstream dam, embankment and sand mining is still a major control of river dynamics and adjacent landscape. This case study considers the use of various statistical approaches like Mann-Kendall test, Sen's Slope estimator to detect the possible trend in seasonal rainfall pattern, Friend & Sinha's 'Braid-Channel Ratio' to identified the changes of channel pattern, Gumbel's extreme value distribution (EV-I), Extreme value distribution-III (EV-III), Log-normal (LN) and Log-Pearson Type III (LPT-3) to detect the probable stream flow and discharge pattern and illustrates the applicability of Goodness of Fit (GOF) and D-Index tests procedures in identifying which distributional model is best for the specific data. The results of this study may help in maintaining the health of rivers in the Anthropocene world.

ABSTRACT NUMBER: 514

## A GEOMORPHOLOGICAL STUDY OF SUBERNREKHA - A DYING RIVER

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The Subarnarekha is one of the longest east flowing inter-state rivers. It originates near Nagri village in Ranchi district of Jharkhand at an elevation of 600 m. The Subarnarekha basin extends over States of Jharkhand, Odisha and comparatively smaller part in West Bengal having a total area of 29,196 Sq.km with a maximum length and width of about 297 km and 119 kms. Towards the mouth the river Subarnarekha also enters a small part of Balasore district of Odisha.

The major part of basin is covered with agricultural land accounting to 53.76% of the total area and 2.39% of the basin is covered by water bodies. The reduction of water in the river is leading to the decline in the groundwater tables. Because of widespread deforestation, soil erosion has increased. Owing to these, the dissolved solids and the turbidity of the river increase significantly during the monsoon.

The River is in very crucial stage due to mining of copper, uranium, coal and industrial deposit of steel manufacturing industries along the course. It has estimated that the reducing the water level due to severe pollution and unprecedented industrial and mining growth may lead to vanish the river ecosystem. The reduced runoff in catchment area affecting seriously on freshwater resource. The study will provide the critical watershed of the basin which can be improved and rejuvenate the mighty river. The river and its catchment basin has been studied geomorphologically.

**Keywords:** River catchment basin, environmental pollution, degradation of water level

ABSTRACT NUMBER: 582

## INCORPORATION OF GEOMORPHIC CRITERIA TO DEFINE ENVIRONMENTAL FLOW IN A HIMALAYAN RIVER, YAMUNA RIVER SYSTEM, INDIA

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Anthropogenic disturbances have created significant modification due to geomorphic and hydrological alteration. It is a fact that for river to perform its functions and maintaining ecological integrity, certain minimum flow is a necessary prerequisite, which is broadly referred to as Environmental Flow (Rapport et al., 1998; Tharme and King, 1998; King et al., 1999; Shekhar 2016). E-Flow is defined as an assessment of magnitude and quality of fresh water flow with respect to original flow regime so as to maintain specified features of river ecosystem. Review of various E-Flow approaches suggest that geomorphology acts as link between hydrology and ecology, and its contribution in E-Flow has been a challenge.

The present work is a robust methodology to incorporate geomorphic data in E-Flow. The methodology has been used for estimating E-Flow on urbanized stretch of the Yamuna River flowing through the National Capital Region (NCR) Delhi, which is extremely deteriorated and geomorphologically inactive.

The methodology involves defining discharge into categories like Monsoon (June to September) and Non-monsoon (February to May and October to January) and treating them separately based on flow requirements. For non-monsoon period, the river must perform its function of sediment transport and maintain longitudinal connectivity while for monsoon period, the river must connect with geomorphic surfaces such as channel bars, banks, floodplains etc.

Results showed that for non-monsoon times, shear stress required to move sediments was low and minimum shear stress with corresponding discharge values were suggested. For monsoon times, river was unable to connect with geomorphic surfaces and improved discharge values were suggested based on inundation elevation of geomorphic surfaces.

A new methodology for incorporation of geomorphic data in E-Flow estimation is thus suggested which can provide new dimension to the Environmental Flow science by adding process based scientific understanding.

**Keywords:** Environmental Flow; Fluvial geomorphology; Yamuna River

THEME: S16 : COASTAL GEOMORPHOLOGY AND MANAGEMENT

ABSTRACT NUMBER: 59

## SOCIETY'S RESPONSE TO A COMPLEX GEOMORPHIC ENVIRONMENT OF THE BENGAL COASTAL REGIME

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Complexity in geomorphic processes in the coastal plain of West Bengal over a successive period of time has opened new dimension in coastal socio-environmental studies. There are variety of natural and manmade reason for rapid and complex changes in the pattern and processes of geomorphic and social environment in the coast. Behavioral changes in the interrelated natural systems as well as human interventions in natural processes has been bothered the rhythm of geoenvironment. Nature, dimension and magnitude of coastal processes have modified the diversified coastal socio-environment over time. Space congestion for human satisfaction on the fragile landscape disrupts a systematic arrangement of well known coastal socio-environment. Therefore, attempts have been made on the society's response to a complex geoenvironmental condition in the Bengal coastal regime by using advanced statistical techniques and methods. Research reveals that rural and urban societies belonging to the coast responds quickly but differently in front of extremity of geoenvironmental conditions.

**Keywords:** Geomorphic complexity, natural and manmade issues, society's response, social diversity, management options

THEME: S16 : COASTAL GEOMORPHOLOGY AND MANAGEMENT

ABSTRACT NUMBER: 220

## SIGNIFICANCE OF THE DISCOVERY OF A SEA ERODED LANDFORM IN QIXINGGANG OF GUANGZHOU

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Estuary delta is the result of interaction of land and ocean, its formation involves complicated geological process which usually last very long in time scale. Pearl River is the second largest and the third longest river in China. The formation and development of Pearl River Delta have long been concerned since the early 20th century. There was once a decades-long academic debate on the existence of Pearl River Delta. In the year of 1937, a integrate sea eroded landform including sea-eroded cliff, platform and cave was discovered in Qixinggang of Guangzhou, Guangdong province. The discovery strongly support the existence of Pearl River Delta, indicating that seawater once reached over 100 kilometers inland, and the ancient marine eroded landform was considered to be the important part of the material basis of the formation of the delta. In addition, the latitude of the sea-eroded platform can reflect the variation characteristics of crustal movement and sea level change to a certain extent, therefore providing variable information for exploring local geologic process. The feature of the sea eroded landform discovered in Qixinggang is closely related to the evolution of Peral River estuarine and it has prominent academic meaning for geoscience research.

**Keywords:** Pearl River Delta; sea eroded landform; Qixinggang; Estuary development

THEME: S16 : COASTAL GEOMORPHOLOGY AND MANAGEMENT

ABSTRACT NUMBER: 359

## KEY CHALLENGES AND FUTURE DIRECTIONS FOR RECONSTRUCTING HOLOCENE RELATIVE SEA-LEVEL CHANGES IN THE NEW ZEALAND REGION

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Relative sea-level (RSL) change is a key geomorphic control on the Holocene evolution of coastal environments. New Holocene RSL

reconstructions for New Zealand show spatial and temporal variations in the timing, magnitude, and duration of RSL changes around the New Zealand coast. A number of potential drivers operating at a range of scales may be responsible for this variation. Post-glacial meltwater loading on the continental shelf around New Zealand is predicted to have a significant effect on the timing and magnitude of RSL changes through the phenomenon of continental levering. Observed RSL records may also be significantly affected by tectonics, wave climate, sediment regime, sediment compaction, and the marine reservoir effect. However, these variables are currently poorly constrained. Efforts to produce robust, precise, and accurate reconstructions of RSL changes around New Zealand, and thereby elucidate the impacts of these drivers on RSL records, are hampered by a dearth of robust palaeo sea-level indicators: only 206 in the current New Zealand dataset. There are broad gaps, both spatially and temporally, in the current coverage offered by these palaeo sea-level index points. Filling these gaps requires careful geomorphic appraisal of the New Zealand coast, as current sampling strategies may induce temporal bias by favouring the sampling of mid- and late-Holocene deposits while ignoring or omitting to sample early-Holocene deposits.

THEME: S16 : COASTAL GEOMORPHOLOGY AND MANAGEMENT

ABSTRACT NUMBER: 399

## LATE HOLOCENE GEOMORPHIC EVOLUTION OF THE LIVADI COASTAL PLAIN, GULF OF ARGOSTOLI, CEPHALONIA ISLAND, WESTERN GREECE

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This study deals with the late Holocene evolution of the coastal swampy Livadi plain which is located on the northern part of the Gulf of Argostoli (Cephalonia Island). Cephalonia Island is located at the north-west edge of the Hellenic Arc in a tectonically and seismically highly active area. For the purposes of the study, a detailed DEM, produced by topographic sheets (at the scale of 1:5000), was utilized for geomorphological mapping together with extensive fieldwork. In addition, four shallow boreholes, varying in depth from 3 to 5 m, were drilled using a portable vibratory corer. The stratigraphy has been described in detail and four samples (peat - plant material, foraminifera assemblages and shell material) were collected for radiocarbon dating. Additionally, sedimentological and micro/macrofaunal identifications of forty five sediment samples from the various stratigraphic units were performed in an attempt to reconstruct the palaeoenvironments of deposition. The results suggest that cores L1 and L2, which are located close to the present day shoreline, are marine/coastal dominated while cores L3 and L4 have a shallowing-upward sedimentary sequence since the lower units correspond to a marine environment of shore-face conditions which progressively becomes a backshore brackish environment that gradually changes upwards to a terrestrial environment. The dated sea-level indicators (samples of peats, foraminifera and shells) from 5000 – 4000 BP are too high compared to local relative sea-level curves, indicating local coseismic uplift(s) of around 1 m before 1200 BP and after 4800 BP. This uplift idea is supported by recent (ca. 0.2m) uplift observed clearly along the beach face at Livadi caused by the recent Cefalonia earthquake in 2014.

**Keywords:** Palaeogeography; Holocene; Cephalonia; Greece

THEME: S16 : COASTAL GEOMORPHOLOGY AND MANAGEMENT

ABSTRACT NUMBER: 410

## ESTIMATION OF DRAINAGE DEGRADATION IN THE RECLAIMED PART OF INDIAN SUNDARBANS

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Earlier channel network in the reclaimed parts of Indian Sundarbans was identified with the help of Normalize Differential Water Index (NDWI). Linear and continuous arrangement of dissected water bodies are the signature of earlier channel. Extension of degraded channel was recognized from the embankment and overbank settlements located along the channel using the Quick-bird Google Image of 2016. Result indicates that all 19 block experiencing a higher rate of creek degradation with an average of 84.9%. About 430 km<sup>2</sup> areas was completely reclaimed from channel bed among which 107.5 km<sup>2</sup> came from the presently active channel and rest of the

area are from completely choked creek. Degraded channels are widely used for fishing, in channel fishery area increased from 3.88 to 15.96 Sq km during 1990-2017. Minakhan and Sandeshkhali-I have largest gross fishery area with only 7.22 and 6.42 Sq km area of active channel.

**Keywords:** NDWI; Drainage degradation; Choked creek.

THEME: S16 : COASTAL GEOMORPHOLOGY AND MANAGEMENT

ABSTRACT NUMBER: 517

## EVOLUTION OF RELATIVE SEA LEVEL IN OKINAWA, JAPAN THROUGH THE USE OF BEACHROCKS

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Sea level indicators, such as tidal notches and beachrocks, may provide valuable information for the relative sea level (RSL) changes of an area. Although beachrocks have received various arguments regarding their accuracy as sea level indicators, they have often been used to assess Holocene shoreline changes and crustally induced RSL changes.

The study area, Okinawa, belongs to the Ryukyu Islands, Japan (Pacific Ocean), forming the emerged part of an active island arc, where the Philippine Sea plate is subducting beneath the Asian continent. Evidence of emergence has been noted by various studies. Beachrocks have also been studied, however, detailed examinations of their spatial extend and cement characteristics has not been accomplished. In this context, the purpose of this study is to discuss the RSL evolution in Okinawa through the re-evaluation of reported sea level indicators, along with additional observations of beachrocks and notches.

Fieldwork was accomplished in the coastal zone of Okinawa, through detailed spatial mapping and sampling of beachrock occurrences. Coastal transects were accomplished in order to measure the width and depth/elevation of beachrock slabs. Thin sections were prepared to perform petrographic and microstratigraphic analyses using a polarizing microscope.

In this work, we focus on the beachrocks of the coastal zone of Okinawa (Japan) in an attempt to evaluate the RSL changes of the area during the Late Holocene.

**Keywords:** beachrocks; relative sea level changes; cement; Okinawa; Japan

Acknowledgments: The authors thank the Special Account for Research Grants and National and Kapodistrian University of Athens for funding to attend the conference.

THEME: S16 : COASTAL GEOMORPHOLOGY AND MANAGEMENT

ABSTRACT NUMBER: 554

## PHYSICO-CHEMICAL ATTRIBUTES OF THE HOLOCENE SEDIMENTS IN THE EASTERN SUBARNAREKHA COASTAL REGION

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The Eastern Subarnarekha coastal region, extending between the Subarnarekha and the Talpati estuaries and covering parts of East Midnapore district of West Bengal and Baleshwar district of Odisha in eastern India, preserves shore parallel sand ridges or cheniers. To understand spatio-temporal change in the depositional milieu based on sediment attributes, sediment samples were collected from ridge cut sections along shore-normal transects. These were analyzed to document temporal variations in texture and physico-chemical attributes. Results suggest a correlation between salinity / conductivity vis-à-vis mean grain size of the collected sediments in vertical successions. Temporal variations of grain size and complimentary change in salinity / conductivity indicate a consistent coarsening up sediment sequence in all the studied sections with low upward salinity. However, recent trend in sedimentation reveals a fining up inflection suggesting reversal of sediment polarity. Post depositional natural and anthropogenic reworking of sediments cannot be ruled out for the studied samples. More rigorous sampling would be necessary to check the data consistency.

**Keywords:** Coastal cheniers; pore water salinity, sediment grain size, sedimentology, temporal change.

THEME: S16 : COASTAL GEOMORPHOLOGY AND MANAGEMENT

ABSTRACT NUMBER: 563

## UNRAVELLING POSSIBLE CLIMATIC AND/OR SEISMIC SIGNALS PRESERVED IN COASTAL SAND DUNES AND AROUND MODERN LAKE WAIRARAPA, NORTH ISLAND, NEW ZEALAND

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Coastal sand dunes evolve in response to environmental changes such as fluctuations in sea (or lake) level, sediment availability, climate, and human disturbances of the environment. Sand dunes in New Zealand have previously been found to record large-magnitude earthquakes producing pulses of sediment delivered to the coast, and changes in sea-level and climatic conditions. This ongoing research project is the first to investigate and unlock the archive of palaeo-environmental changes preserved in a sequence of dune ridges located along the south-eastern shore of Lake Wairarapa. We explore the formation and timing of these dunes and test two alternative hypotheses. The first hypothesis is that the dunes record earthquake-triggered sediment pulses delivered to Lake Wairarapa ('Wairarapa Bay' during higher sea-levels) by rivers draining the surrounding ranges. Lake Wairarapa lies immediately adjacent to the Wairarapa Fault that is capable of producing earthquakes of considerable magnitude approximately every 2,200 years. The second hypothesis is that the dunes record climatic signals expressed through changes in the level of Lake Wairarapa, or changes in the wind regime of the area, that result in periodic phases of dune-building activity. Sedimentological analysis of the dune sands collected in cores will be used to explore the wind regime and climate responsible for the formation and evolution of dune ridges. A chronology of dune development will be established using a combination of luminescence and radiocarbon dating. Synthesis from these lines of inquiry will be compared with existing records of seismic activity and past climate to elucidate the environmental drivers responsible for the formation of the dunes and the geomorphic evolution of the lower Wairarapa Valley.

THEME: S16 : COASTAL GEOMORPHOLOGY AND MANAGEMENT

ABSTRACT NUMBER: 581

## VARIATION IN BEACH PROFILE AND RELATED TEXTURAL CHARACTERISTICS OF SEDIMENT IN MANDARMANI COASTAL TRACT, EAST MEDINIPUR, WEST BENGAL

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Mandarmani coastal tract, extending from the Jaldah inlet mouth in the west to the mouth of Pichaboni inlet in the east, is one of the longest beaches (about 12.5 km) of east Medinipur district. Beach morphology is influenced by both natural processes like wave, tide and wind as well as by human activities. To understand the morphological and sedimentary characteristics 23 profiles were surveyed during the last phase of monsoon condition.

The beach width shows variation from east to west. Beach width is maximum near the Jaldah and Pichaboni estuarine mouths varying between 250 to 350m, whereas the width reduces to around 200m in the middle portion of the surveyed stretch. The beach gradient varies between 0.01 and 0.03. Granulometric properties of 145 sediment samples collected along the 23 beach profiles from the dune base to low tide line were analysed. The sediments are well to moderately well sorted in nature with mean grain size ranging from very fine to fine sand (0.1mm-0.6mm). In the middle stretch of the beach (profile 10 to 15) the sediment shows platykurtic distribution. Beach morphology is also affected by human interventions. In the eastern section from Dadanpatrabar to Pichaboni estuary the anthropogenic activities are less prominent than the western segment where most of the hotels and resorts have come up. In the eastern section low dunes can be observed, covered by dune binding vegetation. On the western sector most of the natural dunes have been flattened for hotel construction with boulder walls. As a result beach lowering in this part of the beach is a common phenomenon. The waves dissipate their energy directly on the beach protection walls. Some of the hotels are already damaged.

**Keywords:** Beach Morphology; Grain Size; Granulometric properties; Platykurtic; Beach lowering

THEME: S16 : COASTAL GEOMORPHOLOGY AND MANAGEMENT

ABSTRACT NUMBER: 619

## LANDFORM CHANGES ALONG THE KACHCHH COAST LINE: A POSSIBLE IMPACT OF STORMS





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During storms, strong winds generate high, steep waves. These winds often create a storm surge which raises the water level and exposes the beach not ordinarily vulnerable to waves. The storm surge passes over the offshore bar formation without breaking, however, when the waves finally break, the energy is spent in the erosion of the beach, berm and sometimes dunes which are exposed to wave attack. The storm surge and waves change the coastal features like estuaries, bays and tidal flats. The coastal areas of Kachchh are vulnerable to several disasters such as cyclones, flooding due to storm and tsunamis. The present study focuses on marking the geomorphic changes along the Kachchh coastline that have occurred in the past possibly due to storm surges and waves occurring due to cyclones that have passed along the Kachchh Coastline. The basic tools used in the study are archival cyclonic data, satellite imageries and detailed field studies. During the study it is being observed that the high water, resulting from both meteorological and hydrodynamic factors associated with storms and cyclones have resulted into shore modification and also inundation of inland areas and destruction by outflowing waters causing major shore modification.

**Keywords:** Kachchh Coastline; Landform Changes; Storms; Cyclones

THEME: S16 : COASTAL GEOMORPHOLOGY AND MANAGEMENT

ABSTRACT NUMBER: 662

## THE MORPHODYNAMICS OF THE SF. GHEORGHE (DANUBE) WAVE DOMINATED RIVER MOUTH BAR (2004-2017)

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River mouth bars (RMBs) fulfill essential functions (e.g. sediment supply to coasts, LST blocking, LST bypass) that we need to fully understand in order to predict deltaic behavior. In this study, we report yearly and seasonal bathymetric surveys of the Saint George RMB in the Danube Delta between 2004 and 2017 in connection with flood and storm variability. Our results show that the overall sedimentary budget of the RMB has been highly variable with slightly negative trends, despite the fact that this period experienced three extraordinary large floods (in 2005, 2006 and 2010), each of them characterized by (multi)decadal return period of 11-30 years. During strongest river floods (2005-2006),  $Q_{max}=4000 \text{ m}^3/\text{s}$  compared to  $Q_{average}$  of  $1500 \text{ m}^3/\text{s}$ , the RMB crest was pushed offshore up to 250 m and experienced a positive budget of  $3 \times 10^6 \text{ m}^3$ . During this period, the depth of the bars and shoals flanking the river mouth significantly decreased driving increased shoaling and dissipation which boosts the amount of sediment transported to the adjoining beaches and favors local coastal progradation. After floods, the RMB readjusted quickly to previous volumes in just 2-3 years.

Moreover, this period was characterized by some of the most quiescent storm years in the last 6 decades, although a severe storm in February 2012, with maximum ENE winds of 20 to 23 m/s for 24 hours, which encountered ice on the coast, determined extensive sediment loss of sediment on the RMB ( $-3 \times 10^6 \text{ m}^3$ ).

Our data suggest that the present sediment supply values, significantly decreased by upstream dam construction in Danube watershed, are insufficient to maintain a long term stable river mouth bar configuration and will ultimately result in the erosion of the beaches near the river mouth and in RMB deflection.

**Keywords:** river mouth bar, delta, storms, floods.

THEME: S16 : COASTAL GEOMORPHOLOGY AND MANAGEMENT

ABSTRACT NUMBER: 673

## COASTAL GEOMORPHOLOGICAL EVOLUTION OF CAUVERY DELTA DURING HOLOCENE AND LATE PLEISTOCENE

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A 25 m core was retrieved in the vicinity of Vettaikaran Iruppu Village, 2.5 km from the east coast of India in Cauvery delta to reveal the 150Ka climatic history and the coastal evolution of the delta. The core deciphers sea level fluctuations along the coast. The sedimentary record indicates coastal aggradation and progradation of the coastline due to sea-level rise and fall respectively. Depositional ages of the Holocene and late Pleistocene sediments were measured using Optically Stimulated Luminescence (OSL). Of the seven major phases of global sea level fluctuations during the Quaternary period, two phases are recorded. These two events of sea level rise (MIS 1 and MIS 5e), which are above the present sea level are evident by the presence of benthic and planktic foraminifera during 6-9 Ka and 120-124 Ka. Bacterial diversity through paleogenomics was also supported by the presence of marine bacterial diversity. Depositional breaks are observed in the core during periods of lower sea levels as river responded by incision.

**Keywords:** Cauvery Delta, Sea level change, Foraminifera, Bacteria, OSL, Holocene and late Pleistocene

THEME: S16 : COASTAL GEOMORPHOLOGY AND MANAGEMENT

ABSTRACT NUMBER: 717

## ROLE OF SEDIMENT TRANSPORT AND LONGSHORE DRIFT IN FORMATION OF GORGAN SPIT IN SOUTH COAST OF THE CASPIAN SEA

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As the world's largest closed body of water, considerable changes in the Caspian Sea water level make it an unique laboratory to study all aspects of coastal zones. The sefid roud, Tajan, Neka, Babol and another small river, draining the northern slopes of Alborz mountain to the sea. This Reiers annually supply around 40 million tons of sediments to the shoreline. This sediment forms alluvial fan, Coastal plain and fan delta in south coast of Caspian Sea. sediments of rivers discharge to sea and carried by longshore drift and form Coastal geomorphology features of the Caspian Sea. In these research, we studied role of sediments budget and morphodynamic process of these rivers on geomorphology of south coast of Caspian Sea especially in Gorgan Spit. On the basis of the field reconnaissance, nine principal sampling stations were chosen. Sediments were sampled by divers along profiles at right angles to the coast at 5 depths. Hydrographic profiles also were surveyed. Laboratory analysis on the sediment samples were made, and the sediment characteristics and morphological features were divided into distinct zones based on their response to sea level changes. probability of occurrence of various wind directions in the summer and winter were investigated. Observations on speeds, showed that speed of swash can reach at foot of cliff 3-5m/s even in the time of waves of 3-4 marks, but primary speeds of swash can exceed 15m/s. Critical speeds of water current necessary for erosion, shifting and accumulation modeled. role of Caspian rapid Sea level fluctuation were investigated during the time to formation and evolution Coastal geomorphology of study area. Results showed, formation of geomorphological features especially Gorgan spit and their evolutions are affected by sediment budget and longshore drifts and sea level fluctuations and role of each parameter investigate in geomorphology of Coastal Zone.

THEME: S16 : COASTAL GEOMORPHOLOGY AND MANAGEMENT

ABSTRACT NUMBER: 720

## COASTAL GEOMORPHOLOGY: MAJOR PROBLEMS FACED BY THE COMMUNITY ALONG THE KARNATAKA COAST AND THEIR MANAGEMENT

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Most of the beaches of southern Karnataka coast experience major erosion from June-August and minor erosion from December-February. Eroded beaches are fully developed by April/May. Due to development of spits, width of river outlets decreased, and river borne sediments deposited in estuarine regions.

Erosion of beaches/spits, siltation of navigable estuaries/harbors, migration of spits/river mouths and damage due to SW monsoon waves on dwellings of coastal communities and their properties are the major problems.

Beach profiling and tracer techniques conducted for ~three decades. Littoral environmental parameters and impact of natural/ anthropogenic activities on coastal geomorphology were observed. SoI topomaps and multi-dated Satellite Images were analysed in GIS platform.

Seawalls have either enhanced erosion problem or shifted erosion sites to adjacent areas. Sand dunes protected the property behind them from wind and wave activities, but they have been destroyed by developmental activities. Net littoral drift is towards south and any natural/anthropogenic features/structures act as barriers to this, results in significant morphological changes.

Breakwaters constructed in 1980s at Udyavara River mouth, have lead to its migration northwards and growth of southern spit at the rate of ~45 m/year. Mouth of Sita-Swarna Rivers shifted towards south by ~2.30 km. Width of Kollur-Chakra-Haladi Rivers mouth reduced from ~600m during 1910 to ~380m during 2008 and the inlet has been shifted southerly by ~200 m. The Kasaba Kodi spit is reduced by ~500m during 1967-97. Length of Gangolli spit is increased by ~ 450m during 1967-1992, then, reduced by ~200m during 1992-2012.

Breakwaters at Netravathi-Gurpura Rivers' mouth have lead to accretion and progradation of shoreline by about a km on updrift side and negative impact of similar magnitude on downdrift side during 1993-2000. Gurpura River is migrated ~6km and joined with Netravathi.

**Keywords:** Beach erosion; seawalls; breakwaters; spits; navigation problems

THEME: S16 : COASTAL GEOMORPHOLOGY AND MANAGEMENT

ABSTRACT NUMBER: 763

## ANALYSIS OF COMPACTION DIFFERENCES AND MATERIAL COMPOSITION BETWEEN COASTAL PLAINS OF THE NORTH (TRIMMED) AND SOUTH (OPEN) LITTORAL, IN SÃO PAULO STATE.

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On passive coast, the coast of São Paulo has 600 km of extension and geomorphological configuration that stands out for differences. Serra do Mar presents morpho-structure from north to south, and in the transition between the plateau and the coast, it had its origin from the continental drift to about 225 Ma (ALMEIDA & CARNEIRO, 1998). Coastal plains were formed in the Quaternary, originated by the marine deposition, mainly in the regression, and its thickness is directly related to the sedimentation rate, corresponding to the resistance of the rock upstream of the coastal system. In the north coast, intrusive rocks predominate, a configuration formed by innumerable recesses formed in coves embedded between rocky promontories of crystalline basement, with intrusive rocks of charnockite type, granites and metamorphic ones of high metamorphism. In the south, the geological constitution of the Serra do Mar is mainly formed by metamorphic rocks of gneiss, mylonite, phyllites, and mica schist types, less resistant rocks, and material deposited by the sea in transgressions and regressions, especially from the last; Cananéia Transgression, about 120 thousand years BP, and the last regression of 5,100 BP years (SUGUIO, 1980). In order to verify the differences between the compositions, layers were sampled and analyzed in the laboratory. The compaction degree was performed by using Stolf penetrometer. As results the distribution mapping of analysis points in the field along the coastal plains and their influence on the relief variation in geomorphological profiles are presented. It was verified the material compaction is higher in the north, due to the presence of primary minerals, and the Serra-do-Mar proximity.

**Keywords:** Coastal Geomorphology; Coastal Plains; Deposition Process; Composition, Profiles.

THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 56

## RELATIONS OF DEGRADED RIVERINE DUNEFIELDS IN SEMIARID ZONES TO OVEREXPLOITATION OF GROUNDWATER: WITH THE CASES FROM THE KORQIN SANDY LAND, NORTHEAST CHINA

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There are such master rivers as Laoha River, Jiaolai River, Wuliji Mulun River, Xiangshui River, etc., in the Korqin Sandy Land, which

follow the strike of northeast-southwest, just transverse to the local dominant wind directions of NW and NWW. As a result, active and persistent aeolian-fluvial interactions occur along these river courses under the semiarid temperate monsoon climate and on the extensive Xiliaohe Plain, whereby creating large-scale riverine dunefields, especially along their right flanks. Based on field observations and satellite imagery analysis, the author found that sufficient sand is supplied from the downwind escarpments of rivers by way of side-erosion generated by either lateral migrations of channel or meandering, which expose the bare loose fluvial-lacustrine, more possibly plus aeolian, sediments of late Pleistocene (Q3) to the violent prevailing winds, and the riverine dunefields, as a consequence, could progressively come into being and continuously grow and extend downwind. Nevertheless, the majority of the rivers stopped flowing and dried-up during the latest two decades owing to excessive groundwater extraction in order to meet the huge demands from rapid urbanization, cropland expansion and industry development. Termination of fluvial functions leads to the end of sand supply, and the riverine dunefields tend, in turn, to be stabilized by vegetation and soils, whereby inducing the degradation of dunefields. Therefore, much more close attention ought to be paid on the odd phenomenon: the inconceivable coincidence between overall amelioration of regional ecological situation and deterioration of regional hydrological status. More efforts must be made to reveal the intimate mechanisms and answer the extremely urgent question: Can the circumstance sustain for a long time?

**Keywords:** the Korqin Sandy Land; riverine dunefield; groundwater; aeolian-fluvial interaction; sand supply

THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 245

## THE USE OF CONVERGING EVIDENCE TO ASCERTAIN THE ORIGIN OF DESERT SAND

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Contrary to the aridity theoretical explanations of Farouk El-Baz, (1988) and Scarborough (2016), it is hypothesized in this paper that desert sands are remnants left behind by the receding oceans while the continents drift apart.

Convergence of evidence or concordance of evidence refers to the principle that evidence from independent, unrelated sources can "converge" to enable strong conclusions to be reached. In geomorphological studies, scholars have not been indulging extensively in in-depth academic discourse on the implications of theories postulated by the founding fathers of the different realms of the discipline. For example, in the formation of granitic tor landscapes, to understand the implications of Linton's (1955) hypothesis of deep weathering under tropical conditions followed by removal of regolith by an episode of periglacial activity has implications of changing palaeoenvironmental conditions over vast geological timescale. The change from tropical to periglacial conditions could not have been an overnight affair, but was occasioned by drifting continents into periglacial environments where the regolith was then mowed down by vast continental thawing glacial ice sheets.

The hypothesis that all desert sand came from the sea is therefore explained in this paper using conversing evidence derived from Wadi al-Hitan in the Valley of the Whales in Egypt. The area formed part of the ocean floor of the Tethys Sea about 256 million years ago before the continents drifted apart. Other evidence from The Chalbi Desert in Kenya and from the Namib Desert in Namibia is used to corroborate the hypothesis. Suffice it to say that the Namib Desert sands are doubtlessly much older than the 1.5 MY envisaged.

THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 270

## THE ROLE OF GEOMORPHOLOGICAL FACTORS IN THE FORMATION OF K- AND LI-RICH BRINE DEPOSITS IN ARID Q Aidam BASIN, CHINA

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Qaidam Basin is the largest inland basin on the Tibet-Qinghai Plateau. It is in hyperarid conditions due to rain shadow effect. Playas and hypersaline lakes occupy one fourth of the basin, which include the largest potash deposit of China and ~80% of China's brine lithium reserve. Our investigation reveals that geomorphological factors play a key role in the formation of K- and Li-bearing brine deposits in the terminal salt lakes of the Hongshui-Nalinggele River watershed in addition to other geological factors. Previous investigations consider evaporitic deposition in the salt lakes of Qaidam Basin as a consequence of cold and arid climate. Our work provides the

first a case study showing that the topographically-induced differential effect of dry westerlies is the fundamental cause of contrasting hydroclimatic conditions between the wetter high-altitude mountains and hyperarid basin. Consequently, the large mountainous catchment collects huge amount of precipitation draining through large rivers into the arid basin, where intense evaporation rapidly enriches the lake water, resulting in evaporitic deposition associated with K<sup>+</sup>- and Li<sup>+</sup>-rich brine deposit. The differential effect was stronger during warmer periods, such as in the early-middle Holocene, during which more precipitation occurred in the mountain areas because warmer land surface advances vertical airflows, triggering condensation in mountainous topography for more precipitation. As a result, today's desiccated playas were inundated with shallow brines by receiving increased river runoff than today. In the meantime, warmer climate resulted in enhanced summer evaporation in the basin, facilitating evaporite deposition. Progradation of alluvial fans and shifting water course of rivers constrained by geomorphological features in the basin also played a role on the temporal and spatial deposition pattern of evaporitic sequences and associated K<sup>+</sup>- and Li<sup>+</sup>-rich brine deposit. Acknowledgement: NSFC Grant Nos. U1407206; 41471013; 41171171.

**Keywords:** Arid Geomorphology; Qaidam Basin; Lithium Brine Deposit; Evaporitic deposition

THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 282

## GEOCHEMICAL EVIDENCE FOR THE PROVENANCE OF AEOLIAN SANDS IN THE ORDOS DESERTS, NORTH CHINA

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Identifying the provenance of aeolian sediments in the Ordos deserts is of great importance for understanding the responses of earth surface processes to climate change and the linkage with the Yellow Rivers which is still controversial. We investigate the major, trace and rare earth element composition of sandstones, lacustrine sediments and aeolian sands collected in the Ordos deserts. Different mineralogical maturity of aeolian sands in east and west Mu Us sandy land indicates that aeolian sands in east and west Mu Us sandy land may have different sources. Geochemical composition indicates that the lacustrine sediments and sandstones underlying are the main sources of aeolian sands in the east part of the Mu Us Sandy Land, but they may not contribute much to aeolian sands in the west part of the Mu Us Sandy Land. Particles carried by the Yellow River and its tributaries from northeast Tibetan Plateau the main sources of aeolian sands in west Mu Us sandy land and Hobq sand sea. No obvious genetic linkage between the Helan Mountain, the Yinshan Mountain and the aeolian sands in the Kubq Desert. Further studies are still needed to determine which part of the Tibetan Plateau contribute more to aeolian sands in Ordos desert, and the connection between Tengger desert and Ulan Buh desert with the Ordos desert.

**Keywords:** The Ordos deserts; Major and trace element; Sources; The Yellow River

THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 312

## IDENTIFICATION OF AEOLIAN LOESS DEPOSITS ON THE INDO-GANGETIC PLAIN (INDIA) AND THEIR SIGNIFICANCE

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Aeolian loess deposits contain abundant information about the evolution of the paleoenvironment. For example, paleoclimate changes recorded in Chinese loess area obtained significant achievement in the past few decades. Compared to Chinese loess, research on Indian loess is lacking. Currently, most studies focus on the Kashmir area located in the southern Himalayas, and studies on other areas are rare. However, field observations demonstrate that the sediments around the New Delhi-Agra-Jaipur Plain are similar to Chinese loess-paleosol sequences. For example, the boundary between two strata is transitional and without horizontal bedding. Moreover, obvious pedogenic horizons developed among sediment sequences, probably indicating unrecognised aeolian deposits in the Indo-Gangetic Plain (IGP). To confirm this, pilot samples were obtained from the IGP and detailed indoor measurements conducted. The

results indicate that the distribution patterns of particle size and rare earth elements (REE) of the pilot samples are similar to Chinese loess. Furthermore, the scanning electronic microscopy (SEM) images of pilot samples show obvious conchoidal fractures, dash-shaped concavities, and abundant small pits that usually form through mechanical impact. These are typical characteristics of aeolian particles. In addition, environmental and rock magnetic measurements indicate that the dominant magnetic minerals in the pilot samples are magnetite and maghemite, and that they likely contain small amounts of hematite. Furthermore, conventional magnetic parameters are comparable with Chinese loess. Based on this, aeolian loess deposits are widely distributed in the IGP, which may have promoted the development of Indian farming and contributed towards the prosperity of ancient Indian civilisation. This study also provides a new and valuable record for the research on paleoclimate changes in the study area in the future.

**Keywords:** Indo-Gangetic Plain, loess deposits, particle size, SEM, REE, environmental magnetism, ancient civilisation

THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 476

## IDENTIFICATION AND CHARACTERISATION OF MICRO LANDFORM FEATURES AS CLUE TO RECENT DESERTIFICATION PROCESSES IN INDIA'S ARID ZONE

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India's arid zone is spread over 12 % of its total geographical area and majority of it (62 %) occurs in the NW part of the country in the state of Rajasthan. A dominant Aeolian terrain (85 %), arid climate and moderate vegetation characterize this desert terrain. Interplay of wind and surface has sculpted the terrain into Aeolian-fluvial-tectonic-lacustrine landforms.

The present study deals with identification and delineation of some micro landform features and their pattern which may provide geomorphic evidences of desertification in the region. Such features are not easily visually interpreted on coarser satellite images. High resolution satellite images (IRS-LISS IV (MX) and the user-friendly Google Earth images (GE) have been used to identify erosional/depositional aeolian bedforms (low dunes, sand sheets, sand ripples) and also fluvial forms (defunct, desiccated and buried stream channels) in the sandy terrain of western Rajasthan.

Buried and defunct river courses have been delineated in GIS platform in Barmer and Jalor and their network with major river systems has been reconstructed. Many of the riverbeds are now shallow with sandy hummocks and weed invasion. In the partially canal irrigated regions of Bikaner district, spatio-temporal changes in croplands have been assessed. The processes of land fallowing followed by barrenness, blown sand deposits and hummock formations over croplands as known indicators of desertification have been mapped. There are marked occurrences of secondary dunes, sand ridges and new bedforms. Similarly irrigated croplands, tree plantations over sand dunes and vegetation cover have also been mapped. Temporal analysis indicates how such activities have brought surface stability to reduce sand drifts and have improved the situations of desertification.

**Keywords:** Micro landforms, desertification, arid region, India

THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 483

## AEOLIAN SAND FIELD WITHIN AN INTRAMOUNTAIN BASIN, QINGHAI-TIBETAN PLATEAU: SAND SOURCE AND DEPOSITION CONTROLS

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A unique landscape composed of aeolian sand dune fields and lakes within intramountain basin was found in Qinghai-Tibetan Plateau. In this paper, we studied sand source and deposition controls of the sand dune field in Cuona Lake Basin of the Plateau. X-ray fluorescence spectrometer (XRF) was used to analyze elemental content of 31 surface sand samples collected from the aeolian deposition field and four potential sediment supply areas (lake beach, underlying mountain, southern mountain and northern valley), and multiple composite fingerprints technology was applied to identify the main sand source area. We interpreted remote sensing images (Google Earth images) in order to classify the deposition area into sand-covered part and non-sand part, and then conducted

the independent sample T test for wind and topographic factors to determine whether they are significant different. Wind factors including speed and its change were simulated by CFD software based on weather station data. Topographic factors including slope gradient and slope direction were analyzed by ArcGIS based on DEM data. The results show that the aeolian sand mainly comes from lake beach (50.30%) and the contribution of underlying mountain, northern valley and southern mountain is 26.48%, 15.66% and 10.31%. The sand-covered part and non-sand part are quite different in various factors. The wind speed, wind speed change and slope direction show significant difference (95% confidence interval). The average variation in wind speed per 100 meters along prevailing wind direction is -0.198m/s over sand-covered part in which mainly slope directions are leeward, and the average variation is 0.089m/s over non-sand part in which mainly slope directions are windward. There is no significant difference in slope gradient between these two parts.

**Keywords:** Aeolian sand field; Sand source; Control; Intramountain basin; T test

THEME: S17 : ARID AND SEMI-ARID GEOMORPHOLOGY

ABSTRACT NUMBER: 533

## MODERN AEOLIAN PROCESSES AND LANDFORMS OF THE VILYUI RIVER BASIN (CENTRAL YAKUTIA)

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Modern processes and aeolian landforms are widespread in the Vilyui river basin of Central Yakutia. Typically aeolian landforms consist of sandy dune complexes, almost devoid of vegetation which locals call tukulans. The tukulans of the Vilyui river basin are usually of the oval shape and lie from north-west to south-east. The frontal benches height of dune complexes reaches up to 20 meters above the surrounding landscape.

In the field studies of 2014-2016 and satellite image interpretation of several key tukulans in the Vilyui river basin we found the dunes of longitudinal and cross types along with parabolic dunes.

Elementary dunes are different on morphology: crescent-shaped, javelin-shaped or annular-shaped. Their length reaches vary from 100-120 to 200-250 meters. The height of dunes varies from 3-6 to 18-20 meters.

The windward slopes of active parabolic dunes are usually gentle (2-4°). The vegetation cover is practically absent. The downwind slopes of active dunes are steeper (25-30°). Sometimes they are fixed partially with single hummocks of *Artemisia karavaevii* Jurtz. and *Thymus sergievskajae* Karav. The sand-grass hummocks are of roundish or ellipsoidal form. Their height is from 10 to 60 cm, diameter varies from 5 to 45 cm.

The deflation basins are round or elongated shape and practically devoid of soil and vegetation cover. Their width vary from 150 to 300 meters, their depth varies from 2 to 6 meters. Different structural elements such as specific cracks 3-7 cm in width filled with bleached quartz sand, the round-shaped "clay mushrooms" and micro-dunes of 2-5 cm height, can be often observed here.

The radiocarbon dates of the buried soil horizons and trees obtained by the authors indicate that the age of active modern dunes does not exceed 500-600 years in the Vilyui river basin.

**Keywords:** aeolian landforms, tukulan, geomorphological structure, the Vilyui river basin.

THEME: S18 : TROPICAL GEOMORPHOLOGY

ABSTRACT NUMBER: 89

## ANALYSIS OF ORGANIC MATTER, TEXTURE AND CEC OF SURFACE MATERIALS ON BRAZILIAN CERRADO SLOPES UNDER RECOVERY STAGE

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The distribution of surface materials on slopes in the Brazilian Cerrado is related to the topographic position, the shapes of slopes and

runoff. All these aspects are also correlated with the climatic seasonality typical of this environment. Physical and chemical attributes of surface materials relate strongly to the geomorphological characteristics, influenced by their spatial variability, playing an important role in the quality of these ecosystems and in landform evolution. Thus, it was studied an area located in Uberlândia in the state of Minas Gerais in central area of Brazil. The methodology was based on the analysis of the physicochemical properties by boxplots and spatialization by kriging, which were evaluated the Organic Matter, Texture e Cation Exchange Capacity (CEC) parameters. The material samples presented four textures: sand, loamy sand, sandy loam and sand clay loam. The organic matters value varied from 2,0% of 2,3% to sand texture and loamy sand texture, 2,0% of 2,5% to sand loam texture and 2,4% of 2,5% to sand clay loam. The CEC presented values from 2,07 of 2,94 cmol.dm<sup>-3</sup> to sand texture; 2,06 of 5,97 cmol.dm<sup>-3</sup> to sand loam texture; 3,99 of 9,26 cmol.dm<sup>-3</sup> to sand loam and 11,66 of 12,52 cmol.dm<sup>-3</sup> to sand clay loam. The physicochemical attributes were spatially dependent and correlated respectively with the texture and topography, observed through its spatialization by kriging, dynamic and explanation of the relationship of materials surface with the landscape. The high levels of organic matter and CEC verified, suggest high heterogeneity due to the formation processes of surface materials, accumulation and distribution of particles of these materials depending on the form of landscape (convex, linear and concave) and the flow of water in the area.

**Keywords:** Physicochemical attributes, Geochemistry, Geomorphology, Kriging and Slope.

THEME: S18 : TROPICAL GEOMORPHOLOGY

ABSTRACT NUMBER: 590

## URBANIZATION INDUCED THREAT TO GEOHERITAGE IN WEST BENGAL, EASTERN INDIA: A CASE STUDY OF THE KHOAI, NEAR SHANTINIKETAN

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Urban growth has markedly affected and modified the lateritic, badland landscape in and around Shantiniketan, near Bolpur, in the eastern Indian state of West Bengal. Located on the interfluvium between the Kopai and Mayurakshi Rivers, this town, at whose epicenter lies a university named Visva Bharati, founded by the Nobel Laureate Rabindranath Tagore, has experienced a recent boom in construction, with resultant urban sprawl that has either encroached on and modified large lateritic tracts (termed 'Khoai' by Tagore) or completely removed portions of these badlands. The fragmentation and loss of this physical landscape, which was frequently referenced and represented in Tagore's and others' artistic expressions, further resonates as a loss of geoheritage. Analysis of satellite imageries and maps from 1984 to 2014 suggests that the town has expanded in all directions, but primarily towards the southeast, west and southwest. This urban expansion, primarily for tourism purposes and other infrastructural development, includes two mouzas (local administrative units), altering a considerable portion of the Khoai, reducing its area by about 20% in the last two decades. This manifests a paradoxical situation, where a society is seemingly interchanging the physical basis of its cultural ethos, in return for habitations and infrastructure. The ongoing loss of this physical landscape has adversely affected the locals' and outsiders' perception of the town, its surroundings, and has important implications for local geo-tourism and cultural geology. Detailed mapping of the Khoai has been done from high-resolution imageries and terrain models and the entire area has been classified following the SEA and Big-S models for geosite assessment, to identify the most important locations in terms of scientific, educational, aesthetics and cultural values, which are most vulnerable to future urban sprawl, and whose conservation is of paramount importance.

**Keywords:** Khoai, Geoheritage, Urbanization, Mapping, Geoconservation

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 3

## GPR SIGNAL AND IMAGE PROCESSING FOR GEOMORPHOLOGICAL ANALYSIS

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Geophysical signals are multiscale and nonstationary in character. The instantaneous frequency is an important feature of Ground Penetrating RADAR GPR image and signal. Instantaneous spectral analysis of GPR signal is applied for precise subsurface imaging. We make it fashionable following electromagnetic waves that travel at a specific velocity which is determined primarily by the permittivity of the material. The relationship between the velocity of the wave and material properties is the fundamental basis for using GPR to



investigate the subsurface. The velocity is different between materials with different electrical properties, and a signal passed through two materials with different electrical properties over the same distance will arrive at different times. One of the problems of GPR signals is that they are easily corrupted by environmental noise, which might mask the weak reflections from inhomogeneities located deep in the test structure. Wavelet transform for time and frequency analysis, the received signal by the GPR is composed of parts with different origins, resulting in discrepancies between the characteristics on different scales for each frequency compositions, together with different contributions of the energy distribution of each frequency to the total signal energy. Independent component analysis and principal component analysis is employed for GPR signal processing to rectify cluttering effect. Partial differential equations (PDE) is employed for image denoising smooth out the high frequency oscillation while keeping the edges in the high noisy level images. Image analysis follows three steps image processing (image → image), Analysis (image → attributes), Understanding and interpretation (attributes → attributes). Wavelet transform is also employed for image processing of GPR Signal. Glaciology - rock glaciers can originate from complex and multi-phase evolutions, composed of imbrications of spatial and stratigraphic units of varying complexity. By integrating subsurface information from GPR surveys, geomorphological analyses is done. Interpretation provide insights into the composition or even the way of deposition of the rock glaciers.

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 67

## DISCOVERY OF AN EARLIER PLEISTOCENE GLACIATION IN BODUIZANGBU VALLEY, SOUTHEASTERN TIBET

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Southeastern Tibet display high mountains and deep valleys in geomorphology and is the most wet- warm area in Tibet Plateau because of Bengal bay vapor influence through the Great Gorge of Yarlung Zangbo River. As a center of glaciers, ancient glaciations have been studied in past decades. Two Pleistocene glaciations Guxiang and Baiyu were suggested by Li Jijun et al 40 years ago. They have been dated to MIS-6 and MIS-4-2 glaciations using CRN and OSL methods.

Recent years we found some evidences for an earlier glaciation also in the Boduizangbo River Valley. The evidences are mainly two higher moraine platforms high 870m (3770m asl) and 730m (3550m asl) above river level on the north side of the valley. The moraine platforms are higher 540m, 490m and 440m above the Guxiang lateral moraine summits respectively and keep reverse slope. The moraine above Nitong village keeps 8m reverse slope, implying a thickness of the moraine at least 8m. The moraines contain big granite boulders in both places. Some of granite boulders on the platform opposite Baiyu Village reach 3m in diameter. These granite boulders and tills deposited on underlying limestone bed rock. We think that these moraines should be trace remains of an older glaciation. We tentatively use ESR method dated these moraines to about 490ka. Since then the valley has been cut down about 800m, possibly signifying a violent uplift of southeastern Tibet Plateau during late Quaternary.

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 84

## TWO NEW CONTRIBUTIONS TO TURKEY'S GLACIAL GEOMORPHOLOGY: ŞAHINTAŞI GLACIER (MUNZUR MOUNTAINS) AND KARADAĞ (WESTERN TAURUS)

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Turkey as a Mediterranean country has strong climatic and topographical differences due to its location. Owing to these features, today there are still many active glaciers in the mountains having higher elevations above snow line altitude (asl). The Şahintaşı Glacier is one of these glaciers situated near to Şahintaşı Peak (3310 m) in the Munzur Mountains, and whose existence had not been known until its discovery in 2015. Furthermore, in Turkey, there are several mountains undergone severe glaciations in Pleistocene but not having any glaciers today, yet they preserve fresh traces of the last glacial age. Karadağ is one of these glaciated mountains located the Teke Peninsula. The glaciation on this mountain have not known recently and consequently not included in glaciated mountain inventories in Turkey.

Munzur Mountains which extend between Tunceli and Erzincan provinces from the west-east direction have Şahintaşı Glacier in its central part. The glacier has a surface area of 104587 m<sup>2</sup> and a length of 410 m and a width of 386 m and its maximum thickness is about 90 meters. In the fore of the glacier, we identified 4 well-preserved terminal moraines.

Karadağ, which reaches 2418 m summit at a 30 km straight distance from the northeast of Fethiye Bay and has many peaks over 2300 m. The mountain has distinctive cirques and moraines on the slopes of high peaks. After the field studies, we mapped five different cirque developed in different sizes and aspects and frontal and hummocky moraines in front of them.

In this study, we have been tried to reveal geomorphologic features of two new glacial areas, one of which is have an active glacier and the other have fresh traces of the last glacial age, with the aid of geographical information systems, remote sensing methods and extensive field studies.

*THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY*

**ABSTRACT NUMBER: 92**

## **GEOMORPHOLOGICAL FORCING OF PROGLACIAL LAKE DYNAMICS IN MOUNTAIN AREAS**

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Proglacial lakes are characteristic features of high-mountain areas in a warming climate. In an idealized system of regionally uniform topography, one could postulate that the rates of lakes forming in front of the retreating glaciers, and of those detaching from their mother glaciers are equal, i.e. the systems are in dynamic equilibrium and the number and total size of proglacial lakes throughout a given mountain area would remain constant over time. These rates would depend on the rate of glacial retreat.

Analyses for some mountain areas worldwide over the past 5–8 decades indicate (i) a certain shift from proglacial lake formation to detachment; and (ii) varying rates of lake formation and detachment over time. These findings are nevertheless noisy and uncertain, and vary among the different study areas (eastern and western Alps, southwestern Pamir, and Cordillera Blanca).

In the present contribution we focus on the geomorphological forcing of the observed behaviour. Thereby we note that:

1. The assumption that lakes can only develop in ±flat valley sections, becoming rare as glacier tongues retreat upwards, could explain the observed behaviour. Indeed, the availability of valleys with gradients <5° decreases in the upper ranges of proglacial lake distribution in all investigated areas, even though this pattern is noisy and highly variable among the various study areas.
2. This broad-scale forcing is superimposed by local effects: in the western Italian Alps, for example, terminal moraines formed in the 1920s and 1970s impounded some small lakes, whereas fewer lakes may have formed in other periods.
3. Particularly in those areas where small lakes with a highly dynamic behaviour predominate, some intervals may be too long to appropriately display the temporal patterns of lake formation and detachment.

Future work will aim at confirming the key findings, considering a set of additional study areas.

*THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY*

**ABSTRACT NUMBER: 198**

## **CONTROL OF SEA LEVEL TEMPERATURE AND ATMOSPHERE VAPOUR CONTENT ON MODERN AND LGM SNOWLINES AT GLACIERS OF CENTRAL HIMALAYAN, INDIA**

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Present study reconstructs the modern and paleo-Equilibrium line altitudes (ELA) from central Garhwal Himalaya and correlates it

with vapor content of glacial time. The modern ELA altitude for central Himalayan glaciers averages at about 5200 m asl. However, the ELA depression ( $\Delta$ ELA) from modern day to Last Glacial Maxima (LGM) is fall in the range of 500-600 m asl with a temperature decline of  $\sim$ 2-3° C. If we adjust it for a sea level reduction of -120 m asl at the glacial maximum then the additional reduction in temperature of nearly 0.7° C is observed. Although, during the LGM the tropical sea surface temperature were 1-3° C cooler than present leads to the fact that the altitude of tropical snowlines would also be lower.

We have modeled the possible combinations of sea surface temperature and relative humidity for the reduction of 500-600 m asl elevation difference at modern to LGM ELA with sea level. The magnitude of the adiabatic cooling used as 9.8 °C/km and 1.53° C air mass warming for each millimole per mole of water condensed as rain. The present day sea surface temperature (28° C) used to calculate condensation induced warming at ELA (5200 m asl) to reach 0° C isotherm. At 0° C isotherm values the 29° C warming producing the 18.94 m mol condensate per mole of air. We have included the atmospheric convection mixing for modern and LGM temperature and RH calculation at ELAs. The lowering of snowline places constraints on water vapor content of the atmosphere. The conclusion for required lapse rate for glacial period found to be steeper than modern in central Himalaya glacial region which can be used to estimate climatic differences between the modern and glacial times.

**Keywords:** Himalaya, Last Glacial Maxima, Equilibrium line altitude depression, water condensation.

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 199

## EXTREME PROCESSES SHAPING ARCTIC COASTS – IMPACT OF TSUNAMIS AND ICEBERG-ROLL EVENTS ON GREENLAND COASTAL SYSTEMS

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The unstable nature of Arctic landscape in terms of landslides provide potential tsunami sources. Moreover calving glaciers and rolling large icebergs are sources of extreme waves, particularly in the fjords, the shape of which can amplify the size of the wave.

Here we report on the effects of a landslide-triggered tsunami that occurred on 21.11.2000 in Vaigat, west Greenland. The wave destroyed the town Qullissat on the opposite site of the strait, however, material losses were observed in distant places by as far as 150 km from the landslide. We studied the geomorphological and sedimentary features of this extreme event along coast-perpendicular transects in a range of settings. The field descriptions were supplemented by TLS and DGPS mapping, as well as grain size, mineralogical and geochemical analyses. The tsunami run-up reached 50 m a.s.l. and inundated over 300 m inland. The tsunami frequently caused erosion of existing beach ridges whilst erosional niches were formed inland. The tsunami deposits mainly comprised gravels and very coarse sand and formed sheets up to 30 cm thick. A characteristic feature related to tsunami deposits were "mud pats" - up to 1 m in diameter and about 20 cm thick silty deposits arranged in circles and covering the tsunami deposit. They are interpreted as the result of melting of icebergs washed inland by the tsunami. The same region is also one of the most threatened by large, often over 5 - meters high incident long waves, which are caused by calving glaciers and icebergs overturning.

Presented results will serve as a guide for further studies of palaeotsunami in Greenland and elsewhere in the Arctic. The results are also of importance for Arctic coastal risk assessment.

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**Keywords:** tsunami; icebergs; deglaciation; coastal zone; Arctic

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 211

## SEDIMENTOLOGICAL CHARACTERIZATION OF SUSPENDED SEDIMENTS EVACUATED FROM DEBRIS-COVERED CHORABARI GLACIER, GARHWAL HIMALAYA, INDIA

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Recent researches show that the suspended sediments (SS) transported with glacier melt runoff consists aggregates of hard composite grains with a varying size and shape that reduces the reservoir capacity damaging hydromechanic structures (especially turbines) in the hydroelectric power projects (HPP). Present study deals with sedimentological characterization of SS fractions (<1000 µm) evacuated from debris-covered Chorabari Glacier. Temperature and rainfall exert significant influence on sediment entrainment and evacuation processes during the ablation season (June-Sept.). For understanding sediment transport dynamics, we report monthly grain micro-textures of silt- and sand-sized sediments analyzed by scanning electron microscopy (SEM) for the study period 2009-2012, (June-Sept.). Results show various types of microstructures on SS such as small and large conchoidal fractures along with precipitation and pitting surfaces with few other cleavage flakes that reflects sediment formation through crushing process over abrasion. Intense weathering over quartz surface is seen during peak monsoon months (July and August) indicating higher intensity of mechanical weathering. SS grain size reflects dominance of fine silt- to fine sand-sized grains that corresponds to 80–90% with size ranging between 7.8-250 µm that are mostly angular and poorly sorted grains confirming low textural maturity. Semi-quantification of SS was carried out for calculating mineralogical composition using X-ray diffraction (XRD) which provided particulars on compositional and sediment textural maturity. Quartz and feldspar are the most dominant minerals followed by micas and other accessories. These analyses conclude that thick debris cover over the glacier acts as an important source for formation of fine-grained sediments and its probable entrainment in a high energy environment from crevasses and moulins transported through subglacial transport pathways.

**Keywords:** Micro-textures; Mineralogical Composition; Mechanical Weathering; Rainfall; Indian Himalaya

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 251

## PALEOCRYOGENESIS, SOIL FORMATION AND DEVELOPMENT OF EROSION PROCESSES IN THE WESTERN TRANSBAIKALIA FOREST-STEPPE LANDSCAPES (EASTERN SIBERIA, RUSSIA) DURING THE LATE GLACIAL AND THE HOLOCENE

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In the Western Transbaikalia cryogenic processes (punching, cracking) and relief forms (tuffurs, small pingoes, thermokarst craters, river icings) are locally developed. Simultaneously, the relic cryogenic polygonal-block relief is widely spread on the territory under consideration, varying in different degrees in the Holocene. This type of relief determines the mosaic structure of modern soil cover and the specific development of erosion-accumulative processes.

To reveal the distribution areas of the ancient cryogenic relief, aerial and space images of high resolution were deciphered, field studies were conducted, quaternary deposits of slopes, draws, river terraces were studied and dated.

At watersheds, slopes and in river valleys, a wide distribution of the hilly-valleys relief was revealed. The dimensions of the hillocks range from 4 to 50 m, height 0.5-2 m. The hummocks are divided by depressions and hollows. Time of formation of the paleocryogenic relief on the watersheds and slopes is 29-23 kyr BP and 14.5-11.7 kyr BP. Subsequently, the polygonal-block relief experienced several stages of aggradation and degradation and in the Holocene turned into a hilly-valleys relief with the island distribution of permafrost. 1 to 3 horizons with cryoturbations in Late Glacial (15-11.7 kyr BP) sediments of Western Transbaikalia were defined.

Paleocryogenic ice wedges occur in the Late Pleistocene deposits of the Western Transbaikalia. The soils of the Late Glacial are cryomorphic and formed under conditions of continuous permafrost. They are characterized by various cryogenic features (undulating bedding, platy structure, pocket-like and wedge-shaped strike of humus horizons, gleying).

Degradation of permafrost in the warming of the Late Glacial and early Holocene caused the activation of thermal erosion, linear erosion, suffusion and changes in the microrelief in the upper links of the erosion network. Modern dells, rills, gullies partially inherit paleocryogenic depressions and hollows.

**Keywords:** paleocryogenesis, pedogenesis, Late Glacial, Western Transbaikalia

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 275

## REFLECTION OF ENVIRONMENTAL CONDITIONS IN THE INTERNAL STRUCTURE OF TALUS SLOPES: THE EXAMPLES FROM SW SPITSBERGEN AND POLISH TATRA MOUNTAINS



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Talus slopes are a typical form of relief within mountain areas. Information about their development comes mostly from observations of contemporary morphogenetic processes. However, environmental conditions and processes shaping the slopes change over time. The conducted study attempted to identify whether these changes were reflected in the internal structures of talus slopes. We chose slopes of SW Spitsbergen and Polish Tatra Mountains, which differ in age and geological, topographical and climatic conditions of development. We used electrical resistivity tomography (ERT) and ground-penetrating radar (GPR) to identify the bedrock. In this way, it was possible to document the structures that clearly reflect the three main stages of talus slope evolution: paraglacial, periglacial and alluvial.

**Keywords:** talus slopes; ERT and GPR surveys; permafrost; periglacial zone; paraglacial period

*THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY*

**ABSTRACT NUMBER: 278**

## MAPPING ON GLACIER SURFACE FACIES OF NY ALESUND IN SVALBARD USING HIGH RESOLUTION SATELLITE REMOTE SENSING DATA AND GIS TECHNIQUE

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Glacier surface facies, reveal a great deal about the sensitivity and mass balance of the glacier. Using multi spectral (MS) and SWIR high resolution World View 3 imagery and stereo DEM World View 2 data, we have attempted to map glacier facies in this study. We have used object oriented and supervised classification methods and compiled four spectral band ratios for classification, (1) Normalized Difference Snow Index (NDSI) from spectral band green and SWIR, (2) Normalized Difference Glacier Index (NDGI) from tradition band green and red, (3) Normalized Difference Snow/Ice Index NDSII) from multi spectral band red and SWIR, (4) Near Infra-Red Threshold (NIRTI) is new customized Index from NIR1 and NIR2. Seven glacier facies were identified, viz., fresh snow, wet snow glacier ice, melting ice, dirty ice, debris and shadow ice. We have also mapped the geographical directional distribution of glacier facies. Our results based on spatial directional glacier facies mapping analysis, classification and accuracy assessment all indicate that the object oriented classification scheme is superior to the pixel based method.

**Keyword:** Glacier Facies, Spectral index ratio, classification, World View-3

*THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY*

**ABSTRACT NUMBER: 301**

## SOUTHERN CARPATHIANS PERMAFROST PROBABILITY MAP

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The sporadic permafrost in the Southern Carpathians has long been acknowledged and studies have been published for different parts of the mountain range. But until now no regional scale map for the permafrost extent has ever been created.

We analysed the probability of permafrost occurrence in the whole mountain range and found suitable conditions in three mountain groups: Retezat, Parâng and Făgăraş. The map was created using a Random Forest (RF) classifying algorithm that searched for similar conditions to the ones in known permafrost sites.

The input data for the model is based on areas with known presence or absence of permafrost, based on previous studies. Because the extent of permafrost is limited to small patches the input data is split about 2/3 for areas without permafrost and 1/3 for areas with permafrost, rather than an equal proportion. As predictor variables we used 21 topographical variables derived from a 30m spatial resolution digital elevation model (DEM) and a land cover variable derived from a Landsat8 satellite image. For validating the permafrost probability map we used the rock glacier inventory for the Southern Carpathians.



The map shows a high probability of permafrost occurrence within deep north facing glacial cirques, mostly where rock glaciers are present, at altitudes between 1950 and 2300. Most of the ridges are found to have a low probability of permafrost existence although they are at higher altitude. This finding confirms the previous studies that, until now, didn't documented permafrost occurrence on ridges and rock walls. The results clearly demonstrate that within the Southern Carpathians, permafrost conditions are favoured mostly by shading and terrain surface roughness than by altitude.

**Keywords:** Southern Carpathians, permafrost, Random Forest, modelling, rock glaciers.

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 302

## THE GEOMORPHOLOGICAL CHARACTERISTICS OF ROCK GLACIERS AND PROTALUS RAMPARTS IN THE RILA AND PIRIN MOUNTAINS

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Being visible morphological indicators of the mountain permafrost occurrence, rock glaciers (RG) are identified, mapped and studied in high mountains around the world. In the Balkan Peninsula the studies regarding the formation, evolution and current state of rock glaciers and other periglacial landforms is at its infancy.

We analyzed 122 rock glaciers and 143 protalus ramparts, located in Rila and Pirin Mountains, Bulgaria. Topographic characteristics where computed from a DEM with a 30m spatial resolution and analyzed by using ArcGIS 10.2.

The results show that 74% of the rock glaciers and 61% of the protalus ramparts are concentrated within the northern quadrant. The rock glaciers are spread at altitudes between 2080-2600m, having an average slope up to 20 degrees. They have a mean area of 10.54ha with a maximum area measuring 71.49ha while the protalus ramparts are significantly smaller with a mean area of 1.2ha and a maximum area of 5.38ha. The protalus ramparts have the same minimum altitude but their upper limit is located at about 100m higher than the RG, lying on slopes that reach up to 30 degrees. Our results also demonstrate a strong relation between the area of the rock glaciers and the extent of their contributing area ( $r=0.84$ ). The uneven distribution of rock glaciers and protalus ramparts across the investigated mountain ranges is determined by topography, lithology and local climatic conditions. These RG characteristics show a higher altitude distribution and also a greater expansion than the ones in the Romanian Carpathians.

Our future studies on rock glaciers in the Balkan Peninsula will focus on the dynamics and the potentially ice or permafrost content.

**Keywords:** rock glaciers; protalus ramparts; Pirin; Rila; periglacial landforms.

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 341

## INFERRING GLACIER SUMMER MASS BALANCE FROM TREE-RINGS IN RHAETIAN ALPS (ITALY)

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Middle latitude glaciers and the associated glacial and periglacial environments are particularly sensitive to the ongoing climate change, which mostly consists in increasing air temperatures. Since the middle of the 19th Century glaciers experienced a progressive reduction, interrupted by short-lived minor advances, the most recent of which occurred around 1980 AD. Because the sustained shrinking of glaciers has serious impacts on water resource and hydrogeological hazard, and implications for their management, there is the need for temporally-extended high-resolution glacier mass balance reconstructions for improved understanding of glaciers response to climate change. Evidences of past climatic change are supported by meteorological observation series, which can be extended in the past using dendroclimatology. However, meteorological data are available and reliable only for the most recent decades, whereas

dendroclimatological reconstructions typically come from wide geographic areas, thus implying a loss in the local climate signal. The advantage of local dendrochronological series lies in the chance of amplifying the local reconstructed climatic signal, which results in higher correlation with glaciers mass balance series. Here we present preliminary data on the summer mass balance of the Careser Glacier (Rhaetian Alps, Italian Alps), reconstructed in the last five centuries using local dendrochronological series. The comparison between series high frequency components promises new results opening the prospective to use dendrochronological series for reconstructing glaciers mass balance even in the Alps.

**Keywords:** Mass Balance; Tree-Rings; Careser Glacier; Dendroglaciology; Italian Alps

*THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY*

**ABSTRACT NUMBER: 354**

## THE CHARACTERISTICS AND FORMING PROCESS OF GLACIAL PERIPHERAL MORAINES AT GONGBA GLACIERS IN MT. GONGGA, CHINA

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Mt. Gongga is at the eastern edge of the Tibetan plateau. The Gongba Glaciers are at the west side of Mt. Gongga, their geographical position is 29°32'--29°36'N, 101°46'--101°52'E. There are two glaciers including in the Gongba Glaciers; the Large Gongba Glacier is with a length of 11.7 km, area of 20.86 km<sup>2</sup> and the end at altitude of 3700 m; the Small Gongba Glacier is with a length of 7.1 km, area of 6.67 km<sup>2</sup> and the end at altitude of 4150 m.

Based on the field observations on the glacial peripheral moraines at Gongba Glaciers, there are differences in shapes between the younger moraines and the older ones, there are also differences at different slopes. The inner-slope of lateral moraine is much steeper than the out-slope, and is pressed and plastered by the glacier. The debris becomes from less sharp to less round. In the cross sections of the lateral moraine, the debris is parallel to the out-slope surface. The grain-size analyzing data show that in the inner-slope of the lateral moraine the grain-size is smaller than the out-slope, but the degree of sorting of the inner-slope is poorer than the out-slope. At the margin of glacier, the force of glacier to lateral moraine can be separated into three components, they related to the components of the velocity at the ablation area. The forces can be combined into an acting force parallel-to the lateral moraine and an acting force vertical to the moraine. The fore has a "pruning acting" to the moraine, the later forms shear plan between glacier and lateral moraine. The debris can be brought to the super-glacial surface from sub-or in-glacial places, and then slips or falls on the out-slope of the moraine under the gravity. In this way, the lateral moraine is made up.

*THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY*

**ABSTRACT NUMBER: 395**

## GLACIERS' FLUCTUATIONS IN THE ITALIAN ALPS DURING THE LAST GLACIAL CYCLE: A LITERATURE REVIEW

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The aim of this paper is to review the state of knowledge on past ice surface fluctuations in the Southern Alpine foreland since the Last Glacial Maximum (LGM). A synthesis of geological and geomorphological information on former glacier fluctuations in the Italian Alps since the LGM is presented. Deglaciation timing has been based on compilations of calibrated (cal) radiocarbon dates available in literature.

The former extent of Italian Alpine glaciers was investigated by a series of authors since the second half of the 19th century. The most recent studies have benefited from new technologies such as high-resolution remote sensed data, numerical paleo-glaciers' simulations, surface exposure dating techniques etc. In addition, since the last 50 years, the definition of empirical relationships between glacier physical parameters and past climate conditions has enabled to use former glaciers' fluctuations as proxy data to examine past climate changes providing information on modern climate change.

During the LGM almost the whole Italian Alps were covered by extensive icefields which fed a network of interconnected outlet glaciers confined in the main Alpine valleys and piedmont glaciers spill out into the Alpine Italian foreland. Records from Italian moraine

amphitheatres suggest that the last glacial peak occurred between 29 and 23 ka cal BP.

Records from pede-Alpine and foreland regions suggest that glaciers' retreat was underway by 22-18 cal ka BP followed by progressive re-advances of minor glaciers (Lateglacial stadials). At present a series of uncertainties on mode and timing of deglaciation still remain.

This review intends to identify key issues which are still a matter of debate and to clarify the framework of past glacier fluctuations. In this context, the work presented would be an outline for paleo-landscape and paleo-environment reconstructions at local scale.

**Keywords:** paleo-glaciers; Last Glacial Maximum; Lateglacial; Italy; Alps

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 460

## A 10-YEAR SERIES OF SURFACE KINEMATICS OF PERIGLACIAL SORTED CIRCLES FROM SfM CLOSE-RANGE PHOTOGRAMMETRY

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Sorted circles are one type of periglacial patterned ground, created by large-scale cryoturbation due to freezing and thawing of the active layer. It is one of the most conspicuous types of patterns created by geomorphic processes on the earth surface, and widely used as an example of emergence in complex systems.

Since 2007 we have attempted to document the spatial pattern of displacements going on in sorted circles at 79°N on Kvadehuksletta, Ny-Ålesund, Svalbard using Structure-from-Motion (SfM) photogrammetry and feature-tracking. Earlier published results by the authors show the applicability of this method in terms of gaining high-resolution information on vertical and horizontal displacements within the sorted circle system. This presentation will document challenges, solutions and new directions for long-term SfM monitoring of sorted circles.

During 2007 and 2010 campaigns, images were first taken from a portable ladder. In 2015, 2016 and 2017, images were acquired from a camera attached to a long pole via a wifi connection to the camera. The design was set up to yield a theoretical resolution of the digital elevation model of around 1 mm. The presentation will also report on attempts of using SfM for modelling short-term temporal development of a sorted circle using images from multiple cameras mounted on a stable frame above a sorted circle.

**Keywords:** sorted circles, SfM, displacement monitoring, feature-tracking

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 467

## IN SITU <sup>10</sup>Be EXPOSURE AGES DOCUMENT A DOUBLE GLACIERS RESPONSE TO YOUNGER DRYAS IN THE UPPER PEIO VALLEY (RHAETIAN ALPS, ITALY).

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The end of the Pleistocene was characterized by a relevant climate reorganization that involved the Northern Hemisphere, where glaciers reacted to climate variations leaving landscape features that are fundamental for reconstructing their behavior in that period. Because of their location and characteristics, Alpine glaciers are particularly useful in geomorphological and glacial-geological investigations aimed at reconstructing glacial variations starting from the Last Glacial Maximum. In this study we studied in detail the upper Peio Valley in the Ortles-Cevedale Group, (Rhaetian Alps, Italy). The well preserved and undated moraines of La Mare and Careser glaciers



were surveyed and sampled for Surface Exposure Dating (SED), obtaining eleven new  $^{10}\text{Be}$  dates which chronologically constrain the reconstructed glacial phases in the study area. SED allowed us to attribute different glaciers response to the Younger Dryas (YD) cold event. Both glaciers expanded before  $11.1 \pm 0.5$  ka and this advancing phase can be correlated to the Egesen Stadial, well documented all over the Alps. The La Mare Glacier reacted to the YD cold event with a double response, the older one preceding  $12.2 \pm 0.4$  ka. After reconstructing the glaciers' geometry during the Egesen Stadial, we calculated the areal and volumetric variations of the studied glaciers since the YD, as well as their Equilibrium Line Altitude (ELA).  $\Delta\text{ELA}$  have been used for comparing lateglacial conditions with the Little Ice Age maximum extent, both at local and regional scale. The detailed geomorphological mapping in the study area, combined with the new cosmogenic dates, strongly highlight the sensitivity of alpine glaciers to climatic changes and confirm their reliability as a tool for reconstructing past climate changes and for modelling future glacier behavior under sustained global warming.

**Keywords:** glacial geomorphology; glacial history; Late Glacial; Surface Exposure Dating; Italian Alps.

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 470

## GEOMORPHOLOGICAL EVOLUTION OF THE CHANGLA BASIN, LADAKH, NW TRANS HIMALAYA, INDIA DURING LATE QUATERNARY

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ChangLa basin (an area of 3029 sq km) is the largest basin of the Ladakh range, lies in the vicinity of Indus Suture Zone southwards and the Karakoram Fault northwards. The area is the part of the Ladakh Range and is dominated by westerly influence for precipitation, however in Abrupt Summer monsoon phases the ISM also affects the area. This basin comprises main ChangLa stream originating from the glacier at ChangLa which eventually drains into the Tangste River and posses a sub-dendritic to trellised drainage pattern covering. Upper reaches of the ChangLa stream's longitudinal profile shows the absence of gradation and has high SL index. The knick points are indicative of glacial activity in the upper reaches and stream gradation varies with differential erosion. Karakorum fault effect is seen in middle part as indicated by sudden elevation in stream profile and the tributary effect is observed in lower reaches and gradually the stream profile flattens out. The cross-valley profiles generated throughout the stream course are indicative of a typically glaciated terrain with pronounced U-shape and V-shape valleys created by glacier and stream erosion which are occupied by moraines, streamlined mounds, huge erratics, scree with several foot slope deposits and the depressions filled by glacial and pro-glacial lakes. These pro-glacial lakes are moraine dammed lakes formed during the glacial recession at the terminal moraine and occur all along the arms of these moraines and glacial deposits. The glacier is no longer there, but an ice patch remains in the summer months only at the summits. The region has experienced series of former glacial activities and both, the Neoglacial and the recessional stage of Kar Stage are observed here, as seen through the moraines at 5122, 4983m and 4719, 4883m respectively.

**Keywords:** ChangLa; glacier; pro-glacial lakes; moraines; Ladakh

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 473

## RECENT GLACIERS VARIATIONS IN ALTA VALTELLINA (ORTLES-CEVEDALE GROUP, ITALIAN ALPS): QUANTITATIVE ANALYSIS OF AN ACCELERATED GLACIAL DECLINE DURING THE LAST 60 YEARS

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Alpine glaciers are very sensitive to climate variations that modify their shape and size in response to changes in their mass balance. In the framework of detailed investigations concerning global change-induced glacier variations and loss of water resources stored in the Italian glaciers, this work presents an analysis of recent changes (1954-2012) in the Alta Valtellina's glaciers (Ortles-Cevedale

Group). The analysis was based on a multi-temporal dataset of aerial photographs and historical maps, which have been organized and processed in a multi-temporal glaciological database using Geographic Information Systems (GIS).

This work provides quantitative evidence of accelerated glacial decline, in particular since the end of the 20th century. Our results highlight an areal reduction of about 45% in the last 60 years, with a strong increase in the areal reduction rate from -0,51% yr<sup>-1</sup> during 1954-1982 to -1,26% yr<sup>-1</sup> during 1982-2012. Applying empirical formulas of volume-area scaling, we estimate a volume loss of about 700 million mc, for the period 1954-2012. More than 400 million mc have been lost in the period from 1982 to 2006. Geodetic mass balance calculations for the 1982-2006 time interval indicate a strongly negative annual balance of about 0,55 m w.e. yr<sup>-1</sup>, and also suggest that volume loss estimates require a correction factor of 1.3.

Results underline the strong imbalance of glaciers in the study area, and highlight the rapid increase in their reduction rate during the last decades, which is leading to impressive change in glacier shape and dimensions.

**Keywords:** Glaciers retreat; Geodetic mass balance; Volume-area scaling; Ortles-Cevedale Group; Rhaetian Alps.

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 553

## QUATERNARY GLACIAL CHRONOLOGY AND ITS DRIVING FACTOR IN THE MONSOON INFLUENCED REGIONS OF THE HIMALAYA-TIBETAN OROGEN.

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To define the timing, extent and factor responsible for the Quaternary glaciation in the Himalaya-Tibetan orogen, many studies have been done. These studies provide abundant evidence for significant glacial advances throughout the past 60 ka. Modern glacial snout monitoring indicates rapid deglaciation in the monsoon dominated southern front of Himalaya and glacial surge in the westerlies dominated Trans-Himalaya. Geomorphic mapping of Gangotri Glacier region and dating of moraines helped building up the hypothesis that the factor responsible for the glaciations in the monsoon dominated region is precipitation. The glaciers in the southern front and in the trans-Himalaya reached their maximum extension during the wet and cool Marine Isotope Stage-3. Advance and retreat of the glaciers of Himalaya-Tibetan orogen is largely controlled by changes in temperature and precipitation, but the relative importance of these drivers is still debated. However increasing number of studies and glacial chronology show that throughout most Himalayan-Tibetan regions, significant glacier advances occurred during the Last-glacial Maxima and early Holocene, with minor advances in some regions during the mid-Holocene. The limited chronological control in the Himalayan-Tibetan orogen, however, makes it difficult to make correlations across the region, which in turn makes it hard to assess the relative importance of the different climatic mechanisms that force glaciations across the Himalayan-Tibetan orogen. Presently the workers are putting their efforts to quantify the age of the well preserved records of late glacial and Holocene glaciations. The result shows that the glaciations in the monsoon dominated region are mainly controlled by the temperature. These glacial successions have the greatest potential to be examined in detail using developing numerical dating and geomorphic method to derive high-resolution terrestrial records of glaciation that will help in paleoclimate reconstruction for high altitude regions.

THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

ABSTRACT NUMBER: 650

## EVOLUTION OF IMJA, LOWER BARUN AND THULAGI GLACIAL LAKE AND ITS GEOMORPHOLOGICAL RELATIONSHIP

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Most of the world's alpine glaciers are undergoing retreat and showing negative mass balance due to climate change. In many cases, negative mass balance is accelerating, and one result is the formation and growth of potentially dangerous glacial lakes. In this study, we analyzed three large and hazardous glacial lakes in Nepal Himalayas – Imja, Thulagi and Lower Barun. Specifically, we established correlations between glacier dynamical changes and the valleys' geomorphological changes by analyzing surface area growth rates of the lakes, retreat of glacier termini, thinning and stagnation, glacier dynamical changes, debris cover impact, basin morphometry,

dynamics of the ice-cored moraines, and potential glacial lake outburst flood triggers. Our preliminary results show a substantial increase in moraine-dammed lake surface areas and terminus retreats over the past 30 years, with accelerated velocities and significant calving of the glaciers in cases of Imja and Lower Barun, although, glacier lake growth has stalled since 2010 for Thulagi Lake. In evaluating these three lakes, we considered both long-term and short-term geomorphological relationships and response dynamics. This presentation will also reflect on the successful Imja lake lowering project from 2016 and how this will impact lake evolution in future.

**Keywords:** Glacial lake; GLOF; Glacier retreat; Himalayas

*THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY*

**ABSTRACT NUMBER: 701**

## **RECONSTRUCTING GLACIER CHANGE POST LITTLE ICE AGE (LIA) IN THE NORTH-WESTERN HIMALAYA, INDIA: AN OVERVIEW AND SPECIFIC EXAMPLES**

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Several studies reported that Himalayan glaciers responded to the global cooling associated with the Little Ice Age (LIA), however, there is no realistic estimate to suggest how the recession occurred after the termination of this globally important climatic event with few exceptions. Besides, the pattern of deglaciation following the LIA is important towards understanding the role of natural versus anthropogenic contribution in glaciers response, considering significant debate pertaining to the rising global temperature and its likely impact on the mountain glaciers. Thus, the present study document, analyse and reconstruction the fluctuation of index glacier (based on glacier location, size, geometry, debris cover and geomorphology) located in the North-Western Himalaya since LIA maximum advance using historical records, repeated photographs, remote sensing data and field observations including geomorphological evidence. Preliminary results show an advance in glacier terminus during the late 18th-early 19th century. After mid-19th century, general state of glacier retreat has been observed for the studied glaciers in this region with varying recession rate from one glacier to other. The advance of studied glaciers in the late 18th-early 19th century can be attributed to cold climate whereas recession trend from mid-19th century associated with rising temperature and reducing precipitation in the north-western Himalaya as same observed from reanalysis data and field data and same reported by previous studies based on field based. Moreover, the varying retreat rate between glaciers can be attributed to the influences of topographical factors, individual glacier morphology and the nature of debris cover. Further analyses are under way by incorporating the glacier equilibrium line altitude calculations, volume estimations and short to long term in-situ and geodetic glacier mass balance measurements to look into the overall response of climate and topography on the glacier dynamics in different climatic zone of this region and will be addressed.

*THEME: S19 : GLACIAL AND PERIGLACIAL GEOMORPHOLOGY*

**ABSTRACT NUMBER: 714**

## **GLACIAL-GEOMORPHOLOGY AND VALLEY DEVELOPMENT; A CASE STUDY OF THE THAJWAS GLACIER VALLEY, KASHMIR HIMALAYAS, INDIA**

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Glacial-geomorphic studies provide vital information to make inferences about the effect of glacial advance and retreat on the geomorphology of an area. In the present study, glacial-geomorphic landforms of the Thajwas glacial valley in the upper reaches of the Indus, Kashmir Himalayas were mapped using geospatial technology validated with GPS-based field observations and ground photography. The glacial-geomorphic landforms were digitised using ASTER DEM (30 m resolution), Landsat ETM+ satellite imagery (30 m resolution) and Google Earth (1m resolution) data. Results showed that Google Earth imagery, supported by field validation, is very useful for the interpretation of glacial-geomorphic landscapes and relief features at micro- and meso-scales. However, morphometric characteristics of landforms are best obtained using DEM overlaid onto the Landsat ETM+ satellite data. Glaciers in the valley are presently confined along the south and southwestern slopes. However, the significant role played by glaciers in shaping the geomorphic landforms and their subsequent preservation within the scenic landscape under the Late Quaternary climatic conditions are remarkably evident. The glacial-geomorphic landforms, especially terminal moraines, glacial trough and cirques observed in the valley aided the reconstruction of palaeo-glacial setting of the area. Morphology, shape and location of terminal and lateral moraine

ridges were used to establish the palaeo-glacial extents, glacial volume and the number of glacial advances of the Thajwas glacier. The maximum elevation of the lateral moraines was used to define the former Equilibrium-Line Altitude (ELA). The greater rock excavation to form a large valley during the last glacial maximum might have induced isostatic rock uplift/exhumation in the glacier source area. It is observed that the concomitant retreat of the north-facing glacial cirques has played an important role in expanding the glacial valley and limiting the topographic relief.

**Keywords:** Late Quaternary; Glacial-geomorphology; Palaeo-glacial reconstruction; Cirque retreat; Thajwas

THEME: S20 : MOUNTAIN GEOMORPHOLOGY

ABSTRACT NUMBER: 212

### ASSESSMENT OF THE SHORE ABRASION SIZE IN A MOUNTAIN RESERVOIR (POLISH CARPATHIANS)

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Functioning of retention reservoirs leads to changes in valley morphology due to abrasion and accumulation processes. These processes are conditioned by hydrodynamic reservoir activity, which are revealed by water level fluctuation and wind waves on the reservoir. The most noticeable morphological changes within reservoirs include shoreline abrasion and the bluffs development.

An attempt was made to reconstruct the slope of the mountain valley (Ropa river in the Upper Vistula river catchment) in selected morphological profiles and to determine the shore abrasion size. The research was conducted on the Klimkówka reservoir, which was running in 1994. The slope reconstruction was carried out base on the geodetic measurements, topographic map (1: 10000), terrestrial laser scanning (TLS) and the height of the soil layer washed out from under the tree trunks, cutted before reservoir opening.

Slope reconstruction of the Ropa valley in selected fragments of the Klimkówka reservoir based on the topographic map did not give reliable results. Much better effects can be obtained by measuring the soil layer washed out from under tree trunks occurring within the boundary zone of the reservoir. Uneven distribution of the trees is the main problem of this method. The most accurate method is TLS, allowing for a very precise determination of morphological changes, in particular shore abrasion size.

**Keywords:** shore abrasion, TLS, mountain reservoir, Carpathians Mountain, Poland

THEME: S20 : MOUNTAIN GEOMORPHOLOGY

ABSTRACT NUMBER: 479

### GEOMORPHOLOGICAL MAPPING OF VAL PIANA (ADAMELLO-PRESANELLA GROUP, RHAETIAN ALPS): FROM MULTI-TEMPORAL ANALYSIS TO DEBRIS FLOWS SUSCEPTIBILITY

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Highest elevations Alpine area are particularly sensitive to climate changes inducing significant modifications in the extension and occurrence of the cryosphere and increasing the frequency and intensity of slope processes. Since the deglaciation following the Last Glacial Maximum, the morphoclimatic conditions changed to widely diffused paraglacial condition, inducing rapid evolution of both erosional and accumulation landforms to reach a new equilibrium state with the changed climatic conditions. In the Adamello-Presanella Group (Rhaetian Alps, Italy), the most incisive morphogenesis is presently due to mass wasting, water runoff and cryonival processes.

We investigated the geomorphological evolution of Val Piana, a glacial valley in the Adamello - Presanella Group, through field surveys, geomorphological mapping and interpretation of aerial photographs taken in different years (1983, 1988, 1994, 1999, 2006, 2012). All the data were managed in GIS environment allowing the creation of a multitemporal geomorphological database.

Multitemporal analysis suggests high dynamicity of debris flows of Val Piana, which represent the most hazardous processes in the alpine environment.

The collected data were processed for evaluating debris flow susceptibility in Val Piana applying a method, previously developed for investigating landslide susceptibility, based on an unbiased procedure for causal factor selection among factors chosen on the basis of geomorphological criteria. The adopted procedure is based on some intuitive statistical indices, finalized to detect the most discriminant factor among different potential factors surveyed in the study area. Conditional analysis allows to define the susceptibility index value for a combination of selected causal factors (vector Unique Condition Units).

The susceptibility model has been validated using the multitemporal debris flow database showing that many areas resulting as highly susceptible agree with the area effectively affected by debris flows in the period following that considered for the susceptibility evaluation.

**Keywords:** Geomorphological map; aerial photographs; debris flow; susceptibility map; Rhaetian Alps

*THEME: S20 : MOUNTAIN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 602**

## **HYPSOMETRIC AND DRAINAGE NETWORK ANALYSIS OF THE EASTERN CORDILLERA OF THE COLOMBIAN ANDES.**

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The Eastern Andes Cordillera of the Colombian Andes, which extends from nearly 2° to 11° of latitude, is currently thought to have risen 1500 to 2500 meters, 3 to 6 My ago, which makes it a unique example of rapid uplift in the world. However, this uplift rate has been suggested for the entire Cordillera based mainly from paleobotanical data from the savanna of Bogota, which might not reflect the entire span of the mountainous range. Moreover, climatic changes that this uplift produced (which changed the ecological niches from the plants studied) were also not considered. Here we present a hypsometric and drainage network analysis for the entire range of the Eastern Cordillera. This was done by delineating watersheds for the whole mountain range and calculating its respective hypsometric curve with the ArcMap extension CalHypso, parameters such as hypsometric integral, skewness and kurtosis were calculated for each curve. Also a drainage network analysis was made using 30m resolution DEM data, drainage patterns and flow directions were calculated in order to establish if there has been a major tectonic re-arrangement of drainages. Based on the hypsometric integral we propose three main zones in which to divide the Cordillera: a young Cundinamarca-Boyacá high-plain zone (in which the savanna of Bogotá is located), an old Cocuy zone (which corresponds to the highest peaks of the Cordillera) and a middle-age south section of the Cordillera. Drainage analysis suggest there has not been a major tectonic re-arrangement for drainages for a long time. Given these results we suggest that the zones shown by the hypsometric integral might reflect spatial-temporal variability for the Cordillera uplift, and therefore the previously calculated uplift age for the cordillera should not be applied for the whole range.

*THEME: S20 : MOUNTAIN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 627**

## **VULNERABILITY ASSESSMENT OF FLOOD HAZARDS IN THE TECTONICALLY ACTIVE BASINS USING SRTM DATA AND GIS IN THE EASTERN PART OF ARUNACHAL PRADESH, INDIA**

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Arunachal Pradesh suffers from frequent geomorphological hazards due to its unique geoenvironmental setting, monsoon system, unanticipated 'cloudburst', geohydrology and tectono- geomorphological dominion. Erratic rains and 'cloudbursts' have set new records and caused unprecedented damage to the rural areas occupied by the native people, communication network (roads, bridges, water supply, telecommunication posts, electric posts, culverts, etc.), agricultural fields and also affected the urban areas. Flash floods triggers landslides causing twofold vulnerability. The flood impact on downstream areas severely affect the people of upstream safe areas because of disruption of road communication. Therefore, spatial information on flood and landslide affected areas on requisite scale is necessary as it provides disaster footprints of higher accuracy which helps in scientific assessment of vulnerable areas. Flash floods, Landslide Dam Outburst Flood (LDOF), landslides, avulsion and bank erosion are major problem in the study area. The orientation of rivers and streams, channel migration and avulsion is controlled by ongoing tectonic activity. The field data of flood affected villages were acquired from various departments and from the archives of the print media. These data were mapped as point layer in ArcGIS. A land use map was prepared showing following classes: the rural and urban areas, agricultural fields, forest, etc. The drainage network, slope, geomorphology, elevation (ruggedness index) information were extracted from SRTM data. By integrating all

the above information and using river proximity buffer, vulnerability maps were prepared showing, severe, very high, high vulnerable areas were identified and mapped. The landslide affected areas were also mapped. It was inferred from the study that vulnerability analysis using spatial information is useful for land use planning for Disaster Risk Reduction.

THEME: S20 : MOUNTAIN GEOMORPHOLOGY

ABSTRACT NUMBER: 666

## ROCKWALLS MORPHOMETRY AND DISTRIBUTION IN THE ROMANIAN CARPATHIANS: CONTROLS OF LITHOLOGY, TOPOGRAPHY AND FROST WEATHERING PATTERNS

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It is widely acknowledged that present and past dynamics of rock surfaces in mountain areas are significantly related to thermal weathering patterns and intensity. This work presents the inventory and morphometrical analysis of 788 rockwall surfaces in the formerly glaciated Romanian Carpathians (44°30' - 47°45' N, 21°30' - 27°10' E) corroborated with high accuracy rock thermal monitoring, in the attempt to assess the importance of the lithology on rock surfaces distribution (density, frequency, orientation) and dimensions (area, slope, relative height) in relation to differential freeze-thaw manifestation in the 1800 – 2544 m altitude range. Rock surfaces were inventoried in 24 mountain massifs based on Google Earth® imagery, while their morphometrical characteristics were derived from the 25 m resolution EU-DEM digital surface model. The total mapped surfaces sum 21.7 km<sup>2</sup> and were grouped into three main rock types: sedimentary, metamorphic and igneous.

The rockwalls inventory highlights the higher vertical extension (mean relative height) of the limestone and conglomerate rockwalls with mean areas one order of magnitude higher than of those developed on metamorphic rocks, the latter showing the smallest but the most numerous rockwalls. In terms of aspect, both frequency and mean covered area show that rock surfaces are more developed on the north-facing slopes in the detriment of the southern ones (5:1 ratio). Correspondently, the analysis of frost-related processes reveals important differences between the north and south-facing rock surfaces, as the first experiences deep continuous freezing throughout most of the cold season whereas the latter is subject to high day-night thermal amplitudes and up to 120 freeze-thaw cycles. This reflects into the characteristics of weathered rock fragments, weathering rate and into the long-term resultant configuration of the slope, which on a local scale should also consider the control of rock properties and structural imprint.

**Keywords:** rockwall, frost weathering, lithology, Carpathians

THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND  
GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY

ABSTRACT NUMBER: 23

## APPRAISAL OF LANDSLIDES TRAJECTORIES AND VULNERABILITY MAPPING IN JOS SOUTH LGA : USING REMOTE SENSING AND GIS

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Landslide has become a threat to properties, and safety of man and other living organisms in Jos South L.G.A, This paper aimed at identifying and mapping the landslides vulnerable areas using remote sensing and GIS. The developed susceptibility maps were intended to support the hazard mitigation and landuse policies for sustainable development in the area. Geospatial and ancillary data were generated and collected from satellite imageries, shuttle radar topographic mission (SRTM), GPS, topographic maps on soil, geology, drainage, DEM, population and landuse-landcover. These data were processed and classified using ArcGIS 10.1 and ENVI 5.0. Overlay performed to produce five landslide susceptibility (severely high, high, moderate, low and very low), and the vulnerability areas. Moderate areas ranked highest with 234.85km<sup>2</sup> (46%), low susceptibility 175.5 km<sup>2</sup> (34.4%), very low susceptibility 79.9 km<sup>2</sup> (15.7%) while, high and severely high were below 4% in areal extent. The study recommended intensive mitigation measures from all stakeholders (the government, agencies, miners and mining companies, local people) for trees planting culture, spontaneous post-mine sites reclamation and landfills, and thorough feasibility and EIA studies before, during and after mining operations.

**Keywords:** Landslides, GIS, Remote Sensing, Jos South, Nigeria

THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY

ABSTRACT NUMBER: 43

## EVALUATION OF GLACIAL LAKES EXPANSION AND PROBABILISTIC VOLUME ESTIMATION BY DIFFERENT TECHNIQUES IN CHHOMBU CATCHMENT OF UPPER TISTA BASIN, SIKKIM HIMALAYAS

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In recent times, Glacial Lake Outburst Flood (GLOF) risks are receiving increased attention and its catastrophic impact on continuously growing settlements along the upstream river valleys as well as a genuine threat to nature and adventure lovers in the Himalayan region. However, contemporary information about the spatial distribution and recent dynamics of glacial lakes within the Chhombu catchment of upper Tista basin in Sikkim Himalaya is still limited. Thus, a systematic evaluation of the selected glacial lakes within the study area is conducted through various image processing methods and indices (NDSI and NDWI) based on the multi-source satellite images i.e. Landsat Series from 1970 ~ 2015 and Google Earth imageries. Using a time-series inspection method it is also revealed that the lake boundary is changing consistently. Digital Elevation Model (DEM) and topographic map are also used to get the elevation information. Furthermore, in this study, various empirical relationships are implied to predict the lake volume. Such relationships are based on the approach that lake depth, area, and volume scale predictably in various literature. Although, it is also suggested that further in-situ field measurements of emerging as well as growing glacial lakes are required for better understanding about their development in the study area.

**Keywords:** Glacial Lakes; Volume estimation; Remote Sensing; Chhombu Valley; Sikkim

THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY

ABSTRACT NUMBER: 127

## DEVELOPMENT OF WATER POTENTIAL ZONE (WPZ) FOR GAD WATERSHED, INDIA - AN INTEGRATED GEOMORPHOLOGICAL AND GEOINFORMATICS APPROACH

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The water resource potentiality depends on drainage morphology, geomorphic constrains and sub-surface lithological characteristics of a particular region. Most of the coastal watershed in Deccan trap region, India faces water storage problem during non-monsoonal season due to presence of heterogeneous topography. Hence, the main objectives of present research are to identify and develop water storage potentiality zones for basaltic terrain of GAD watershed by analyzing drainage morphological parameters which integrated with existing geological and geomorphic conditions.

The various geomorphic and morphometric parameters have been analyzed using satellite remote sensing data and geospatial databases have been generated to find out the geomorphic constrains for water recharge in the study area. Suitable rank has been assigned to various classes of geology, geomorphology, soil and morphological parameters as per its influence towards water resource potentiality special reference to improve water resource and mean score has been computed by compiling ranks to produce water storage potential zones (WPZ) for study area.

The result shows that high potentiality zone is Janvali and lower gad sub-watershed covering by laterite and quartzite, lower Gad sub watershed which is also a part of coastal plain with pediplain signifying geomorphic efficiency for sufficient water recharge. Similarly, low potential zones are found in Upper Gad sub-watershed which occupies mainly the Megacryst flow and cliff geomorphology where meta basalt, amphibole and granite rocks are dominant indicating recharge of rain water is less as the presence of significant geomorphic

constrains namely homogeneous hard rock, higher altitude with effective slope, high rate of overland flow with less infiltration and structural control. Kasal and Middle Gad sub-watersheds represent as medium water potential zone which is associated with less slope and undulating terrain. The field analysis also resembles with geomorphic constrains and authenticate the above findings.

**Keywords:** Geomorphic indices; basaltic terrain; WPZ ; Geomorphology; Geoinformatics

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND  
GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 147**

## **HYDROMORPHOGEOLOGICAL STUDY OF DHAMANI RIVER SUB-BASIN USING REMOTE SENSING AND GIS TECHNIQUES**

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The Dhamani river sub-basin is trending NNE-SSW direction and covers an area of about 196.36 sq. km. in Gaganbawada taluka of Kolhapur district, Maharashtra. Deccan Volcanic Basalt mainly "aa" type of compact basaltic lava flows of Upper Cretaceous to Lower Eocene age covers whole study area. Lateritic rock formations are also found on top of the hills at height of above 930 m. elevation belonging to Pleistocene period. In the present study, availability of surface water is nominal and most of the farmers depend on groundwater for drinking and irrigation purpose. Evaluations of the groundwater prospecting zones have been undertaken for present study by using Geographic Information System (GIS) and Remote sensing technique. The GIS techniques are used for data generation and map creation, for this ArcGIS 10.1 and ERDAS 10.4 software's are used. ASTER DEM (downloading from USGS), "LANDSAT-5" satellite Image (downloading from USGS), Google Earth and SOI toposheets on 1:50000 scales are used for the preparation of base, drainage, slope, geological, lineament, geomorphological and hydrogeological maps of study area. Geomorphological analysis of present study is carry out by using six morpho-units, such as alluvial plain, pediplain, pediment, valley fill sediments, highly dissected plateau, hill and lateritic plateau. The morphometric analysis reveals that, Dhamani river is of 5th order stream having total 961 streams covering the total length of 687.55 km. Drainage density is 3.50 km/km<sup>2</sup>, stream frequency is 4.89 streams/ km<sup>2</sup> and textural ratio is 11.43 km-1 which indicates study area is impermeable having high relief and drainage is very fine. In the present study groundwater is restricted mostly to the zones of secondary porosity developed due to fractures, joints and weathering. The hydrogeomorphological characteristics of the area indicate the good quantity of groundwater occurs in pediplain, pediment and valley fill areas of the sub-basin.

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND  
GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 207**

## **DIFFERENCES BETWEEN SPECTRAL ANGLE MAPPER AND EUCLIDEAN DISTANCE CLASSIFIERS IN LANDFORM MAPPING**

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Geomorphometry science studies quantitatively the topographic surface. Among the landform classification methods highlight supervised classification by geometric signatures. Geometric signatures classification can use similarity and distance metrics. In this context, our objective was to compare the results of landform classification made with both approaches. The study was conducted in the Campo de Instrução Militar de Formosa (CIF), located at Preto River Basin in Central Brazil. We used Euclidian distance (distance method) and Spectral Angle Mapper (similarity method) for landform classification. The geometric signatures were created as a single multiband image by joining the Longitudinal, Cross-sectional, Minimum, and Maximum curvatures derivate from a Digital Elevation Model (Hydrosheds data). The geometric signatures were selected by (a) reducing the amount of information by Minimum Noise Fraction algorithm, separating the fractions noise/signal; (b) reducing the amount of spatial information by selecting the purest pixels by the Pixel Purity Index; and (c) selection of geometric signatures in a n-dimensional viewer. We used 14 geometric signatures to classify the six landforms: Convex/Convex; Convex/Concave; Concave/Concave; Concave/Rectilinear; Convex/Rectilinear; Rectilinear. Spectral Angle Mapper presented a mapping with predominant forms Concave/Rectilinear, Convex/Rectilinear and Convex/Concave,



indicating a heterogeneous terrain with many transition areas. The Euclidean distance showed a plot with the predominance of forms Rectilinear which is more consistent with the characteristics of CIF terrain. Although Euclidian distance method generated maps more consistent with field reality, Spectral Angle Mapper method was important to evidence transitions between concave and convex landforms. Therefore, future works should use both similarity and distance methods together to detail the landform mapping.

**Keywords:** landscape; Brazilian central plateau; profile curvature; geomorphometric signature; supervised classification

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND  
GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 262**

## **ANALYSIS SPATIOTEMPORAL LAND USE/COVER DYNAMICS USING REMOTE SENSING IMAGERY AND GIS TECHNIQUES**

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Land use/land cover is a significant element for the interconnection of the human activities and environment a monitoring which is useful to find out the deviations to save a maintainable environment. Remote sensing is a very useful tool for the affair of land use or land cover monitoring, which can be helpful to decide the allocation of land use and land cover. Supervised classification-maximum likelihood algorithm in GIS was applied in this study to detect land use /land cover changes observed in KAN basin using multispectral satellite data obtained from Landsat 5 and 8 for the years 2000 and 2016 respectively. The main aim of this study was to gain a quantitative understanding of land use and land cover changes in KAN basin of Tehran over the period 2000- 2016. For this purpose, firstly supervised classification technique is applied to Landsat images acquired in 2000 and 2016. The KAN basin was classified into five major LU/LC classes viz. Built up areas, garden, pasture, water and bare-land. Change detection analysis was performed to compare the quantities of land cover class conversions between time intervals. The results revealed both increase and decrease of the different LULC classes from 2000 through to 2016. The results indicate that during the study period, built-up land, and pastures have been increased by 0.2% (76.4km<sup>2</sup>) and 0.3% (86.02km<sup>2</sup>) while water and garden and bare land have decreased by 0, 0.01% (3.62km<sup>2</sup>) and 0.4% (115.65km<sup>2</sup>) respectively. Hence, the information obtained from change detection of LU/LC aids in providing optimal solutions for the selection, planning, implementation and monitoring of development schemes to meet the increasing demands of human needs has lead to land management.

**Keywords:** Land use/land cover, Remote sensing, GIS, Supervised classification, KAN basin

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL  
INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 286**

## **DETERMINATION OF THE BOUNDARY BETWEEN THE MID-EUROPEAN LOWLANDS AND THE POLISH HIGHLANDS IN THE LIGHT OF THE CONFORMITY OF PROFILES ALONG FOSSIL AND CONTEMPORARY SURFACES**

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The analyzed area is located in Central Poland, the middle part of the Pilica river valley. In the south is a monoclinical Mesozoic Przedborz-Malogoszcz Range, covered with Pleistocene sediments. North, the surface of glacial uplands is built by Middle Polish Glaciation sediments, Warta stadial.

In Scandinavian ice sheets and subsequent erosion-denudation processes in the last 130,000 years, the lowlands and highlands boundary is blurred. Hill remnants of Mesozoic rocks forming the morphogenetic zone of Polish Highlands are as high as moraine hills in the periglacial zone in Mid-European Lowlands. In physico-geographical regionalization, individual mesoregions to upland or lowland areas is often debatable. If solution of a research problem requires the definition of relief types and relationship between them, such analysis is often a visual comparison of the conformity of the fossil and contemporary surfaces. This method is subjective and difficult for comparisons of various research areas.

One research method solving the problem described is making and terrain profiles analysis along given lines. GIS tools provide a fast way to generate such objects, but because of the automated nature of the process, results are difficult to compare.

This paper proposes fast profiles comparison of the subquaternary and contemporary areas on the example of Central Poland. The authors believe this method enables a simple geometry assessment of different surfaces on selected lines using basic GIS tools, without need for advanced statistical methods. However, the method presented is one of many pathways to solving the problem.

The path is: 1. Data extraction. 2. Correction of height information between input layers. 3. Reading surfaces elevation values on profile lines from DEM. 4. Geometry analysis of profile lines on different surfaces. 5. Results evaluation. Boundary thus defined ran along the ordinate of ca. 250 m a.s.l.

**Keywords:** GIS, terrain profiles, Pearson correlation coefficient, Central Poland

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 287**

## **GEOTECHNICAL CHARACTERIZATION OF THE SITE ALONG ROODBAR HIGHWAY**

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The linear engineering structures are considered, including that due to the passing of the units and various geological conditions, engineering geology and geotechnical always a wide range of variations are met. Construction has always been a bed of specific problems that are common in geotechnical projects (dot structures such as buildings) are faced with is not considered. The major geotechnical problems in road construction projects, due to the complexity and risks of Engineering Geology different areas that Roads that cross the region. The lack of geotechnical studies for such things practically blindfolded step in the way risk is putting the lives of passengers and road users at the end of it. This importance of this type of geotechnical projects far more than other projects in the usual shows. The thesis examines geotechnical issues facing the Roodbar highway as part of the National Highway Qazvin - Rasht deals. The highway 4/137 km in length, one of the main pillars of the country's vital areas of the Caspian Sea to the southern slopes of the Alborz and motorway network connects the country. The focus of this Thesis on geotechnical problems of highway in the city limits Roodbar length of 10 km. In this regard the study of geological conditions and geotechnical engineering, remote sensing and field studies engineering drawings of the proposed range and by specifying sensitive areas, large-scale sampling is. The samples are shipped to the laboratory and in situ and laboratory tests, the parameters of resistance - masses of site geotechnical highway ROODBAR been met. Finally, by combining surveys and geotechnical test results and case studies have identified risk areas.

**Keywords:** Roodbar Highway, Geotechnical, Remote Sensing, ArcGIS.

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 288**

## **LOCATING OF UNDERGROUND DAMS WITH USING REMOTE SENSING & GIS (CASE STUDY: MAKEKAN)**

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The solutions to cope with water shortage are summarized in the two strategies of water resource proper management and new resource exploitation. Ground water dams due to diversity, mechanism and function in sustainment and optimal operation of groundwater can have significant contribution. First and foremost step in constructing ground water dams is to identify appropriate locations. Since this step incorporates both profit and loss of the project, it has to be done more precisely. Using remote sensing techniques along with GIS can turn out to be highly effective in this concern. The present study has been conducted in the city of Malkan aimed at locating ground water dam construction. For this purpose the factors influencing location determined. In this study among the effective factors six factors include geology, soil, gradient, channel density and vegetation density took into account then the data relevant to each factor collected. The necessary data collected from remote sensing (satellite images) and the available maps. Having been collected the data were analyzed classified and became a single structure in the soft ware of Arc GIS. Then according to expert opinion and the importance

of layers stratum, the inter layer weight transferred to each layer. With respect to the unequal significance of factors in location using the method of analytical hierarchy process (AHP) the weight of each layer calculated. Finally to draw conclusion and set appropriate sites for ground water dams the above mentioned layers were combined together using index overlay method and the maps of appropriate locations to construct ground water dams were prepared.

**Keywords:** Underground Dams, Remote Sensing, GIS, Malekan

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 431**

## **GEOMORPHOLOGICAL UNITS AS NATURAL BOUNDARY TO LAND COVER CHANGE ASSESSMENT**

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The Brazilian Cerrado has been suffering from the advancement of anthropogenic activities, mainly land-cover change. In this context, the natural resources management is important and should be done considering natural boundaries rather than the commonly used political boundaries. In many Brazilian Cerrado regions, geomorphological units can be used as natural limits for environmental studies and management. Our objective was to evaluate the influence of geomorphological units on the land-cover change in a central region of Brazilian Cerrado. For this purpose, we mapped geomorphological units using a Digital Elevation Model (DEM) from the Shuttle Radar Topography Mission (SRTM) data. Subsequently, we mapped the land-cover for each year from 1985 to 2015 using medium resolution images (30 meters) from the TM and OLI sensors of Landsat 5 and Landsat 8 satellites, respectively. After, we overlaid multitemporal land cover map and geomorphological units map to identify distribution patterns and changes in land cover over time in function of natural boundaries. The results showed the presence of two large environments. The first geomorphological unit is flat and continuous, had a land-cover pattern for multiple uses, mainly for agricultural activities and the establishment of urban regions. The second geomorphological unit is rough, presented a limitation for human development, and its coverage was primarily natural. We conclude that the geomorphological characteristics determine the land-cover dynamics in the central region of Brazilian Cerrado. This approach should contribute to the development of public policies for the natural resources management and land use planning.

**Keywords:** Relief-Land Cover Relationship; Multitemporal Analysis; Landsat; SRTM; Environmental Boundaries

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 459**

## **MORPHOMETRIC ANALYSIS OF PACHNAI RIVER BASIN, ASSAM (INDIA) USING GEOSPATIAL TOOLS**

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GIS is an effective tool to analyze spatial and non-spatial data on drainage, geology, landforms and soil parameters to understand their inter-relationships. GIS provides an excellent means of storing, retrieving and analyzing data at river basin level to find out their association. It also provides a powerful mechanism not only to upgrade and monitor morphometric parameters but also to permit the spatial analysis of other associated resources database. Water resource and strategic planning on a basin greatly depend upon the basin morphometry. At present day context, geographical information system has efficient tool in water resource management and its planning. GIS and image processing techniques have been adopted for the analysis of morphometric characteristics of the Pachnai river basin, Darrang district, Assam, India, covering 300.01 km<sup>2</sup>. The present study deals with some important parameters stream number (Nu), Stream length (Lu), Bifurcation ratio (Rb), Drainage density (Dd), Stream frequency (Fs), Elongation ratio (Re), Circularity ratio (Rc), and Form factor ratio (Rf) etc. The morphometric parameters evaluated using Geospatial tools helps in better understanding the nature of landforms and their processes, drainage pattern demarcations for basin area planning and management. This study would

help to management of natural hazard as well as water resources and decision making for strategic planning.

**Keywords:** Geo spatial; Morphometry; River basin

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 491**

## **LANDFORM FRAGMENTATION ANALYSIS IN DIFFERENT ETCHPLANTION STAGES**

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Central Brazil etchplains have been developed in tropical environments since the Tertiary, where a wetter and warmer paleoclimate prevailed, causing denudation, desiccation, and fragmentation of the landscape. A challenge for Geomorphometry is to model plain landforms from Digital Elevation Model. The objective of this work was to develop a landform fragmentation approach to evaluate the etchplation stages. The study area is located in Brasilia Fold Belt, characterized by seven geomorphological units: Slightly Denudated Plateau of Paranoá, Slightly Denudated Plateau of Bambuí-Canastra, Dissected Plateau Araxá-Canastra, Dissected Plateau Paranoá-Canastra Karst Depression Vazante-Bambuí, Karst Depression Paranoá-Canastra, Karst Depression Paranoá-Bambuí. The landform classification was made with geometric signatures created by curvatures and classified by Minimum Distance algorithm. The landforms fragmentation is measured primarily for geomorphologic unit, considering the Frequency (Fr) and Patches Proportion (PP). These parameters vary according to denudation stage, which is closely related to the balance between convex, concave and plain landforms. Geomorphometric Denudation Index (GDI) was generated from the Fr and PP, considering the convex and concave ratio and plains and concave ratio. These landforms were also measured by patch size (MPS and PSSD), patch edge (MPE), complexity (MPAR), diversity (SHDI) and density (PD and ED). Principal Components Analysis (PCA) showed that the density metrics determined Dissected Plateaus, the size metrics determined Slightly Denudated Plateaus and diversity metrics determined Karst Depressions. The geomorphometric analysis aided by the soil, lithological and geomorphological information allowed to establish etchplation stages: Slightly Dissected Mantles Etchplain, Dissected Mantles Etchplain, Partly Stripped Etchplain, Stripped Etchplain Covered Etchplain and Covered/Exhumed Etchplain.

**Keywords:** geometric signature; landform classification; patch metrics; landscape metrics; tropical relief

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 585**

## **DRAINAGE DYNAMICS SYSTEM ANALYSIS DUE TO THE URBANIZATION PROCESS IN THE DEVELOPMENT OF EROSION PROCESSES**

**Anesmar Ollino de Albuquerque<sup>1\*</sup>; Renato Fontes Guimarães<sup>1</sup>; Roberto Arnaldo Trancoso Gomes<sup>1</sup>; Osmar Abílio Carvalho Junior<sup>1</sup>**

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The constant demand for areas of urban expansion coupled with the absence of planning makes the growth of cities occur in a disorderly way, causing a series of social and environmental damages. The processes of urbanization cause significant modifications in the surface runoff, especially by the waterproofing of the soil caused by pavements and buildings the waterproofed surfaces reduce the infiltration of rainwater, consequently increase the surface runoff, both in volume and velocity, allowing the development of erosive processes. In this regard, mathematical modeling has been widely used for studies related to terrestrial dynamics, using the Digital Elevation Models (DEMs). The objective of this research is to analyze the dynamics of the pre and post-urbanization drainage network in an urban area in the municipality of Jacareí, São Paulo. The methodology was based on the following steps: construction of the Digital Surface Model-DSM (post-urbanization); construction of the Digital Terrain Model-DTM (pre urbanization); hydrological modeling to compare modifications between pre and post-urbanization. Based on photogrammetric techniques, the MATCH-T DSM and DTMaster modules (both of the INPHO photogrammetric system) were used to build the digital models to represent pre and post-urbanization. In order to obtain the Digital Terrain Model at original conditions, the photogrammetric restitution allows the simulation of the bare

ground surface by eliminating all the constructions. Pre and post urbanization area contribution and slope maps were elaborated using digital models consistent with a 5-meter grid. The pre and post-urbanization contribution area maps were subtracted, indicating not only the changes in the drainage system but also the locations of the areas of greater flux convergence. The results identified changes in the drainage system after urbanization, where convergence and divergence of flow took place. This methodology allowed elaborating a susceptibility map of erosive processes.

**Keywords:** erosion; DTM; DSM; photogrammetry; INPHO

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 609**

## COMPARISON OF LANDSLIDES HAZARD MAPS PRODUCED FROM DIGITAL TERRAIN MODELS GENERATED FROM LIDAR DATA AND DIGITAL AREA PHOTOGRAPHS.

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An important problem of physically based models of landslide hazards is how to build a Digital Terrain Models (DTM) disregarding forest coverage that interfere in landslides hazard maps. In this context, new technologies as laser radar acquire altimetric data that represent the terrain surface without vegetation cover. In this sense, the objective of this work is to compare landslide hazard maps produced from DTMs generated of the LiDAR data with DTMs obtained by photogrammetry restitution in a basin located in Ubatuba, São Paulo, southeastern Brazil. The methodology was divided into the following steps: Elaboration of DTM from the photogrammetric restitution of digital aerial photographs; elaboration of DTM from LIDAR data; elaboration of landslide hazard maps from the generated DTMs and comparison between the produced maps. The DTMs generated from the aerial photographs were made from the MATCH-T and DT Master modules, edited to eliminate vegetation cover. We use SHALSTAB to produce landslides hazard maps. This model is based on combining a hydrological model and a slope stability model to determine the critical steady-state rainfall capable to initiate slope instability in a landscape. The results showed that the landslide hazard maps have distinct levels of detail despite having the same spatial resolution. Both products presented good quality to identify susceptible areas, but the map from the LIDAR sensor presented a better terrain surface compared to DTM obtained by the aerial photographs. The obtained products demonstrated that the DTM produced by the LIDAR sensor have the potential to be used in a physically based model because they have the capacity to represent small elevation changes, detecting past slides. These characteristics aid in identification of landslides hazard by improving the performance of predictive models.

**Keywords:** Landslides; LiDAR; Photogrammetry; Digital Terrain Models and SHALSTAB.

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 690**

## PREDICTION OF LANDUSE-LANDCOVER CHANGES IN THE FLOOD-PRONE AREAS OF DOMBIVALI TOWNSHIP, MAHARASHTRA

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Dombivali, situated on the southern banks of River Ulhas, is one of the growing townships in Maharashtra. Spread of settlement is mainly seen in the flood-prone area of River Ulhas after year 1995. This paper aims at comparative study of three scenarios of the newly developing area of Dombivali township. The first one is the actual present day ground scenario, the second one that is depicted in the development plan of the area and the third one is the predicted scenario using prediction models -Regression analysis. It is found that the area near channel was initially a marshy land. Now it is being reclaimed and converted into plain land. It is also confirmed from local residents of Dombivali west and analysis of satellite images (years - 2001, 2005 and 2017) that this area is getting reclaimed and brought under construction especially after 1995. The natural channels are blocked which carry water from the inland area to the main river. The third scenario is created by using the two time image data (2005 and 2017) by applying the technique of Markov chain. The third scenario suggests that there would be still more growth of settlements in the flood-prone area in next 10 years. If this process of

continues at the current pace, more and more area, thus more population will become vulnerable to flood.

**Keywords:** Markov chain, landuse-landcover prediction, flood vulnerability,

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND  
GEOGRAPHICAL INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 727**

## **DEVELOPING OPEN-ACCESS E-LEARNING MATERIALS FOR GIS EDUCATION RELATED TO TERRAIN ANALYSIS**

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Several projects have been conducted for enhancing GIS (Geographical Information System) education in Japanese universities. As a result, a basic core curriculum and teaching materials for university lectures were developed. However, comprehensive materials for exercises using GIS software have not been developed. Therefore, we launched a new project for developing and publishing materials for GIS exercises in 2015, entitled “Development of Open-access E-learning Material for GIS Education Based on the Existing Core Curriculum and the Body of Knowledge”. In this project, materials explaining analytical methods using GIS were developed based on the basic core curriculum. These materials utilize free and open-source GIS software packages such as QGIS. This presentation focuses on materials related to terrain analysis. It is a core part of a section for raster data analysis, explaining how to use elevation data for various analyses such as the calculation of slope gradient and the creation of topographical profiles. In addition, we produced videos to explain equipment related to GIS and terrain analysis such as UAV (Unmanned Aerial Vehicle) and 3D printers. The materials will be published using the GitHub platform with a license that permits access by anybody.

**Keywords:** GIS education; learning material; open-access; terrain analysis; GitHub

*THEME: S21 : APPLICATION OF REMOTE SENSING (RS) AND GEOGRAPHICAL  
INFORMATION SYSTEM (GIS) IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 735**

## **RELATIONSHIPS BETWEEN COASTAL SAND DUNE VEGETATION AND LANDFORMS BASED ON ALS AND UAV-SfM PHOTOGRAMMETRY: TOTTORI SAND DUNES, SOUTHWEST JAPAN**

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Coastal sand dunes are frequently subject to human activities. The landward sides of dunes are often modified by the development of farmlands, erosion control forests, and residential areas. On the sea-sides of dunes, coastal structures are often installed to prevent wave erosion. Therefore, the total area of natural coastal sand dunes in Japan has significantly decreased, and the ecosystems therein have been greatly affected by human modifications. For the conservation and restoration of such sand dunes and their ecosystems, investigating both natural and human-affected sand dunes is indispensable. This study focuses on relationships between coastal dune landforms and vegetation, the primary producer in ecosystems. Although previous studies suggested that the accretion of sand greatly affect the distribution of vegetation, detailed geomorphological studies on the dynamic environment with frequent sand movement have been limited.

Here we investigate spatial relationships between landforms and vegetation in the coastal Tottori Sand Dunes, Southwest Japan, using high-resolution ground surface information obtained from airborne laser scanning (ALS) and unmanned aerial vehicle-based structure-from-motion (UAV-SfM) photogrammetry. Vegetation was classified into several communities, and their distribution was mapped based on orthorectified aerial images. We analyzed the spatial correlation using the Jacobs index. The results indicate that the distribution of vegetation is influenced by western to northern wind in winter and southern wind in other seasons. We found that short communities tend to occur on gentle and slowly growing dunes, whereas tall communities tend to occur on steep and quickly growing dunes. We also found that high vegetation cover communities usually occur in sand accumulation areas, whereas low vegetation cover communities characterize erosional areas.

ABSTRACT NUMBER: 736

## EROSION RATES WITH RELATION TO TECTONIC ACTIVITY

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For decades scientists have been attempting to determine what controls erosion rates as this is of critical importance in understanding landscape evolution. Tectonic activity was identified as one of the prominent controlling factors of erosion rates. One study has found that in an alpine-like relief rates of erosion were slow due to a tectonically quiet cratonic setting and another study has found that erosion rates are linearly correlated to uplift rate. In this study we use simple tectonic activity indicators to define the relation between tectonic activity and rates of erosion. The data for this study are based on previously obtained erosion rate data and erosion rates derived from sediment yields published by the USGS. As tectonic activity indicators we use fault distribution, peak ground acceleration (PGA) and distance to tectonic plate boundary.

Our study confirms that erosion rates are strongly related to tectonic activity and has found the following characteristics.

- 1) Erosion rates are positively correlated to PGA and negatively correlated to distance to tectonic plate boundary.
- 2) Despite the difficulty to accurately define and measure tectonic activity, and even though there is a complex relationship with erosion rates, it is possible to define a connection between erosion rate and a simple to obtain tectonic activity indicator such as distance to tectonic plate boundary.
- 3) The relation of erosion rate to tectonic activity might be through slopes as they are positively correlated to PGA and negatively correlated to distance to tectonic plate boundary. Tectonically active areas tend to develop steep slopes which in turn are responsible for higher erosion rates.
- 4) On a global scale almost 30% of variance in erosion rates can be explained by a combination of only two factors – distance to tectonic plate boundary and PGA.

ABSTRACT NUMBER: 759

## EFFECT OF THE NEOTECTONICS ON THE DRAINAGE SYSTEM IN THE PIEDMONT OF THE DARJEELING-SIKKIM HIMALAYAS, NORTH BENGAL, INDIA.

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The collision of the Indian and the Eurasian plate resulted in the southward propagation of thrust faults. The southernmost fault system in Himalayas is known as Himalayan Frontal Thrust (HFT) which is the principal tectonic displacement zone. In western Himalayas it has been reported that the HFT has migrated further south into the Indo-Gangetic plain. The Baradighi fault in the piedmont zone of Darjeeling-Sikkim Himalayas is an example of one such fault. The objective of this paper is to study the role of neo-tectonics and active tectonics on the fluvial system in the North Bengal, India. The study area is drained by large number of rivers viz. Mal, Neora, Kurti, Murti and Jaldhaka. The study area has some N-S lineaments viz. Neora and Murti and E-W thrusts viz. Murti, Chalsa and Baradighi. The remote sensing data of different satellites along with field survey was used to carry out the study. The interpretation of satellite data was done based on visual interpretation along with integration of various GIS techniques to calculate different morphometric indices. The drainage system has been highly modified by the tectonics resulting in several palaeochannels. The Neora and Murti lineaments predate the Chalsa fault. The Baradighi fan has been tilted due to the neotectonic activity. In transition zone from Baradighi fan to alluvial plain, tectonics as well as sediment flux and discharge has resulted in migration of river channel.

**Keywords:** Neotectonics; Baradighi fault; Himalayas

THEME: S22 : QUANTITATIVE GEOMORPHOLOGY AND MODELING

ABSTRACT NUMBER: 417

## ESTIMATING DISCHARGE FROM SUB-BASINS OF THE GANGA RIVER- A SWAT BASED ANALYSIS

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The water availability at Farakka shows serious limitations in lean season sharing of Ganga water between India and Bangladesh. In the context of non-availability of runoff data at Farakka, Soil and Water Assessment Tool (SWAT) is often used to estimate the surface runoff at catchment scale using ArcSwat 9.3.1. Digital Elevation Model (DEM), slope derived from DEM, Weather data (1979-2014), Soil types (FAO) and Land use/Land cover (LULC) data are used as inputs to calculate the surface runoff at the catchment outlet of the sub-basins of Ganga river. The sub-basins are delineated and subdivided into different Hydrologic response units (HRU) with different topographical, soil and land use characters. Study revealed that estimated surface water discharge of the sub-basins have remarkably reduced in April and May months.

**Keywords:** Water availability, Lean season, SWAT.

THEME: S22 : QUANTITATIVE GEOMORPHOLOGY AND MODELING

ABSTRACT NUMBER: 599

## RELATIONS BETWEEN TIME VARIABILITY OF HYDRO-SEDIMENTARY RESPONSES, CLIMATIC SIGNALS AND CATCHMENT CHARACTERISTICS USING A LANDSCAPE EVOLUTION MODEL (CAESAR-LISFLOOD)

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Within the Critical Zone, the sensitivity of hydrodynamic and sedimentary responses of catchments to climate variability at different time-scales (event to multi-decadal) is a major issue in the context of Global Change. Among key challenges is the understanding of erosion and runoff processes variations according to time-scale; the sediment and solute routing, the prediction of floods and mass movements as the determination of the involved factors (time variability and importance). In this respect, our main goal is to study the time variability of output signals ([SPM], Q) over multiple time-scales from catchments regarding the characteristic variability of input signals (for instance, in terms of spectral content of rainfall) and the internal properties of catchments (geomorphology, land-cover). We have also focused on the relation between Q and [SPM] which is prone to change at different time scales.

The methodology is based on the coupled use of a landscape evolution model (CAESAR-LISFLOOD) and signal processing techniques as follows: (i) at constant input climatic signal of precipitation, the sensitivity of output signals to geomorphic and land cover properties, (ii) at constant internal properties of the catchment, the sensitivity of output signals to those of input climatic signals (short or long time-scales). The approach was conducted using numeric catchments and one well-instrumented catchment from the French Critical Zone Observatory (OZCAR).

Here we present results of the several runs of CAESAR-LISFLOOD model bringing some pieces of knowledge of the role of some internal properties of catchment, yet seen as a black box, on the distortion of climatic signals in the hydro-sedimentary ones. Relations over time of [SPM] and Q are also discussed for the long time series data (>25yr) of the instrumented catchment, which are promising for the understanding and the prediction of [SPM] variability.

**Keywords:** climate, signal, discharge, catchment, LEM





THEME: S23 : GEOMORPHOLOGICAL MAPPING

ABSTRACT NUMBER: 10

## GEOMORPHOLOGICAL MAPPING OF THE REGION OF NEPENTHES MENSAE, MARS. EVIDENCE OF AN ANCIENT SEA

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Nepenthes Mensae is located in the equatorial region of the eastern hemisphere of Mars, near the escarpment that defines the highland-lowland boundary. The study area displays numerous relict landforms attributed to past water-related activity, such as the drainage networks that dissected the highlands. A 1:1,500,000 scale geomorphological map of the region of Nepenthes Mensae was elaborated using high-resolution digital elevation models and panchromatic images in a GIS environment. The analysis of the mapped landforms and their spatial relationships enabled the identification of numerous fluvial and coastal features, including channels, deltas at the mouth of river basins and shore platforms around isolated massifs. Topographic profiles of deltas and shore platforms reveal the existence of an ancient sea with mean elevation at  $-1,955 \pm 25$  m and a maximum depth of 960 m. The presence of shore platforms at different elevations under the main sea-level seems to indicate that the sea-level drop was punctuated by periods of stability that allowed the development of erosional straths along the coast. The lack of deltas below the main shoreline suggests that fluvial activity decreases after the start of the sea-level decline. The age of the main geomorphological units was estimated by the crater counting method, whereby the higher the crater density, the older the age of the planetary surface. Accordingly, the age of the heavily cratered highland unit is the oldest ( $4.12 \pm 0.18$  Ga). Conversely, the age of the sea basin unit, the most poorly cratered, is the youngest ( $3.86 \pm 0.15$  Ga). Ongoing research on glacial and periglacial landforms and the presence of permafrost in the region would shed light on its recent environmental evolution. Hence, the detailed study of landforms in the Nepenthes Mensae area provides relevant data for reconstructing the hydrological and climatic changes that occurred in this region of Mars.

THEME: S23 : GEOMORPHOLOGICAL MAPPING

ABSTRACT NUMBER: 107

## TOPOMORPHOLOGICAL SURVEY USING ANALOGICAL AND DIGITAL TECHNIQUES

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This paper concerns a topographical and morphological survey of a 830-meter long hillslope located at the foot of a cuesta escarpment in the Sao Pedro region, Southeastern Brazil. The objective was to construct and compare two detailed hillslope topomorphological profiles, characterized by Triassic age sandstones and Jura-Cretaceous basalt fragments, besides tilling by mechanized agriculture and crop rotation. Two techniques were used to delineate the respective profiles: an analogical one, using a pantometer (an equipment that registers the terrain inclination angle by means of a level and a protractor supported by two vertical bars 1.5 m long joined together by horizontal bars); and a digital one, employing a Sokkia total station model SET 610, jointly operated by a topographer, responsible for the equipment at a fixed point, and an assistant whose work consisted in carrying the prism as a mobile point. By displacing along the hillslope and using GPS coordinates, altitudes and distances measuring points were collected in order to get the profiles. As a result, it was found that both surveys allow verifying morphological characteristics of the hillslope in greater detail. The first method allowed to identify the existence of a series of changes of slope of convex and concave aspects, from top to bottom of the valley; it was also possible to distinguish these changes from the terrain variations representing contour curve boxes created by motorized agricultural activity. On the other hand, the second method made possible to notice the geomorphic predominances of the hillslope under analysis. It was still found out that such results enabled to point out in both topomorphological profiles characteristics related to superficial and subsuperficial hydric circulation, pedological cover and bedrock alteration.

THEME: S23 : GEOMORPHOLOGICAL MAPPING

ABSTRACT NUMBER: 128

## DETAILED OFFSHORE SEAFLOOR MAPPING AS THE BASIC METHOD IN



## IDENTIFICATION AND ASSESSMENT OF ENVIRONMENTAL CONDITIONS

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Nowadays, application of an integrated set of non-invasive methods allows thorough identification of geological and geomorphological features of seafloor as well as it produces sharp cartographic images. Opportunities offered by this method were presented on the example of a fragment of morainic seafloor from the Southern Baltic with relics of a moraine and with modern abrasive and accumulative seabed formations. Results of MBES and SSS measurements were elaborated in the form of bathymetric and geomorphological charts. There were presented also profiles and cross-sections obtained in the course of MBES and SES measurements, as well as images of seafloor surface based on SES measurements and images of smaller forms, e.g. ripple marks, sand waves and other forms recorded with use of ROV TV. The measurements conducted in the survey polygon constitute a preliminary stage to the works that are to be performed over bigger areas. These works shall be associated, among others, with habitats and monitoring of condition of the seafloor and its changes generated by natural and anthropogenic impact (such as laying of cables and construction of wind turbines).

**Keywords:** geomorphology, Baltic Sea, sand waves, seafloor

THEME: S23 : GEOMORPHOLOGICAL MAPPING

ABSTRACT NUMBER: 194

## OBJECT-BASED APPROACH FOR GULLY FEATURE MAPPING IN THE HILLY LOESS PLATEAU REGION OF CHINA USING HIGH-RESOLUTION IMAGERY AND DEM

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Gully feature mapping is an indispensable prerequisite for the motioning and control of gully erosion which is a widespread natural hazard. The increasing availability of high-resolution remote sensing imagery and DEM, combined with the developed object-based method make it possible for automatic gully feature mapping. In this paper, an object-based approach for gully feature mapping, including gully-affected areas and bank gullies, was developed and tested on Worldview-3 imagery and 1 m DEM of a catchment in the Chinese Loess Plateau. The methodology includes a sequence of data preparation, image segmentation, metric calculation and random forest based classification. A discussion of whether terrain information can improve segments goodness was conducted in the segmentation step. The final mapping was based on random forest model after investigating the effects of the feature selection and the class-imbalance problem. Results showed that the highest overall accuracy in the gully-affected area mapping was 93.06% with four topographic features. As for bank gully mapping, the highest overall accuracy was 78.5% when all the features were adopted. For validating the extension of this method, two catchments located in Changwu and Ansai were chosen as the validation areas. The experiment results show that the overall extraction accuracy in Changwu and Ansai can achieve 84.62% and 86.46%, respectively. The proposed approach could be regarded as a creditable option for obtaining gully feature information which is related to soil conversation and environmental change.

**Keywords:** object-based image analysis; gully feature mapping; gully-affected area; bank gully; DEM

THEME: S23 : GEOMORPHOLOGICAL MAPPING

ABSTRACT NUMBER: 201

## BOMB CRATERS MAPPING AND QUANTIFICATION ON THE VERDUN BATTLEFIELD (1914-1918, FRANCE)

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Under the effect of artillery, the First World War greatly modified the landscapes along the Western Front. In Verdun, where nearly 60 million of shells were fired during the year of the battle (1916), the bombardments exposed the ground and sculpted a lunar landscape on a territory of approximately 175 km<sup>2</sup>. On the right bank of the Meuse River, today covered by the Verdun forest, the craters inherited from the war have been conserved under the forest mantle. The digital terrain model (DTM) of decimeter level accuracy acquired in 2013 by an airborne LiDAR mission makes possible to observe and quantify them. This research proposes to establish from the DTM a precise mapping of the craters recovering the 10,000 hectares of the battlefield, in order to better estimate the damages caused by guns during the conflict. The methodology used is twofold: (i) Firstly, it consists in extracting the hollow reliefs from the DTM by means of a semi-automatic algorithm. This step allows both to map and calculate their geometry; (ii) Secondly, an analysis of these morphometric values is conducted using multivariate statistics in order to separate the craters and the other reliefs. The produced map is a tool for measuring erosion caused by artillery. It makes possible to quantify the part of disrupted surface over the whole battlefield and to estimate the volumes of displaced soils thanks to the three dimensions of the DTM. Moreover, it enables to assess the craters distribution and to reveal a gradient between the first lines and the rear of the front. In the end, the proposed mapping method is reproducible and adaptable to other battlefields provided there is access to a high resolution DTM.

**Keywords:** conflict-induced landforms, LiDAR, mapping, inventory, spatial analysis

THEME: S23 : GEOMORPHOLOGICAL MAPPING

ABSTRACT NUMBER: 257

## GEOMORPHOLOGY AND MAPPING OF THE VOURAIKOS BASIN, NORTH PELOPONNESUS, GREECE.

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Vouraikos basin, which is located in Kalavryta area, in the northern part of Peloponnesus in Greece, drains the area around Kalavryta and it ends in the Corinth gulf. Corinth Gulf is one of the most active tectonic areas in Europe. Its valley is characterized of a diverse relief, which is dominated by different landforms. This is the result of a mixture of different processes and complex geology, along with intense tectonic activity (uplift rate ~1,3mm/year) which dominates the area of the Corinth gulf. The geomorphology of the basin has mostly affected by fluvial processes, the tectonic uplift of the north Peloponnesus and the last Glaciation during Pleistocene of the Chelmos Mountain.

The methodology used, was based on contemporary techniques for the geomorphological mapping and analysis with the combination of the Geographical Information Systems, Remote Sensing data, spatial (elevation, topographic, geological) data, literature review and fieldwork. The semi-automated methods and multi criteria analysis achieve to assess and combine all the above with GIS software.

Specifically, the Arc GIS software version 9,3 & 10,3 by ESRI, it is used to create the geodatabase, to process, to combine and illustrate the numeric models and maps.

The Digital Elevation Model with cell size ~5 m from National Cadastre of Greece, was used to construct the Aspect, the Hillshade and the Slope models. From the study and interpretation of the automated models (Slope, Aspect), the principal landforms can be depicted. The results were evaluated through the fieldwork and the use of remote sensing data as well as Google Earth images.

The final product is the geomorphological map, scaled 1:25.000, presenting, with symbols derived from the literature review, the principal landforms, which specify the dominant processes of the present landscape and indicate the evolution of the relief.

THEME: S23 : GEOMORPHOLOGICAL MAPPING

ABSTRACT NUMBER: 291

## SURFACE RUNOFF COEFFICIENT OF HYDROGRAPHIC BASINS ACCORDING TO PHYSIOGRAPHIC COMPARTMENTATION

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In the to earth dam breaking analysis, many attributes have to be considered related to surface, subsurface conditions and rain regime, in order to recognize the geological processes (Erosion, mass movement, etc.) that could induce disaster. Considering that intensification in these processes relates with rainfall intensification, this study relates landscape physiographic information (geology, geomorphology, pedology and land use) at 1:50,000 scale of the Roque River Basin - SRRB (São Paulo State, Brazil) with objective to produce a susceptibility map (SIG) using the classification of the surface runoff coefficient available in the literature. Once the rainfall is not homogeneous over whole basin, the SRRB was divided into sub-basins with area smaller than 50,000 m<sup>2</sup>. Information on landscape morphology, soil infiltration, vegetal cover and surface accumulation were analyzed according to runoff classified as high, medium and low values in the literature. Urbanized and non-urbanized areas were also pondered. The relation between surface runoff with the regional rainfall intensity formula shows that the sub-basins with higher values in rainfall, were those that already have presented dam breaking events. We concluded that physiographic compartmentation is a fundamental tool and easy to be applied in planning projects for other basins according their land ponteciality and fragility in order to determine its vulnerability to dam breaking.

**Keywords:** Physiographic mapping; hydrologic parameters; dam break analysis; disaster susceptibility.

THEME: S23 : GEOMORPHOLOGICAL MAPPING

ABSTRACT NUMBER: 296

## SEMI-AUTOMATED GEOMORPHOLOGICAL MAPPING FROM A DIGITAL TERRAIN MODEL APPLIED TO THE CHAPADÃO DO DIAMANTE, SERRA DA CANASTRA, MG-BRAZIL

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The mapping of landforms in the Chapadão do Diamante located in the Serra da Canastra, Brazil, was carried out using semi-automated procedures through the DTM, using algorithms and spatial analysis tools; with the aid of investigations at different spatial scales, such as field surveys and satellite image interpretation. The proposed methodology shows the relationship between parameters as drainage density, roughness concentration index and topography. The geomorphological mapping of the area demonstrated a variety of forms that creates a landscape mosaic. The routines at SIG associated to field surveys allowed the observation of three main landforms, which can be defined in general from the topographic aspects, surface materials and types of vegetation. As far as landforms are concerned, some patterns have been mapped out. Those located in areas without outcrop rocks, where about 9% are flat surface, 18% refers to gentle interflaves, 22% to undulated hills and 10% to very dissected hills. Another group of landforms are associated to quartzitic outcrops, where 15% are associated to hills, 9% to the escarpments/fault lines and finally, the 17% to the strong dissected hills. In general, areas with rugged landforms are associated with quartzitic outcrops and persistence of this lithology to the weathering, with shallow superficial regolith mantle; while the gentle relief areas are concentrated at topographically eroded areas, and are associated with a deepening of the rock alteration profiles. The results suggest that the application of the semi-automated method of classification of the landforms in conjunction with the field surveys can be effective in the geomorphological analysis of the area.

THEME: S23 : GEOMORPHOLOGICAL MAPPING

ABSTRACT NUMBER: 449

## GEOMORFOLOGY OF THE BRAZILIAN CERRADO - REPRESENTATION OF THE RELIEF BY MEANS OF GEOMORFOMETRIC PARAMETERS

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This research is aimed at presenting a standard procedure of geomorphological cartography of the Brazilian Cerrado, the second biome of Brazil in extension. The relief mapping method is based on hypsometric and clinographic metrics. The methodology developed is based on the integration of classes of altimetric amplitude and slope of a digital elevation model. The choice between these two morphometric parameters are related to the first perception of the terrestrial surface, which defines altimetric and inclination patterns of landscape. The hypsometric and slope intervals are defined through the curves that relate the altimetric amplitudes and the slope variations with the frequency in the occurrence area of these variables. The hypsometric inflection and maximal points (Hif and Hmax)

and clinographic inflection and maximal (Cif and Cmax) of these curves determine the limits of the intervals. The classification process of the relief units is dynamic and automated. The principle of the proposed methodology is to evaluate relief metrics, without involving genetic aspects. The lack of a standardization in the geomorphological representation associated to the peculiarities of the process of obtaining the data that characterize the surface can be pointed out as factors that make the elaboration of the geomorphological charts difficult. The area is mostly formed by flat terrain, the smooth corrugation interspersed by surfaces to the north with high rates of dissection. The applied method obtained consistent and reproducible results. Previous methods, which standardized the morphology mainly by visual analysis, ended up not maintaining a pattern of identified classes of relief. Not only did the methodology developed here standardize the class interpretation process, especially with regards to morphology, but it also controls the small nuances that determine the differences of the relief classes.

**Keywords:** Geomorphometry; Geomorphological Mapping; Cerrado.

THEME: S23 : GEOMORPHOLOGICAL MAPPING

ABSTRACT NUMBER: 600

## THE GEOMORPHOLOGY AND SOILS OF THE LETABA FLUVIAL TERRACES, SOUTH AFRICA

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Fluvial terraces are remnants of ancient floodplains that resemble flat-topped benches in stair-like sequences. Each step represents an ancient floodplain abandoned due to either climatic or tectonic changes. The Letaba Water Catchment Area (LWCA), situated within the Limpopo Province in north-east South Africa, has received little attention from geologists due to a lack of economic placer deposits.

However, the river association with the Kruger National park and its importance for the agricultural production in its middle reaches as well as water supply to municipalities and industry has drawn attention of both agricultural and conservation scientists. Sustainable development of the land resources is inseparable from understanding of geomorphology for land use optimization in the region.

This study combines knowledge from existing literature with high-resolution terrain analysis and a recent soil survey to investigate and describe the geomorphology and soils of the LWCA fluvial terraces. Visual inspection of cross-profiles, extracted from a 5m digital elevation model, coupled with results from one reconnaissance and two detailed soil surveys showed that the fluvial terraces are extensive and that they represent one of the dominant geomorphological features in the landscape. Mapping of these terraces presents a difficult problem within the object-oriented landscape segmentation paradigm. Several approaches to solve the problem of mapping fluvial terraces are discussed.

We conclude that each terrace step is spatially distinct from its neighbour and displays different soil properties, which in turn affects its hydrological properties and regional hydrology. Future research should aim to create fine resolution maps of the fluvial terraces to facilitate quantitative environmental models in support of regional water management programs and disaster risk analyses.

**Keywords:** terrace, mapping, object-oriented, segmentation, South Africa

THEME: S23 : GEOMORPHOLOGICAL MAPPING

ABSTRACT NUMBER: 618

## GEOMORPHIC FEATURES OF GRANITE TORS - ROCK CONTROL AND CARTOGRAPHIC REPRESENTATION, WEST SUDETES, POLAND

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Granite tors are common type of landforms in the West Sudetes, southwestern Poland. They are developed in different types of granite within the Karkonosze-Izera granite massif. Granitic bedrock is characterized by various textural and petrographic features, hence equigranular fine-grained and porphyritic coarse-grained variants are distinguished. This study presents results of the comprehensive analysis of structural and lithological (petrographic differences of bedrock, joint systems) and topographical (slope position, altitude) factors. Morphologically rock forms in the area show diverse shapes and sizes, including large clustered groups (e.g. Paciorki tor group), "rock cities" (e.g. Starościńskie Skały tor group), parallel elongated castellated outcrops (e.g. Pielgrzymy, Progi) or small, solitary tors

at various stages of decay (e.g. Kotki). A wide spectrum of granite forms allowed us to create an extensive list of 40 symbols to be used in the detailed geomorphic mapping of rock forms. The findings of the study show that the type of joint pattern, including the density of discontinuities play a key role in controlling the general shape and size of tors, as well as pathways of their subaerial degradation whilst the importance of lithological differences is seen the distribution of tors and microrelief of their surfaces. Numerous examples and evidence of tor degradation in subaerial conditions, such as sliding, toppling and in situ blocky disintegration enable us to propose a model outlining pathways of tor decay, a theme rarely addressed outside formerly glaciated terrains.

**Keywords:** granite tors, geomorphological mapping, rock control, tors degradation, Sudetes

*THEME: S23 : GEOMORPHOLOGICAL MAPPING*

**ABSTRACT NUMBER: 706**

## **DIGITAL GEOMORPHOLOGICAL MAPPING IN POLAND**

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At the beginning of the 21st century, thanks to the growing of geotechnology, it was possible to proceed with the works which started over half a century earlier, in 50. of the 20th century. Firstly, there were individual works, then, after a few years, long-term works (2011-2015) on resuming geomorphological mapping could be taken up within Association of Polish Geomorphologists. This initiative coincided with the implementation of the European INSPIRE directive and the actions of Head Office of Geodesy and Cartography in Poland resulting from the directive mentioned. These were the favorable conditions for highly professional preparation for modern geomorphological mapping and support from various academic and scientific institutions in Poland. The preparation for geomorphological mapping is divided into three stages: (i) a formulation of content assumptions; (ii) a creation of object catalog, i.e. categories of landforms (the most important stage of work); (iii) a formulation of technical standards; (iv) a formulation of editorial and technical assumptions. The catalog of landforms lists 10 morphogenetic divisions: endogenic, denudational, periglacial, postglacial, fluvial, karstic, aeolian, littoral and lacustrine, biogenic as well as anthropogenic forms. In the legend of the scale map 1:100,000, there are 134 subdivisions (10 point, 47 linear and 77 aerial entities) and for map 1:500,000, there are 91 subdivisions (10 point, 30 linear and 51 aerial entities). Landforms are presented on the background of hillshaded DEM. Quite new issue in terms of geomorphological mapping is the inclusion of marine/lake submerged areas. Group of over 60 persons (geomorphologists, Quaternary geologists, specialists of geoinformation/informatics) achieved preliminary goals mentioned above and initiated a systematic nationwide geomorphological mapping and, subsequently, to edit digital geomorphological maps for test areas with different morphological landscapes. The poster presents eight geomorphological maps on a scale of 1:000 000

*THEME: S27 : SEDIMENT BUDGETS (IAG-WG SEDIBUD)*

**ABSTRACT NUMBER: 53**

## **STUDIES ON THE MORPHOCLIMATE AND CONTEMPORARY MORPHODYNAMICS OF THE BOREAL HOMLA DRAINAGE BASIN SYSTEM IN MIDDLE NORWAY (TRØNDELAG)**

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Ongoing and future climate change will cause major changes in Earth surface systems and environments. Accordingly, it is of increasing importance to develop an improved understanding of the existing relationships between contemporary geomorphological surface processes and present-day climatic conditions to come to more reliable assessments of the possible geomorphological effects of climate change. The present-day climate has often only been characterized by monthly and annual means or sum values of wind speed, air temperature and precipitation. However, as most geomorphological surface processes consist of discrete events which are only partly (or not) correlated to such meteorological means or sum values, there is an obvious need for an additional approach of statistical analysis of meteorological raw data. In this study, the "morphoclimate" of the Homla drainage basin situated in a boreal environment in middle Norway (Trøndelag) is analyzed. The "morphoclimate" according to Ahnert (e.g., 1982) is particularly related to geomorphological needs and is defined as the totality of those climatic characteristics of a defined area that influence the type, frequency, duration and intensity of the geomorphological processes in this area. The statistical method primarily used is the magnitude-frequency analysis. Special emphasis is on (i) the frequencies or recurrence intervals of meteorological events of given magnitudes, and (ii) the frequencies of geomorphologically important thresholds. Aspects of the current wind, temperature and precipitation regimes that control the

type, frequency, duration and intensity of contemporary denudational surface processes as well as the sedimentary budget in the selected study area are presented. As a result, runoff is occurring year-round and the contemporary morphodynamics are altogether characterized by a clear dominance of chemical denudation over mechanical fluvial denudation. The general intensity of the present-day denudational surface processes operating under the present-day morphoclimate in the boreal Homla drainage basin is altogether low.

*THEME: S27 : SEDIMENT BUDGETS (IAG-WG SEDIBUD)*

**ABSTRACT NUMBER: 54**

**KEY ACTIVITIES AND OUTCOMES OF THE I.A.G./A.I.G. SEDIBUD  
(SEDIMENT BUDGETS IN COLD ENVIRONMENTS) PROGRAM (2005 - 2017)**

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There has still been a significant lack of quantitative data on environmental drivers and rates of contemporary denudational surface processes in cold climate environments worldwide. However, contemporary cold climate environments generally provide the opportunity to identify solute and sedimentary systems where anthropogenic impacts are still less important than the effects of ongoing climate change. Accordingly, it is still possible to develop a library of baseline fluvial yields and sedimentary budgets before the natural environment is completely transformed. The central research question of the global I.A.G./A.I.G. SEDIBUD (Sediment Budgets in Cold Environments) program (2005-2017) is to: Assess and model the contemporary fluxes in cold climates, with emphasis on both particulate and dissolved components. SEDIBUD research carried out at 56 defined SEDIBUD key test sites (selected catchment systems) varies by scientific program, logistics and available resources, but typically represent interdisciplinary collaborations of geomorphologists, hydrologists, ecologists, permafrost scientists and glaciologists with different levels of detail. To support the coordinated efforts conducted within SEDIBUD, the SEDIFLUX manual and a set of framework papers and book chapters have been produced to establish an integrative approach (with inter-site comparisons within the program) and common methods and data standards. Comparable field-data sets on contemporary denudational surface processes from different SEDIBUD key test sites are analyzed and integrated to address key research questions of the SEDIBUD program as defined in the SEDIBUD working group objective. A key SEDIBUD synthesis book was published in 2016 by the group and a synthesis key paper is currently in preparation. The SEDIBUD synthesis book provides new key findings on environmental drivers and quantitative rates of contemporary solute and sedimentary fluxes, and on the spatial variability of chemical and mechanical denudation rates within global cold climate environments. Detailed information on all SEDIBUD activities, outcomes and published products can be found at <http://www.geomorph.org/sedibud-working-group>.

*THEME: S27 : SEDIMENT BUDGETS (IAG-WG SEDIBUD)*

**ABSTRACT NUMBER: 108**

**SOIL EROSION AND SEDIMENT YIELD MODELING FOR  
THE GANGA RIVER SYSTEM USING RUSLE AND SDR BASED APPROACH**

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Soil erosion is a serious problem in the Himalayan Rivers and it influences the current geomorphic and hydrologic regime of the system. Modification of land use and land cover (LULC) for agricultural purpose and operation of controlling and diverging structures on river basin amplify the soil erosion and sediment delivery in the rivers. The vast Gangetic alluvial plains are drained by several small and large rivers that are significantly different in terms of their hydrological and geomorphological characteristics. For instance, the rivers draining the western Gangetic plains (WGP) are characterised by high stream power and low sediment yield whereas those in the eastern Gangetic plains (EGP) have low stream power and high sediment yield. We apply the Revised Universal Soil Loss Equation (RUSLE) and Sediment Delivery Ratio (SDR) based approach to compute gross soil erosion and sediment fluxes in two different parts of the Ganga basin: (a) the Upper Ganga Basin (UGB) from source to Allahabad and (b) the Kosi river basin in Nepal and north Bihar plains. The Kosi basin is marked by a large sediment production region in the Himalaya and by a large fan in the alluvial part representing a largely aggradational regime. On the other hand, the UGB has a comparatively smaller sediment production region with a large incised river trunk suggesting a degradational regime in the alluvial plains. The model predicts a soil erosion rate of 30 t/ha/year

for the Kosi basin, and sediment flux of 120 & 50 Mt/year at upstream (Chatra) and downstream (Baltara) stations respectively. The UGB shows soil erosion rate of 18 t/ha/year and total sediment flux of 47 Mt/year at Kanpur. Further analysis suggests that rainfall and topographic steepness play a major role in soil erosion for both the basins and it is further enhanced by land use practices.

THEME: S27 : SEDIMENT BUDGETS (IAG-WG SEDIBUD)

ABSTRACT NUMBER: 114

## ANALYSIS OF THE SPATIO-TEMPORAL VARIABILITY OF POSTGLACIAL ROCKFALL ACTIVITY IN WESTERN NORWAY

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The mountainous fjord landscape in western Norway exhibits a high number of rockfalls. However, neither the temporal patterns of these rockfalls nor the specific causes and triggering factors have yet been systematically investigated. The focus of this study is (i) to reconstruct a chronology of rockfalls within two defined and lithologically mostly homogenous study areas (the inner parts of the Nord- and Sognefjord in western Norway) and (ii) to identify the likely triggers and controlling factors of these rockfalls.

Forty-eight potential rockfalls have been selected for dating using nine established age-control points (moraines and bedrock outcrops). At first, Schmidt-hammer exposure-age dating (SHD) was applied at seven larger rockfall deposits supported by test on five moraines of known age within two glacially sculpted mountain valleys in the inner Nordfjord. At each site, 50 to 100 impacts using a mechanical N-type Schmidt-hammer were sampled from the surface of 5 to 50 individual rockfall boulders located at the outer rims of the rockfall deposits. Preliminary results show that mean rebound (R-) values measured at the seven rockfall deposits fall into significantly different age ranges. Compared to the R-values obtained from the moraines, determined rockfall age ranges are spread between the Preboreal (with R-value means and 95% confidence intervals ranging from 39.7±2.0 to 45.2±1.4) and the "Little Ice Age" (R-values from 54.0±1.8 to 60.0±1.8). An age-control point in form of a glacially scoured bedrock surface considered being exposed following regional deglaciation c. 9700 years ago provides an R-value of 35.6±2.4.

To establish a chronology of postglacial rockfall activity a combination of different relative and numerical dating techniques will be applied (multi-proxy approach). Possible controlling factors will be explored using detailed geomorphological mapping combined with hillslope morphometry analyses and investigations of lithological/structural rock properties.

**Keywords:** rockfall activity; chronology; controlling factors; relative/numerical dating techniques; western Norway

THEME: S27 : SEDIMENT BUDGETS (IAG-WG SEDIBUD)

ABSTRACT NUMBER: 641

## THE ZOOGEOMORPHOLOGICAL IMPACT OF SNOW VOLE (*CHIONOMYS NIVALIS*) IN SUBALPINE PRAIRIES OF PARÂNG MOUNTAINS, SOUTHERN CARPATHIANS, ROMANIA

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For the last decades, the activity of animals has been explored and reported as a potential source of natural hazards, like the destruction of a beaver dam, which might trigger a flash flood down the river. However, sediment source or sediment budget related to animal activity has so far received very little attention from geoscientists. The main goal of this study is to quantify the biogenic activity of the European snow vole (*Chionomys nivalis*) as a sediment source in the subalpine prairies of the Parâng Mountains, Southern Carpathians. Only the direct action of this rodent was analyzed, namely the spatial distribution and frequency of burrowing, quantitative analysis of the mounds, rate of sediment displacement and mass transfer caused by burrowing and digging of tunnels. Therefore, 362 burrows/mounds were mapped and measured in five plots, each soil disturbance (n=362) was weighed with a high-resolution numerical balance and the mass transfers and excavated volumes of sediments were calculated by measuring the volumes of each mound. The preliminary results show an average density of 55.55 to 71.42 burrows on 100 m<sup>2</sup> and mainly three preferred aspects: South-East, South and South-West. The amount of soil displaced is highly variable at a local scale ranging from a few grams to a few kilograms corresponding to a sediment



displacement potential of  $6.2 \text{ t ha}^{-1} \text{ y}^{-1}$  and a value for the mass transfers of  $1116 \text{ t m y}^{-1} \text{ km}^{-2}$ . Bioerosion and bioconstruction reflect the biggest impact induced by *Chionomys nivalis* activity, the sediments freshly exposed becoming available for redistribution by other geomorphic processes. In that regard, this biogenic activity should be considered an important sediment source in the subalpine and alpine level of the mountainous environment.

**Keywords:** Sediment budget, erosion, zoo geomorphology

THEME: S27 : SEDIMENT BUDGETS (IAG-WG SEDIBUD)

ABSTRACT NUMBER: 654

## PROVENANCE STUDY OF RIVER SEDIMENTS FROM SIKKIM-DARJEELING HIMALAYA; UNDERSTANDING SOURCE TO SINK RELATION

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The Mahananda River, Balsan River, Sevok Khola and their tributaries are flowing through major lithotectonic units of Sikkim-Darjeeling Himalaya. These rivers are shading their large sediment load at the foothills of Himalaya. Hence, these sediment deposits provide excellent opportunity to understand source to sink relation. The textural and compositional maturity provides useful information to develop a link in this relation. Therefore, methodology used in present study consists of grain size and compositional analysis. The grain size analysis results show Mahananda River, Sevok Khola and their tributaries indicating dominance of finer size fractions comparative to Balsan River and their tributaries. The compositional analysis shows dominance of Lithic fragments (Qm28%F8%L64%) in all river sediments. In which Lithic metamorphic show dominance over Lithic sedimentary fragments (Lm83%Lv0%Ls17%). This is also supplemented by Quartz polycrystalline dominance (Qp79% Lv0%Ls21% and Qt53% F5% L42%). Thus, metamorphic source is contributing in higher amount in these sediments. The compositional results within these rivers show Mahananda River and its tributaries content more lithic fragments comparative to Balsan River and their tributaries. The overlay of regional maps as topography, drainage, lithology and structural map show structural elements are strongly influencing topography and drainage basins of the area. They are also controlling lithological distribution in these thrust system and influencing source to sink relation. Hence, textural and compositional study of sediments infers Mahananda River, Sevok Khola and their tributary comprising comparatively immature sediments than Balsan River and their tributaries.

**Keywords:** Himalaya, Sediments, Provenance, Source to sink, Lithic Fragments

THEME: S27 : SEDIMENT BUDGETS (IAG-WG SEDIBUD)

ABSTRACT NUMBER: 708

## SOURCE-TO-MAINSTEM: LINK BETWEEN GEOCHEMISTRY OF DEPOSITS AND HYDROCHEMISTRY OF STREAM WATERS, BRØGGERDALEN, NW SPITSBERGEN

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Present-day paraglacial areas arising in the High Arctic during the Holocene are evidence of large changes in relief and deposits of polar regions. Geosuccession, thus the change of the morphogenetic domain from subglacial to subaerial one implies changes of morphogenetic factors and processes in areas recently exposed to the ice covers. The effect of changes in the morphogenetic domain is the constitution of a new set of landforms. Among the dominant processes that transform contemporary areas freed from the glaciers are slope and fluvial processes expanded in periglacial conditions. During the summer campaign of the project "Late-glacial and present landscape evolution following deglaciation in a climate-sensitive High-Arctic region" we made two field mapping, namely geomorphological, sedimentological and hydrogeochemical in the area left by the retreating glacier Brøgger in the valley Brøggerdalen west of Ny-Ålesund on Brøggerhaløvyva (NW Spitsbergen). Intensive glacier recession since the Little Ice Age has created a new set of landforms, for which we examined the chemical properties of sediments and water flowing down the slopes of the valley to the valley floor, i.e. main stem of Brøggerelva. Hydrochemical transformations of fresh waters flowing in paraglacial watercourses on the background of the geochemical properties of the surface sediment covers became the main objective of the study. On the poster we present the results of field studies, the spatial distribution of hydrochemical properties of surface water, alternating directions hydrochemical these waters and pointed out the nature of the water transition from the slope system to a fluvial one. It was found that

despite the major relief changes in the valley of the Brøggerbreen contemporary hydrochemical transformations of fresh waters do not stand up now too great diversity.

THEME: S28 : TROPICAL RIVERS (IAG-WG)

ABSTRACT NUMBER: 172

## UNDERSTANDING PLANFORM DYNAMICS FOR RIVER MANAGEMENT: A CASE STUDY OF THE KOSI RIVER IN NORTH BIHAR PLAINS, INDIA

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River dynamics and sediment transport are manifestations of the complex interactions between natural as well as the human factors, at both local and regional scales. River dynamics is generally attributed to changes in the geomorphic characteristics of the river channels in terms of geometry, gradient, and planform. Direct consequences of the human interventions through engineering works, including channelization, dam construction, diversion, and culverting have long been recognized impacting river channels in a major way.

Over the last 5-6 decades, the planform and long profile of the Kosi River have been altered by flood control and bank stabilization projects such as barrage and embankments on both sides of the river. The embankments on both sides of the river were completed in 1955-56 and the Kosi barrage was commissioned in 1963. It is now well established that the problem of flooding has exacerbated due to confinement of the channel, reduction of the carrying capacity of river channels and extensive siltation within the embankments. In addition, the channel has become very unstable leading to unpredictable changes in morphology and its position.

This paper will report the mapping of spatial and temporal changes in channel pattern of the Kosi River between Chatara and Baltara using remote sensing and geographic information system analysis to identify the hotspots of planform dynamics and associated hazards. Apart from Landsat images, the Corona images corresponding to 1965 have also been used to map the baseline condition and the plan form changes have been quantified in terms of channel width, bar area, sinuosity, and braid-channel ratio. Integrating all data, hotspots of planform dynamics have been identified and the risk of river hazards has been assessed.

THEME: S28 : TROPICAL RIVERS (IAG-WG)

ABSTRACT NUMBER: 628

## PRELIMINARY EVALUATION OF PEAK DISCHARGE REDUCTION IN FLUVIAL MEANDRIC SYSTEMS, RIVER RIBEIRA DE IGUAPE, BRAZIL.

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Floodplain storage capacity is broadly correlated with the reduction of the peak discharge, and it has been crucial for the risks evaluation and effects of floods. Despite its importance, the quantification of the wave attenuation capacities of floodplains in fluvial systems of humid tropical environments must be expanded, particularly in meandering systems. We intended to evaluate the real reduction of peak discharge for extreme events in a reach of the Ribeira de Iguape River, SE Brazil. Based on extreme events extracted from 54 years of daily flow data, we compared peak discharges and resultant wet area of two monitored cross sections. The reach ( $\approx 50$ km length) comprises 47 tributaries and a floodplain of  $\approx 77$ km<sup>2</sup>. We selected 39 events grouped according to Return Time (RT by Gumbel distribution) in years: 2 to 5 years (24), 5 to 10 (10), 10 to 25 (4), 25 to 50 (1). The mean difference between the upstream and downstream discharge was 291m<sup>3</sup>/s, which means  $\approx 15\%$  reduction. The maximum difference occurred in 13/01/1995 event (25-50 RT), with 3060.7 m<sup>3</sup>/s (upstream) and 1862m<sup>3</sup>/s, corresponding to 39.2% discharge attenuation. The mean reduction percentages by RT were 25.1% for 10-25, 19.05% for 5-10, and 8.5% for 2-5, evidencing a progressive increase of the peak reduction according to the magnitude of the event. This was corroborated by the 0.7 correlation between upstream peak flow X difference in peak flow, resulting in an increasing percentage of reduction. The correlation between wet area difference between the two sections X reduction of peak flow is positive (0.2), but not sufficiently explanatory. We conclude that the reduction of the peak flow is directly affected by the magnitude of the event, possibly due to the increase of the flooded area, to be considered in the continuity of the study.

THEME: S28 : TROPICAL RIVERS (IAG-WG)

ABSTRACT NUMBER: 704

## BACKWATER EFFECT ON SUSPENDED SEDIMENT TRANSPORT PATTERNS IN THE LOWER MADEIRA RIVER, BRAZIL

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At Fazenda Vista Alegre (FVA), the lowermost gauge station of the Madeira River located approximately 250 km upstream from the confluence with the Amazon River, significant backwater effects on seasonal water discharge and water level have been documented. In this study, suspended sediment transport seasonal variability of the lower Madeira River induced by the backwater effect produced by the Amazon River is investigated integrating the hydrosedimentologic data (ADCP, sidescan data and suspended sediment samples) collected in the field during June-July of 2017, hydrodynamic model, and multi-temporal remote sensing analysis of surface water types distribution at the confluence. We estimated that between Porto Velho and FVA, a 800 km reach along the Madeira, 80 million tons of suspended sediment is lost each year on average over 15 years (2001-2015). Further loss of suspended sediment is expected between FVA and the confluence, and that we hypothesize that suspended loads are deposited at the lowest reach of the Madeira when the backwater effect is strong, and flushed out through the confluence when backwater effect is reduced around April. In April, discharge contribution of the Madeira on the Amazon is the highest (up to ~30%), while other months such as June (peak discharge at Obidos) and September (lowest discharge) are less than 10% and 5%, respectively. Multiple ADCP transects collected longitudinally along the Madeira indicate the decrease in average velocity downstream toward the confluence. Remote sensing analysis revealed that in April, surface water dominance of the Madeira River was the highest compared to other seasons at the confluence, where three different types of surface waters are present: Negro, Amazon, and Madeira Rivers. Finally, the bed height variability under the backwater condition estimated using 1D morphodynamic model showed that deposition rates of sandy and fine materials increased downstream toward the confluence.

THEME: S28 : TROPICAL RIVERS (IAG-WG)

ABSTRACT NUMBER: 747

## MORPHOMETRIC DIFFERENCES OF LARGE ALLUVIAL FANS AND MEGAFANS

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Megafans are 'large' fan-shaped bodies of sediment that form from lateral migrations of a river as it exits a topographic front. They differ from large alluvial fans (radial length between 30-100km) with sizes greater than 100-km in radial length. This study characterizes and describes megafans and large alluvial fans through morphometrics. We cataloged these fans into a geodatabase delineating size and extent of basins both upstream and downstream from the apex. Through remote sensing and elevation modeling, we populated the geodatabase with morphometric measurements, qualitative descriptions, and basin parameters. Metrics include planform area, catchment area, gradient, relief indices, drainage density, and others. These were compared to longitudinal/transverse profiles, satellite imagery, and geomorphic maps. The database is global with over 450 fans and we aim to find morphometric differences between large alluvial fans and megafans. These include differences in relationships between morphometrics, for example, the ratio between catchment and fan size area. Morphometrics could be a better approach in differentiating megafans from large alluvial fans. The current criteria is an artificial scale divide, which varies in the literature, with the most common being a 100-km apex-to-toe length. Alternative values as little of 30-km apex-to-toe length have been proposed, as well as alternative metrics like coverage areas of greater than 10,000 square-km. We explore alternative morphometrics in order to provide an intrinsic approach to differentiating megafans from larger alluvial fans.

THEME: S28 : TROPICAL RIVERS (IAG-WG)

ABSTRACT NUMBER: 773

## NEW PIECES FOR THE GEOLOGICAL PUZZLE OF THE FORMATION OF AMAZONIAN RIVERS SINCE THE LATE NEOGENE: COUPLING LUMINESCENCE AND COSMOGENIC NUCLIDE DATING

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The modern Amazonia landscape and biodiversity are strongly related to the evolution of the Amazon River system. Paleogeographic models suggest that the modern Amazonian drainage configuration is the result of the shift from a wetland dominated by flooded forests (Pebas system) to an incised transcontinental river valley bounded by non-flooded forests (Terra Firme) during the Miocene. This change in the fluvial landscape would be a significant geologic control on the biotic diversification in Amazonia. In Brazil, this landscape shift would be recorded by the transition from the Solimoes Formation to the Iça Formation. The build-up of Terra Firme in western Amazonia is still poorly known due the lack of numerical ages to constrain changes in fluvial sedimentation since the Late Neogene. Here we used optically stimulated luminescence (OSL) dating and cosmogenic nuclides (<sup>26</sup>Al/<sup>10</sup>Be) to determine the age of the Iça and Solimoes formations in western Brazilian Amazonia. Four sediment profiles of the Iça Formation were sampled along the margins of the Solimoes and Iça rivers for OSL dating of quartz using a single-aliquot regenerative dose protocol. The resulting sediment burial ages range from 48 to 112 ka. Sediments from Solimoes Formation were sampled from four well-drilling cores (approx. 300 m depth); <sup>26</sup>Al/<sup>10</sup>Be burial dating is in progress. Our first OSL ages contrast with the hypothesis that the deposition of the Iça Formation ceased during the Pliocene-Early Pleistocene. Instead, we suggest that the western Amazonian lowlands have been geologically dynamic during the Quaternary, with the build-up of large areas of Terra Firme forest during the late Pleistocene. New cosmogenic nuclide burial ages will provide novel insight into the long-term development of the Amazonian rivers. Such records will be used to shed light on the challenging problems concerning how changes in western Amazonia landscape shape the current patterns of biodiversity.

THEME: S29 : GEOMORPHOLOGY OF ROCKY COASTS (IAG-WG)

ABSTRACT NUMBER: 756

## RAUK - FORGOTTEN WITNESS OF HOLOCENE SEA-LEVEL CHANGES AND DEVELOPMENT OF BALTIC ROCKY COASTS - PROJECT CONCEPT AND PILOT RESULTS

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The post-glacial history of Baltic Sea evolution is definitely one of the most interesting and intriguing stories of environmental change in Europe. To date, the key information on changes in sea-level and shifts in the environment associated with climate fluctuations were found in coastal lakes, marshes and wide stripe of barrier-lagoon systems of southern Baltic. Only limited research was conducted along rocky coasts, so characteristic features for Baltic islands from Bornholm, through Oland, Gotland, Fårö, Hiiumaa, Saaremaa to thousands of isles of Åland Archipelago.

Among the most thrilling natural wonders found along Baltic coasts are rauks or raukars, unique limestone stacks—often with humanlike features—that tower above rocky shore platforms in northern Gotland and on Fårö, Gotland's sister island. Raukar coasts are one of the greatest touristic attractions in Sweden and the mythical coastal landscape of northern Gotland and Fårö had inspired many artists, including one of the greatest director in the cinema history – Ingmar Bergman. Surprisingly, what attracts tourists and art and culture people, have been neglected by geomorphologists and those fascinating landforms still wait for detailed explanation of their origin and preservation.

The RAUK project is designed to 'cross swords' with raukar's mysterious history and explain what controlled the formation of hundreds of limestone stacks along coasts of Gotland and Fårö, and to test if the morphology of those rocky landforms bear traces of numerous

environmental changes that occurred in Baltic region over the Holocene.

Here I report the results of pilot investigations of raukar coastline developed in Gotland carried out in 2016-2017.

This paper is a contribution to the National Science Centre project 'RAUK' (NCN SONATA award no. 2016/21/D/ST10/01976).

**Keywords:** raukar, rock-weathering, stacks, RSL, Baltic

THEME: S30 : SUBMARINE GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 9

## MATHEMATICAL MORPHOLOGY FOR SEISMIC IMAGING AND INTERPRETATION

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Mathematical morphology is employed for submarine geomorphology, virtual seismic atlas-sharing the geological interpretation of seismic data analysis. Morphology has the capabilities of performing quantitative analysis of images using morphological operation. Application of multi-scale mathematical morphology which is a branch of mathematical morphology in seismic data processing seismic signal resolution improving and amplitude compensation. Multi-scale mathematical morphology is used to multi-scale decompose amplitude information of seismic signal, and make an analysis of the morphological characteristics of every scale, and make the choice of multi-scale structural elements. Mathematical morphology method to seismic exploration to solve multiple attenuation problem. Multiples have similar seismic wavelet with that of primary reflection, and also have distinct seismic event. These seismic events give us a chance to distinguish the multiples and the primary reflections. Morphological filter is based on multiscale decomposition method. It use different structuring element to separate the multiples and the primary reflection clearly, and thus making multiple attenuation as well as saving subtle signal of primary reflection. Mathematical morphology and Partial Differential Equation are used to enhance images, image cleaning, image enhancement, feature selection and extraction, quantitative analysis, etc. There are four basic operations in mathematical morphology, erosion, dilation, opening and closing. By combining these four basic operations, geoscientists complete complicated tasks. Image analysis techniques such as a tophat transformation (mathematical morphology) is applied for feature extraction, morphological approach to segmentation: the watershed transformation an efficient tool for image segmentation. Seismic energy dispersion compensation by multi-scale morphology-Seismic energy decays while propagating subsurface, which may reduce the resolution of seismic data. The energy of seismic waves decays as seismic waves propagate, which results in low resolution of seismic data.

**Keywords:** Mathematical morphology, seismic image analysis, seismic signal processing, top hat transform, watershed transform, submarine geomorphology, virtual seismic atlas, Partial Differential Equation

THEME: S30 : SUBMARINE GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 112

## MARINE GEOMORPHOLOGY AND ENVIRONMENTAL STATUS OF ELEFSIS BAY AND INNER SARONIKOS GULF, GREECE.

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Saronikos Gulf is located in the Aegean Sea between Attica and eastern Peloponnese Peninsula and is considered one of the most important gulfs of Greece. Through the ages, the coastal areas surrounding the gulf were used for economic and strategic purposes, the most important of these being the Piraeus port and Elefsis Bay. Both are located on its NE part and are strongly linked to human activities since ancient times.

The area holds a great geomorphological and environmental interest, due to human intervention since ancient times but also due to the various landforms and processes that form its underwater and coastal landscape, such as the active submarine volcano "Pausanias", the volcano of Methana peninsula and the area's tectonic profile. Saronikos Gulf is characterized by mild recent seismicity. In its north and east margins occurred both historical and recent earthquakes.

The industrial activities along the coast of Elefsis Bay affect the ecosystems of NE Saronikos Gulf, leaving traces of human activity that impact the environmental status of the inner gulf.

To create the geomorphological map we used a combination of data collected from field studies and available archive data from the Hellenic Center for Marine Research (HCMR) and the Institute of Geology and Mineral Exploration (IGME). Gis techniques (ArcGis) were used to record the gulf's coastal and marine geomorphology.

In order to relate the marine landforms with the recent processes and environmental conditions, we studied and analysed the benthic foraminifera sampled on the surface water collected from 12 locations across the gulf. A low-diversity assemblage, dominated by stress-tolerant *Ammonia tepida* and *Bulimina* spp., was characteristic of samples from Elefsis Bay. Samples from the western and central part of Saronikos Gulf were the most variable, characterized by a mix of stress-tolerant and more sensitive taxa.

**Keywords:** Marine Geomorphology; Benthic foraminifera, Saronikos Gulf

THEME: S30 : SUBMARINE GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 309

## IMPACT OF BENTHIC ORGANISMS ON SUB-CM SCALE SEAFLOOR MICROTOPOGRAPHY

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The impact of benthic organisms on physical seafloor properties on the sub-cm scale is poorly investigated. However, knowledge on the physical parameters of benthic organisms is of huge importance for a number of geological and ecological topics, including habitat monitoring by remote sensing. Remote sensing of the seafloor allows for analyzing spatial and temporal dynamics, monitoring of natural seabed variations, and evaluating possible anthropogenic impacts. One aspect of ongoing remote sensing research is the identification of marine life, including both fauna and flora, which is typically done using optical imaging systems and sample retrieval. The identification of new remote sensing indicator variables characteristic for the physical nature of the respective habitat would allow an improved spatial monitoring. A poorly investigated indicator variable is mm-scale seafloor microtopography and corresponding roughness. These parameters strongly affect acoustic scatter. To measure seafloor roughness at these scales an underwater laser line scanner was attached to an autonomous lander system. Several field campaigns have been conducted offshore Sylt Island and in Mecklenburg Bight (Germany) to measure the microtopography of the seafloor. The mm-scale microtopography of seafloor covered by benthic organisms was transformed into the frequency domain and the average of the magnitude at different spatial wavelengths was used as a measure of roughness. The presence of sand masons causes a measurable difference in roughness magnitude at spatial wavelengths between 0.02 m and 0.0036 m, with magnitude depending on sand mason abundance. This effect was not detected by commonly used 1D roughness profiles but required consideration of the complete spectrum. The impacted spatial wavelengths correspond to acoustic frequencies in water of 75 kHz and 400 kHz, with the highest magnitude difference at ~ 300 kHz. The impact of other considered species is currently being analyzed.

THEME: S30 : SUBMARINE GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 343

## THE GRAHAM BANK (SICILY CHANNEL, CENTRAL MEDITERRANEAN SEA): SEAFLOOR SIGNATURES OF TECTONIC AND VOLCANIC CONTROLS

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We present the results of a geomorphological analysis of the Graham Bank (central Mediterranean Sea) based on: (i) a new high-resolution dataset acquired during the ACUSCAL 2015 and (ii) published multi-channel seismic profiles (ViDePi Project). In this study we demonstrate how volcanic and tectonic controls can have a significant and diverse impact on seafloor geomorphology across a relatively small area.

In the last 100 years, Graham Bank was affected by many well documented eruptions. The eastern region of our study area shows a jagged morphology that is dominated by several mounds, seepage plumes and an acoustic substrate that has been interpreted as evidence of volcanic activity.

The western region comprises a flat seafloor covered by Pleistocene-Holocene outer shelf sedimentary deposits. Aligned mounds and

pockmarks are predominantly oriented NW–SE or NNW–SSW, running parallel to the two main fault systems in the study area as well as with main trend of the Sicily Channel. The pockmarks, which have sub-circular planform shapes and U-shaped cross-sections, are indicative of fluid migration and escape. In the north-eastern region of the study area, numerous isolated, clustered or aligned mounds that reach heights of 2-10 m form hummocky surfaces. Mass transport deposits are distributed across both regions. Their spatial distribution, geometry, and seismic character suggest that fluid seepage, oceanographic processes and slope oversteepening are preconditioning factors, while the volcanic activity and fault displacement during earthquakes are likely triggering factors of slope instability.

**Keywords:** mass transport deposit; pockmark; plume; Graham Bank; Sicily Channel

THEME: S30 : SUBMARINE GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 381

## APPLICATION OF A NEW GENETIC CLASSIFICATION AND SEMI-AUTOMATED MAPPING APPROACH IN THE PERTH SUBMARINE CANYON, AUSTRALIA

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The acquisition of high resolution marine geophysical data has intensified in recent years (e.g. multibeam echo-sounding, sub-bottom profiling). This progress provides the opportunity to classify and map the seafloor in greater detail, using new methods that preserve the links between processes and morphology. Geoscience Australia has developed a new genetic classification approach, nested within the Harris et al (2014) global seafloor mapping framework. The approach divides parent units into sub-features based on established classification schemes and feature descriptors defined by Bradwell et al. (2016: <http://nora.nerc.ac.uk/>), the International Hydrographic Organization (<https://www.iho.int>) and the Coastal Marine and Ecological Classification Standard (<https://www.cmecscatalog.org>).

Owing to the ecological significance of submarine canyon systems in particular, much recent attention has focused on defining their variation in form and process, whereby they can be classified using a range of topographic metrics, fluvial dis/connection and shelf-incising status. The Perth Canyon is incised into the continental slope and shelf of southwest Australia, covering an area of >1500 km<sup>2</sup> and extending from 4700 m water depth to the shelf break in 170 m. The canyon sits within a Marine Protected Area, incorporating a Marine National Park and Habitat Protection Zone in recognition of its benthic and pelagic biodiversity values. However, detailed information of the spatial patterns of the seabed habitats that influence this biodiversity is lacking. Here we use 20 m resolution bathymetry and acoustic backscatter data acquired in 2015 by the Schmidt Ocean Institute plus sub-bottom datasets and sediment samples collected Geoscience Australia in 2005 to apply the new geomorphic classification system to the Perth Canyon. This poster will present results of the geomorphic feature mapping of the canyon and its application to better defining potential benthic habitats.

THEME: S30 : SUBMARINE GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 543

## INCISED VALLEYS OF THE NORTHERN ADRIATIC SHELF: A WINDOW ON THE LATE-QUATERNARY FLUVIAL AND COASTAL EVOLUTION

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On a global perspective, marine regressions and low stands are associated to the widespread entrenching of fluvial networks through continental shelves. The very low gradient that characterizes the Northern Adriatic shelf inhibited this scouring mechanism during the LGM. On the contrary, stratigraphic and chronological data highlight the occurrence of a set of LGM/post-LGM infilled incisions produced by different driving processes.

The wave and tidal action of the transgressive sea reworked and erased most of the units characterizing the former alluvial plain. Thus, the fillings of the Adriatic incisions constitute one of the few preserved deposits for investigating the morphological and environmental evolution of the period between the LGM and the phase of maximum flooding (i.e. circa 5.5 ka BP). The study was carried out through the analyses of a series of VHR CHIRP profiles, stratigraphic cores and radiocarbon dates.

Two different generations of infilled scours have been described. The older generation (Atl1) reach a depth of up to 30 meters below the

modern sea floor and would have been formed during the peak of the LGM marine low stand (about 25-22 ka BP). The architecture of the infilling unit suggests that Atl1 incisions were abandoned by their formative river and therefore shifted into a fluvio-lacustrine environment, fed from distal fluvial systems. The scouring and infilling process appears to be stretch some 10,000 years. In contrast, the younger generation of infilled incisions (Atl2) is the legacy of the coastal-marine lagoon environment that existed in the study area for just a few millennia in the Early Holocene (10-8 ka BP). They are a network of tidal channels hinged on few deep tidal inlets, likely sheltered by sandy barriers. Atl2 incisions reach maximum depths of 20 m and they are completely infilled.

**Keywords:** Coastal plain; Seismoacoustic profiles; Stratigraphic cores; LGM; Lateglacial.

THEME: S30 : SUBMARINE GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 550

## TRANSITION OF A SLOPE-CONFINED TO A SHELF-INCISED SUBMARINE CANYON ON THE ACTIVE CONTINENTAL MARGIN OF RHODES ISLAND, SE GREECE

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Rhodes Island (Greece) is located in the southeastern part of Aegean Sea and represents an uplifted segment of the Hellenic forearc. The continental margin, characterized by a narrow continental shelf and a steep slope, is incised by numerous submarine canyons.

High-resolution bathymetric and seismic-profiling survey, using a multibeam echo sounder (SeaBat 7125, Teledyne-Reson) and a chirp (2-7 kHz) sub-bottom profiler (GeoPulse, Kongsberg-Geoacoustics), has revealed the existence of more than ten shelf-indenting submarine canyons and a large number of slope-confined canyons and gullies. The majority of the shelf-incised canyons seems to be the seaward continuation of terrestrial drainage systems, since they are associated with rivers that have crossed the shelf during Quaternary sea-level lowstands.

However, in the southeastern part of the island, a blind, almost headless, canyon starts to breach the shelfbreak, forming a small size head of dendritic shape. Since no other erosive feature has been detected on the adjacent shelf, the development of the identified canyon head has been probably resulted due to headward erosion. The spatial expansion of this recently created canyon head reveals a transition from a slope-confined (early evolutionary stage) to a shelf-incised (mature stage) submarine canyon.

THEME: S30 : SUBMARINE GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 629

## GEOMORPHOMETRY AS A TOOL TO ESTIMATE VOLUME AND DISTRIBUTION OF CORALLIGENOUS HABITATS ALONG THE APULIAN CONTINENTAL SHELF.

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Coralligenous bioconstructions represent an outstanding example of calcareous build-ups of biogenic origin of the Mediterranean Sea. They provide sensitive and vulnerable habitats actually included in the list of endangered habitats by governmental organizations and conservation agencies (e.g. OSPAR; red list habitats). They are especially sensitive to the ongoing global change (i.e. ocean acidification) that can produce a negative impact on the calcification of the organisms' skeleton of which they are formed (mainly calcareous algae and invertebrates). The extent to which the coralligenous bioconstructions can modify the submarine environment, affecting the evolution of submerged landforms is extremely variable. Within the framework of the BIOMaP Project (BIOcostruzioni Marine in Puglia, - P.O. FESR 2007/2013), promoted by Puglia region, Italy, new high resolution acoustic data were acquired in order to identify and locate Coralligenous Habitats along the Apulian continental shelf (South Adriatic Sea – Northern Ionian Sea), from 10 down to 100 meters of water depth, in 21 Site of Community Interest and 3 Marine Protected Areas. The dataset covered an area of 1000 km<sup>2</sup> and was obtained through the use of MultiBeam Echosounder Systems and Side Scan Sonars. Ground-truthing were collected by 3 ROV dives (Prometeo ROV) and more than 30 underwater camera transects. The present study is based on a new experimental methodology designed to analyze multibeam data by means of geomorphometric analysis in order to (1) figure out relationships between the



observed morphologies and the associated distribution and (2) quantify the total volume of selected Coralligenous build-ups. Our work underlines the importance of combining acoustic survey techniques and geomorphometric analysis in order to offer quantitative information for a new understanding of the importance of Coralligenous Habitat as carbonate deposits of the Mediterranean shelf.

**Keywords:** Coralligenous; Geomorphometry; Seafloor Mapping; Mediterranean Sea

THEME: S30 : SUBMARINE GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 630

## TESTING THE USE OF UNMANNED AERIAL VEHICLE AND STRUCTURE FROM MOTION TECHNIQUE FOR ACQUISITION OF ULTRA-SHALLOW WATER BATHYMETRIC DATA

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Bathymetric surveying in shallow water can be performed by multiple ways: traditionally using a vessel but also techniques like LIDAR, satellite bathymetry or hovercrafts (and smaller) are used. For ultra-shallow bathymetry, data acquisition, using either singlebeam or multibeam echosounder systems, often present difficulties in obtaining reliable data where submerged obstacles are present; whereas the use of LIDAR technology or satellites data implies relatively high-costs. Multiple studies on land environment have validated the accuracy of Structure from Motion (SfM) techniques for high-resolution 3-dimensional (3D) topographic reconstruction and analysis, and in some cases found SfM to be highly comparable to substantially more expensive LIDAR techniques. In the last 5 years this methodology start to be applied in ultra-shallow marine environment, using the collection of videos or still images by underwater cameras along snorkelling transect, especially on coral reefs, where ship-based survey are unfeasible. The small spatial extent of the resulting 3D models, in this peculiar marine setting, is the main limit of this technique.

Our methodology attempt to increase the coverage of SfM techniques in ultra-shallow water environment coupling the snorkelling video transects with an Unmanned Aerial Vehicle (UAV) survey in order to obtain: (1) a complete submetrical scale DEM (Digital Elevation Model) on reef-flat areas, and (2) provide unique opportunities to better quantify topography, rugosity and other structural characteristics of this ultra-shallow marine environment.

This study utilized SfM 3D reconstruction software tools to create textured mesh models of a coral reef flat area of a small Maldivian island (Magoodhoo Island, Faafu Atoll) and used a proper GIS-based tool to further extract geomorphometric parameters from the surveyed area, providing evidence of the adeptness of the survey design for a number of applications.

**Keywords:** Structure from Motion; Shallow water; Geomorphometry; Coral reef

THEME: S30 : SUBMARINE GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 684

## SUBMARINE GEOMORPHOLOGY OF THE STRAIT OF OTRANTO (SOUTHERN ADRIATIC, MEDITERRANEAN SEA)

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The Strait of Otranto, which connects the Adriatic Sea with the Ionian Sea and separates Italy from Albania in the Central Mediterranean Sea, has been surveyed in the latest years, from the continental shelf down to the basin floor on both margins. In this work we analyse 6973 km<sup>2</sup> of multibeam data, seismic profiles acquired with a CHIRP sub-bottom profiler, and seafloor samples. The area is characterised by a variable width of the continental shelf, reaching down to 200 m water depth, bounded by a steep and morphologically complex continental slope reaching 1200 m at its toe. The latter is mainly characterised by the presence of canyons and associated mass transport deposits, which differ in style and size in the western and eastern side of the Strait. On the eastern continental slope, the presence of large-scale mass wasting features was highlighted by multichannel seismic investigations at regional scale and no high resolution bathymetric data have been available until more recent years. Moreover, in literature, studies focused on the geological processes shaping the South-Western Adriatic Margin or the Montenegro-Albanian Continental Margin separately. But a detail geomorphological

study of the Italian and Albanian slopes, that separate this 75-km-wide seaway, which hosts a complex oceanographic setting with the Adriatic outflow of dense waters and the Ionian inflow, has not been carried out yet. In this work we focus our investigation on the geomorphological mapping of the slopes and basin floor of the Strait, highlighting the different characteristics of the two sides and possible relationships with the bottom oceanographic circulation of water masses.

**Keywords:** Submarine geomorphology; Submarine landslides; Bottom currents South Adriatic Sea

*THEME: S31 : LANDFORM ASSESSMENT FOR GEODIVERSITY: GENERAL GEOMORPHOLOGY, GEODIVERSITY, GEOCONSERVATION (IAG-WG)*

**ABSTRACT NUMBER: 149**

## MAPPING “GEODIVERSITY HOTSPOTS” AT A REGIONAL SCALE: A GIS-BASED INTEGRATED APPROACH WITH APPLICATION TO THE CEARÁ STATE (BRAZIL)

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As a parallel to the “biodiversity hotspot” concept used in conservation biology, “geodiversity hotspots” can be defined as geographic areas that harbor very high levels of geodiversity while being threatened by human activities. Identifying geodiversity hotspots may offer a powerful way to set geoconservation priorities, but numerical methods integrating both geodiversity values and threats are still lacking. Here we propose a new integrated approach using GIS and geoprocessing to map geodiversity hotspots at regional scale, with application to the Ceará State (Northeastern Brazil). The method is based on the quantification and mapping of two numerical indices: a geodiversity index (GI) and a threat index (TI). On one hand, the GI is calculated as the sum of four sub-indexes representing the main components of geodiversity, i.e. geological diversity (rocks, minerals, fossils), geomorphodiversity (topography and landforms), pedodiversity (soils and palaeosoils) and hydrodiversity (surface and underground waters). On the other hand, the TI is calculated as the sum of three sub-indexes including the level of environmental protection, the degree of land degradation and the type of land use. Mapping and delineation of geodiversity hotspots are automatically obtained from a multiplication of the two previous indices, i.e. in areas where high geodiversity indexes meet with high threat indexes. In the study area, results show the spatial delimitation of five geodiversity hotspots, including the Araripe basin (to the South), partly recognized as a UNESCO Global Geopark since 2006, and the Fortaleza metropolitan region (to the North), both concerned with severe threats to geodiversity (land degradation, rapid urban growth). As such, those areas should concentrate the main efforts and priorities of geoconservation actions for the Ceará State in the next years, in order to protect the many geodiversity features of high heritage value from partial degradation or destruction.

**Keywords:** Geodiversity; Hotspots; Threats; Geoconservation; Brazil.

*THEME: S31 : LANDFORM ASSESSMENT FOR GEODIVERSITY: GENERAL GEOMORPHOLOGY, GEODIVERSITY, GEOCONSERVATION (IAG-WG)*

**ABSTRACT NUMBER: 178**

## GEOMORPHOLOGICAL MAPPING AND GEODIVERSITY: STUDY AT THE MINAS DO CAMAQUÃ GEOSITE PROTECTION AREA (BRAZIL)

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Geomorphological mapping allows the evaluation of geoheritage and subsidizes geoconservation efforts. This work aimed at identifying and analyzing the landforms at the Minas do Camaquã Geosite Protection Area (MCGPA) RS - Brazil, emphasizing the anthropogenic morphologies, in order to subsidize the conservation of the studied area's geomorphological heritage. A geomorphological map (2015) of the MCGPA was made (1:25.000) to recognize and identify the natural and anthropogenic landforms. Based on this map, four sectors were identified according to the representativeness of the landforms in the studied area: (1) Mineral extraction sector; (2) Tailings deposition sector; (3) Structural features sector; and (4) Boundary sector. The mining activities were the main reason for the geomorphological alterations and the creation of anthropogenic morphologies in the area. Despite the significant disturbance caused by the mining activity, there are still features of geologic-geomorphological interest fairly preserved. The identified and analyzed anthropogenic morphologies can describe the history of the mining activities that took place in the area and which formed a set

of landforms currently present in the MCGPA. Although the surface features are not originated from natural morphogenesis, they belong to the area's geodiversity. Furthermore, considering these features as geoheritage would create the need for management aiming at avoiding the collapse and degradation of these forms. Nowadays, the mining activities have remained inactive, and this set of anthropogenic morphologies need to be understood under a geomorphological point of view which will allow future exploitation of its potential touristic, scientific, pedagogical and cultural uses. The best way to promote and develop strategies of geoconservation for this place is to create and foment geotourism in this area.

**Keywords:** mining; geoheritage; anthropogenic morphologies; geoconservation.

*THEME: S31 : LANDFORM ASSESSMENT FOR GEODIVERSITY: GENERAL GEOMORPHOLOGY, GEODIVERSITY, GEOCONSERVATION (IAG-WG)*

**ABSTRACT NUMBER: 274**

## **AUTOMATIC RECOGNITION OF LOESS LANDFORMS BASED ON RANDOM FOREST METHOD**

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The automatic recognition of landforms is regarded as one of the most important procedures to classify landforms and deepen the understanding on the morphology of the earth. However, landform types are rather complex and gradual changes often occur in these landforms, thus increasing the difficulty in automatically recognizing and classifying landforms. In this study, small-scale watersheds, which are regarded as natural geomorphological elements, were extracted and selected as basic analysis and recognition units based on the data of SRTM DEM. In addition, datasets integrated with terrain derivatives (e.g., average slope gradient, and elevation range) and texture derivatives (e.g., slope gradient contrast and elevation variance) were constructed to quantify the topographical characteristics of watersheds. Finally, Random Forest (RF) method was employed to automatically select features and classify landforms based on their topographical characteristics. The proposed method was applied and validated in seven case areas in the Northern Shaanxi Loess Plateau for its complex and gradual changed landforms. Experimental results show that the highest recognition accuracy based on the selected derivations is 92.06%. During the recognition procedure, the contributions of terrain derivations were higher than that of texture derivations within selected derivative datasets. Loess terrace and loess mid-mountain obtained the highest accuracy among the seven typical loess landforms. However, the recognition precision of loess hill, loess hill-ridge, and loess sloping ridge is relatively low. The experiment also show that watershed-based strategy could achieve better results than object-based strategy, and the method of RF could effectively extract and recognize the feature of landforms.

**Keywords:** Landform recognition; Random Forest; Feature fusion; DEM; Loess landform

*THEME: S31 : LANDFORM ASSESSMENT FOR GEODIVERSITY: GENERAL GEOMORPHOLOGY, GEODIVERSITY, GEOCONSERVATION (IAG-WG)*

**ABSTRACT NUMBER: 707**

## **GEODIVERSITY ASSESSMENT OF THE SŁUPSK BANK, BALTIC SEA**

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Recognizing the most diversified parts of the land surface turns out to be very crucial for management and planning of natural protected areas. There is an increasing number of studies concerning assessing geodiversity of the land areas in different spatial scales. However, there is a noticeable lack of such publications for submerged zones of marine and lacustrine environments. The main aim of the poster is an attempt to assess geodiversity of the submerged area using field mapping and digital processing within a geoinformation platform. The study area consists of 100 square km Słupsk sandy shoal sporadically covered with boulder layers, located in the southern part of the Baltic Sea. It is characterised by landscapes of a significant nature value. The basis for the geodiversity assessment is the proper selection of features of the marine environment, its reclassification and integration by the analysis of the map algebra. The map of geodiversity is based on three factor maps: a relief energy map (classification based on bathymetric model), a landform fragmentation/geomorphological map (expert classification using BPI – Bathymetric Position Index), and a lithological map (classification of the

average fraction of grain size distribution for bottom sediments). It was decided to use four classes of diversity from low through medium and high, up to very high. The designation of the lowest class was abandoned because it characterizes areas with noticeable evidences of high anthropopressure. The map of geodiversity may prove to be helpful in determining the directions for management of the most valuable parts of the areas from the nature point of view, as well as delimitation of the geodiversity hotspots for the purpose of the strict abiotic nature protection. This study is the first attempt to use methods of geodiversity assessment for the marine environment.

*THEME: S31 : LANDFORM ASSESSMENT FOR GEODIVERSITY: GENERAL GEOMORPHOLOGY, GEODIVERSITY, GEOCONSERVATION (IAG-WG)*

**ABSTRACT NUMBER: 728**

## **LANDSCAPP: A NEW TOOL FOR A SHARED KNOWLEDGE OF TERRITORIAL GEODIVERSITY**

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Knowledge of the country where individual/ community/ society are living in, represents an objective of primary importance: it is the starting point to activate balanced planning politics, referring to both of sustainable development and risk prevention. Geomorphologic settings of an area are often deeply related to local cultural tradition: the main objective of this project is in developing some tools for a shared and correct knowledge of the most significant characteristics of our Country.

Such kind of tools have to be performed using simple and popular codes in communicating Earth Science, making it comprehensible to the widest range of public.

A new, recent project, is dedicated to create a new App, that shows the main landscape's settings of a land, thanks to the visualisation of thematic maps and correlated images (3D modelling,) integrating information on local environment and culture: "LandscApp".

A special attention is devoted to geodiversity: geosites and geolandscapes become anti-crisis resources GIS and 3D modelling, are flexible and friendly tools in educational plans as well as in territorial promotion. The proposed App, fits for the purpose of a twinning with TV sport transmission.

LandscApp gives the public a chance to try an alternative approach to the knowledge of the natural and cultural territorial heritage, thanks to a set of information related to the geological, morphological, environmental settings of the Landscapes, integrated with other information, for example, on the traditional wine and food production.

Moreover, considering the vocation of some natural areas, for some outdoor sports, this App will include information on the most important sport challenges, performed into the magnificent natural sceneries in a country.

The presence of UNESCO WHS and /or protected areas, gives a further opportunity to deepen the relationship between the nature of the land and its own developed culture.

**Keywords:** landscape, geodiversity, LandscApp. knowledge

*THEME: S32 : PLANETARY GEOMORPHOLOGY (IAG-WG)*

**ABSTRACT NUMBER: 283**

## **MARTIAN VALLEY NETWORKS: ESTIMATION OF FLUVIAL EROSION RATE DURING EARLY MARS FROM MARS EXPRESS HRSC DATA**

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Martian valley networks have been mainly identified in the heavily cratered uplands dated Noachian (>3.8 Gyr). Their formation processes and implications on the early Mars climate have been considerably debated: wet/dry, warm/cold climate...

From orbital images, Martian valley networks show a branching pattern and sedimentary fan deposit at their outlet for the younger ones only, indicative of fluvial erosion. For older ones, no erosion product is usually observed because their outlets are frequently buried by younger episodes of lava flows. They formed between the Late Noachian and the Early Hesperian (a time period extending over 200 Myr at max).

We have studied dense valley networks from the Mars Express HRSC nadir images (10 m/pixel) and DEMs (50 m/pixel). We show that they have the same geometry as terrestrial fluvial networks (2D pattern, Hack law, drainage density, concave longitudinal profile). Although the lithology and climatic proxy were not constant spatially and temporally during the Mars history, the power of fluvial erosion was higher during the late Noachian with a higher vertical incision related to wider valleys (i.e. average incision of ~30m for 45 Noachian networks, suggesting a continuous erosion rate of ~150 nm/yr during the whole period of 200 Myr).

However, fluvial erosion is dependent on available water volume, discharge rates and lithology. Assuming valleys were continuously eroded by river flows in which the water/sediment ratio was 1000:1, the minimum time period of formation could be 120 kyr as recorded in quaternary terrestrial valleys, involving a precipitation rate of 250 mm/yr characteristic of a semi-arid climate and an erosion rate 2000 times higher. The latter value is a strict minimum that does not take into account probable periods of lower erosion rates, but shows that fluvial erosion over the whole 200 My is not necessary.

**Keywords:** Mars, Valley networks, erosion rate, climate

THEME: S32 : PLANETARY GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 300

## MASS WASTING FEATURES IN JUVENTAE CHASMA, MARS: CLUES FROM DEBRIS FLOWS IN LADAKH, INDIA

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This study compares mass wasting features in Juventae Chasma with those in Ladakh, India, a potential analogue site for debris flow processes on Mars. Ladakh is a high altitude cold desert with a substantial part under the permafrost region, low annual precipitation (102 mm) high diurnal and annual temperature variations (ranging from -30 to 30°C) and high UV influx. The study region is a part of the permafrost region of Ladakh. Orbital imagery shows mass wasting features, such as debris flows, originating from the south-east and south walls of Juventae Chasma, Mars. These features typically originate from the mouths of tributary canyons or alcoves, and show no associated landslides crown. The presence of multiple generations of flows indicate that the formational process spanned substantial geological time. The lobes of these features vary from fan shaped (width>length) to tongue shaped (length>width) to irregular. Similar debris flow and associated gully features were observed in the mountain spurs in Ladakh. Debris flows in Ladakh are characterized by the presence of source alcoves, leveed channel and debris apron at the terminus. The debris aprons of these flows show chaotic and mixed particle size ranging from gravel to boulders. There are multiple episodes of superposed debris flows within the same region. The analogies between mass wasting features in Ladakh and Juventae Chasma indicate that the former can be used to understand the processes involved in mass wasting in Martian chasmata.

**Keywords:** Mass-wasting; Landslide; Debris Flow; Tributary Canyon; Mars; Ladakh;

THEME: S32 : PLANETARY GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 635

## FLUVIO GEOMORPHIC SET-UP OF SYRIA PLANUM PROVENANCE IN SYRIA-THAUMASIA, MARS.

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The modern era of planetary exploration has revealed fluvial or fluvial like, landforms on the extraterrestrial surfaces of planets and moons which have posed as interesting challenges for advancing our fundamental understanding of fluvial processes and their associated landforms. It has been recognized through earlier studies that the channels and valleys are extensively dissected on the surface of Mars. The Valleys are low lying, elongate troughs on planetary surfaces that are surrounded by elevated topography. Valley networks on Mars are the most obvious features attesting that different geologic processes and possibly climatic conditions that existed in the past. Channel incision results from both surface runoff and groundwater sapping. The component of surface runoff and tectonism or both can be deciphered with the help of morphometric exercises. Further, the geomorphological studies of these landforms are critical in understanding the regional tectonics. The present work will be an assessment of Fluvio geomorphic set-up of Syria Planum provenance

in Syria-Thaumasia, Mars. The main concentration of the work is on Noctis Labyrinthus, Claritas Fossae and the two provinces of Syria Thaumasia. This study focuses on the fluvio geomorphology of the southern highlands (00 to 400S to 850-1200W) to determine when these features were formed and which process formed these valleys.

**Keywords:** Noctis Labyrinthus; Syria-Thaumasia; Syria Planum; Mars

THEME: S32 : PLANETARY GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 753

## FACTORS CONTROLLING RECENT ROCKFALLS ON MARS

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Mars is known to have a plethora of active surface processes at the present day, and the role of water is vigorously debated. Here we study rocks falling from exposed outcrops of bedrock, which have left trails on the slope over which they have bounced and/or rolled. The presence of these trails shows that these rocks have fallen relatively recently because aeolian processes are known to infill topographic lows over time (estimations from rover-track erasure rates date these trails at <100My). Our initial hypothesis was that the presence of water ice should influence the rate of rockfall and therefore a systematic variation in the frequency of boulders-with-trails should be seen with orientation and latitude. We predicted equatorial craters should show no orientation preference and craters at mid-latitudes should have more rockfalls on pole-facing slopes, where water ice is expected. In order to reduce the influence of slope-inheritance from other longer-term processes, we have studied these rockfalls within impact craters which appear morphologically fresh. To account for variations in rockfall frequency related to lithology, we have studied both craters located in volcanic and non-volcanic terrains. Our initial results indicate trends in rockfall frequency with orientation, which depend on the latitudinal position of the crater. Craters in the equatorial belt (between 20°N and S) exhibit higher frequencies of rockfall on their N-S oriented slopes compared to their E-W ones. Craters >20°N/S have notably higher frequencies on their equator-facing slopes as opposed to the other orientations. These trends suggest that insolation plays a key role in determining the modern rockfall rate, indicating that thermal stress is playing a more important role than ice-presence in rock break down on modern Mars.

THEME: S32 : PLANETARY GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 754

## HIGH RESOLUTION TOPOGRAPHY AND NUMERICAL SIMULATIONS OF LANDSLIDES ON MARS

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Landslides on Mars have been studied since the Mariner missions in the 1970s. These landslides were found to be exceptionally large by terrestrial standards and were also found to be abnormally mobile. Here we study three martian landslides that have a more terrestrial scale (1.1-3.2 km long) with the aim of discovering if these smaller landslides obey the same rules as their larger cousins. By virtue of their size and through the size-frequency of superposed impact craters we know that these three landslides must be younger than the larger landslides included in previous studies. Hence, this gives us a vision as to whether conditions for landsliding (possibly related to activity of water in the crust, through alteration or the hydrosphere) have changed over Mars' history. Because of their more manageable size we are able to take advantage of stereo images taken by NASA's High Resolution Imaging Science Experiment to reconstruct their topography at 2 m/pix horizontal resolution, with a vertical accuracy of ~0.5 cm. This enables us to accurately reconstruct their volumes, which range between  $4.5 \times 10^6$  and  $9.5 \times 10^8$  m<sup>3</sup>, but also enables us to simulate their dynamics. We do this by making a best-guess estimation of the initial topography and the release area and then run the model SHALTOP. This model can simulate gravity-driven dry granular flow using different friction laws. We vary the density, the friction coefficient and the friction law calculation (Coulomb or Pouliquen) in the model and "good" solutions are those where the spatial distribution of deposition thickness and deposit morphology most closely match those measured from our elevation data. Our preliminary results suggest that these three martian landslides do not have the same friction coefficient. Morphological similarity with mudflows in one case suggests fluid may have been involved in its formation.

THEME: S32 : PLANETARY GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 764

## GROUND SHEAR STRENGTH MEASUREMENTS USING LUNAR ROVER WHEELS

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The shear strength of the lunar and Martian regolith is a critical piece of information on both, its drivability as well as the general physics and mechanics. Differences in shear strength can for example be used to infer density and thus composition of regolith mantles. The measurement of shear strength can be accomplished by all rovers with individually powered wheels. In this study, we present a procedure designed for the PT Scientists lunar rover.

Once all or just one wheel of the rover are placed on a surface of interest, the shear strength of the ground can be measured by slowly ramping up the torque of one wheel. The torque is proportional to the current, which can be controlled with pulse width modulation and feedback from the current sensor. As soon the wheel starts turning an encoder will start to measure the speed, which will in turn be recorded with the torque. Conversion into shear strength can be done by considering the ground pressure of the wheel. A simple approximation is a quarter of the rovers weight. More accurate results are achieved by repeat measurements using all four wheels and considering the weight distribution on the wheels based on topography. The data collected on the Moon during the PT Scientists rover mission will be calibrated against ground measurements on Earth aimed at identifying the litho-mechanical reasons for the observed shear strength differences.

The shear strength measurement procedure described above illustrates how a small rover can generate valuable scientific data and highlights the potential of private missions such as the one by PT Scientists to contribute to the scientific exploration of the Moon.

**Keywords:** Lunar regolith, shear strength, rover, wheel measurements

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 48

## QUANTITATIVE ASSESSMENT OF NEOTECTONIC EFFECT ON LANDFORM, DRAINAGE AND SEDIMENT IN DARJEELING HIMALAYAS

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To feel the ever-fecund pulses of ground tremors that frequently threaten life and property a quantitative assessment of landform, drainage and sediment, focusing upon the Mountain-front thrust is intended in the Darjeeling-Himalayas. Its sinuosity <1.4 elicits tectonic deformation. Digitized coarse topographic texture on its flanks also corroborates. The distinctly higher relief ratios, considerably shorter dimensions and greater elongation ratios of watershed basins are related to greater steepness of its southern flank. Significantly more frequent occurrence of parallel drainage pattern, comparatively lower stream orders, less frequent river bifurcations and consequent reduction in drainage density on this thrust front are well anticipated.

The six mightiest rivers in the area achieve minimum gradient on the crest of the MFT eliciting uplift. Frequent changes in river gradients without any correlation with lithologic changes clearly testify tectonic effect. High hypsometry indices, convex hypsometric curves and <0.5 valley floor-width/height ratios derived from these rivers bear clear attestation to tectonic youthfulness of the studied terrain. Variations in Stream Gradient Index along these rivers and the related ratios (SL/K) often exceeding 2 are in perfect agreement with the tectonic restiveness of the terrain.

Rapid subsidence allowed localized sediment accretion. One such ~100 m thick pile of sediment at Kalijhora on the River Tista is now deeply incised. Uplift of a previously subsiding zone is implied. Vertical stacking of valley cycles record the previous subsidence. At least five terraces measuring around 15 m on average in height on this sediment piles record, at least, that many events of uplift. Progressive upward increase in clast size and share of distal crystalline rocks in clast composition within the pile is consistent with progressive southward migration of the adjacent thrust. Common presence of mass-flow products in the pile is also suggestive of intermittent tectonic disturbance.

**Keywords:** Neotectonism; Landform; Drainage; Sediment; Darjeeling-Himalayas.

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 64

## ESTIMATING THE GEOSTATIC UPLIFT OF EASTERN SHORE OF THE HORMUZ STRAIT (IRAN) THROUGH DATING OF MARINE TERRACES

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Unlike Quaternary Eustatic and Steric sea level changes that resulted in fairly evenly changes along the coastlines of the world, Geostatic changes show great spatial differences. These changes were the reason of different transgression or regression in nearby coastlines. From this point of view, Iran's southern coast from Chabahar coastline to the Hormuz Strait are important. Quaternary landforms, particularly marine terraces in this region are the most outstanding results of the above mentioned changes. The major concern of this research is the reconstruction of old coastline in the East of the Hormuz Strait, through measuring rate of deposition and dating marine terraces. In this research during the fieldwork, 4 marine terraces in the East Hormuz Strait were identified and the exact altitude and location of them were measured by dual frequency GPS. In the next stage shell samples were taken from surface of terraces. Carbon-14 dating of these samples were carried out in Poznan University laboratory in Poland. The results show that the highest terrace (height of 25 meters) was 5700 years old and the lowest terrace (height of 6 Meters) was 3050 years old. Correlation of dating results represented that over the past 5700 years, according to the slope of the back shore, shoreline area regressed between 500 and 700 meters and the annual rate of uplift is about 3.8 mm.

**Keywords:** The Strait of Hormuz; Geostatic Uplift; Marine terrace; Coastal changes; Dating.

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 85

## TECTONIC CONTROL ON THE CHANNEL PATTERN OF ALAKNANDA RIVER IN SRINAGAR VALLEY (GARHWAL HIMALAYA)

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River morphology is the field of science dealing with changes of river form and cross-section shape mainly due to sedimentation and erosion processes (Chang, 1988). This paper describes the results of a continuing investigation of tectonic control on channel pattern and morphology of Alaknanda River in Lesser Garhwal Himalaya. An investigation of the tectonic controls of the channel pattern and meandering of the Alaknanda River in Srinagar valley is conducted using remote sensing data and conventional method. The style of active tectonic on the deformation and characterization of fluvial landscape has been investigated on typical strike-slip transverse faults near the zone of North Almora Thrust (NAT). The structural and lithological controls on the Alaknanda River system in Srinagar valley are reflected by distinct drainage patterns, abrupt change in flow direction, incised meandering, offset river channels, straight river lines, palaeo-channels, multi levels of terraces, knick points and pools in longitudinal profile. A litho-tectonic map of the Srinagar valley has been prepared by the using of morpho-tectonic features and field investigation. The results indicate a sinuosity index of 1.35 which shows sinuous to meandering trend. All 8 sets of meanders are controls by tectonic features. All eight sets of meanders are controlled

by tectonic features including six levels of terraces at Chauras. It is concluded that the river channel is closely controlled by structural features in the study area.

**Keywords:** Tectonic, Meander, Channel pattern, Structure, Knick point.

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 98

## EVIDENCE FOR QUATERNARY DISPLACEMENTS IN THE TRANS YAMUNA SEGMENT OF THE DOON VALLEY IN NW HIMALAYA: IMPLICATIONS FOR EARTHQUAKE HAZARD ASSESSMENT

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Active faults in Himalaya directly reflect the evolution and ongoing tectonics in this youngest mountain belt of the world. The Trans-Yamuna Active Fault (TYAF) delineated in the northwestern Doon Valley in the Sub-Himalaya has been investigated with reference to its paleoseismicity. The present study focuses on the Bharli Active Fault (BAF), an E-W striking normal fault developed in the easternmost segment of the TYAF. The south side up of this fault has varying dip from 30° to 35° N, which obliquely cuts across the Main Boundary Thrust. Strike-slip component is confirmed by the presence of two sag ponds in the vicinity of the fault scarp. Explicit use of high resolution satellite data integrated with geophysical surveys and paleoseismological investigation across BAF is presented.

Ground Penetrating Radar (GPR) Survey helped comprehending the subsurface features of the fault. A high resolution DEM (mean vertical error of 0.277) generated from Cartosat-1 stereo pair, with Ground Control Points (GCPs) collected by Differential Global Navigation Satellite System (DGNSS) survey, could delineate the prominent terrain features. Lateral offset of few streams substantiate strike slip fault motion along BAF. Paleoseismological investigation through trench excavation survey across the BAF revealed earthquake induced deformation features. Highly deformed lithounits along with offsetted quartz veins and soft-sediment deformation features identified in the trenches suggest their genetic link with major paleoseismic activity. Preliminary C14 ages obtained from the trench suggest the probable timing of the faulting events to have occurred after 3000 B.C and before 900 A.D.

The TYAF, recognized to north of the Himalayan Frontal Thrust, demonstrates that recent strain release is not only concentrated in the frontal Himalaya but also distributed over a broader area further to its north. Detailed study on TYAF should reveal its potential for future earthquakes in the highly populous mountainous belt of NW Sub Himalaya.

*THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)*

**ABSTRACT NUMBER: 113**

## **DRAINAGE NETWORK EVOLUTION, ACTIVE TECTONICS, GRAVITATIONAL MASS MOVEMENTS: SPATIO-TEMPORAL CAUSAL RELATIONS IN A SECTOR OF THE NORTHERN APENNINES OF ITALY**

**Marta Della Seta<sup>1</sup>; Carlo Esposito<sup>1</sup>; Giulia Iacobucci<sup>1</sup>; Salvatore Martino<sup>1</sup>; Francesco Troiani<sup>1\*</sup>**

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The topography of tectonically active mountain landscapes results from the interactions among crustal uplift, valley incision and hillslope denudation. The slope-to-channel system morphoevolution plays a key role in predisposing mountain slopes to failure. Slope failures can produce stream blockages and/or diversions, inducing vertical-step knickpoints on stream longitudinal profiles, as well as marginal spillways and epigenetic gorges. On the other hand, slope failures can be triggered by intense valley entrenchment due to upstream migrating slope-break knickpoints, the latter being often generated by base-level changes due to active tectonics and climate. Analyses aiming at the assessment of the morphoevolution of slope-to-channel systems must consider the causal link in space and time between active tectonics, valley incision, gravitational mass movements, and stream longitudinal profile anomalies.

This study focuses on such a challenging subject and applies to the Bidente River basin in the Northern Apennines of Italy, as a representative case. Aiming at the spatio-temporal causal relations between slope instabilities and the evolution of drainage network over the Quaternary, we applied a combined geomorphological approach based on i) analysis of heights distribution and along-stream correlation of a well-developed sequence of strath terraces; ii) stream long-profiles metrics; iii) time-dependent, catchment-scale metrics.

The approach revealed useful to distinguish different generations and types of stream long-profile knickpoints to be correlated with relict valley-floors remnants (strath terraces). We demonstrate that the adopted methodology is suitable for distinguishing effects of ongoing upstream migration of knickpoints and related dramatic valley incisions on slope gravitational processes from effects of hillslope processes which can be regarded as directly responsible for local stream morphoevolution.

*THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)*

**ABSTRACT NUMBER: 144**

## **MORPHOEVOULTION OF THE SEYMAREH RIVER VALLEY IN THE TECTONICALLY ACTIVE ZAGROS MTS. (IRAN): PREDISPOSING FACTORS AND GEOMORPHIC RESPONSE**

## TO THE LARGEST LANDSLIDE ON EARTH SURFACE

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The Seymareh Landslide, detached 10-9 ka from the eastern flank of the Kabir-Kuh fold (Zagros Mts., Iran), is worldwide recognized as the largest massive rock slope failure (44 Gm<sup>3</sup>) ever recorded on the emerged Earth surface. Controversial theories have been developed by the scientific community to explain the exceptional nature of the event and different scenarios have been proposed. This work provides constraints to the Seymareh River valley morphoevolution, before and after the giant landslide occurrence, to correctly identify the predisposing factors and the geomorphic response to the slope failure. This kind of research is framed in an already tested multi-modeling approach that includes also contributions from engineering-geological modelling and stress-strain numerical modelling to analyze the time-dependent evolution of valley slopes related to mass rock creep processes.

Field activities have been aimed at detailed geological and geomorphological mapping, as well as at sampling of the terraced alluvial and lacustrine deposits of the Seymareh River valley, for OSL dating as geomorphic markers. A suitably constructed, high-resolution DEM allowed detailed geomorphological and morphometric analyses. River longitudinal profiles have been analyzed to find evidence of the transient landscape in response to active tectonics and to the emplacement of the Seymareh landslide. Several orders of alluvial terraces (both older and younger than the Seymareh landslide) as well as a lacustrine terrace (linked to the temporary landslide damming of the Seymareh Valley) have been recognized and projected along the present longitudinal profile of the Seymareh river. The plano-altimetric distribution and the OSL ages of such geomorphic markers, correlated to the detectable knickpoints along the river longitudinal profiles, allowed to constrain the main morpho-evolutionary stages of the valley. Four sectors of the valley have been defined, where different predisposing, preparatory and triggering conditions for massive rock slope failure have been recognized based on the related landforms.

*THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)*

**ABSTRACT NUMBER: 182**

## APATITE FISSION TRACK (AFT) LOW TEMPERATURE THERMOCHRONOLOGY CONSTRAINTS ON THE TECTONIC-GEOMORPHIC HISTORY OF THE GRAMPIAN HIGHLAND AREA-SCOTLAND.

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The persistence of topography and long-term rates of landscape evolution has attracted broad interest from over the last 20 years. The mountains of the Grampian Highlands, which still stand proud in the landscape, were created hundreds millions of years ago by different tectonic processes. The survival of many of these mountains for such a long time has long been the subject of debate for researchers. There is considerable evidence that in some places the present-day topography of Scotland has been affected by tectonic uplift that started during the Early Tertiary, although it remains unclear to what degree the present topography of the Scottish Highlands has retained remnant features of the topography from Caledonian Orogeny c. 420 Ma.

Low temperature thermochronology methods including apatite fission track and (U-Th)/He analysis have been used successfully to constrain long-term rates of landscape evolution in many geological settings; from mountain belts to passive margins. They have also been used to quantify the surface uplift and denudation of rocks during tectonic and surface processes. This project focusses on the Grampian Highland area in Scotland, including key vertical profile sections where feasible (e.g. Ben Nevis, Ben Cruachan) to quantify the rate of syn/post- Caledonian denudation. Preliminary AFT results from Ben Nevis and Ben Cruachan yield AFT ages between 208±18 Ma and 238±41. Model thermal histories constrained by these data indicate simple monotonic cooling at moderate rates (c. 3.07 °C/Ma) from depth between c. 400-260 Ma followed by much lower rates of cooling (c. 0.23 °C/Ma) through to the present. The rate of denudation between c. 400-260 Ma is higher, but it decreases after 260 Ma to the present which is about 9.23m/Ma. These preliminary thermal history models indicate that the first order topography at these two locations has changed little in the past 260 Ma.

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 233

## TOPOGRAPHIC METRICS OF TRANSIENT STREAM NETWORKS FOR THE DETECTION OF THE DEFORMATION STYLE OF ACTIVE NORMAL FAULTS: THE CASE OF CITTANOVA FAULT (CALABRIA, SOUTHERN ITALY)

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Extracting tectonic signals from the landscape is an important challenge for constraining the style and the rate of deformation associated to active faults, especially where their displacement history cannot be independently determined. Through DTM-derived analysis of geomorphic markers, footwall relief and stream long-profiles parameters (i.e. SL and  $\chi$ ), we provide evidence of drainage network disequilibrium and reorganization in response to fault growth and deformation style for the Cittanova Fault (Calabria, Southern Italy), whose activity is already documented and constrained. Our analysis was performed on the trunk valleys that flows with a sub-parallel pattern across the faulted coastal slope from the regional divide on the Aspromonte Massif down to the Tyrrhenian Sea.

Integrating results from geomorphometric analysis with existing paleoseismological data, geomorphological field work and radiocarbon dating of Upper Pleistocene alluvial deposits, we provided evidence of the geomorphic signal of the along-strike differential throw of the Cittanova Fault.

A methodological test on the reliability of the  $\chi$  metric as proxy of the differential throw along-strike of active normal faults provided good preliminary results, showing a strong inverse linear correlation with fault throw.

**Keywords:** Geomorphic markers; Longitudinal profiles;  $\chi$  metrics; Fault throw; Italy.

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 256

## STUDY OF NEOTECTONICS IN AND AROUND DIKTRONG RIVER, ASSAM-ARUNACHAL PRADESH

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The study area is a part of Eastern Himalaya which is consisted of low hills of Sub Himalaya, high hills of Lesser Himalaya and river terraces. The geomorphic landforms of the area is product of tectonics and denudation processes. In the Dikrong River section around Banderdewa, Himalayan frontal fault(HFF) marked the boundary between alluvium and low hill of Siwalik rock. The mountain front in the area propogate southward along series of thrust developed as splays from the earlier thrust. The dispositions of beds are comparatively steeper in the east bank then the right bank of Dikrong River. This differential compression probably resulted is development of NW-SE trending strike slip fault. The strike slips fault result in development of an extensional basin along which the Dikrong River flows. This is the reason for the presence of very wide valley (4-5Km) of Dikrong River with recent sediment. The rise of Harmoti surface above the recent alluvium is along a splay of HFF and presence of fault scrap is evident of ongoing tectonic activity. In the present study, various morphotectonic parameters such as mountain front sinuosity, asymmetry factor etc, of the area around Dikrong River are calculated. Survey of India Topographic maps and SRTM data are used for the parameters calculation. The morphotectonic analysis indicates that the area is less active but area has ample evidences of neotectonic activities. Difference in result is because there is a deviation of data obtained for various parameters from the standard data ranges for different classes of active tectonics given by different authors. This paper also includes the discussion on the causes of deviation of results and the need of revised study to develop new set of standard data ranges of tectonic classes in case of the Eastern Himalayas.

**Keywords:** Morphotectonic parameters, Himalayan frontal fault, Eastern Himalaya, active tectonics.

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 264

## TECTONIC GEOMORPHOLOGY OF THE SIHOR FAULT, EASTERN SAURASHTRA, WESTERN INDIA

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A detailed geomorphic evaluation of a previously known E-W trending Sihor Fault in eastern Saurashtra was carried out. The Sihor Fault is geomorphologically expressed as a linear series of scarps formed in the basaltic lava flows of Deccan Trap Formation. The southern upthrown block comprises a hilly topography developed over south dipping basaltic lava flows. The northern downthrown block comprises northerly sloping alluvial plain. The northerly flowing rivers arise from the basaltic hills and flow northwards incising through the Quaternary alluvial deposits before merging with the mudflats of Gulf of Khambhat. The alluvial sediments exposed in 5-10 m high incised cliffs along various rivers consist mainly of unconsolidated sands, silts with gravel layers. The Quaternary deposits show low northward dips which is in conformity with the northerly sloping alluvial surface. The Quaternary deposits are underlain by Deccan Traps in the vicinity of the uplands and by the largely gravelly deposits of Lakhanka Formation of Neogene age in the lower reaches. The overall geomorphic set up including northward decreasing incision and prominent northward tilt of the Quaternary alluvial plain suggest post-depositional uplift due to reactivation of the Sihor Fault. Two N-S trending strike-slip faults are also observed which laterally offset the Sihor Fault. The Sihor Fault is reflected in the form of highly sheared trapezoidal rocks; however, the fault does not displace the overlying Quaternary sediments.

**Keywords:** Tectonic Geomorphology; Quaternary; Neotectonics; Sihor Fault; Saurashtra

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 391

## SIGNATURES OF MORPHOTECTONIC ACTIVITIES IN WESTERN UPLAND MAHARASHTRA AND KONKAN REGION, INDIA

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Catastrophic tectonic activities are essentially slow but leave remarkable signatures on the landforms. The study is focused to understand morpho-tectonic activity over western upland Maharashtra and Konkan region. Many scholars have suggested that Western Ghat escarpment is a result of post Deccan uplift. In order to find out and affirm the tectonic activities and evidences of it in this region, 12 river basins were selected which are Pravara, Mula (N), Ghod, Bhima, Mula (S), Nira, Krishna, Koyna from upland region and Vaitarna, Ulhas, Savitri and Vashisthi from Konkan region. By using SRTM DEM, longitudinal profiles were plotted for all the rivers. Lineament map was prepared by using ASTER-GDEM and CartoDEM. Segment wise stream gradient index, concavity-steepness index and geomorphic indices of active tectonic (GAT) parameters have also been calculated, analyzed and mapped. Analysis of tectonic indices suggests that, in upland region out of eight river basins only Koyna river basin is having comparatively higher tectonic activity. Few river basins in north-west Maharashtra which are Pravara, Mula, Ghod, Vaitarna and Vashisthi from south-west Maharashtra are having moderate tectonic activity, rest of all are having very low tectonic activity over the study area. As indicators of tectonic activity, geomorphic features such as incised channel, natural knickpoints, active faults, river terraces are also found over the study area. All these signatures of active tectonics suggested that some part of Konkan and Maharashtra plateau region are tectonically active.

**Keywords:** Western Ghat; Active tectonics; Longitudinal Profile; Koyna; SRTM; GAT

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 392

## COMPARATIVE STUDY OF LISH AND GISH RIVER SEDIMENTS, SIKKIM-DARJEELING HIMALAYA; A TECTONIC GEOMORPHOLOGICAL APPROACH

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The Lish River and Gish River are flowing through similar lithotectonic units of Sikkim- Darjeeling Himalaya. These lithotectonic units consist of different lithologies as well as bounded by thrust system. Therefore it is need to undertake sedimentological and geomorphological studies of these rivers, which provide information about control of tectonic geomorphology on sediments. The methodology used for present study includes compositional analysis for sediments, while tectonic geomorphic analysis using overlay different maps as topography, drainage, lithology and structural along with calculation of Vf ratios. The compositional analysis of Lish river sediments shows dominance of Lithic fragments (Qt39% F2% L59%), in which Lithic sedimentary (Lm44% Lv0% Ls56%) show dominance over lithic metamorphic fragments. This is also supplemented by Lithic sedimentary (Qp41% Lv0% Ls59%) dominance over Quartz Polycrystalline. While, Gish River sediments show Quartz dominance (Qt63%F4% L33%) in which Lithic metamorphic (Lm62% Lv0% Ls38%) show dominance over Lithic sedimentary. This is also supplemented by dominance of Quartz Polycrystalline (Qp62% Lv0% Ls38%) over Lithic sedimentary. The compositional analyses of these river sediments show differential contribution of source lithology. The overlay of regional maps as topography, drainage, lithology and structural map is analyzed. The rivers of study are flowing through major thrust system of area as MCT, MBT, RT, and MFT. These structural elements are strongly influencing topography and drainage basins of the area. They are also controlling lithological distribution in these thrust system. Therefore assessment of activity of these thrust become important for their control on sediment composition. The Valley Width-to-Height (Vf) Ratio along Lish River show tectonically active area comprising lithology of sedimentary and metamorphic sources infer contribution to Lithic dominance. While along Gish river show lithology consists of gneisses and metamorphic sources that infer Quartz dominance in sediments.

**Keywords:** Gish River; Lish River; Petrography; Geomorphology, Vf ratio

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 465

## ASSESSING THE CONTROL OF VARIABLE SEDIMENT ROUTING ON REGIONAL TECTONIC SETTING: A PERFECT SETTING TO DISENTANGLE THE COMPLEXITY

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Critical Coulomb wedge model illustrates that the tectonic activity near the toe of any growing orogen is sensitive to changes in the mass of the wedge. Therefore, variations in sediment routing over time could potentially impact the regional tectonic setting: greater sediment storage within the wedge would trigger forelandward propagation of the wedge-front and removal of sediment storage would proliferate out-of-sequence thrusting. However, this relationship is yet to be established from any natural laboratory. Here we present a unique geological setting to prove this relationship in the NW Himalaya.

The Kangra-Chamba sector of the Himachal Himalaya extends across major Himalayan thrusts accommodating the shortening within Himalaya. Present understanding of the Himalayan deformation suggests that majority if not the total shortening is consumed within the Sub-Himalayan fold-and-thrust belt and more importantly, over the late Quaternary the deformation is focused on the southernmost Main Frontal Thrust (MFT). In this study area, we have found several intermontane basins (such as, Chamba Basin, Kangra Basin and Soan Basin etc.) which transiently store voluminous valley-fills (>200m). We are processing sediment samples to obtain OSL-based burial ages and terrestrial cosmogenic nuclide-based terrace-exposure ages to understand the aggradation-incision history of the basin and to obtain fault slip rates from dated geomorphic markers (i.e., terraces). We aim to quantify the sediment volumes and its' potential impact on the regional stress field. Preliminary results from the mechanical modelling of the wedge front hints that a >200m thick valley fill spread over ~100 km<sup>2</sup> area can induce changes in the Sub-Himalayan tectonic stress-field. With preliminary results from the OSL and TCN dating, numerical simulations of the sediment volume and Sub-Himalayan structural architecture and field observations, we strongly believe that we will be able to put some light on this decade-long debate.

**Keywords:** Intermontane valley-fill, cosmogenic nuclide, OSL dating, Tectonics, critical wedge.

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 495

## TEESTA RIVER RESPONSE TO NEOTECTONIC ACTIVITY; SEDIMENTOLOGICAL STUDY OF RIVER DEPOSITS, NEAR RANGPO, SIKKIM, INDIA

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The Teesta River flows through major lithotectonic units and thrust system of Sikkim-Darjeeling Himalaya. The river deposit near Rangpo characterizes thick sedimentation in a localized area in proximity of thrust. Therefore it is essential to undertake sedimentological study of these deposits to reveal the interaction of river with these active thrust systems. The methodology used in present study consists of detailed sedimentological documentation and grain size analysis. The geomorphology of study area shows meandering in the northern part while localised ridge barrier deposit near thrust line in southern part. The meandering consists of raised unpaired river terraces in northern part indicating flow migration from west to east. Channel fill deposits show dominance in northern part and characterised by coarser size sediments. While Flood plain deposits are dominating in southern part and consist of finer size fractions. The soft sediment deformation structures are observed only in southern end of this meandering deposit. These flood plain dominated part continues in dominance within southern ridge barrier deposit. It comprises three marked bedform variation sequences. The basal sequence is consisting of channel fill and near channel sedimentation. While, middle sequence is of debris event characteristically shows cross-cutting relation. The upper sequence is mainly of flood plain sedimentation. The colours of mud in basal (gray, dark gray and black) and upper (greenish, purple and yellow) sequence are of distinctly different. The middle sequence is characterized by debris flow is indicating subaqueous condition during deposition. Hence, debris flow event has preserved record of anomalous subaqueous flow conditions in sedimentary succession. Therefore, sedimentological variation throughout deposit with presence of SSDS and debris flow event near the proximity of thrust indicating thrust related seismotectonic activities in the area.

**Keywords:** Himalaya, Teesta River, thrust, SSDS, debris flow

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 510

## RELATIONSHIP BETWEEN LANDSLIDE AND ACTIVE TECTONIC ZONES (CASE STUDY: JAJROOD WATERSHED, IRAN)

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The geomorphic setting of Alborz Mountain is a result of complex interactions involving neo-tectonic movements and processes of erosion and deposition. Based on 10m-resolution DEM data, a total of 39 basins were extracted using ArcGIS. The Jajrood basin is located at the longitudes east of 51°22' to 51°51' and latitude of north 35°45' to 36°50'. A total of 28 landslides were visually interpreted from satellite images and published documents. Seven geomorphic indices were calculated for each basin including the relief amplitude, hypsometric integral, stream length gradient, basin shape indices, fractal dimension, asymmetry factor, and ratio of valley floor width to height. These geomorphic indices were divided into five classes and the ratio of the number of the landslides to the number of the basins for each geomorphic index was computed and analyzed for every class. Average class values of the seven indices were used to derive an index of relative active tectonics (IRAT). The ratio of the number of the landslides to the number of the basins was computed for every class of IRAT. The degree of probable risk level was then defined from the IRAT classes. Finally, the landslide hazard was evaluated for each drainage basin based on the combined effect of probable risk level and occurrence frequency of the landslides. The results showed approximately, 85% of the drainage basins with occurred landslides are at a high risk level, while 33% of the drainage basins without occurred landslides are at a high risk level. According to Table 4, more than 85 percent of the slip intensity zones at Jajrood basin are in high and very high risk of landslides.

**Keywords:** Alborz mountain; Jajrood basin; Landslide; Geomorphic indices; IRAT.

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 511

## TECTONIC GEOMORPHOLOGY OF CENTRAL ALBORZ RANGES (IRAN) AN INITIATIVE TOWARDS SEISMIC HAZARD ASSESSMENT

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No places on Earth are entirely free of the risk of earthquakes. Earthquakes are among the most destructive natural phenomena on the planet, having substantial social and economic consequences. Tectonic geomorphology investigations are important because the results of regional studies on neotectonics are significant to assessment natural hazards in populated areas Central Alborz corresponds to the E-W trending mountain range bounding the Oceanic Caspian domain to the South. Central Alborz contains different geological units from Precambrian to Quaternary. In Central Alborz, the recent activity is controlled by the E-W trending structures such as the North Tehran fault, the Musha fault in the South and the north Alborz fault and the Khazar fault in the North. Several large historical earthquakes occurred along these inherited structures, which represent a high seismic potential. The Tehran basin is located at the southern edge of the central Alborz and is the result of the Arabian- Eurasian convergence and clockwise rotation of the south Caspian basin with respect to Eurasia. Hence, assessment of the drainage pattern permutations and mountain fronts appears necessary. We used six significant morphometric indices for this evaluation: stream length gradient (SL), drainage basin asymmetry (Af), hypsometric integral (Hi), ratio of valley floor width to valley height (Vf), drainage basin shape (Bs), and mountain front sinuosity (Smf). The combined analyzed indices represented the relative active tectonics (Iat). The study area was divided into four regions according to the values of Iat. These classes include class 1, class 2, class 3, and class 4. The regions with high relative tectonic activity mostly correspond with the active structures in the basin.

**Keywords:** Geomorphological indices; Earthquake; central Alborz

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 521

## TECTONIC INFLUENCE ON THE LONGITUDINAL PROFILE OF ALAMARVDASHT RIVER, SOUTH OF IRAN

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Rivers are highly sensitive to tectonic changes, so they response to tectonic activities by changes in their geometric attributes. Geomorphic indices which extracted from river profile define profile properties and their response to tectonic activities and base level changes. Active tectonics in the uplifting anticlines in the Folded Belt of the Zagros structural zone, has produced various fluvial landforms. The aim of this paper is to evaluate the effects of tectonics on longitudinal profile changes of Alamarvdasht river in south of Fars province. For this purpose the study area divided to three main sub-basins and geomorphic indices including: Asymmetry Factor (AF), Hypsometric Integral (HI), Stream Length-gradient (SL), Profile Deviation Index (PDI), Stream Concavity Index (SCI) and Normalized Longitudinal Profile were calculated by using the Digital Elevation Model (DEM) in ArcGIS, Excel and MATLAB software. The highest value of AF index was found in the east of study area which shows the effects of thrust faults along the main folds in this part of basin but the results of longitudinal profile, SL, PDI and SCI indices show the clear changes in longitudinal profile of Alamarvdasht River by active tectonics especially in the northwest of the basin. The highest values of SL, HI and SCI indices were found in northwest of basin where the river crosses some active faults. Applying the method for three sub-basins shows that the geomorphic indices are useful methods for evaluating the effects of active tectonics on the Alamarvdasht river profile Because there isn't any distinct lithological change along the river, high values and anomalies of geomorphologic indices are related to active tectonic factors which their evidences such as river traces and knickpoints could be found by satellite images and field observations.

**Keywords:** Alamarvdasht River; Tectonic Geomorphology; River Profile; Geomorphologic Indices

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 524

## GEOMORPHOLOGICAL EXPLANATION OF SWAMPS ON THE BARAK VALLEY, NE INDIA

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There are several natural water bodies (bils) in the Barak Valley of Assam, India. From the SOI topographic maps (1:50,000), surveyed during 1971-1972, it has been observed that in a study area of the Barak Valley there were about 552 bils; whereas the satellite data of 1988, 2002 and 2011 reveal that the numbers of bils were 328, 274 and 249, respectively. There are 156, 150 and 145 bils formed newly within the periods 1972-1988, 1988-2002 and 2002-2011, respectively. It is also observed that in majority of the cases, the number of bils with increasing area was more in the periods 1972-1988 and 1988-2002, whereas the same was less in 2002-2011. Moreover, there are about 102 and 118 numbers of dried up bils in 1988 as compared to 1972 in the north bank and south bank of the Barak River, respectively. It is observed that the number of bils decreased but area of the most of the bils has increased by 1988. It is also supported by increase in number of irregular type of bils by 2011 as compared to 1988, whereas compact type of bils was dominant in 1972 in that area.

The Barak Valley is situated in the tectonically active Assam Arakan fold belt where there is convergence of Indian Plate and Burmese Plate. Hence tectonic activity might be one of the major factors which played a dominant role in changing the nature of swampy lands within the Valley. In the Barak Valley region continental stretching and transtensional tectonics are favorable for development of tectonic lakes, bils and swamps.

**Keywords:** Swamp, Assam Arakan fold belt, Tectonic activity

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 525

## EXTRACTION OF RIDGES ORDERS FROM DEM TO EVALUATE OF ACTIVE TECTONICS IN CENTRAL ALBORZ MOUNTAINS

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The central Alborz are a 3000-5000 m-high mountain range surrounded by lowland area at the north and south, having been uplifted since quaternary. The southern and northern mountain fronts of the area are fault-bounded, while are drawn the ridges along all aspects. We have carried out a geomorphic study by examining ridges orders and characteristics of mountain in order to reveal areal variations and active tectonic. To extraction of ridges, we have operated in the following steps: (1) inverse the DEM; (2) used the TOPAZ model to extraction of ridges; (3) classification (ordering) the ridges and then (4); analyzing the relation of ridge orders, faults and others index of active tectonics. Based on results, ridge orders index indicate the central part of the area, probably related to the uplift of the north and south fault-system. Ridges orders analysis suggests that the eastern part of the area is tectonically active by means of a combination of thrust faults along the mountain front and E-W oriented active folds, which, in turn, likely have a convergent zone related to the exposure of the footwall of the normal fault-system.

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 556

## MORPHOTECTONIC STUDY OF THE GANG RIVER BASIN, WEST KAMENG, ARUNACHAL PRADESH, INDIA.

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Tectonic events are responsible for shaping the topography and formation of mountain ranges such as Himalaya. In the present study



we consider the Gang River basin and its sub-basins situated in the eastern Himalaya, northeastern India. The Gang River basin occupies an area of about 1360.3 km<sup>2</sup> lying in the western ridge of Arunachal Pradesh. It flows towards south east direction about 51.38km cut across by the major regional structures and joined at the Bichum River. This basin is investigated to examine the influence of active structures by applying an integrated study on supportive field evidences, geomorphology, morphotectonics, Digital Elevation Model (DEM), using topographic map and satellite imageries. The measured indices for morphotectonic analysis, viz. Asymmetric Factor (AF), Transverse Topographic Symmetry Factor (T), Stream Length gradient index (SL), Basin shape indices (Bs) and lineament analysis indicated that the area is tectonically active. It has been observed that the northern part of the basin in Sela Group of rocks have mostly southerly tilted whereas in the rocks of Dirang Formation in the southern part of the basin have tilted SE and SW. The Main Central Thrust (MCT) is the prominent tectonic feature present in the study area which might controls the major geomorphic pattern in the region. From the of present investigation, we can assume that during Lower Miocene to Early Miocene time with the advancement of the MCT, erosion and upliftment of the region have played the key role in the evolution of the geomorphic landscape of the Gang River basin. Moreover, this region may create havoc with loss of life and property due to rapidly developing infrastructure as the area is tectonically active.

**Keywords:** Gang River Basin; Main Central Thrust (MCT); morphotectonics; lineaments; Sela Group

*THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)*

**ABSTRACT NUMBER: 597**

**MORPHOTECTONICS OF A TILTED BLOCK  
(ORLICKIE – BYSTRZYCKIE MOUNTAINS BLOCK, SUDETES, CENTRAL EUROPE)  
- WHAT STREAM LONGITUDINAL PROFILES AND VALLEY MORPHOLOGY TELL**

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Fluvial landforms of various order, from drainage patterns to stream longitudinal profiles, have considerable potential in morphotectonic studies, allowing one to detect areas subject to long-term uplift/subsidence, to recognize fault zones for which scarce evidence in rock record exists, and to identify recent tendencies of vertical and horizontal movements. Stream longitudinal profiles are of special interest, mostly due to their low topographic inertia, i.e. relatively quick response to tectonically induced disturbances. In order to detect knickpoints possibly related to tectonics, stream length – gradient index (SL index) and steepness index are calculated along river courses. Features of valley morphology, in turn, develop over longer timescales and provide context for stream profile analysis. The study area represents an asymmetrically uplifted block c. 60 km long and 10–25 km wide, which was subject to complex Late Cenozoic up- and downfaulting, apparently associated with tilting of some blocks. Further complicating factors are lithological diversity and drainage inheritance from the now largely gone Cretaceous sedimentary cover, once present over the basement. The obtained values of indices calculated on the basis of stream profiles were then interpolated for the purpose of areal presentation and compared with one another using statistical methods. In this way, considering non-tectonic factors at the interpretation stage, localized areas which experienced enhanced tectonic uplift were identified within the Orlickie – Bystrzyckie Mountains Block.

**Keywords:** morphotectonics; stream longitudinal profile; SL index; Sudetes

*THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)*

**ABSTRACT NUMBER: 624**

**WATER DIVIDE POSITION AND DRAINAGE PATTERN DIVERSITY IN REGIONAL  
MORPHOTECTONIC ANALYSIS – A STUDY FROM THE SUDETES, CENTRAL EUROPE**

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The Sudetes are a large tract (c. 300 x 80 km) of upland and medium-altitude mountain terrain in central Europe north of the Alps, interpreted as subject to differential uplift and subsidence in the late Cenozoic in the predominantly extensional regime. However,

the spatial pattern of vertical displacements is poorly known and regional drainage pattern has not yet been systematically analyzed in this context. In this study we focus on the position of the main water divide, frequently analyzed in morphotectonic research. It is significant that no central or shifted axis of maximum uplift can be traced along the range. In terms of altitude, high (>1000 m a.s.l.) terrains alternate with less elevated uplands and wide intramontane basins across the Sudetes, whereas the main water divide follows a highly sinuous course, with considerable shifts to the north or south. In several sub-regions it runs perpendicular rather than parallel to the elongation of the range, separating fluvial systems draining the mountains in opposite directions. Of special interest are sections where the main divide crosses intramontane basins and troughs, being almost imperceptible. This study explores the resultant asymmetry of the mountain range and applies a series of indices to quantify the anomalous position of the main and some 2nd order divides, as well as the shapes of major drainage basins. A parallel recognition of knickpoints on major rivers and fluvial gorges, followed by analysis of their spatial distribution in respect to the main divide, adds to the interpretation and helps to indicate locations where enhanced uplift, drainage pattern changes and reversals may have taken place.

**Keywords:** tectonic geomorphology; geomorphometry; drainage patterns

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 672

## TECTONIC CONTROL ON DRAINAGE EVOLUTION AND DEVELOPMENT IN THE SOUTHEASTERN SEGMENT OF PIR PANJAL RANGE

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Deformation within Kashmir basin is generally associated with distributed faulting and seismic activity as revealed by historical and instrumental earthquake data. However, within such broad deforming region, an understanding of how drainage pattern respond to tectonics can provide an insight into past deformational events. Southeastern segment of Pir Panjal Range is characterized by Distributive Fluvial System (DFS) where the transverse rivers (Veshua and Rambiar) leave the confinement of a highland valleys and become unconfined in the sedimentary basin depositing a sediment wedge due to energy loss from flow expansion. These transverse rivers draining the southeastern segment of Pir Panjal Range show sudden diversions to axial courses, bifurcates into numerous small channels diminishing in size and the capture of lateral systems producing beheaded streams that break through the thrust front at structurally controlled points. The entire southeastern segment forms a promontory traversed by multiple fault strands with anomalous drainage pattern strongly suggest that these morphological signatures resulted due to ongoing tectonic activity across multiple faults. Moreover, SRTM DEM and aerial photography analysis substantiated by field work indicate a very strong and well delineated fault traces which cuts through various relief bedrock and alluvial deposits.

**Keywords:** Kashmir; Tectonics; Drainage deflection; Thrust fault; Transverse stream

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 719

## MUD VOLCANOES OF MAKHRAN COAST, IRAN

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Mud volcanism is a global phenomenon usually associated with compressional tectonics that favor extrusion of fluid- and clay mineral-rich sediment both on land and offshore. Iran's coastal, bordering the western Makhran Coast, has more than 50 prominent onshore MVs. In this research, after data collection, including topography and geology maps, IRS satellite data and aerial photos, remote sensing verifications were implemented. Then, mud volcanoes determination was completed by field work studies and checking. Their geomorphology characteristic such as area and height were measured. One sediment and one water samples were taken from each mud volcano in the field work, then analyses of major, minor and trace elements were carried out through ICP-OES. About 20 small or big mud volcanoes were determined in Hormozgan province that they have not been introduced before. In the meantime, hydrogeochemistry studies or determination of the percentage of available elements in water for all mud volcanoes were implemented. Since this geomorphological phenomenon indicates tectonic activity of a region, hence there is a possibility of mild earthquake and faulting occurrence. After determine correlation analysis cluster and factor analysiss determine between different

factors from scatter plot map characterized that source of elements Al, Fe, Ni, V, Sc, Ti, Cr, Zn, Cu, Mn, Na, K, Li, Be is geogenic and source of elements Ca, Mn and S is biogenic

**Keywords:** Mud volcano, Geomorphological, Geochemical, Makran

THEME: S33 TECTONIC GEOMORPHOLOGY (IAG-EGU JOINT SESSION)

ABSTRACT NUMBER: 726

## THE INFLUENCE OF LUOTIAN DOME UPLIFTS ON THE EASTERN JUSHUI DRAINAGE PATTERN

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The Dabieshan mountain is one of the largest metamorphic belt in the Central China, which is also the dividing line of North and South China blocks. The uplift of Dabieshan mountains changed the climate and geomorphology of Central China. Luotian Dome is the biggest dome in Dabieshan mountains. The uplift of the Luotian Dome have a great influence on drainage system evolution of the southern rivers in the Dabieshan mountains. Nowadays we could use modern GIS methods to find out the geomorphic characters of rivers near to the Luotian Dome in a very large spatial scale. Based on the 30m resolution ASTER GDEM data, we used ArcGIS and GrassGIS to extract the drainage characteristics in order to find out how the Luotian dome influence Jushui drainage pattern. We analyzed the drainage patterns of 6 catchments in the eastern Jushui drainage basin, which named by r1 to r6 from north to south. The results show that rivers in the north Luotian Dome have more knickpoints than south rivers. These knickpoints mainly caused by the many faults in these drainage basins. The north rivers have higher ksn values indicates the Luotian Dome have more influence on them because they are near to the dome. The results also show that the main channels of the north rivers migrate to the north, suggesting the drainage basin tilt northwardly. On the contrary, the south drainage basins tilt southwardly. In the 6 rivers, the r2 basin has the maximal basin asymmetry value, the river maybe pirated other rivers before. The Luotian Dome still have a great influence on the drainage patterns in this region. It is feasible to use ASTER GDEM data to do the morphotectonic studies on the drainage basins.

THEME: S33-A : TECTONIC GEOMORPHOLOGY OF KACHCHH BASIN

ABSTRACT NUMBER: 179

## THE ROLE OF THE CLIMATE AND HILLSLOPE GEOMETRY IN THE EROSION PROCESSES IN THE CONTINENTAL MARGIN OF SOUTHEAST BRAZIL

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The widespread dataset of <sup>10</sup>Be-derived denudation rates in passive margin context has revealed general small erosion rates, below 100 m/Ma, but with a considerable range, suggesting that these areas are still evolving differently each other. Continental margin of Southeastern Brazil, characterized by two parallel to coast mountain ranges (Serra do Mar and Serra da Mantiqueira) and high precipitation variability is an excellent area to evaluate which factors controls landscape change. <sup>10</sup>Be-derived denudation rates range from  $5.19 \pm 0.46$  to  $53.33 \pm 4.22$  m/Ma. Catchments on ocean side of Serra do Mar erode twice faster than catchments both in continental side of Serra do Mar and in Serra da Mantiqueira. Hillslope geometry and local relief regulates erosion everywhere but as they reach threshold conditions in many catchments, amount of rainfall defines the intensity of erosion, triggering mass movement processes in hillslopes. Drainage network, controlled by geological structure also play an important role in landscape evolution, since river captures increase the area of escarpment catchments and promotes escarpment retreat. A geomorphological unit of Serra da Mantiqueira called Itatiaia plateau represents an end-member for this model of evolution: escarpment retreat reached an important continental divide and relict plateau was entire dissected. Incision river is almost similar in all side of the continental divide, consequently the erosion rates are homogeneously in Itatiaia plateau, simulating a steady state condition.

**Keywords:** Serra do Mar; Serra da Mantiqueira; catchment-averaged erosion rate; escarpment; relief; precipitation.

THEME: S33-A : TECTONIC GEOMORPHOLOGY OF KACHCHH BASIN

ABSTRACT NUMBER: 365

## TECTONIC IMPACT ON EPHEMERAL RIVERS, AS APPREHENDED BY GEOMORPHIC INDICES WITHIN NW KACHCHH MAINLAND, KACHCHH, INDIA

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The Kachchh region is seismically active pericratonic palaeorift basin placed at the western margin of Indian Peninsula. The landscape of Kachchh basin has evolved due to present as well as past tectonic activities in the area. Intensive tectonic activity has been reported and also assessed by many researchers within EW trending major fault systems. Here the focus of the study is on the E-W trending Kachchh Mainland Fault (KMF). It can be apprehended that the tectonically affected region must be sensitive to the drainages and the quantitative study through the drainage system within active region can furnish the amount of tectonic activity. To assess the tectonic activity of any region, quantitative geomorphic parameters like Longitudinal Profile, Stream Gradient Length ratio (SL Index), Hypsometric Integral and Steepness Index can be used. Result showing very high ks values, high SL index values and higher HI values can be attributed to tectonic distortions, particularly with an absence of correlation with lithological factors. From the whole study, the result has been grouped into 4 divisions: highly active to least active region. The study from all used parameters indicates Bhuki River is the highly tectonically affected basin while Nirona, Kadrai and Charri rivers and Gandi, Katesar River from western tip of Kachchh mainland are moderate active. Nara and Pinjorwali River basins have absence of tectonic activity. The above analysis proving that the effect of Kachchh Mainland Fault (KMF) is not only limited to the central region but it also extends upto the western fringe.

**Keywords:** Neo Tectonic activity; Kachchh Mainland Fault (NW Kachchh Mainland)

THEME: S33-A : TECTONIC GEOMORPHOLOGY OF KACHCHH BASIN

ABSTRACT NUMBER: 407

## DRYLAND FLUVIAL RESPONSE TO LATE QUATERNARY CLIMATE, TECTONIC AND SEA LEVEL CHANGES FROM SOUTHERN KACHCHH MAINLAND, WESTERN INDIA: INSIGHTS FROM OPTICAL CHRONOLOGY, SEDIMENTOLOGY AND GEOCHEMISTRY

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Dryland Rivers by virtue of their preservation potential, serve as suitable archives towards understanding climate-tectonic coupling. In the present study we have studied the fluvial records of southerly-draining rivers in the semi arid southern Kachchh mainland situated in seismically active intraplate region of western India. The logic of employing fluvial landforms was derived from the fact that the fluvial systems are considered to be sensitive enough to record shifts in climate, sea level or tectonic instability which is manifested in the nature and type of sedimentary succession deposited along the river valleys. Here, we employ a suit of detailed geomorphometric, geomorphological, sedimentological and chronological methods to ascertain the role of these external forces in shaping the Late Quaternary landforms of the southern Kachchh region.

In the study we have used conventional morphometric technique to understand the role of past seismic activity in the evolution of the fluvial landforms. The spatial variation in relative tectonic activity along the Katrol Hill Fault (KHF) suggested that the central segment of KHF was undergoing relatively more tectonic deformation since the Holocene period compared to eastern and western segments. Based on sedimentology, geochemistry and optical dating, we illustrate that the valley fill sequences of southern Kachchh region successfully archive the signatures of climatic fluctuations since the past 50 ka. However this record is discreet and hence occurs in patches in the various river valleys. The coastal segment of Kachchh region also hosts fluvial-marine sequences which exhibits evidences of past high sea stand during the Middle Holocene period (3 to 6 ka).

THEME: S33-A : TECTONIC GEOMORPHOLOGY OF KACHCHH BASIN

ABSTRACT NUMBER: 408

## PROVENANCE AND PATHWAYS OF THE MODERN AND LATE HOLOCENE SEDIMENTS OF THE CENTRAL AND WESTERN GREAT RANN OF KACHCHH, WESTERN INDIA

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The 'great white dessert' is the term popularly used for the Great Rann of Kachchh ~ a salt encrusted flat terrain, situated in the extremely arid zone of Kachchh, Western margin of India. The term 'rann' means wasteland, is a hyper saline terrain and is often regarded by some as unique as having no counterpart on earth. The unique feature of this terrain is that it gets submerged by the marine wave during the monsoonal months due to high tidal waters pushed by the south-westerly winds towards the western Great Rann region. In present study we attempt to evaluate the modern and Late Holocene (<1 ka) provenance of sediments and their probable pathways. We studied a total of 50 surface samples and two trenches/shallow cores. The shallow sedimentary archives were samples at 1cm interval and 2 cm intervals. We employ elemental geochemistry to evaluate the provenance of sediments and also attempt to get first hand estimates of their pathways. The results suggest that the major sources contributing to the western and central Great Rann of Kachchh regions are a) Himalayan source (from west and north), b) Indian continental source (from east) and c) Kachchh Mainland source (from south). The dominance of Himalayan source in western most and northern regions of Great Rann and dominance of Kachchh source from southern fringes of Northern Hill Range are indicative of present day sedimentation pattern in the western and central Great Rann region. The temporal variations in sedimentary record along with an average sedimentation rate of Rann sediments as 3.8 mm/yr, suggests atleast during the last 500 years the palaeoenvironmental conditions have remained stable (i.e. same as present).

*THEME: S33-A : TECTONIC GEOMORPHOLOGY OF KACHCHH BASIN*

**ABSTRACT NUMBER: 428**

### **GEOMORPHIC EVIDENCE OF ACTIVE TECTONICS ALONG ISLAND BELT FAULT, KACHCHH: WESTERN INDIA**

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The landscape of Kachchh is a unique example of active intraplate region enduring rift reversal. The first order topography and the youthful appearance of Kachchh landscape indicate continuous rejuvenation of the area, which has kept pace with the erosional. The structure of Kachchh is designed by major E-W striking faults viz. Nagar Parkar Fault (NPF), Island Belt Fault (IBF), Goradongar Fault (GDF), Gedi Fault (GF), South Wagad Fault (SWF), Kachchh Mainland Fault (KMF), Katrol Hill Fault (KHF) and North Kathiawar Fault (NKF). These faults are bounded by uplift on their up thrown sides. These uplifts are characterized by narrow linear flexures which are splits into individual domes and anticlines of the secondary order which from the individual hills of the bordering ranges. IBF is not well exposed along the island chain of Island Belt uplifts (IBU) being buried under Rann sediments. The faulting is indicated by steeply dipping beds of the forelimbs and the imposing escarpments facing Great Rann of Kachchh in the north. The fault appears to have been dislocated by several transverse strike-slip faults, which separated Island Belt Uplift (IBU) into four discrete blocks viz. Pachham Uplift (PU), Khadir Uplift (KU), Bela Uplift (BU), and Chorar Uplift (CU). The present work has attempted to understand active tectonism along IBF. The present study focuses on the study of Quaternary sediments and structures, Quaternary landforms and drainage systems, which are direct expressions of the ongoing tectonic processes along IBF. Using topographical / geological maps, remote sensing data and Geological / Geomorphological Mapping in field, geomorphic features of active tectonics have been documented and mapped. These features are manifestation of recent tectonic over Island belt Fault.

*THEME: S33-A : TECTONIC GEOMORPHOLOGY OF KACHCHH BASIN*

**ABSTRACT NUMBER: 669**

### **TRANSVERSE FAULT SYSTEMS AND THEIR SIGNIFICANCE IN KACHCHH RIFT BASIN: WESTERN INDIA**

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Kachchh pericratonic rift basin is evolved in early Triassic time with breakup of quaternary land. Post – collision geotectonic evolution during early tertiary reactivated E –W basin banding fault system and uplifted the Kachchh landscape along them which has given rise to the reverse tectonics in Kachchh. However during reverse tectonic environment. The fault plane of Master Faults become almost vertical

to semi – vertical resulting into stress regime change to strike-slip in mid-tertiary. Therefore the vertical upliftment in the Kachchh Basin resulted into separate domes of varied size and shape following the transverse faults passing from the E or W sides of the domes. These transverse fault trending N-S, NW –SE, NE-SW, NNE-SSW shifted the domes and Master Faults (Kachchh mainland Fault, Katrol Hill Fault, Island Belt Fault) at several places. In present study we have documented various neotectonic features along transverse faults. These features are: gorges in bedrock and Quaternary sediments, youthful nature of fault scarp, Structurally Controlled drainage, hanging Quaternary paleochannels etc. Geological and chronological data along these features indicates its activeness in Quaternary time.

**Keywords:** Kachchh Basin; regional stress; transverses Faults; Neotectonic

THEME: S34 : GEOARCHAEOLOGY (IAG-WG)

ABSTRACT NUMBER: 187

## THE ENVIRONMENTAL CHANGE AND HUMAN LIFE IN PREHISTORIC TIMES BASED ON THE BANGUDAE PETROGLYPHS ALONG TAEHWA RIVER IN ULSAN-SI, SOUTH KOREA

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The lots of history, folklore as well as archeological researches on the drawings left on the wall of sedimentary rock of the downstream of the Taehwa River at Bangudae in the Ulsan-si as National Treasure #285. The vibrant engravings of various animals, people, objects, hard to find anywhere else in the world. These pictures and symbols suggest the lifestyles and spiritual worlds of prehistoric man. The approximately same decrement 37-42% of whales at each face of Bangudae Petroglyphs probably means physical environmental change along the Taehwa River and the living style of the residents during Neolithic age of 7000-3000yr BP. The main means of life for the communities that made the rock engravings were hunting, fishing, and gathering. As they lived along the river, they did the rock engravings realistically based on experiences gained as the communities hunted mountain beasts and caught whale according to the changes of environment. The petroglyphs were starting around the maximum phase of transgression in the Holocene and the ancient shoreline had reached Gullhwa-ri near the middle and downstream of the Taehwa River. The river of the eroded valley during LGM would have almost impossible to be filled up. As a result, it would have been possible for small sized boats to come and go in the downstream of the Taehwa River. The change in content of the petroglyphs were examined by the change of shoreline with the sea level change during the Holocene. The communities did not move as the Taehwa River aggraded and the catching grounds grew further away and instead looked for their supply of protein in the surrounding mountains and rivers.

**Keywords:** Environmental Change; Human life; Prehistoric Times; Bangudae Petroglyphs; sea level change

THEME: S34 : GEOARCHAEOLOGY (IAG-WG)

ABSTRACT NUMBER: 188

## THE SPATIAL DISTRIBUTION OF THE ANCIENT 'LIAOZE' ALONG THE LIAO RIVER AND SHORELINE CHANGE SINCE THE MIDDLE HOLOCENE AROUND LIAODONG BAY IN CHINA

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Liao River, which is the 3rd largest river in China, has constructed huge floodplain along the lower reach with rectangular shape in the northeastern part of China. Especially marshes distribute around estuaries and shoreline near Liaodong Bay. The vast marsh was called as 'Liaoze' in historical document during Han dynasty (BC 202~AD 220). These marshes, which are important for understanding the ancient human life, widely distributed along the lower reach of Liao River, near estuary, and tidal flat around Liaodong Bay. As the spatial distribution of 'Liaoze' is estimated to relate with the shoreline change since the middle Holocene, the shoreline near Liaodong Bay was reconstructed by phase in references to historical literatures and previous studies on geomorphic development of alluvial plain. It is assumed that the landward boundary of 'Liaoze' reached to 20~30m.a.s.l. from Heishan to Liaoyang during Han dynasty, which is coincided with the shoreline of maximum phase of transgression during 7,000 yr BP. And the coastal boundary of 'Liaoze' possibly reached to ca. 10 m.a.s.l. corresponding to the shoreline ca. 2,000 yr BP. The shoreline during ca. 5,000 years between maximum

phase of transgression and the period of Han Dynasty, was regressed 60~70km seawards. These velocity of regression is relatively very slow because the sediments supply along the Liao River was not enough, which is caused by weak human activities and well preserved vegetation cover. Therefore, the marsh environment could be strongly maintained in the Liaodong Bay during Han dynasty. The shoreline of Liaodong Bay was progressed seaward 30km/ka from ca. 1000 AD to early 20 centuries. These rapid regression velocity is presumed to be the result of an increasing human activities in the Liao River basin area.

**Keywords:** Liao River; marsh; the Liaodong Bay; spatial distribution of Liaoze; shoreline change

THEME: S34 : GEOARCHAEOLOGY (IAG-WG)

ABSTRACT NUMBER: 400

## OPTICALLY STIMULATED LUMINESCENCE DATING OF SHELL MIDDEN LAYERS FROM UMHLANGA ROCKS, NATAL NORTH COAST, SOUTH AFRICA

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Early Iron Age remains of shell middens are a critical archive for understanding past human activities in South Africa. Previous excavations at Emberton Way and Umhlanga Rocks, Natal north coast, have revealed ~1.5 m of stratified sands containing ceramics, stone artifacts, shells and shell fragments. In this study we present the results of Optically Stimulated Luminescence (OSL) dating of four unconsolidated coarse-grained sand samples and one sample from the upper midden layer collected from a new coastal natural exposure located at the Umhlanga Rocks in Natal north coast (South Africa), approximately 100 m from the shore. The samples were dated following the OSL dating method, using the Riso TL/OSL DA-20 reader. The OSL ages were obtained from chemically purified coarse grain quartz and a single-aliquot regenerative-dose (SAR) protocol was followed for the equivalent dose (De) determination. Also, the natural radioactivity of soil from the surroundings of the original sample location was assessed, using gamma spectrometry. The dose rates were calculated using the appropriate dose conversion factors and corrected for the humidity content of the surrounding soils. Our investigations of luminescence characteristics using various tests confirmed the suitability of the material for OSL dating. Ages, produced using the central age model, range from  $4.55 \pm 0.14$  ka to  $1.08 \pm 0.04$  ka, are in stratigraphic order (except one sample), and agree with independent age control from radiocarbon ages. This study demonstrates for the first time that OSL dating using quartz has great potential in this area, and is an appropriate method for establishing precise chronologies for coastal sediments in this region of the Natal north coast.

**Keywords:** Midden, OSL, Umhlanga, South Africa

THEME: S34 : GEOARCHAEOLOGY (IAG-WG)

ABSTRACT NUMBER: 532

## GEOARCHAEOLOGICAL APPROACHES TO THE PALAEOLITHIC SURFACE ARTEFACT DISTRIBUTIONS AND HOMININ LANDSCAPE USE IN SW SAUDI ARABIA

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The Palaeolithic record of the Saharo-Arabian belt occupies a key position in debates surrounding the dispersal of hominin populations from Africa, and the majority of artefacts are distributed across the surface of present-day landscapes. Whilst archaeological work has focussed mainly on the location of stratified, dateable artefacts, the surface record poses its own set of unique challenges and

opportunities for Palaeolithic archaeologists that are, in the main, bound up in the geoarchaeological context of these artefacts.

The SURFACE project examines the Palaeolithic record of SW Saudi Arabia through a geoarchaeological lens. Utilising remote sensing, geomorphological and archaeological survey, it employs an interdisciplinary approach to the region's important but under-researched Palaeolithic record, the landscape it is situated within, and its implications for our interpretations of hominin activity in these landscapes.

The locality of Wadi Dabsa, SW Saudi Arabia, has yielded >2000 Early and Middle Stone Age lithic artefacts recovered from the surface of tufa deposits in a basin headwaters. The richest recorded Palaeolithic site in SW Saudi Arabia, it has a major potential to inform on early hominin activity in its environmental setting. Multi-scalar geoarchaeological investigations were undertaken at the site in early 2017: remote sensing and geomorphological survey to develop a landscape stratigraphy and map surface sediment cover across the tufa exposure; systematic collection and recording of artefacts within a 100 m x 60 m area, and recording of their geomorphological context; targeted excavations to refine the relationship between the artefacts and tufa; collection of samples of basalt and tufa to constrain landscape evolution and provide palaeoenvironmental information. This paper will present the initial findings of the investigations and their interpretations, and will discuss the potential for the site to inform on early hominin activity in SW Saudi Arabia and its implications for global dispersals.

*THEME: S35 GEOMORPHOLOGICAL HAZARDS AND RISKS (IAG-WG): RISK MITIGATION TROUGH NEW TECHNIQUES UNDER THE CHALLENGES OF ENVIRONMENTAL CHANGES*

**ABSTRACT NUMBER: 186**

## **STUDY ON THE RELATION BETWEEN SEDIMENT-RELATED DISASTERS AND WEATHER CONDITION FACTORS**

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The extreme weather such as downpours causes sediment-related disasters, and residents incur the numerous damages. Japanese government takes computer software measures for such disasters, not only equipment measures. For example, they are the forecasting technologies which can evaluate sediment-related disasters risks in future. In the previous research, the risk has been estimated using risk line, which is generally call critical line (CL), constructed by hourly accumulated rainfall and the soil water index (SWI). However, that technology often mistakes occurrence/nonoccurrence of disaster, because this issue is treated as the categorization problem of occurrence/nonoccurrence.

This study should be analyzed by stochastic means since the disaster is not always occurred even if it is heavy rain. In this paper for those methods, the factors of atmosphere conditions were used, in addition to hourly accumulated rainfall and SWI. The frequency of occurrences (disaster rate) is calculated in each factor to investigate whether those are important in risk evaluation. Some data at districts in Japan were used from May throughout October in 2006 to 2014.

The disaster rate was compared to time-periods or districts. Consequently, the probability distribution for each factor was similar, though there are differences of peak values in hourly accumulated rainfall or SWI to a certain extent.

As a result, the disaster rate depends on neither terms nor districts. Therefore, the weather condition factors were effective for the sediment-related disaster risk evaluation.

**Keywords:** sediment-related disaster; weather condition factors; probability distribution; accumulated rainfall; soil water index

*THEME: S35 GEOMORPHOLOGICAL HAZARDS AND RISKS (IAG-WG): RISK MITIGATION TROUGH NEW TECHNIQUES UNDER THE CHALLENGES OF ENVIRONMENTAL CHANGES*

**ABSTRACT NUMBER: 451**

## **WOE MODEL BASED PREDICTION OF SUBSIDENCE OVER THE UNDERGROUND COAL MINES**

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Subsidence over abandoned or working underground mine results serious problems like fracture, tilting and deformation of ground



surface in the Raniganj coalfield of India. Present study aimed to predict the ground subsidence using Weights of Evidence (WOE) model based on Bayesian probability theorem. Fourteen parameters have been used from six broad subsidence influencing factors (geologic, geomorphologic, hydrologic, soil, LULC and mine related factors). 2m x 2m grid count is done in Arc GIS platform for the weight analysis among the dichotomous classes of each factor. Single predictor class is selected from the dichotomous classes by the studentized value of weight contrast (Difference between W+ and W-). Binary combination (percentage of intersection grid) among the predictor classes of all factor shows Rock Mass Rating (RMR) with the uniaxial tensile strength ( $\sigma = 25.6-27.2$ ), surface slope (1 - 2 degree), ground water depth (3.33 - 3.86m), buffer distance from flow accumulation (200 - 400m), Surface Soil (Silt Loamy Soil), LULC (Wasteland), maximum depth of coal mine (701 - 704m) are positive predictor and frequently combine each other to generate a subsidence. A subsidence hazard map has been produced by the overlay analysis of such positive predictor classes.

**Keywords:** Underground mining; Subsidence; Weights of evidence; Predictor class; Hazard map

*THEME: S35 GEOMORPHOLOGICAL HAZARDS AND RISKS (IAG-WG): RISK MITIGATION TROUGH NEW TECHNIQUES UNDER THE CHALLENGES OF ENVIRONMENTAL CHANGES*

**ABSTRACT NUMBER: 541**

## EVALUATING THE 4 NOVEMBER 2015 FLASH FLOOD DISASTER- A CASE STUDY IN WADI A-NATRUN AND WADI AL-FARIGH DEPRESSIONS, WESTERN DESERT, EGYPT

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Flash floods are among natural hazards frequently recorded in Egyptian deserts. By the November 4, 2015 a sever flash flood hit the northwestern part of the Nile Delta and surrounding desert margin in Wadi A-Natron and Wadi Al-Farigh Depressions. This event left large economic damage and fatalities. In the current study, field works have been carried out in disaster sites, namely in Wadi A-Natron and Wadi Al-Farigh. These allow a detailed observation of flood impacts. As well Landsat-based spectral indices and GIS change detection operations are utilized in quantifying damage. It is found that physical factors such as exceptional rainfall event and topography control flood runoff and inundation. Moreover, miss-land uses in the study area yields a disastrous flash flood.

**Keywords:** Flash floods; Desert; Inundation; Damage; Landsat; Spectral indices

*THEME: S35 GEOMORPHOLOGICAL HAZARDS AND RISKS (IAG-WG): RISK MITIGATION TROUGH NEW TECHNIQUES UNDER THE CHALLENGES OF ENVIRONMENTAL CHANGES*

**ABSTRACT NUMBER: 572**

## VULNERABILITY ASSESSMENT OF BUILDINGS TO DEBRIS FLOW THROUGH THE METHOD PTVA (PAPATHOMA TSUNAMI VULNERABILITY ASSESSMENT) APPLIED IN SERRA DO MAR, BRAZIL

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The PTVA method (Papathoma Tsunami Vulnerability Assessment) has been applied in different countries as United States, Austria, France and Germany to measure the physical vulnerability of risk elements to different natural hazardous events such as floods, shallow landslides and debris flows. In Brazil, the research related to debris flow, especially, is still in its early stages compared to the study of other processes, even generating significant socio-economic losses. In this sense, this study aims to identify the physical vulnerability of buildings exposed to debris flows in the city of Caraguatatuba (SP) located in Serra do Mar, a southeast Mountain range in Brazil, using the PTVA method. Follow methodological steps: a) Classification of deposits of debris flow; b) Selection of criteria that affects the vulnerability of buildings and systematization of the database; c) Multi-criteria evaluation (Simple Linear Transformation and Combined Linear Weight); d) Representation of the final vulnerability. As results were mapped 38 areas with a final vulnerability of 7.9% high, 68.4% average and 23.7% low. In this sense, a variation is observed of approximately 30% between the lowest vulnerability (55%) and the highest one (83%). Besides that, the absence of high walls surrounding most of the households mapped comes as the most important criteria increasing vulnerability. Given the need for more methods for risk assessments to debris flow in Brazil, it is believed that this research highlights the importance of recognizing the vulnerability scenarios, especially in landscapes as the Serra do Mar.

**Keywords:** Debris Flow; Vulnerability; Buildings; Serra do Mar.

THEME: S35 GEOMORPHOLOGICAL HAZARDS AND RISKS (IAG-WG): RISK MITIGATION THROUGH NEW TECHNIQUES UNDER THE CHALLENGES OF ENVIRONMENTAL CHANGES

ABSTRACT NUMBER: 691

## AN ASSESSMENT OF ADMINISTRATIVE BLOCK-WISE FLOOD VULNERABILITY INDEX IN THE ERSTWHILE DISTRICT OF JALPAIGURI, WEST BENGAL, INDIA

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The concept of vulnerability, like risk and hazard, indicates a possible adverse future state due to flood. Timmerman (1981) defined vulnerability as 'the degree to which a system, or part of a system, may react adversely to the occurrence of a hazardous event'. Vulnerability is used very differently throughout the literature pertaining to the studies of geohazards. There are three schools of thoughts of vulnerability definition. These are namely, i) those focus on exposure to biophysical hazards, including the analysis of distribution of hazardous conditions, human occupancy of hazardous zones, degree of loss due to hazardous events and analysis of characteristics and impact of hazardous events (e.g., Heyman et. al. 1991, Alexander, 1993); ii) those focus on social context of hazards and relate (social) vulnerability to coping responses of communities, including societal resistance and resilience to hazards (e.g., Blaikie et. al. 1994, Watts and Bohle, 1993) and iii) those, being the third school, focus on both of the above approaches. It encompasses biophysical risk as well as social response and action. (Cutter 1996, Weichselgartner 2001) The analysis of the vulnerability of any physical event is necessary for the proper management. Taking consideration of all schools of thought, in this paper the author tried to assess flood vulnerability with exposure, susceptibility and resilience indicator in the erstwhile flood prone district of Jalpaiguri, West Bengal, India. To fulfill the work successfully PCA and Z score like statistical methods has been adopted.

**Keywords:** vulnerability, exposure, susceptibility, resilience.

THEME: S35 GEOMORPHOLOGICAL HAZARDS AND RISKS (IAG-WG): RISK MITIGATION THROUGH NEW TECHNIQUES UNDER THE CHALLENGES OF ENVIRONMENTAL CHANGES

ABSTRACT NUMBER: 738

## FLOOD FREQUENCY ANALYSIS OF PACHNOI RIVER, ASSAM (INDIA)

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Flood is a relatively high flow which overtakes the natural channel and has the potential to cause loss of lives and properties. Flood control and flood management are necessary not only because flood impose a curse on the society, but also for the protection of land from degradation and management and control of water resource of the concerned area. For adopting any water resource development plans and flood control projects, it is very important to have knowledge about the probable magnitude of floods and their occurrences in the area. In this paper, based on recorded past events, useful predictions of future probabilities and risks of flood hazard of Pachnoi river in Assam are studied, which can be used in many engineering purposes viz. design of dams, culverts, bridges, flood control structure, to determine the economic values of various flood control projects, to delineate flood plain etc. This study of flood frequency analysis is carried out using different methods specially Plotting Position Method, Log Pearson Type-III Distribution and Gumble's Method to predict the future probabilities of flood in the drainage basin on the basis of past 26 years of recorded data. As flood frequency analysis guidance the expected behavior of future flood so, it has a great significance. Study of river basin is significantly important in the regional development and planning.

**Keywords:** Flood analysis, flood control, plotting position etc

THEME: S36 : GEOMORPHOSITES AND GEOTOURISM (IAG-WG)

ABSTRACT NUMBER: 420

## GEOMORPHOSITE RECOGNITION AND ASSESSMENT IN NORTHERN MALTA (MEDITERRANEAN SEA): A TOOL FOR SUSTAINABLE TOURISM DEVELOPMENT



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The Maltese archipelago, situated in the centre of the Mediterranean Sea, has a long and rich history of cultural heritage, rooted in the presence of ancient civilizations on the islands due to their strategic location. Additionally, over the past five decades, the Maltese Islands have rapidly developed into a popular tourist destination, especially sought after for outdoor activities such as sun-bathing, diving, hiking, and country-walking. These activities have particularly developed in the northern part of mainland Malta, encouraged by the presence of embayed sandy beaches, clear marine waters, and contrasting topographies nestled in a pristine natural landscape. When compared with the rest of the island, northern Malta is less intensively built up and thus still conserves remarkable geomorphological features.

The aim of this research is to demonstrate the relevance of this study area as a geomorphological and geological heritage site, through the use of current inventory and evaluation methods. The results show that northern Malta includes a significant number of geomorphosites, of great relevance for their scientific, additional and use values.

The ultimate goal of the study is to take advantage of these results and bridge them with current tourism promotion and geoconservation measures. This research offers an indispensable basic knowledge for enhancement activities to be carried out by public institutions responsible for the protection of the Maltese natural environment. Such measures are of current relevance, due to the fact that the Maltese Islands have the highest population density in Europe and annually receive a considerable tourist influx, which result in a high degree of human impact.

**Keywords:** Geomorphosites assessment; Sustainable tourism; Malta

*THEME: S36 : GEOMORPHOSITES AND GEOTOURISM (IAG-WG)*

**ABSTRACT NUMBER: 475**

## **GEOPARK OF TOBA CALDERA AS EDUCATIONAL ASPECTS OF GEOMORPHOSITES IN NORTH SUMATRA INDONESIA**

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Toba Lake is the largest tectonic volcanic lake in the world. In 2014, Toba Lake is designated as a national geopark of Toba Caldera by the President of Indonesia. Geopark of Toba Caldera is a geotourism in North Sumatra Province. It is also a favorite tourism destination in Indonesia. The research objectives are to explore the interesting site of Toba Caldera as educational aspects of geomorphosites, to identify the educational aspects that consist of moral, social, and economic values of geomorphocites, and to map the distribution of the geomorphosites in Geopark of Toba Caldera.

Remote sensing techniques were done to analyze landforms and geomorphological characteristics. Interpretation of landform units performed on screen digitation using techniques of Geographic Information System (GIS). Geological map analysis also was used to obtain the information of constituent materials of landform. The territory's cultural heritage was analyzed based on secondary data and field survey. Furthermore, qualitative content analysis was used to identify the educational aspects of geomorphocites.

The results show that Geopark of Toba Caldera has various geomorphosites. They consist of landforms and territory's cultural heritage. The distribution of the geomorphosites in Geopark of Toba Caldera are varied. However, the cultural heritage generally was find on Samosir island. The educational aspects of geomorphocites of Geopark of Toba Caldera consist of moral, social, and economic values. They were shown on Batak Toba culture. The moral values of Batak Toba people are steadfast and maintain honor. The social values of Batak Toba people are high kinship and upholding the legal value. The economic values of Batak people are tenacious and hard work.

**Keywords:** geomorphosites; geotourism; geopark; educational aspects; Toba Caldera

*THEME: S36 : GEOMORPHOSITES AND GEOTOURISM (IAG-WG)*

**ABSTRACT NUMBER: 626**

## **GEOMORPHOLOGICAL FEATURES OF ARUNACHAL PRADESH, INDIA: A CASE STUDY OF**



## TAWANG AND WEST KAMENG DISTRICTS (POTENTIAL GEOMORPHOSITES)

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The Tawang and West Kameng districts are located in the western part of Arunachal Pradesh. The major geomorphological landforms in the basin are denudo-structural hills, glaciers, valley fills, mountain passes, waterfalls, high altitude lakes, hot springs and snow covered areas. The Tawang and Kameng river basin are also very important for snow and glacier studies in the perspective of Climate Change. The wild life sanctuaries, apple orchards, orchidarium are the famous ecotourism sites for tourists. Adventure tourism like trekking expedition to Gorichen peak also very makes Tawang hot spot for mountain trekkers. The scenic beauty of the snow clad landscape, traditional handicrafts and the serenity of monasteries raises the spirit of the visiting tourists. The cultural, economical, ecological, aesthetic, religious, and ethnoheritage places the two districts in a advantageous position to be tagged as Geomorphosite.

THEME: S36 : GEOMORPHOSITES AND GEOTOURISM (IAG-WG)

ABSTRACT NUMBER: 653

## GEOMORPHOSITES AS A VALUABLE RESOURCE BASE FOR TOURISM DEVELOPMENT: A CASE STUDY OF JHARKHAND (PALIMPSESTS TOPOGRAPHIC MUSEUM IN INDIA)

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Geomorphologic features are immediately recognizable and represent most attractive non-living natural elements of the landscape. These landforms aroused people by their memorable shapes and unusual aspect. By value given by the people these forms become heritage, or a value. This value is given by its attributes and allows the landform to be declared a geomorphological natural value (Erhartic & zorn, -2012). Geomorphosites are those landforms that have scientific, cultural, aesthetic, ecological and /or economic value.

The plateau region of Jharkhand is an ancient landmass and designated as palimpsests topography in the geomorphic realm. Erosion has very effectively changed the face of the area. The granite-gneiss core has been exposed and the landscape has been reduced the ridges. With increased energy the rivers have engraved new features within the sharply uplifted belts of plateau presenting a great contrast to the remainder of the landscape. It has diversified the topographic expression marked by rejuvenated features of landscape.

The area records a complicated geological history pregnant with geomorphic problems where facts are buried in erosion intervals marked by unconformities, the correct interpretation of which can often only be made by analogy and close study of buried landscape and existing morphology. The variety of geological formations of the area presents numerous topographic expressions. Granite and gneiss topography dominates most of the landscape and widely differs in profile from the flat topped topography of the volcanic Rajmahal and Netarhat area. The Dalma lava flows presents a different kinds of landscape. Thus the region is a great inequalities having plateau of different elevations and intermontane valleys of varying girth and volume presenting diversified geomorphosites which may be utilized as resource base with developing geotourism. The aim of this paper to enhance geotourism.

**Keywords:** Palimpsests; Unconformities; Rejuvenated landscape; Engraved; Entermontane valleys

THEME: S36 : GEOMORPHOSITES AND GEOTOURISM (IAG-WG)

ABSTRACT NUMBER: 786

## THE GEOMORPHOSITES OF LEFO AND SANTA-MBU CALDERAS (BAMENDA VOLCANO, CAMEROON VOLCANIC LINE): ASSETS FOR POTENTIAL GEOPARK DEVELOPMENT

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Several volcanic apparatus are found in the Cameroon Volcanic Line. Bamenda Volcano is one of the most voluminous apparatus in this structure. It is a stratovolcano situated precisely between Bambouto and Oku volcanoes. Its summit present two main Neogene ignimbritic calderas: Lefo (elliptical in shape (4x3 km), opened to the south-west of the volcano) and Santa-Mbu (elliptical in shape (10x5 km), opened to the west of the volcano). Both calderas present interesting geotouristic assets. These assets are made up of numerous geomorphosites namely trachytic domes and ramparts, valley and lake. These geomorphosites have been selected and assessed through field and laboratory studies. It emerges that the average scientific value of the geomorphosites is high; because they are well preserved, rare and representative of the local geomorphology. They also play significant role for Bamenda volcano's geographical history in the way that they modified the previous natural and rural landscapes. Although they did not play cultural role, their ecological and aesthetic value that have been qualitatively assessed are high. There are not sound nuisances around the majority of geomorphosites. The rareness of high vegetation or infrastructures gives rise to several panoramic viewpoints of geomorphosites. Besides, these sites have meaningful features that can be described for geotourists so that they can learn about their evolution or operating. Lefo and Santa-Mbu calderas appear as an utmost geotouristic destination. Geotourism could increase the number of tourists in Cameroon and could be an opportunity for rural development in alleviating poverty and rural migration. In order to improve tourist offers and raise the Lefo and Santa-Mbu calderas in geopark in the future, some recommendations have been suggested:

- popularisation of geomorphosites through field trips, leaflets, websites, conferences;
- establishment of interpretative panels around each geomorphosites;
- development of tourism infrastructures such as hotels/inns and restaurants.

THEME: S37 : DANXIA GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 58

## RESEARCH ON AESTHETIC CHARACTERISTICS AND LANDSCAPE VALUE OF THE DANXIA LANDFORMS IN LANGSHAN, HUNAN PROVINCE, CENTRAL CHINA

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In the light of both geological and landform maps of different periods and data from in situ investigation, the authors analyzed aesthetic characteristics and landscape value of the Danxia landform scenery in the Langshan Landscape and Famous Scenery, a member of the World Natural Heritage Inventory, Hunan Province, China, with the perspectives of geology, geomorphology and landscape aesthetics. Primary conclusions are drawn as follow: 1) Due to the extensive terrestrial red clastic rock facies (i.e. conglomerates and sandy conglomerates) of Late Cretaceous (90-65 million years B.P.) with well-developed reticulate vertical joints, the Danxia landform scenery in Langshan exhibits splendid and marvelous landscape and surprising aesthetic attraction. Meanwhile, Langshan is located in a subtropical moist climate region with abundant rainfall, where soil erosion by water and collapses by gravity are active and intensive, accommodating performance arenas and exterior driving forces for development of Danxia landform scenery. 2) Aesthetic characteristics of the Danxia landforms in Langshan lie in four aspects as follow: beautiful morphology, embodied by steep cliffs and precipitous peaks, various figures of personage, animal and other natural object, peculiar scenery arrangement, differing in size, shape, density, orientation, etc. with delivering feelings of layering and rhythm, harmonious color, either in bright red or obscure dark brown, and impressive artistic conception, characteristic of grandeur, precipitousness, peculiarity and elegance. 3) Rivulets of different length flow among peaks of the Danxia landforms, building an amazing landscape along with rivers, peaks, forest, and cave with splendid colors and shapes. Thanks to its gorgeous, delicate, natural and graceful scenery, charms of Danxia landform in Langshan accord with the feelings and mentality of people such as curiosity, sense of adventure, beauty appreciation and pursuit of peculiarity, whereby in turn increase their development value in tourism.

**Keywords:** Langshan; Danxia landforms; aesthetic characteristics; landscape value

THEME: S37 : DANXIA GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 222

## THE CHARACTERISTICS OF DANXIA GEOMORPHOLOGY AND SOCIAL APPLICATION IN HEYUAN, GUANGDONG

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The Danxia geomorphology is widely distributed in China, especially in Guangdong province. It is of great practical significance to study the Danxia geomorphology and its development and utilization. The landscape characteristics and social value of Danxia geomorphology was studied in this paper, taking mount Yuewang's Danxia geomorphology in Heyuan City as the research object, at the manner of field investigation and historical data mining. The preliminary results are as follows: (1) The forming conditions, types, distribution features and natural landscape of Danxia geomorphology in Heyuan city was expounded. (2) The landscape elements, distribution patterns and landscape features of Danxia geomorphology was discussed, and the peculiar characteristics, combination structure and ornamental value of Danxia landscape and natural coupling was analyzed. (3) According to the present situation of the development and utilization of the landscape of Danxia scenic area, the relationship of Danxia geomorphology resource protection and tourism development and utilization, the effect of artificial landscape modeling and landscape structure design to the natural landscape was explored. (4) The natural landscape culture of Danxia geomorphology was investigated from the multi-disciplinary perspectives of geography, geology, geomorphology, hydrology, biology and so on, aim at the needs of youth popular science education, teaching practice and popular science tourism, the connotation of Danxia geomorphology natural landscape culture was extracted hierarchically. The research results can provide the basis for government decision-making, and provide reference for the development and protection of Danxia landscape.

**Keywords:** Danxia Geomorphology; peculiar characteristics; ornamental value; The natural landscape culture; popular science education; tourism development and utilization

THEME: S37 : DANXIA GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 255

## CHARACTERISTICS AND SPATIAL-TEMPORAL DISTRIBUTION OF SOIL EROSION IN SHENZHEN

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Based on the integration of GIS, RS, GPS and Environmental radionuclides technology, the soil erosion in Shenzhen was predicted and analyzed. The results indicated that soil erosion area of Shenzhen occupies almost 10% of the total land area of the city, the average soil erosion module was  $675 \text{ t} \cdot \text{hm}^{-2} \cdot \text{a}^{-1}$ , mild erosion was the main erosion grade. The most serious area of soil erosion in Shenzhen was farmland on more than  $9^\circ$  slope in Bao'an District and Longgang District. The soil erosion in mining area should be taken seriously. Soil erosion was mainly constrained by soil structure, rainfall, elevation, slope and other natural conditions. Excessive human activities have accelerated the urban soil erosion.

From the analysis of the dynamic changes of soil erosion, the majority of soil erosion in Shenzhen in the 1980s was mainly caused by natural erosion. In the early 1990s, the area of soil erosion increased, the intensity of soil erosion increased greatly. In the late 1990s, the number and proportion of severe soil erosion areas decreased significantly. In 2010, the area of the general erosion and the severe erosion decreased, and the soil erosion was effectively controlled.

The soil erosion in Shenzhen has a wide distribution area and exacerbated by severe human disturbance, with relatively concentrated runoff and sediment and severe erosion intensity. Land development and steep farmland are the main factors that influence urban soil erosion. After nearly 30 years of reform and opening-up policies in Shenzhen, the rapid urbanization accelerated the urban soil erosion. Therefore, projects for soil and water conservation should be implemented as a significant strategic measure, such as returning steep slopes into forests and grasslands, and other ecological management reforms.

**Keywords:** Shenzhen; Soil erosion; Spatial and temporal distribution

THEME: S37 : DANXIA GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 294

## MORPHOLOGICAL CHARACTERISTICS OF DANXI LANDFORM IN QINGHAI-TIBET PLATEAU

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Fifteen Danxia landforms were surveyed in Qinhai Province and Tibet Autonomous Region in June 2014. Three Danxia landforms were discovered for the first time through this investigation, which are located in Garang town of Guide County, Hebei town of Tongde County and Jinisai town of Guide County, respectively. Generally, the Danxia landforms present the following characteristics: 1) The Danxia landforms have obvious vertical distribution characteristic, which are distributed from altitude 2200m (Guide County) to 4500 m (Biru County) with an area between 1.0 and 100 km<sup>2</sup>, and the rocks of the Danxia landforms are mainly glutenites in the period of Jurassic, Cretaceous and Tertiary. 2) The geomorphic development level of the Danxia landforms have inverse relationship with the altitude. There are obvious red precipices and flat tops below the altitude 3500 m, but the red precipices are not clear above the altitude 3500 m with only ridgelines in these Danxia landforms. 3) The relative height of Danxia Mountain is influenced by the regional water undercutting action, and it reaches 500 m on the Tongde County Jiashidan Danxia groups along the coast of the Yellow River, Changdu City Danxia groups along the Lancangjiang River, Jue'en village Dingqing County Danxia groups along the Nujiang River.

**Keywords:** Qinghai-tibet Plateau; Danxia landform; Geomorphic development

THEME: S37 : DANXIA GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 295

## THE PRELIMINARY STUDY OF MICRO DANXIA GEOMORPHOLOGY

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Danxia geomorphology refers to Continental red beds landforms with steep cliffs. A large number of fissures and joints occurred in the red beds of the Tertiary sandstone and shale under the action of tectonic movement and intermittent uplift, the Danxia geomorphology with the typical topography of " flat top, steep cliff and gentle slope of Piedmont " was formed under the action of water and gravity erosion, et al. Most of these areas are landscape and famous scenery, geoparks, nature reserves, forest parks, and the world natural and cultural heritages. The micro geomorphology formed by different exogenic actions was studied in this paper. 1) The horizontal rock groove, the cave and the faveolate cave group with a variety of shapes and directions, rock column, and 0 rock egg was formed under the characteristics of the lithology and weathering. 2) The pothole, parallel rill, incised meander, sand and mud ridge, stone step, mini waterfall, water curtain cave and rift was formed by water erosion. 3) Cone of collapse, natural arch, lune shaped recess formed by gravity erosion. 4) The stone buds, melting groove Stalactite, stalagmite and travertine formed by Karstification. 5) The color diversity on the rock face, differential weathering effected by lower plant. 6) Sea cliffs and caves formed by wave action. 7) Rock caves and niches formed by wind erosion. 8) Stone cavern, cliff, grotto, stone carving and clay sculpture formed by human activity (quarry and inscriptions on precipices). 9) The varied forms of pictographic stones (personage, animal, plant, legend image, utensil, ornament, food, building, other natural object) formed by the combined effect. The micro geomorphology is mainly formed in the later period of the development of Danxia geomorphology, which enriches the types of Danxia geomorphology, and increases the observability of landscape.

THEME: S37 : DANXIA GEOMORPHOLOGY (IAG-WG)

ABSTRACT NUMBER: 305

## THE PROBLEMS OF REDBEDS DESERTIFICATION IN THE HUMID REGION OF SOUTHERN CHINA

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The land degradation of redbeds land is a serious environmental and socioeconomic problem in China nowadays. The redbeds area covers about 9% of China, whereas it resides about 144 million people, 83% of which distribute in humid regions, the research on red beds soil erosion in China should focus on the humid region. We conclude that extreme land degradation in sub-humid and humid regions should be classified as desertification by reviewing the development of domestic and foreign concepts, and past research of desertification. Due to the lithology of the soft redbed rocks, along with excessive resource exploitation by humans and the humid climate, a kind of special desertification occurred in redbed regions in Southern China. As preliminary research concerning redbeds desertification, we put forward the concepts of redbed deserts and redbed desertification. We as well elaborate on features of

desertification developing in redbed regions, such as landform features, ecological features, and soil features. Then, utilizing Nanxiong Basin as a case study, the spatial patterns of redbed desertification and the patterns of desertification at the basin scale are analyzed. The process of redbed desertification begins as spotty uncovering, and then develops into patches. Redbed desertification has mostly occurred on hills formed of soft rock in the central parts of the basin. Based on the field work, the mechanism of redbed desertification is discussed from the aspects of lithological features, natural impacts, and human activities. The triggers of redbed badland desertification are complex, but mainly are impacted by activities such as, severe reclamation, forest fires, tree planting disturbances, dry-land degradation, acquirement of topsoil, and so on. Once redbeds are exposed, the extension of the desert region can be caused by both nature and human activities.

**Keywords:** redbeds desert; desertification in humid region; redbeds soft rock; Nanxiong Basin

*THEME: S38 : EXTREME EVENTS IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 26**

## **MAPPING EARTH TREMOR VULNERABILITY IN NIGERIA**

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The Earth is a combination of inhomogenous natural systems which occurred uninterruptedly before the existence of human beings. To determine the vulnerability of the Earth tremour in Nigeria a Geospatial Technique was used to carry out the investigation. A total of 15 earth tremour have been recorded in Nigeria at the time of study which includes: Ijebu Ode, Ijebu Remo, Kurba, Osun, Akko amongst others. The major results of the study includes production of Earth tremour locations, maps, settlements vulnerable to the earth tremour points, the Ifewara-Zungeru fault line; which runs across Nigeria, from southwest through Niger to Northwest part of Nigeria.

**Keywords:** Earth Tremor, Mapping, Nigeria, GIS

*THEME: S38 : EXTREME EVENTS IN GEOMORPHOLOGY*

**ABSTRACT NUMBER: 95**

## **EXTREME GEOMORPHOLOGICAL EVENTS IN THE BAIKAL REGION**

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An analysis is made of the manifestations of fluvial and aeolian processes in the southern, developed areas of Irkutsk oblast belonging to the upstream part of the Angara basin. We examine the formation probability and the recurrence frequency of disastrous geomorphological events. The study revealed their association with positive (fluvial processes) and negative (aeolian processes) extremes and anomalies of atmospheric moistening. It is shown that at the time of an extreme event the rate of the processes and the volumes of transported material increase abruptly (by an order of magnitude), and the affected areas show an increase. The criteria for an extreme fluvial event can be represented by a spasmodic buildup of gullies and appearance of new gullies, an abrupt increase in soil losses due to erosion of agricultural lands reaching 100–200 m<sup>3</sup> ha<sup>-1</sup>, death of crops, releases of mud streams, and destruction of roads, dams, bridges and other structures. The geomorphological consequences of the 1960 summer storm rains are considered to exemplify the disastrous fluvial events. The extremes of aeolian processes have the character of hurricanes encompassing most of the agricultural areas of Irkutsk oblast. The hurricanes are accompanied by a powerful removal of aeolian material from north-west to south-east to the water area of Baikal, to windward slopes and watershed divides of the mountain ranges along the eastern coast. The finest dust particles are transported to neighboring areas of Buryatia, Mongolia and China. The negative consequences of extreme aeolian events include agricultural crop destruction or damage, soil deflation, pollution of surface waters by deflation products, fires, damage to power transmission lines or even death of people. The findings were used in zoning the Baikal region according to the degree of geomorphological security of the territory.

**Keywords:** disastrous geomorphological events; deflation; soil erosion; mud streams; Baikal.



ABSTRACT NUMBER: 677

## CALIBRATION AND EVALUATION OF FLOOD FORECASTING USING WRF-HYDRO SYSTEM

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WRF-Hydro is a community-based hydrologic and hydraulic modeling environment used in assessing the flood potential by employing multiple physics-schemes across geographical scales, based on inputs derived from the Weather Research and Forecasting (WRF) model and the Tropical Rainfall Measuring Mission (TRMM). The impacts of TRMM and WRF precipitation estimates on WRF-Hydro simulated stream flow are compared, both with and without data assimilation. The ten rainfall-runoff events that occurred in the Kumari basin, India were used for testing and evaluation. The calibration is performed on the Kumari sub-basin using two such events with the available stream flow data across rainfall-runoff events and the calibrated parameters are then transferred to other neighbouring three un-gauged sub-basins in the study area. The rest of the events from all sub-basins are then used to evaluate the performance of the WRF-Hydro system with the calibrated parameters. Thus the WRF-Hydro model could be calibrated to reproduce the observed flood hydrographs efficiently in terms of the volume of the runoff produced and the overall shape of the hydrograph. The performance of the simulation could be significantly improved through assimilation of data using 3DVAR scheme to predict stream flow accurately. Substantial dry bias feature of TRMM leads the data to perform poorly when compared with data from surface rain-gauges. Overall, Root Mean Squared Errors (RMSE) for runoff was reduced by 23.9% when hydrological model calibration is performed with WRF precipitation. Errors were reduced by 43.6% (above un-calibrated model performance) when both WRF model data assimilation and hydrological model calibration was utilized. Results from the current experiment also indicates that when data assimilation and model calibration is performed jointly, the calibrated parameters at the gauged sites could be successfully transferred to un-gauged neighbouring basins where WRF-Hydro could reduce the mean RMSE from 9.38 m<sup>3</sup>/s to 7.25 m<sup>3</sup>/s.

ABSTRACT NUMBER: 104

## PROGETTO GEOSOGIE: INTEGRATED STUDIES ON RAINFALL THRESHOLDS AND SUSCEPTIBILITY TO LANDSLIDES IN SARDINIA (ITALY)

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Sardinia is the second largest island of Italy having an area of about 24,000 Km<sup>2</sup>. It dwells in a relatively central position in the West Mediterranean Sea, shows a typical Mediterranean climate and it is a geologically and morphologically variegated region. Sardinia is sparsely populated (it hosts only 1,600,000 inhabitants, with an average population density of 69 people per Km<sup>2</sup>) however, recently, the frequency and intensity of catastrophic flood and landslide events appear to be increased. This is probably due to both environmental and anthropic changes, such as climate and traditional land-use changes, related to incorrect territorial planning policies. Spontaneous building of main cities fringe areas led to rural land abandonment and consequently to a lack of territorial presidium. The results are intense deforestation, forest fires, soil erosion and land degradation.

The Civil Defence System is delegated to RAS (Regione Autonoma della Sardegna) and CFD (Centro Funzionale Decentrato) represents the sardinian node of the National Civil Defence network. CFD daily deals with weather forecasting and with on-land effects of rainfall.

CFD currently suffers of a significant lack of both updated landslides database and detailed environmental data. As a matter of fact, rain thresholds currently exploited for daily risk analysis activities derive from a national level dataset, therefore do not reflect the specific sardinian territory peculiarities. Furthermore the so-called warning areas are too wide to be considered homogeneous.

This project aims to define appropriate warning areas and associated critical rainfall thresholds as triggering factors for shallow landslides. A detailed analysis of main landslide events during the last 20 years has been planned to produce rainfall threshold possibility curves.

Environmental maps will be collected to produce the susceptibility map by means of a mixed approach, both deterministic and physical, using geomatics, field surveys and available data collection.

**Keywords:** geomorphological risk; rainfall thresholds

ABSTRACT NUMBER: 513

## IMPACT OF PRECIPITATION AND LAND USE CHANGES ON SOIL EROSION IN SMALL CARPATHIAN CATCHMENT

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Intensity of soil erosion is mainly depends on land use and land cover changes (LULC), soil properties, heavy rainfalls and slope gradients. The aim of the study is to calculate and evaluate the soil erosion changes related to precipitation and LULC changes in Homerka catchment within the last 150 years. Various methods were used, including GIS analysis of historical and contemporary data and modeling Revised Universal Soil Loss Equation (RUSLE). In the 19th century, the Polish Carpathians and also Homerka catchment were typically agricultural and economically backward areas. Individual small farming continued in the ownership system following the World Wars and involved a gradual withdrawal from agriculture, just before the collapse of communism and during the early stages of the free-market economy. The analysis of LULC in Homerka catchment between 1846 and 2009 indicates an increase in the forest area by 58% and a decrease of cultivated land by 92%. The grasslands did not change significantly in their area. On average soil erosion in the study area decrease by 85%. While both LULC and precipitation changes took place in Homerka catchment, changes in LULC have a much larger impact on soil erosion.

**Keywords:** land use changes, precipitation, soil erosion, RUSLE, mountain catchment, Carpathians

ABSTRACT NUMBER: 527

## THE IMPACT OF LAND USE ON STREAM CHANNELS IN THE MARGIN OF THE DARJEELING HIMALAYAS IN INDIA

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Two headwater catchments (19-24 km<sup>2</sup>) and two catchments with outlets in the foothills of the Darjeeling Himalayas (72-81 km<sup>2</sup>) were selected. Each of these pairs contains forested (>97% forest) and agricultural (<63% forest) catchment for comparison of the impact of land use on the discharge, morphology and sedimentology of stream channels. The selected catchments have similar annual rainfalls (~5000 mm), lithology (deep weathered metamorphic rocks) and soils (sandy loam and silty loam brown soils). It was hypothesized that the streams in the agricultural catchments would have significantly higher runoff and discharge, wider channels and finer sediment than the stream in the forested catchments. A set of cross-sectional data was collected for characterization of the hydrology, morphology and sedimentology of the stream channels. The majority of the runoff, discharges, morphological parameters and sediment patterns do not differ significantly (at the 0.05 probability level) between the headwater channels in the agricultural and forested catchments. These results have shown that the headwater areas are mainly controlled by a combination of natural factors such as: extreme rainfall, permeable regolith and high drainage density that predispose subsurface flow formation. Moreover landslides that deliver both large blocks and fine material to the channels can locally determine channel gradient and geometry and can mask the impact of cultivated fields on sediment patterns. In contrast, consistent and significant differences in morphological parameters and sediment patterns are demonstrated by the channels in the agricultural and forested catchments with outlets in the foothills of the Darjeeling Himalayas. The differences are most likely the effect of the low river slope which facilitates deposition of fine material eroded from cultivated fields in the mountains as well as the lower intensity of natural hazards such as landslides.

**Keywords:** extreme rainfall; channel morphometry; sediment pattern; small catchments; land use

ABSTRACT NUMBER: 32

## TERRAIN ANALYSIS USING GEOMORPHIC AND SEDIMENTARY INDICATORS ; A CASE STUDY OF HAZARIBAGH PLATEAU , JHARKHAN, INDIA

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A geomorphic unit e.g. Barakar drainage basin which flow over Hazaribagh plateau is extended inside latitude: 23040'00"N to 24030'00' N & longitude: 85015'00"E to 860 50'00"E. The major objectives of research are-- Terrain analysis on the basis of digital geomorphometry, drainage pattern and heavy mineral analysis. To draw above objectives Digital Elevation Model (DEM) has been generated with twenty two CARTOSAT Stereo pair data. DEM data has been utilized in morphometric analysis. Sinuosity index of Barakar river e.g.1.80 tells that river has meandering course with abundance of sand bar deposition. Over all Stream frequency, Drainage density, Drainage texture and Infiltration rate for Barakar river basin are 0.95, 1.26, 1.11 and 1.20 respectively. Drainage density and stream frequency of Barakar river basin are very low which indicates that the relief is mature and permeability is moderate. The drainage texture of Barakar river basin indicates that basin has low relief, gentle slope and old stage topography. Barakar basin's Form factor, Circulatory ratio and elongated ratio are 0.20, 0.24 and 0.28 respectively. Barakar basin has dendritic to sub dendritic drainage pattern which suggests that the basin has homogeneous lithology, impermeable rock, horizontal bed, and gentle regional slope and lack of structural control. Erosion surfaces, existing literatures and field verification suggests about glaciations in Permo- Carboniferous period. Very little evidences are preserved in upper part of Sukna fault valley in the form of Talchir boulder beds, Giridih Gondwana sedimentary basin.

In the present work heavy minerals are studied in the different lithofacies of depositional geomorphic units of Barakar River. The heavy minerals are dominantly angular to sub-angular indicating their derivation from primary igneous rocks and metamorphic rocks. The ZTR index for most of the studied samples lies below 45% indicating low sediment maturity.

**Keywords:** Terrain Analysis, DEM, Geomorphometry, drainage pattern ,Heavy mineral

ABSTRACT NUMBER: 438

## CONTROLS OF ANTHROPOGENIC ACTIVITIES ON THE STREAM POWER DISTRIBUTION OF THE DAMODAR RIVER, INDIA

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The anthropogenic activities are the external controlling factors that affect the fluvial processes severely. The stream power that is the primary contributing factor for erosion and deposition at the river channel bed as well as the bank and it is also influenced by the artificial construction and the natural configuration of the river. The Damodar River originates from the Peninsula India and flows through the plateau and plain region, is influenced by several human activities. The Damodar River runs through the coal-mining, and industrial region of eastern India and the middle section (~180 km) of the river is taken for the study. This section of the river is mostly altered by several human activities such as dam construction, sand mining, industries and coal mining. The morphological variation or the alteration of the river through the anthropogenic activities has been analysed by the stream power distribution over the section. For the estimation of stream power distribution, the flow velocity is used, and it is generated from eleven sites the middle section of the river. The longitudinal profile and channel or bed slope have been generated using SRTM DEM which is authenticated by the GPS points in the field and the Topographical sheets. The stream power distribution of the artificially controlled section is characterised by downward increase of stream power with some exceptionally increase due to bedrock reaches and dam and barrage constructions. Multimodal stream power distribution of the river reflects several energy alterations due to the dominance of human activities. Various human activities produce some irregularities in slope and channel flow that results in the stream power as well as erosional and degradational processes of the river.

**Keywords:** Anthropogenic activities; Stream power; Slope; Discharge; Coal Mining and Industry

THEME: S40 : YOUNG GEOMORPHOLOGISTS' SESSION

ABSTRACT NUMBER: 578

## QUATERNARY DOME-LIKE RELIEF IN THE NORTHERN PARAÍBA BASIN, NORTHEASTERN BRAZIL

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Previous geomorphological investigation in the Paraíba Basin, northeastern Brazil, suggested the presence of at least three main sets of dome-like reliefs. These features trend in the NNW-SSE direction and are located in terrains of Quaternary deposits displaying altimetric values higher than adjacent Precambrian basement terrains. Such characteristics suggest that the Paraíba Basin was affected by a recent tectonic deformation that resulted in basin inversion possibly due to folding, as verified in other basins of northeastern Brazil. The detailed morphological characterization of the dome-like reliefs from this basin has the potential to contribute to test this hypothesis. In this work, we characterized the Quaternary dome-like reliefs of the northern Paraíba Basin aiming to provide new information that can be used to demonstrate that a process of basin inversion occurred in this South American passive margin in a relatively recent geological time. The regional topographic pattern of the study area was analyzed based on four 5 km-wide swath profiles derived from a 1 arc-second digital elevation model. The swath profiles included statistical information that combines elevation and local relief. These profiles had asymmetric patterns in the west-east direction, with convex elevation curves around the dome structures. The low depths of the upper quartile of elevation detected in areas adjacent to these structures are compatible with a young relief. In addition, the local relief values were higher over the dome areas, a possible indicative of higher incision rates, which was interpreted as due to installation of drainage networks after uplifting. The radial to recurved drainage pattern of these uplifted areas is consistent with the proposed tectonic control. Together with the geological framework of the study area, the results presented herein leads to claim that neotectonic uplift produced the dome-like reliefs of the northern Paraíba Basin.

**Keywords:** Dome-like relief; Folding; Quaternary deposits; Remote Sensing.

THEME: S40 : YOUNG GEOMORPHOLOGISTS' SESSION

ABSTRACT NUMBER: 781

## APPLICATION OF SWAT AND GEOWEPP MODEL IN PREDICTING THE IMPACT OF STONE BUNDS ON THE GEOMORPHOLOGY, RUNOFF AND EROSION PROCESSES IN ETHIOPIAN HIGHLANDS

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Land degradation is a serious problem in the Ethiopian highlands. Heavy rainstorms during the rainy season in summer create soil erosion which affects soil fertility and food security. To tackle this problem soil and water conservation is considered top priority to maintain the natural ecosystem. Massive effort is being made in soil conservation strategies by the community of Ethiopia. However, the effectiveness of soil and water conservation on the dynamics of the stream flow and soil loss is not studied for long and short term effects. Two adjacent watersheds, Abakaloye and Ayaye, were selected for this study. The Abakaloye and Ayaye watersheds show severe soil erosion problems which show itself in the development of deep gullies. Soil and water conservation structures (SWC) were applied in the Ayaye watershed, as the construction of gabions within the gullies and stone bunds in the farm lands. Abakaloye was used as a reference without SWC. The objective of this study is to assess the impact of stone bunds on the geomorphology and erosion processes by using simulation models and to compare the performance of ArcSWAT and GeoWEPP soil erosion models for both watersheds. Land use map was evaluated based on satellite images and ground truth data. Digital Elevation Model was developed based on conventional terrestrial surveying using a total station. At the outlet of the watersheds weirs with cameras were installed to measure surface runoff. During each event runoff samples were collected and sediment concentration was analyzed. The simulation models were calibrated for the 2011-2013 periods and validated with 2014-2015 data. Results of this comparison will be presented.

**Keywords:** Soil and water conservation structure (SWC), ArcSWAT, GeoWEPP, watershed, Ethiopia







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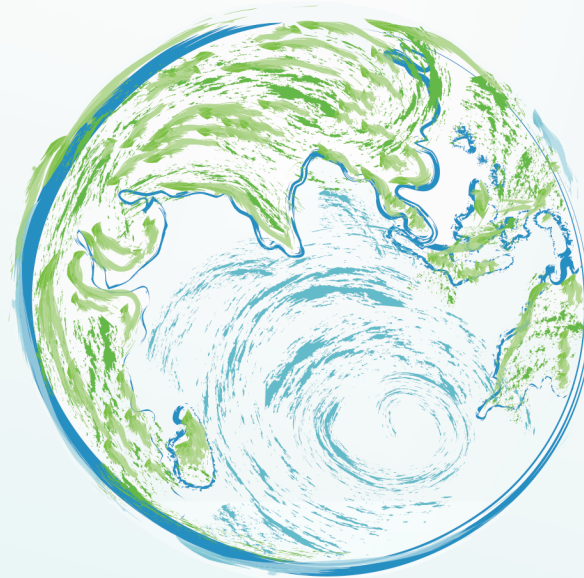


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