

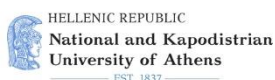


Abstract book

IAG Regional Conference 2019 Geomorphology of Climatically and Tectonically Sensitive Areas

19-21 September 2019
Athens, Greece

National and Kapodistrian University of Athens



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HAROKOPIO UNIVERSITY

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**GEOMORPHOLOGY OF CLIMATICALLY AND
TECTONICALLY SENSITIVE AREAS**

ABSTRACT BOOK

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Preface

The Regional Conference on Geomorphology “GEOMORPHOLOGY OF CLIMATICALLY AND TECTONICALLY SENSITIVE AREAS” (RCG2019) was held from 19 to 21 September 2019, in Athens (Greece), at the Historical Building of the National and Kapodistrian University of Athens. The main objectives of the conference were to a) meet the new challenges for geoscientists and especially geomorphologists to better understand the response of the Earth system, b) to approach with new techniques and methods, c) to make new assessments and predictions for the future, d) to contribute to society’s adaptation and preparedness, e) to promote interaction and networking among and with young geoscientists.

The abstracts’ volume of this conference includes the 214 abstracts accepted for oral (125) and poster (89) presentations. The abstracts were distributed in the 14 scientific sessions covering a variety of geomorphological topics and environments. Four keynote lectures were delivered during the conference by Dr. Emmanuel Reynard, Dr. Taylor Perron, Dr. Andreas Vött and Dr. Piotr Migon.

I would like to express my gratitude to the members of the Organizing committee for dedicating their time to the organization of the conference.

On behalf of the Organizing Committee, I wish to express my warm thanks to the International Association of Geomorphologists (IAG) and its Executive Committee for putting their trust in the Greek Committee for Geomorphology & Environment of the Geological Society of Greece.

Niki Evelpidou,

President of the Organizing Committee

Regional Conference on Geomorphology – Athens 2019

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S01. ADVANCING THEORY AND MODELING OF RIVER SYSTEMS

THE PREDICTION AND SPATIAL DISTRIBUTION OF WETLANDS IN ESWATINI (SWAZILAND)

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The Kingdom of Swaziland (now Eswatini) joined the Ramsar Convention on 15 June, 2013 and currently has only three wetland sites designated as Wetlands of International Importance (Ramsar Sites). In spite of Swaziland becoming a signatory to the Ramsar Convention, the country's wetlands are heavily over utilized and undermanaged. There is a dearth of knowledge relating to all facets of wetlands in Swaziland. The country does not have its own definition for wetlands, but rather has adopted the definitions from the Ramsar Convention. The country does not at present have a meaningful wetland inventory. South Africa has recently released their fifth version of their national wetland map. Instead of using Remote Sensing techniques to map wetlands, (which were used for previous editions of the map) an approach based on fine-scale on-screen digitizing was used. Additionally, the use of a wetland probability mapping technique was utilized. This paper applies the recent mapping, prediction and classification techniques used in South Africa to Swaziland, and determines the distribution of wetlands and wetland types for the country. The study used the approach outlined to map all the watercourses in Eswatini, and proceeded to use environmental variables to differentiate true wetlands from other watercourses, as well as to classify wetlands according to hydrogeomorphic principles. Given that Eswatini is a relatively small country and is underlain by rocks ranging in age from the Archean to the Phanerozoic era (3500 Million-300 million years old), and ranges in elevation from over 1800 m.a.s.l. to under 100 m.a.s.l., wetlands across the country were found to vary considerably, with their distribution relying heavily on geomorphic controls. The results of this research can provide a baseline data set for the Swaziland National Trust Commission when developing Swaziland's National Wetland Policy.

Keywords: Wetlands; hydrogeomorphic units; probability mapping

RESTORATION AND RECONNECTION OF DECAYED RIVERS IN WESTERN GANGES DELTA TO IMPROVE FRESHWATER AVAILABILITY IN THE INDIAN SUNDARBANS

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The Indian Sundarbans is a part of the world's largest mangrove ecosystem and located in the south western part of Ganges delta. The region is crisscrossed by the distributary network of the river Ganges. However, most of the distributaries have been disconnected from the Ganges system and decayed, therefor do not get freshwater flow from upstream. The decayed river channels have been converted into ponds, agricultural fields or aquaculture farms and have also been encroached by settlements. Unavailability of freshwater restricts downstream ecosystem services of the rivers. Restoration of these decayed channels may revitalize the river network and enhance the freshwater flow- dependent ecosystem services. In this perspective, the present papers tries to find out the potential of river restoration and reconnection to augment freshwater flow in the Indian Sundarbans. The HEC-RAS model has been used to reconnect the disconnected river reaches hypothetically. The model has been run in the present and in the hypothetical restored scenario to estimate the present water availability in the river channel and water availability after restoration. The study estimates that around 480 cumecs of flow can internally be managed during lean period through river reconnection and rejuvenation. The estimated flow is adequate to nurture the ecosystem of Sundarbans by reducing the salinity level of the system. To augment additional flow during dry season an international collaboration with Bangladesh is required.

Keywords: Ganges Delta; HEC-RAS; river restoration; river reconnection; sundarbans

ANALYSIS OF FLOOD DYNAMICS USING SENTINEL-1 TIME SERIES IN THE BANANAL ISLAND, BRAZIL

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The Bananal Island is an expressive seasonal humid zone of Central Brazil, containing more than 750 km of extension and 100 km of width. The main channel is the Araguaia river, formed from the confluence of the Mortes river (west) and Javaés river (east), which follows a course in an approximate N-S direction, following geological structures. When the Araguaia river enters the sedimentary basin of the Bananal Depression, energy decreases and results in an extensive floodplain, in which rivers migrate and rework vast river deposits. In the Bananal Plain, the channels have meandering patterns with high mobility that generate many inactive channels and swampy/lacustrine features. The high fluvial dynamics of the environment require constant monitoring, which can be obtained from remote sensing. Due to the persistent cloud coverage in the Amazon region, radar images are more suitable than optical sensors for flood analysis. Therefore, this study aims to analyze the flood dynamics of Bananal Island from a Sentinel-1 time series. The data used were the Sentinel-1 Ground Range Detected (GRD) images, referring to band C and VH polarization (more suitable for the detection of water bodies). The methodology presents the following steps: (a) speckle reduction using time- space filtering; (b) establishing the threshold value for water body extraction using an automatic detection method; (c) elaboration of water masks along the time series; (d) calculation of water permanence in the pixel, and (e) comparison of flooded areas with vegetation. The results allow to show the flood pattern in the Bananal Island and to correlate with the geomorphology and vegetation cover features.

Keywords: Wetlands; remote sensing; radar; image processing

THE “RIVER SCOUR GB” PRODUCT – A GIS SOLUTION TO REINFORCE THE RESILIENCE OF GREAT BRITAIN

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Following severe storms and flooding over successive winters in Great Britain, the British Geological Survey (BGS) recognised scour as an important threat to in-river structures such as bridges as well as surrounding infrastructures located near the riverbanks such as roads, railways or buildings. A gap has been identified in current scour modelling and algorithms, with the geological materials of river systems having little consideration. Our newly developed river scour product aims to address those gaps and identify areas with heightened susceptibility to scour. A three-tiered approach has been developed, scaled from a summary overview of the river catchments, down to the detailed features of individual reaches within river networks. Tier 1 considers the broad scale of the landscape focussing on the catchment stability related to glacial history and landscape evolution. This tier offers behaviour and catchment management descriptors of each individual catchment along with a generic stability level. Tier 2 analyses geological properties such as flood accommodation space, catchment run-off potential and geomorphology types as well as additional summary statistics of key environmental parameters such as land cover, protected sites and urban coverage. Each parameter is provided for individual catchments (as defined by the Water Framework Directive). Finally, tier 3 defines the geological susceptibility to scour for the entire river network based on rock properties (strength and density) and mineralogy. It also provides geological properties statistics (i.e. percentages of material strength, density, mineralogy and bedrock encountered) as well as river morphology descriptors (sinuosity, stream gradient and flood accommodation space) per river reach. This GIS product containing a suite of twelve data layers allow users to easily raise the profile of scour potential, identify river environments under threat and predict future riverbank management. It is aimed at asset managers or infrastructures service providers to prioritise their resources and manage their in-river or proximal-to river assets.

Keywords: Geology; GIS; Great Britain; rivers; scour

SPATIOTEMPORAL VARIATIONS IN RIPARIAN VEGETATION, ISLAND AND CHANNEL EVOLUTION IN RESPONSE TO HUMAN PRESSURE: TALEQAN RIVER, IRAN

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Channel changes in the meandering rivers exhibit complex behavior, and understanding the river dynamics in the environment is challenging. River dynamic system can affect the riparian vegetation and engineering projects, which causes various environmental and socio-economic problems. In recent decades, several Iranian rivers suffered from different types of human activities, which changed their morphological and vegetation patterns. Taleqan river is one of the Iranian rivers which is affected by human interventions such as dam construction, land use changes and gravel mining. In this regard, the aim of the present study is to investigate the evolution of riparian vegetation (according to typology types), islands, and features of the main channel along the four reaches of Taleghan River with special emphasis on vegetation structure. River channel and vegetation patterns were analyzed on four reaches of the River, at decadal scales over the period 1962–2018 from aerial photographs (1971, 1981, 2001) and satellite imagery (GF2) (2018). Analysis of the spatial and temporal patterns of vegetation demonstrates that during the four last decades, the number of islands without vegetation, especially in the downstream of the river, has increased from 38% to 44%. Considering the different vegetation cover types, there was a predominant increase of stable and tall vegetation from around 42% up to a maximum of around 54% (1981), then a decrease to around 46% (2001 and 2018). Analysis of the spatial and temporal patterns of channel revealed that the bank erosion of the river and the river's sinuosity is increasing and because of that, human instructions, physical habitats, and riparian vegetation, especially in reaches with high flow regime, are subject to destruction. Changes have been progressive from upstream to downstream, with higher intensities of processes, particularly cutoffs in downstream reaches. The maximum lateral channel shifting occurs in the left bank side. The findings explore the channel reaches is sensitive to lateral shifting and requires protection utilizing engineering structures.

Keywords: River change; riparian vegetation; lateral shifting; human activities; Taleqan river

PREDICTION OF MONTHLY TIME SERIES OF SUSPENDED SEDIMENTS USING FUZZY SETS

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The common way to analyze time series is to use Box & Jenkins (1970) methodology using ARIMA or seasonal ARIMA models. However, it is usual that the available data sets lack precision, and in this case the fuzzy set theory can be applied, to improve the performance of the analysis. The application of fuzzy sets, demands the fuzzy transformation of the input variables (fuzzification), a fuzzy inference mechanism which relates input to the output variables and the inverse of fuzzy transformation (defuzzification) to obtain the final output. The proposed model is based on this methodology and was applied to time series data of monthly suspended sediment in river Aliakmon (Greece). As input variables we used the lagged variables corresponding to monthly suspended sediments until time and variable representing time series of monthly water discharge at time. We also estimate the functional relations between past input variable and. The output variable is corresponding to the one step ahead predicted value of suspended sediments. We evaluate the accuracy of the forecasts using different error measures such as mean error (ME), mean absolute error (MSE), sum of squared error (SSE), percentage error (PE). This approach can be potentially used to estimate suspended sediments of a river when past data of suspended sediments and water discharge are available, in order to reduce frequency of such measurements, which sometimes are costly and hard to obtain.

Keywords: Time series; suspended sediments; hydrology; fuzzy sets

RIVER CHANNEL-PLANFORM ADJUSTMENTS: AN EVALUATION OF THE APPLICABILITY OF THE EQUILIBRIUM THEORY FOR ALLUVIAL RIVERS

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The upper and lower reaches of the Yellow River develop different channel planforms and all of them have experienced significant morphological adjustments in recent decades due to dramatic changes in both runoff and sediment load. Using remote sensing images and field measurements, we presented a detailed investigation of variations in the channel planforms and cross-sectional forms. Very complex morphological adjustments are identified in spatial and temporal scales. Among all the planforms, the wandering reaches exhibit the most significant adjustments, typically in the width-to-depth ratio, wandering belt width and braided index. While the adjustment in the anabranching reach remains insignificant, the meandering reaches shows a significant increase in the channel sinuosity and yet a decrease in the radius of curvature. The H number, theoretically derived in terms of the equilibrium theory for alluvial rivers with a variational analytical approach, is used to measure the stability of these channel patterns. It is demonstrated that different channel planforms take significantly different H values, with the anabranching reach taking the largest, the wandering reach the smallest and the meandering reach in the middle.

Keywords: Channel-planform adjustment; flow and sediment changes; remote sensing; equilibrium theory; the Yellow river

GEOMORPHOLOGY AND SUSPENDED SEDIMENT TRANSPORT OF THE SECOND LARGEST RIVER OF SOUTHEAST ASIA: THE IRRAWADDY RIVER, MYANMAR

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The Irrawaddy (Ayeyarwady) is one of the less known large rivers in the world and the second largest river of Southeast Asia in water discharge. It is still having a natural regime because regulation by dams is incipient. It is also a hotspot of biodiversity, but the basin is very vulnerable because of human environmental pressure such as mining, dredging, deforestation, and proposed dams. The Irrawaddy delta is the less impacted of the large deltas of Asia, and the most extremely prone to floods by tropical storms and coastal storm surges. The Irrawaddy is a priority among the world's transboundary river basins for risks related to hydropolitical tension and the lack of water governance. The Earth Observatory of Singapore has pioneered research on geologic hazards in SE Asia. In 2018, the South Asian Rivers: long-term basins evolution, morphodynamics, hazards, and global change research program was created. For the Irrawaddy, the objective is generating a long-term research on a geopolitically central system for the region. We cover four major interrelated topics: hydrology, sediment transport, channel morphodynamics and floods. Here we present some new results on suspended sediment fluxes, and assess 28 years (1990-2018) of channel morphological changes and their interaction with sediment transport in a 700 km reach between Mandalay and Hinthada. The study area was divided into four sub-reaches. We combined multiple approaches involving field calibrated remote sensing models for suspended sediment concentration, detailed geomorphic mapping, and a preliminary budget of erosional and depositional areas. One of the main conclusion is that, like other large rivers, the Irrawaddy River in alluvial reaches is an anabranching system. Reaches 2 and 4 are the most dynamics. This relates to their less geologically constrained nature (i.e. wider floodplains) and higher degrees of anabranching that accommodates both, more and larger islands and bars.

Keywords: Hydrology, sediment transport, channel morphodynamics, Irrawaddy River

IMPACT OF CLIMATE CHANGE ON EVAPOTRANSPIRATION IN NORTH CHINA PLAIN

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Evapotranspiration (ET) plays an important role in both energy and water balances. Determining changes in the different types of ET and their influencing factors under climate change is crucial to fully understand the mechanisms controlling ET and regional water cycles. Based on ET and meteorological data measured during 1998–2005 at the Yucheng Comprehensive Experimental Station of the Chinese Academy of Sciences (YCES, CAS), the variation of reference evapotranspiration (ET₀), pan evaporation (Epan), and lysimeter evapotranspiration (the actual ET, E_{lys}) were estimated. Together with a Mann-Kendall trend test, correlation and sensitivity analyses were conducted to determine the effects of climatic factors, crop coefficients (K_c), and leaf area index (LAI) on different types of ET. During 1998–2005, precipitation presented an upward trend at all-time scales, and average temperature (T_a), minimum temperature (T_{min}), relative humidity, Epan, and ET₀ exhibited downward trends. E_{lys} displayed a downward trend at the daily scale and an upward trend at monthly and annual scales. The correlation analysis indicated that Epan and E_{lys} were significantly positively correlated with all climatic factors except precipitation and relative humidity. The sensitivity analysis revealed that except for relative humidity, the influence of the other climatic factors on ET₀ was positive. The highest sensitivity was found for relative humidity, followed by T_a, maximum temperature (T_{max}), and T_{min}. An analysis of the influence of K_c and LAI on the actual ET indicated that with an increase of K_c and LAI, the actual water demand of crops also displayed an upward trend.

Keywords: Reference evapotranspiration; pan evaporation; actual evapotranspiration; North China plain

EVALUATION AND VALIDATION OF CRYOSAT-2-DERIVED WATER LEVELS BY IN-SITU LAKE DATA FROM CHINA

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CryoSat-2 altimetry has become a valuable supplement for monitoring the water level of lakes. In this study, CryoSat-2 altimetry water levels were evaluated and validated by in-situ gauge data from 12 lakes in China. The centralized probability density function (PDF) method, which is an alternative data pre-processing method, was proposed and validated for the CryoSat-2 Geophysical Data Record (GDR) data. This method takes advantage of the flat nature of the lake's surface. The evaluation criteria include the mean difference, the standard deviation (SD) difference, the root mean square deviation (RMSD), and the correlation coefficient (CC). Our results show that the accuracy of the raw GDR data was limited due to outliers in most of the along-track segments. The outliers were generally significantly lower than the in-situ values by several meters, and some by more than 30 m. The altimetry measurements might be affected by land, thick grass, ships, or frozen ice. Outlier detection therefore improves upon the accuracy of CryoSat-2 measurements. The median absolute deviation (MAD) method showed a better performance than the mean and standard deviation (MSD) method in detecting outliers. The centralized PDF method was able to greatly improve the accuracy of CryoSat-2 measurements. The average values of the mean differences, the SD differences, the RMSD, and the CC for all lakes were improved from 0.40 m, 0.36 m, 0.79 m, and 0.57, respectively, to 0.16 m, 0.06 m, 0.32 m, and 0.86, respectively. The centralized PDF method generally showed the best performance in monitoring daily water levels for each along-track for all lakes. The preprocessed CryoSat-2 measurements were able to observe daily lake levels with a high accuracy at nine of the twelve lakes, with the absolute mean difference of 0.09 m, the absolute SD difference of 0.04 m, the mean RMSD of 0.23 m, and the mean CC of 0.84. Overall, the accuracy of CryoSat-2-derived water levels was validated by in-situ lake data from China.

Keywords: Altimetry; water level; CryoSat-2; outlier; lake; in-situ gauge

THE ROLE OF GROUNDWATER OUTFLOWS IN THE DEVELOPMENT OF CHANNEL HEADS AND DRAINAGE SYSTEM (POSTGLACIAL AREA IN NW POLAND)

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The channel head functions as a transition zone between the domain of surface-acting denudation processes, and the domain of linear fluvial processes, leading to the fragmentation of the terrain surface. Groundwater outflows, one of the morphological factors, through the seepage erosion lead to the development of a spring-head alcove, which often becomes the channel head. Seepage erosion can, therefore, be an essential process responsible for the development of the drainage system. The aim of the study is to determine the participation of groundwater outflows in the development of the drainage system (Parsęta catchment, NW Poland). The conducted morphological, hydrological and geomorphological studies give a picture of the groundwater role in the functioning of the channel heads. River channels initiated by groundwater outflows have a different location within the valley system of the Parsęta catchment. The location of most of them is consistent with the valley heads, but out of the 88 analysed channel heads about 27% are located in the lower sections of dry valleys, most often inherited after slope processes. Concerning the initial morphological surface, spring-head alcoves constituting river channel heads can be divided into three types: slope, inserted and scarp. Each of these types represents a different initiation and development mechanism and own way of including into a river network. The increase in the river network density with the participation of groundwater outflows occurs as a result of: 1) headward erosion and the upward development of the stream as well as its branching; or 2) adding stream initiated in the slope subsystem into the existing river system (downward development). An increase in the number of the first-order streams causes the activation of negative feedback leading to the reduction of water supply areas, limited water outflow and - in the end - the inhibition of the seepage erosion.

Keywords: Groundwater outflow; seepage erosion; channel heads; drainage system; NW Poland

SANDSTONE AND CONGLOMERATE LANDFORMS – A (PARTLY) NEGLECTED TOPIC IN GEOMORPHOLOGY

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Some lithologies are known to support distinctive landforms and landscapes, but our understanding of these is still incomplete. Whereas limestone geomorphology (karst) has long been in focus of research and the diversity of granite landforms is fairly well recognized, clastic sedimentary formations have been somehow neglected in international literature. Nevertheless, recent years have seen significant new advances in various sub-themes within sandstone and conglomerate geomorphology. They include improved understanding of characteristic minor relief features on sandstone surfaces such as honeycombs and arcades, greater emphasis on subsurface water-driven processes leading to differential subsidence, cave and canyon formation, new models of escarpment evolution involving non-catastrophic in situ disintegration rather than large-scale rock falls and topples, and better understanding of a rock city/ruiniform relief phenomenon. An increased availability of high-resolution digital elevation data allows now to characterize specific features of sandstone morphology in the quantitative way, opening the possibility of wide-scale comparative analysis. Examples of sandstone landforms from Central Europe, China and Brazil, less known internationally, will be used to illustrate the main points of the presentation.

Keywords: Rock control in geomorphology; sandstone; geomorphometry; subsurface erosion; Sudetes

RELATIVE ACCRETION: A NEW MODEL OF INCISIONAL AVULSION DEVELOPMENT IN LOW-ENERGY RIVER SYSTEMS

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River avulsions are a fundamental geomorphic process on many river floodplains. The element of the incisional avulsion process that has received least attention is how the stream reconnects with the river at the downstream end. From investigations of the River Murray floodplain in SE Australia we have identified a new mechanism of avulsion development that involves 'relative accretion' in which the avulsion paths form by relatively less deposition rather than by erosion. Using this mechanism, and a space-for-time analysis of avulsions on the Murray floodplain, we propose a new model of the complete development of all stages of an incisional avulsion. This model has implications for the development of huge areas of low-energy floodplains.

Keywords: Avulsion; floodplains; anabranch; vertical-accretion; river

THE ROLE OF THE NEOTROPICAL DRY-FOREST DYNAMIC OVER NATURAL CHANGES ON CONNECTIVITY

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In tropical dryland landscapes, the neotropical dry-forest can change impressively between the seasons. It can show the variability of biomass density from rainforest biomass density in the wet season to savannic biomass density during the dry season. The vegetation cover shows an inversely proportional relationship with the potential sediment connectivity. This research aims to understand how the biomass density dynamic modifies the potential sediment connectivity in a Brazilian small semiarid watershed with neotropical dry forest cover. To understand the variation on biomass density the NDVI was used to analyse 39 Landsat 5 images from different seasons, between 1999 and 2010 (range of rainfall from 380mm/year to 1200mm/year, with an average of 800mm/year). The NDVI responses were grouped and the average of 5 scenarios was calculated (lowest to highest). Subsequently, the potential sediment connectivity was estimated using the Sediment Connectivity Index for each vegetation scenario, and the result was standardised and grouped into five classes, from very low to very high connectivity. The average biomass index has a range from 0.18 (driest scenario) to 0.62 (wettest scenario). The connectivity response to each vegetation scenario can be summarised by the difference between the driest scenario and wettest scenario: with 73.7% and 6.1% of the area grouped as high or very high and 5.32% and 82.4% of the area classified as very low or low sediment connectivity. The results show a considerable difference between the potential connectivity levels when the vegetation is in the very high biomass scenario; it acts disconnecting the hillslope from the channels, principally when the riparian vegetation is conserved. On the other hand, during the driest scenes, the increase of the potential connectivity can be responsible – when there are isolated rainfall events – for high rates of erosion and sediment transport from the slopes to the streams.

Keywords: Connectivity index; dryland; NVDI; semiarid geomorphology

MORPHOLOGICAL ADJUSTMENTS AND PHYSICAL MECHANISM OF THE YINCHUAN PLAIN REACH OF THE UPPER YELLOW RIVER, CHINA

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The Yinchuan Plain reach of the Upper Yellow River takes anabranching, meandering and wandering planforms and experiences significant hydro-geomorphological adjustments in recent decades, as the responses to dams' operation and climate change. Using remote sensing images and field cross-sectional measurements, we presented a detailed investigation of the adjustments of channel planform and cross-sectional morphology after the joint operation of the Longyangxia and Liujiaxia Reservoirs. The results show that the whole reach suffered serious shrinkage affected by the altered flow and sediment regime. Spatially, the accretion area, cross-section area and width to depth ratio, from large to small, are wandering reach, meandering reach and anabranching reach, which means the wandering reach is affected most seriously. Temporally, the cross-sections are becoming narrower and deeper while the accretion area is decreasing, especially the left bank. Theoretically, the H number, derived according to the Least Action Principle, explains the morphological adjustments of different channel patterns in terms of energy efficiency. The results of H number show that the channel stability, from large to small, are anabranching reach, meandering reach and wandering reach. In the cases of $H \neq 0.3$, the channel would adjust the channel numbers and cross-section forms for expending the excess energy and approach the efficient status. Under the current inflow conditions, the present channel morphology of anabranching and wandering reach are approaching the stable state via the adjustments of channel morphology in the past years. However, the wandering reach is still unstable with a typical wide and shallow cross-section.

Keywords: Yinchuan Plain reach; Yellow River; morphological adjustment; H number

KEY DRIVING FACTORS OF FLUVIAL PROCESSES IN THE LOWER YARLUNG TSANGPO RIVER

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Rivers in the lower Yarlung Tsangpo basin, which on the edge of the Qinghai-Tibet Plateau, are mostly deep incised and the river morphology in a critical equilibrium state. The equilibrium state is, however, prone to be disturbed by external forces (e.g., earthquake, rainstorm, or even rapid air temperature rising). Geophysical events (such as landslide, debris flow, avalanche and glacial erosion) hence occur frequently, exerting significant impacts on the fluvial processes in this region. Field campaigns and surveys have been carried out in the Yigong Tsangpo and Palong Tsangpo rivers, the two largest tributaries in this region, to examine the fluvial processes under the impacts of the geophysical events. Remote sensing images in the recent three decades are used to compare the channel pattern change after typical events. Investigations indicate that the fluvial processes of different reaches in this region is influenced by different events as key driving forces. The major event which influences the fluvial processes of the lower Yigong Tsangpo was landslides; that of the lower Palong Tsangpo was debris flows; and that of the upper reaches of the Palong Tsangpo River was majorly glacial processes. Huge amount of sediment came down river channel during geophysical events, raise local channel bed. It even forms barrier dams across the channel, driving alluvial channel patterns (normally braided pattern) development upstream of the dam, and forming staircase-like longitudinal profile, while developing streambed structure with high flow resistance downstream of the dam. The dynamic adjustment of fluvial morphology in this region is often in a circulation between states of “stable-unstable-restable”. The occurrence of the geophysical events means out of balance of previous quasi-equilibrium river morphology, in more essential sense, however, it triggers a negative feedback which pushes the river channel morphology back to a new equilibrium state.

Keywords: Yarlung Tsangpo; fluvial processes; equilibrium state; negative feedback; stability

S02. ANTHROPOCENE, GEOARCHAEOLOGY AND SOCIETY

SALT PANS AS NEW ARCHAEOLOGICAL SEA-LEVEL PROXY, TEST CASE FROM MAKIRINA COVE, DALMATIA, CROATIA

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In the Mediterranean, paleo relative sea-level (RSL) is based on multi proxy disciplines including archaeology. Among the archaeological indicators fish tanks are considered the most reliable determining its functional height. Saltpans are also intertidal facilities, used in the Mediterranean at least for the last 2000 years. The Dalmatian shore contains large number of preserved and historically dated ancient saltpans, now flooded by the rising sea, providing great potential for RSL indication. The primary objective of the study is to develop a new holistic approach combining multi-image photogrammetric techniques in archaeological survey for high quality elevation measurements of the structures and estimating paleo RSL during the last 2ka. The study combined areal photogrammetry of the site, bathymetry acoustics scanning, underwater archaeological survey of the man-made structures, wood and mortar sampling. In situ wood samples have been radiocarbon dated. Mortar samples were analyzed mainly for defining the original environmental conditions of the saltpans at the time of construction; marine or terrestrial. In Makirina cove, archival documents testify the use of the bay for salt work on the 13th century, however building technique of the separation wall suggests that it might have started earlier. Dendrochronology and radio carbon analysis of wood samples indicate that the trees were cut in the early 5th to end of the 6th century AD. Elevation measurements on the separation wall and the sluice gate suggest that the past RSL range between -0.74m to -1.06m, but mortar samples from the foundation of the separation wall at depth of 1.05m exhibits solidification in terrestrial environment, which means that past RSL was lower. On-going research continues in other saltpan sites on the Dalmatian shore. Once the suggested approach will be established, it has the potential of becoming a significant tool for estimating RSL for the last two millennia in the Mediterranean.

Keywords: Saltpans; archaeological sea-level markers; digital terrain and underwater modeling; Dalmatian coast

HUMANS, LANDSCAPES AND SEA-LEVEL CHANGE IN PREHISTORIC CROATIA

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The coast of Croatia is a karst terrain with a number of prehistoric human settlements. Vela Spila on the island of Korčula is a cave that has been inhabited discontinuously since 18 ka BP; with a gap between 14.5 – 9.5 ka BP. Though the current coast is high relief with low wave action and shows few coastal landforms, below the 60 m isobath the bathymetry is more flat since it has had relatively little exposure to geomorphological processes between interglacials. We combine existing bathymetric data from satellite and nautical charts using a GIS interpolation algorithm to create a digital elevation model for analysis with recent glacial isostatic adjustment models (corroborated by sea-level indicators when available). The result is a more detailed, accurate reconstruction of local palaeogeographic changes acting on the submerged landscape, which we compare to the archaeological settlement record. By also examining regional and global climate proxies, we show that in addition to large scale climate fluctuations such as the Bølling-Allerød, the Adriatic sea-level change resulted in rapid coastline migration by the end of the Palaeolithic, when sea-level rise was accelerating to approximately 13 mm/a. As a result, in the plains north and south of the island, the coastline would have been moving east ~15 m/a, or around 0.5 kilometres in the typical prehistoric human lifespan. Hunting grounds would have been destroyed and stable coastal environments would not have formed. The combined stress of these factors could have contributed to the hiatus of human settlement in the cave. As such, the study area provides an important example of how humans are effected by climate and palaeogeographic changes in sensitive coastal areas.

Keywords: Croatia; geoarchaeology; sea-level change; submerged palaeolandscapes; prehistory

LATE HOLOCENE COASTAL DEPOSITIONAL ENVIRONMENTS AND CLIMATE CHANGES IN GULF OF CORINTH, GREECE

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Multidisciplinary studies in coastal systems of the eastern Mediterranean region have proven to be excellent tools in understanding palaeoenvironmental, palaeocological and palaeoclimatic changes that took place during the Holocene period, as well as to how these changes interacted with urban development and growth. This paper presents sedimentological, high resolution X-ray fluorescence (XRF-scanning), micropaleontological and X-ray diffraction (XRD) data from three shallow sediment cores that were retrieved from Alikí (ancient Siphai or Típha) salt pond. The study area is located in a unique, highly tectonic geographical region, at the north east part of the Gulf of Corinth in Greece. Beachrock depositions that form a barrier between the salt pond and the marine environment seem to play an important role in the evolution of the area. The chronological framework was set at around 3100 cal BP by four ¹⁴C radiocarbon dates and the evolutionary model that was established, indicates 4 different rapid changes, taking place during this period at the study area. From around 3100 to 1600 cal BP a transition from a closed to an open lagoonal environment was identified, interrupted by a fluvial terrestrial deposit at around 2500 cal BP. A shift towards a closed lagoonal system at around 1600 cal BP and the establishment of a salt pond environment seems to correlate with the tectonic activity in the area and provide important information about the evolution of coastal environments in the Gulf of Corinth.

Keywords: Palaeoenvironment; Gulf of Corinth; late Holocene; sedimentology; XRF analysis; micropaleontology

GEOMORPHOLOGY IN THE ANTHROPOCENE: EXAMPLES FROM ISTANBUL (TURKEY)

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Although not yet approved by the World Stratigraphy Association of the geologists; from the Industrial Revolution to the present, it is possible to say that a new epoch has started in order to protect our Earth's landforms intentionally and deliberately with their own needs and to prevent accidents or disasters or to remove the damages. If you want this 11.000 years ago from the gathering-hunting to the agricultural community by settling on the edge of the stream; you can start this period by getting acquainted with the environment of the human (1) by creating sets that aim to benefit from fresh water or to protect from floods. However, with the beginning of the Industrial Revolution in 1763, the discovery of new continents using the steam engine and the discoveries and inventions, including the New World; hence (2) can be attributed to the discovery of different continents. Thirdly, it can be based on the idea of (3) dominating the Earth by the death of thousands of people with the atomic bombs thrown in Japan in 1945, one of the reasons for the end of World War II. Lastly, the idea of humanity (4) dominating the Universe may be the idea of the discovery of new earths and the discovery of new earths that can be experienced in human beings. Start from where you start; we can now say that there are new man-made landforms on earth and in all parts of the world and the different appearance of nature has emerged. This is the proposed new circuit for that reason; It is known that Anthropocene epoch (Epoch of mankind). In this presentation, in Istanbul, which has changed rapidly in the last 10 years, it was followed by the earth and underground morphology jointly carried out by the engineers of our country and different countries and the traces of the anthropocene as a result of these; therefore, we would like to talk about the Istanbul's Mega Structures. Details will be explained in the presentation; we will present the mega structures that meet or meet the needs of the growing population in the last 10 years of the Istanbul megapol, in the following headings: Marmaray Tunnel, Yavuz Sultan Selim Bosphorus Bridge (or III. Bosphorus Bridge), Eurasia Tunnel, Istanbul Airport (IGA), planned Canal Istanbul and therefore the new Istanbul skyscrapers. As a result, the traces of Antropocene, which is the face of Istanbul, which is an old cultural and industrial city, are rapidly changing and transforming into a megacity of culture, education and trade. All these mega-structures are bridging to the two continents.

Keywords: Anthropocene; Anthropogenic geomorphology; Man-made landforms; Istanbul; Turkey

NEW DATA FOR RECONSTRUCTING LANDSCAPE CHANGE IN THE WESTERN MESSARA PLAIN (PHAISTOS, CRETE, GREECE) FROM THE GEOMETRIC PERIOD TO EARLY BYZANTINE TIMES: ASSESSING SHIFTS IN THE HUMAN LAND-USE AND THE IMPACT OF CLIMATE CHANGES

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This presentation addresses key questions about the landscape configuration in the area of Phaistos, one of the former capitals of the Minoan Kingdom, from the Early 1st millennium BCE to the mid-1st millennium CE. In a previous publication, the general landscape configuration was accurately reconstructed using a paleoenvironmental approach, from the Proto Palatial period (ca. 2000 cal. BC) to the Proto Geometric period (ca. 8th cent. BCE). The existence of a freshwater lake that changed to swampland (after the 3.2 kyr cal. BP RCC event) was highlighted, based on the sedimentological and palynological study of nine boreholes drilled at a short distance from the Minoan palatial site. However, the landscape configuration remains uncertain for the later archaeological periods. Six new radiocarbon dates, combined with additional pollen and mollusk identification and sedimentological analyses (CM diagram), were conducted on specific cores and enable us to reconstruct more specifically the landscape history from the Archaic period to Early Byzantine times. The results indicate the continuous occurrence of swamplands from the Proto-Geometric period (8th cent. BCE) until probably the first stages of the Classical period (5th Cent. BCE). Subsequently, there was a short interval of detrital input (not exceeding two centuries in duration), covering the Classical and Hellenistic periods (approx. the 5th and the 4th Cent. BC), that was linked with the complete drying up of the swamplands. Questions are addressed about a possible climate control of this abrupt hydrological change, in relation to the regional paleoclimate reconstruction and the sedimentary history of adjacent rivers/streams. Tectonic activity in the area is important and can also be invoked as an environmental influence. Anthropogenic factors are also considered, even though there is no archaeological evidence of a drainage system in the western Messara plain during the

Archaic and Classical periods. Finally, from Roman times to the Early Byzantine period, floodplain deposition prevailed in the area and ponds developed locally, in particular from the Hellenistic to Early Byzantine period. Pollen analysis reveals an open forested landscape during the studied period, within which domesticated plants such as *Olea* were present (there is no evidence of *Vitis* sp.). However, the representation of *Olea* decreases continuously from the Late Geometric period to Late Roman times, probably indicating a much lower intensity of human land-use than during Minoan times. During this interval, there is the first evidence of *Vitis* sp. and it may indicate a major change in agricultural practices due to ancient Greek influences.

Keywords: Crete; pollen identification; Classical period; Roman times; sedimentology; antiquity

HUMAN SHAPED LANDSCAPE HISTORY AROUND THE MINOAN TOWN OF MALIA, CRETE: NEW INSIGHTS ABOUT THE MINOAN CIVILIZATION CONSEQUENCES ON VEGETATION COVER IN THE LOWLANDS

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The wetland located near the sea and close to the archaeological site of Malia, (Northeastern coast of Crete), offers rich natural archives and a suitable case study for combined palynology, fire analysis and geoarchaeology. The site is famous for his Minoan town developed during Middle and Late Bronze Ages, but our new palaeoenvironmental data show that the landscape was already intensively disturbed longtime before the palatial time. The two sedimentary sequence studied (cores) located into small marshy area provide first vegetation change records in an area still little investigated. The correlation between palaeobotanical and archaeological data allow us to address some important issues: the questions of chronology and causes of apparent changes are especially important and tricky in the Minoan world where the absolute chronology is still under debate. In this paper, we present the results from the LOI, pollen, non-pollen palynomorphs and fire analyses. Combined with geomorphological and sedimentological results, we can propose a scenario for the landscape evolution, the effect of agropastoral practices on the wetland and a comprehensive view of land use impact from the Late Neolithic. Pollen analysis reveals an open landscape already since Neolithic time, within which some plants such as *Olea* (probably domesticated) were present. Apart from the anthropogenic land use, the major change into the vegetation composition is recorded between ca.4400-4000 cal BP and corresponds with an intense environmental change probably controlled by hydrological event. The fire analysis results indicate three main phases of increase in fire activity around ca. 5200-4800 cal BP (Late Neolithic); ca. 4500-4000 cal BP (Early Minoan period); ca. 1750-1550 cal BP (Late Roman times to Early Byzantine period). We also note some short lived event of fire activity during the Late Neolithic (ca. 5700, 5600 and 5500 cal BP) and Neopalatial-Late Minoan times (ca. 3500 cal BP). This case study highlights the interest to combine geomorphological data to palynological evidence in a rich archaeological context. It points out this necessity to assess the effects of specific farming and herding practices on the dynamics of mosaic landscapes in Mediterranean areas to discuss the question of human society-environment interactions.

Keywords: Human land use; palaeoenvironment; palynology; fire analysis; erosion process

CURRENT STATE OF GEOMORPHOLOGICAL AND GEOARCHAEOLOGICAL RESEARCH IN THE HOLEDNÁ HILL (BRNO, CZECH REPUBLIC)

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The area of the Brno city (southeastern part of the Czech Republic) is situated on the border of Bohemian Massif and Western Carpathians. This implies its high geological and geomorphological diversity which influenced the localisation of prehistorical settlements. The area traditionally served as an important crossroads of the important communication routes and has been inhabited since Paleolithic (the oldest findings approx. 600 000 years BP (Cromerian interglacial) from Stránská skála site). The Holedná Hill (north-western part of the city) represents the end of ridge above the deep incised Svratka valley. The bedrock consists of Proterozoic rocks of the Brno massif (diorites with veins of metaryolites). The area has been a subject of geomorphological research and based on the analysis of LiDAR Data, unknown elongated structures were identified. The fieldworks proved the anthropogenic origin of these landforms (embankments composed of stones and small boulders, sometimes with shallow ditches along them). The structures symmetrically surround the dominant peak of the Holedná Hill. Based on the occurrence of Neolithic and Eneolithic localities in the vicinity, a similar age was estimated. Nevertheless, the radiocarbon dating of organic material confirms the age between 1200 – 1050 BC which refers to the Bronze Age. Within the close surroundings of the study area, there is the only one significant evidence about the occurrence of Bronze Age: the ceramics that refers to the locality Pátevní Street is situated approx. 2 km northwest from the study area. Until now, only the accidental occurrence of ceramics was found, but these findings could be a sign of another, yet unknown larger settlement area. The question is what the purpose of the structures on the Holedná Hill was: the hypothesis about the sacred place was formulated. The possible connections between the Pátevní Street locality and the Holedná Hill are going to be explored in the future geoarchaeological research.

Keywords: Bronze Age; South Moravia; LiDAR; sacred place; geoarchaeology

RECONSTRUCTION OF CHANGES IN TOPOGRAPHY OF CRACOW CENTRE (POLAND) SINCE THE 9TH CENTURY WITH APPLICATION OF ARCHAEOLOGICAL INFORMATION AND WITH USE OF ADVANCED GIS TOOLS

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Changes in topography of the historical centre of Cracow, area 9 km² (former capital of Poland) were studied in the following periods of town development: since the 9th century to the half of the 13th century; to the end of the 19th century; to the present-day. The following questions are the most important in the study: what is the mean thickness of cultural deposits and its spatial differentiation within the study area?; is there a correlation of thickness of these deposits with the original relief of the area studied ?; what are the changes in the rate of deposit increase in the time studied? The studies were based on archaeological information, historical information, field observations (archaeological exposures, historical buildings), and analysis of historical maps. The first stage of the research included 3D modelling of contemporary topographic surface. The next stage included modelling of lower located topographic surface from earlier stages of town development. The result of the studies is a visualisation of Cracow centre topography showing changes in the selected stages of town development with application of GIS tools. Topographic surface of the historical centre of Cracow became uplifted since the 9th century by 5 m on average and flattened due to progressive town development. The final result of investigations includes two maps showing probable original terrain morphology and spatial differentiation of the thickness of cultural deposits. The following landforms are characterized by the most intensive deposition of cultural material: former river channels, back swamps, basement of escarpment of medium Pleistocene terrace, slopes of Wawel Hill. The increase of the cultural deposits thickness was the fastest after changes in the town structure in 1257, and also at the turn of the 18th and 19th centuries and in the mid of the 19th century.

Keywords: Historical centre of Cracow (Poland); archaeological survey; cultural deposits; GIS and geostatistical tools

ENVIRONMENTAL CHANGES AT THE BOTTOM OF THE MINOAN TOWN OF MALIA (CRETE): GEOMORPHOLOGICAL, SEDIMENTOLOGICAL AND MICROFAUNAL EVIDENCES OF LONG-TERM MARSH DEVELOPMENT AND ABRUPT EVENTS IMPACTS

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The site of Malia, on the northwest coast of Crete, is a good example for geoarchaeological studies. A Minoan palatial city developed during the Middle and Lower Ages in a long occupied area, whereas a small marsh near the sea and near the archaeological site provides a rich natural archive. Off-site studies provide an opportunity to assess long-term environmental changes due to climate, tectonic, sea-level changes or land-use changes due to human activities. The proposed paper is based on the study of 11 new core drillings that were added to those published in 2003. The 50 new radiocarbon dates obtained show that all sedimentary records cover the last 6 millennia. Geomorphological investigations combined with sedimentological (granulometry, magnetic susceptibility), geochemical and microfaunal (foraminifera, ostracods) analyses carried out on 4 cores provide an opportunity to reconstruct landscape changes at the bottom of the Minoan site and to discuss the causes of observed environmental changes such as coastal marsh development from the Middle Neolithic to the Late Minoan period. The development of wetland is controlled by the sea level rise and the impact of the land use changes on the wetland is raised from the roman period. Furthermore, several abrupt events of marine and/or continental origin are detected in particular around 3300 BC and 1600 BC. But above all the immediate and lasting impact of the Santorini eruption on the marsh and the city during the late Minoan period is discussed. Indeed, on the basis on sedimentological and ostracods and foraminifera analyses, tsunamite are identified on core C21. This finding is discussed with the results from the other core drilling to evaluate the consequences of the tsunami on the surroundings areas.

Keywords: Coastal marsh; paleoenvironment; microfauna; Minoan times; tsunami

THE FORMATION EVOLUTION AND INFLUENCING FACTORS OF THE HONGJIANNAO

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Located at northwestern Shaanxi, the Hongjiannao is the biggest inland lake in southernmost Mu Us Desert and is honored as "Frontier Pearl". As country's 4A-class scenic spot and local major fishery, the Hongjiannao plays an important role in Northern Shaanxi economic development and is of significance in maintaining ecological safety, climate and environment stability, biodiversity and regulating water resources. However in recent years, as the lake diminishes, degree of mineralization and PH level goes higher while water quality becomes worse so it has no time to delay in protecting the Hongjiannao. The formation of the Hongjiannao experienced 3 phases including basin valley of early Upper Pleistocene to wetland of early Upper Pleistocene and to the inland lake of Holocene. The formation and development of the Hongjiannao were restricted by paleotopography, paleoclimate, geology, geomorphology, hydrogeology and human engineering activities. In recent years, as a geomorphic driving force, human engineering activities directly affect the geomorphology or affect the geomorphology through influencing the surface process, and their influence on the geomorphologic system of the Hongjiannao is increasingly strengthened. The purpose of this paper is to seek an effective way to protect the Hongjiannao by analyzing and studying the evolution of the Hongjiannao and its influencing factors, so as to achieve the goal of harmonious coexistence between human beings and nature.

Keywords: Hongjiannao; evolution; influencing factors; protection

PALEOGEOGRAPHY AND GEOMORPHOLOGICAL EVOLUTION OF AKROTIRI SALT LAKE, LEMESOS, CYPRUS

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Akrotiri Salt Lake is located 5km west of the city of Lemesos, in the southern-most part of the island of Cyprus. The palaeogeographic evolution of the Akrotiri Salt Lake presents a great scientific interest, especially during the Holocene where the eustatic movements combined with local active tectonics and climate changes have developed a unique geomorphological environment. The Salt Lake, today a closed lagoon, which is depicted in Venetian maps (Bordon AD 1528) as being connected to the sea, can provide evidence of the geological settings and landscape evolution of the area. In this study, we investigate the development of Akrotiri Salt Lake through a series of cores which penetrated the Holocene sediment sequence. Sedimentological, micropaleontological (benthic foraminifera and ostracods) analyses and geochronological studies performed on deposited sediments, identifying the complexity of the evolution of the Salt Lake and the progressive change of the area from maritime space to an open bay and finally to a closed Salt Lake.

Keywords: Paleogeography; salt lake; geomorphology; Akrotiri

IMPACT OF SEA LEVEL RISE AND ANTHROPOGENIC ACTIVITY ON THREE LAKES FROM THE LOWER DANUBE FLOODPLAIN IN MIDDLE AND LATE HOLOCENE, ROMANIA

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Since the end of Late Glacial Maximum (20 ka BP) the Danube's floodplain had to adapt to Black Sea level sudden rise induced by the reconnection to the Mediterranean Sea (~ 9.3 ka) and later to its stabilization (~5.5ka). Another major driver for the floodplain changes was the human activities in the river basin, which become relevant during the local Neolithic cultures (Boian, Gumelnița) and then "aggressive" during mid-Antiquity once with the growth of the Roman Empire. Three cores, with a maximum depth of 18m, have been retrieved from three (paleo)lake sediments on which several types of analyses have been performed: grain-size parameters; organic matter and carbon content (using LOI), magnetic susceptibility (MS). Eleven ¹⁴C ages served for building the chronostratigraphic framework. The age-depth model reveals (1) a relatively high aggradation rate (3-6 mm/year) before 5.5 ka BP, with coarse sediments and low organic matter content (OM) (~5.9%), while MS values are slightly higher than in the upper sequences which correspond to the Late Holocene; (2) a decreasing aggradation rate after 5.5ka BP (~0.8 mm/year) and finer sediments upcore, concomitantly with a marked increase of the OM content (19%), associated with the wetlands progressive developments (e.g. marshes and lakes), (3) a double aggradation rate of mineral sediments (~1.3 mm/year) starting with the rise of the Roman Empire associated with high erosional rates triggered by land clearance and agriculture practices. The results of this study reveals the lakes in the Lower Danube's floodplain were sensitive to both natural (eustatic, climatic) and anthropogenic signals and the lacustrine sediments are suitable proxies for documenting sea level rise and historical human impact on floodplain evolution.

Keywords: Floodplain lakes; middle and late Holocene; LOI; age-depth model; human activities

SEDIMENTOLOGICAL VARIABILITY OF THE HOLOCENE DEPOSITIONAL ENVIRONMENT OF ANTHEMOUNTAS RIVER VALLEY (NORTHERN GREECE)

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A great number of palaeoenvironmental scientific publications have focused into the Holocene environmental and climatic changes or depositional history, using mostly lacustrine, lagoon, delta plain, coastal, ice and cave data with multiple approaches but not often (inland) fluvial data. At the same time there is evidence that the Pleistocene- Holocene transition was defined by significant alluviation while during middle Holocene fluvial activity is evident after dry event successions. This study provides new data and insights into the reconstruction of the depositional environment of Anthemountas River, based on granulometric analysis as well as on the chronostratigraphical and lithostratigraphical (macroscopic lithologic) description of the site. In the attempt to obtain information concerning the dynamics of the transporting medium and the environmental energy conditions, the interpretation of cumulative curves, frequency curves and the Passega C-M diagram are used in conjunction with the textural parameters of the sediments. The aim of the present study is to critically examine the connection between fluvial processes and deposition phases of the sedimentary deposits through granulometric analysis approach in order to make inferences about the Holocene environmental conditions which prevailed in the area of Anthemountas River Valley. In this framework, the interpretations of fluvial Quaternary deposits and the division into subenvironments can help to determine the sedimentary environment and a better understanding of the dynamics during sedimentation.

Keywords: Fluvial processes; granulometric analysis, Passega method, paleoenvironment, fluvial deposits

MEASUREMENTS OF THERMIC DAMAGE OF ANGKOR DIMENSION SANDSTONE USED FOR WORLD HERITAGE TEMPLES

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The Angkor temples in Cambodia, which have been proclaimed as a World Heritage Site, mainly comprise dimension sandstone. Most of these temples have been exposed to direct insolation under a tropical climate since the 9th century. The tree cutting done for temple conservation since the 19th century is thought to have accelerated sandstone weathering. Accordingly, the possibility of thermic damage on sandstone has been pointed out because the temperature of sandstone increases during daytime. This study performs measurements of the surface temperature, thermic deformation, and acoustic emission (AE) using a cylindrical sandstone specimen in the test site of the Angkor Wat temple to detect the sandstone microcracks induced by insolation. The measurements are also conducted in an environmental test chamber in a laboratory. The result of the field measurements conducted in the dry season showed that the range of the surface temperature of the specimen was from approximately 21°C to 52°C, and the diurnal difference was approximately 31°C. The maximum increasing rate of the temperature was 1.50°C/min, whereas the minimum decreasing rate was -1.88°C/min. Meanwhile, a heating-cooling experiment ranging from 4°C to 84°C (temperature changing rates: $\pm 2^\circ\text{C}/\text{min}$) detected a specimen deformation; however, definite AE signals could not be detected in the specimen. Although more experiments are needed, these results suggest that the dimension sandstone may not deteriorate because of the temperature changes induced by insolation.

Keywords: Angkor monuments; sandstone; insolation weathering; acoustic emission; thermic damage

S03. COASTAL GEOMORPHOLOGY AND MORPHODYNAMICS

HOLOCENE RELATIVE SEA-LEVEL CHANGES ALONG THE SOUTHERN SHORE OF THE ARABIAN GULF: A REVIEW

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Since the Last Glacial Maximum (LGM), about 20,000 years ago, and during the Holocene, Arabian Gulf coastal areas were characterized by major evolutions, driven by climate changes and coastlines mobility. These environmental changes led to huge landscape modifications, which could have impacted coastal attractivity and human settlement during pre- historic and more recent times. Along the southern shore of the Gulf, numerous Holocene sea level indicators testify complex relative sea level variations. A database gathering all results from published studies have been built, using around 250 geomorphological (mostly beachrocks, beach-ridges, algal mat and hardgrounds) and archaeological sites (used as sea level terminus ad quem). To ensure data consistency, elevations have been recalibrated regarding the same vertical datum (mean sea-level) thanks to tidal data from the British Admiralty and from local municipalities. Radiocarbon dating used have been (re)calibrated by using OxCal 4.3 online software and by applying Delta \pm R correction. In addition to this published data, recent results from fieldworks carried out in Failaka island, Kuwait, and in the western region of Abu Dhabi Emirate have been compared to the previous studies. These new results relied on coastal deposits study and dating by AMS C14 and OSL geochronological methods. Based on the database, local sea- level 2D diagrams, curves and chronologies have been built since LGM to recent. Results obtained indicate different trends in vertical displacement (uplifting and subsidence) along the studied area during Holocene, which cannot be explained alone by the glacio-hydro-isostatic model. Crustal deformation including large-scale tectonic deformations or diapirism, related to the ongoing convergence between Arabian and Eurasian plates might have induced vertical displacement of the southern part of the Arabian Gulf, impacting relative sea-level changes in the area.

Keywords: Arabian Gulf; relative sea level changes; Holocene; sea level indicators

RECONSTRUCTING THE RELATIVE SEA LEVEL AND THE PALEO-SHORELINE DURING THE 1ST CENTURY BC IN THE UNSTABLE CAMPI FLEGREI CALDERA (SOUTHERN ITALY)

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The study area is located along the western border of the Campi Flegrei Caldera, one of the active and most hazardous volcanic areas in the world. This area has been inhabited since the Bronze Age and settled since the first Greek colonization of Southern Italy (800 BC), as evidenced by many archaeological remains positioned along the coast that can help to detect and to date ancient positions of coastline, the relative sea level and to measure vertical ground movements (VGM). This study aims to present new additional data regarding the relative sea level position during the 1st century BC, considering also the accompanying changes of the coastal landscape and the implications in terms of human adaptation as well. By surveying the coastal sector between the modern Baia and Miseno, with a multidisciplinary approach through direct and indirect methods, a Roman sea level at -4.2 m bsl was detected measuring the submersion of three fish tanks. Comparing this value with the eustatic models in stable areas, we can affirm that the coastal sector suffered a subsidence of about 3 m (with an average rate of 1.4 mm/y during the last 2100 years). It is worthy of note that a coastal stability occurred during the 1st century BC, for at least 60 years, leading to the building of new villas today positioned at -3.4 m bsl and at different distances from the coastline. Therefore, this last one has been characterized by a retreat up to 150 m since the 1st century BC until today.

Keywords: Coastal changes; landscape evolution; vertical ground movements; geoarchaeology; Phlegrean Fields

GEOMORPHOLOGICAL EVOLUTION OF DOÑA BLANCA (BAY OF CÁDIZ, SPAIN) COASTAL AREA SINCE THE VIII CENTURY BC (PHOENICIAN TIMES): NATURAL AND ANTHROPOGENIC FORCING

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This work reports the preliminary results related to a joint research between the Università degli studi di Napoli “Parthenope” and the Universidad de Cádiz (UCA), aimed at reconstructing the morphological evolution since the VIII century BC of the coastal area corresponding to the archaeological Phoenician site of Doña Blanca (NE sector of the Bay of Cádiz, South Spain). The study area is dominated by lagoon, salt marsh and estuarine environments and is characterised by Holocene alluvial deposits, supplied by the Guadalete River, which overlie previous marine transgressive facies and marine sands testifying ancient coastal positions. The study is focused on the reconstruction of ancient shoreline positions and on the whole evolution of the bay in this historical time span. The study has been carried out by means of historical map comparison, detailed topographic mapping and multispectral image investigations (aided by UAV devices), stratigraphical analysis from borehole data inventory coupled with geoarchaeological investigation by georadar techniques. The first results evidence a continuous prograding trend of sand barriers during historical times until present. A coastal progradation of about 8 km can be deduced since Phoenician times. The growth of sand barriers produced a more restricted area where salt marshes have developed by intermittent aggradation during historical times, especially since 1700 AD due to human deforestation related to wood needs for local ship industry, flourishing at that time.

Keywords: Coastal changes; landscape evolution; geomorphological analysis; geoarchaeology; archaeological site of Doña Blanca

LAND-SEA DATA CORRELATION FROM THE MT. MASSICO COASTAL ZONE, ITALY: SEISMIC VS LLOG DATA INTERPRETATION

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The current setting of the Tyrrhenian coastal plains is the result of the interaction between long-term tectonic movements and sea level changes during the Quaternary. In particular, during the last glacial-interglacial cycle, the overall sea level variation in the Mediterranean exceeds 120 m. The main objective of this study is to acquire new elements for a better definition of morphotectonic events, sedimentary processes, and climatic variations that have controlled Late Quaternary evolution of the Garigliano coastal plain. The integration of field survey, data from new well logs, and results from several seismic lines led to a refinement of the geological framework of the coastal area at the foots of Mt. Massico, a NE-SW oriented horst-like structure separating two large alluvial-coastal plains, the Volturno and Garigliano river plains. Many studies have highlighted the role of faults bounding Mt. Massico in the morphogenesis of the area, attributing them a relevant activity during the early and Middle Pleistocene. Recent researches have extended their activity up to the Late Pleistocene, while it is still unclear their action during the end of the Late Pleistocene and Holocene. A detailed log stratigraphy from two new boreholes located in that area permitted us to correctly interpret seven seismic lines, parallel and orthogonal to the coastline, so enforcing our ability in recognize crucial information on stratigraphical setting and tectonic structures. In this way, a land-sea 3D geological model has been obtained. This model evidences that many fault lines, both NE-SW and NW-SE oriented, displaced the most recent units overlying the Campanian Ignimbrite deposits (39 ky). In addition, two high-stand stages attributed to the Tyrrhenian and to the Holocene, during which the sea ingression reached part of the current plain, have been identified.

Keywords: Coastal evolution; land-sea geological correlation; Late Quaternary fault activity; Mt. Massico; Southern Italy

COASTAL EROSION ALONG THE MOLISE COAST (SOUTHERN ITALY): INVESTIGATING THE POSSIBLE ROLE OF HARD DEFENSE STRUCTURES

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The coast of the Molise region is approximately 36 km long and part of the Central Adriatic coast. Precisely, it falls within the physiographic unit P.ta Penna (Abruzzo) - P.ta Pietra Nere (Apulia), but consists of two nearly independent, respectively WNW-ESE and NW-SE oriented coastal sectors, which are separated by the promontory of Termoli. The Molise shoreline has undergone significant erosion during the last 60 years that has prevalently affected the coastal segments including the major river mouths (Trigno and Biferno) which reach a total length of approximately 10 km. Erosion has been faced mainly through an engineering approach and nowadays nearly 65% of the shoreline is covered by hard defense structures, especially detached breakwaters (submerged or low-crested) and groins. Nevertheless, erosion has increased from the 1990s onwards and has involved progressively also other coastal segments besides those including the Trigno and Biferno mouths. Today, the short to long-term shoreline trends and related shoreline variation rates are widely documented (Roskopf et al., 2018 and references therein), while a dedicated analysis of the relationship of shoreline variations and the presence of hard defense structures is still lacking. In this study, the numerical model GENESIS, based on the one-line equation of Larson and Kraus (1989), is used to recognize the natural shoreline evolution patterns (potential shoreline trends), to evaluate the effects of hard defense structures and to analyze the potential consequences of their removal. The wave climate has been reconstructed using the data coming from a directional buoy located in the Adriatic Sea, and the concept of Littoral Drift Rose (Dean and Walton, 2010) has been employed to achieve the wave parameters responsible for littoral transport. Results indicate that defense structures play a key role in shoreline recession and their removal could positively influence the Molise littoral regime especially under the umbrella of a responsible coastal management.

Keywords: Shoreline erosion; coastal defense; numerical model; GIS analysis; Adriatic Sea

AUTOMATIC COASTLINE EXTRACTION TOOL (CET) BASED ON VERY-HIGH RESOLUTION WORLDVIEW SATELLITE IMAGERY

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Exact determination of coastline length and characteristics is necessary for studies of coastal processes and consequently for management and protection of coastal areas. Very-high resolution (VHR) satellite imagery has great potential for coastline extraction, however noises in spectral data (e.g. shadows or sea reflections) can cause significant extraction errors. To overcome this problem, we present newly developed Coastal Extraction Tool (CET) that allows accurate and time-efficient automated coastline extraction based on combination of VHR multispectral satellite imagery and stereo-pair derived digital surface model (DSM). Automated coastline extraction is performed and tested with CET on Iž-Rava island group, situated within Northern Dalmatian archipelago (Croatia). CET extracted coastline accuracy was validated at chosen locations through comparison with the coastline extracted manually from centimetre accuracy reference data collected by in-situ terrestrial LiDAR scanning and UAV photogrammetry. Accuracy of CET extracted coastline was further analysed and quantified through 25 ground control points (GCP) collected along true coastline with high-accuracy RTK-GPS. Validation has shown that CET is highly accurate and that it successfully overcomes spectral induced errors. As a result of analysis two small islets are detected within study area that haven't been mapped earlier within official state data. Considering its accuracy and ease of use we suggest that CET can be applied for automated coastline extraction in other large and indented coastal areas. Additionally, we suggest that it could be potentially applied in longitudinal geomorphological coastal erosion studies for detection of spatio-temporal coastline displacement.

Keywords: Worldview imagery; coastline extraction; LiDAR; very-high resolution; CET

EASTERN MEDITERRANEAN CLIMATE VARIABILITY AND RECONSTRUCTION OVER THE LAST 12000 YEARS BASED ON A VARVED SEDIMENT RECORD FROM VOULIAGMENI LAKE, GULF OF CORINTH (GREECE)

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Paleoclimate studies, depending on a broad spectrum of high-resolution proxies and conducted in highly climatic sensitive areas like the eastern Mediterranean provide valuable information on regional and large-scale atmospheric patterns as well as the impact of those changes into early human societies. Annually laminated sediments provide close insight into climate variability during the last post-glacial period. In this study, we present a multi-proxy reconstruction of central-eastern Mediterranean over the last 12000 years, based on a sediment core from Vouliagmeni lake, located in the eastern part of Corinth Gulf, Greece. The compiled dataset consists of: (a) grain size analysis and magnetic susceptibility measurements, (b) Total Organic Carbon (TOC) and (TN) distribution, (c) high resolution X-ray fluorescence data, (d) mineralogical analysis, (e) CT scanning data and 3D reconstruction of the core, (f) AMS radiocarbon dating correlated with varve counting, (g) isotopic composition ($\delta^{18}\text{O}$, $\delta^{16}\text{O}$) on selected samples and (h) diatom analysis. In order to determine lamination boundaries, total number and thickness, the x-ray computed tomography was conducted with the highest possible resolution. Accumulation rates into the system seem to change at around 3000 cal BP, presenting higher sedimentation rates after that time. As indicated from archaeological and historical writings, urban development in the area seems to be well established around Late Bronze age (1700-1075 BC). Different precipitation/temperature and runoff patterns for the catchment area were recognized, through the different proxies examined, providing signals of long scale and regional climatic anomalies. Also, the latest interglacial Rapid Climate Change (RCC) event, which coincides with the Late Bronze/Early Iron age, is clearly documented in the sediment sequence. Therefore, Vouliagmeni core presents one of the most promising geoarchives in the study of climatic changes concerning the last 12 ka years in eastern Mediterranean.

Keywords: Varves; Holocene; gulf of Corinth; XRF; Paleoclimate

BOULDER DEPOSITS ON THE SOUTHEASTERN COAST OF CYPRUS AND THEIR RELATION WITH PALEOTSUNAMI EVENTS OF THE EASTERN MEDITERRANEAN

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Cyprus has a long record of tsunami waves, as noted by archaeological and geological records. Large boulder deposits have been noted in southeastern and western part of the Island. In the area of Cape Greco (southeastern Cyprus) large boulders have been noted, however, no detailed geomorphological research exists so far and the related high energy event remains undated. In this context, we focused at Cape Greco Peninsula at the southeastern coast of Cyprus, in order to record in detail large boulders deposits. The accumulation of the boulders along the uplifted coastline (3m amsl) was recorded. The boulders are fragments of a layer of an upper Pleistocene aeolianite, which is overlaying unconformably a lower Pleistocene calcarenite. Dimensions and spatial distribution of 272 small, medium and large boulders were documented. The precise distance of the boulders deposition from the coastline was recorded by field measurements and remote sensing with the use of GNSS, Drone mapping and GIS technics. Several large boulders weighting more than ~30 metric tons were located up to 60m inland. Geomorphologic mapping and morphometric measurements, along with the presence of marine organisms suggests that some of the boulders were removed from their original intertidal zone and were transported inland by the force of large waves. Samples of *Vermetus* sp. were collected from the displaced boulders in order to date the extreme event. In this work, we report and compare preliminary results from the application of widely accepted hydrodynamic equations, in order to determine the extreme event that caused their transport inland. We further attempt a correlation of the event with already known tsunami events from Eastern Mediterranean, based on the estimated wave heights and the radiocarbon dating of marine gastropods (*Vermetus* sp.).

Keywords: Tsunami; boulders; coastal geomorphology; Eastern Mediterranean

MONITORING COASTAL KARST TOPOGRAPHY AND ITS CHANGE USING HIGH SPATIO- TEMPORAL RESOLUTION UAV PHOTOGRAMMETRY IN KRAKAL COASTAL AREA, YOGYAKARTA, INDONESIA

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Coastal areas tend to experience rapid degradation due to the influence of both natural and anthropogenic processes. The measurement of topographic changes is very essential in many geomorphological studies. Observing rapid changes that occur in the karst coastal region require high-resolution data. In recent years, the use of unmanned aerial vehicle (UAV) has grown rapidly in providing high-resolution topographic data. In this study, fixed wings X-8 was used and equipped with non-metric cameras to acquire less than 10cm ground spatial distance. High-resolution Orthomosaic images and Digital Surface Models (DSM) with approximately 1 cm vertical accuracy were obtained through Structure from Motion (SfM) processes from several overlapped aerial images. In this study, four series of aerial photographs were taken between 2015-2019. The results show significant topographic and land use changes in the coastal area of Krakal. The coastal area of Krakal is located in the tropical karst landform (cockpit karst). The topographic conditions in the cockpit karst area is rapidly changed over 4 years. The most obvious change is due to the development of tourism facilities such as hotels and bus terminal. This research emphasizes the geomorphic changes of coastal karst that occur rapidly and their impact on the environment. Furthermore, this study shows the effectiveness of UAV in providing low-cost and accurate coastal processes analysis.

Keywords: UAV; coastal; karst; Krakal; Indonesia

CLOSE RANGE PHOTOGRAMMETRY AT TIDAL AND NEAR-TIDAL ZONE

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The tidal zone represents a complex mix of landforms related to the interplay of marine and subaerial processes. Recent achievements obtained within the Geoswim project allowed to start the analysis and improvement of digital images to create three-dimensional models of tidal areas along rock coasts. Despite the large database of images collected along rock coasts in the Mediterranean coasts, no works were proposed to model the tidal zone using SfM methods. This paper concerns the evaluation of useful photogrammetric procedures, field and post-processing, to obtain 3D models both above and below the sea level, and the corrections to join together the aforementioned models. In particular, the light transmission between air and water and related problems were investigated in order to automatically align the underwater and subaerial models reducing the ground references. Moreover, we considered the pro- and contra- of a second photographic survey in order to supplement data lying at the sea level. Post-processing of images and the contribution to the improvement of the models and texture were analyzed. The analysis regarded in particular the elaboration of large number of images which cover long sectors of rock coasts in order to reduce the manual data elaboration.

Keywords: Rock coast geomorphology; SfM; geoswim; Istria; Croatia

LONGSHORE DRIFT CONVERGENCE IN EMBAYMENTS

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Longshore drift is an important coastal agent responsible for the transport and deposition of sediment along the coastline. The direction of the longshore drift depends on the angle between the incident wave-front and the coastline. Longshore drift causes erosion and progradation of the coastline, which has its direction changed. Thus, coastline orientation and longshore drift have between each other an important morphodynamic relation in coastal environments. This work is based on drift modeling in a wave-dominant environment and on literature review. The modelling was made by the Software Mike 21 to an embayed paleo-coastline of the São Francisco River delta, in northeastern Brazil. It has been found that, in this embayment, the net longshore drift is convergent. The convergence was also observed in other embayments, what seems to demonstrate that the convergence of the net longshore drift is independent of the direction of the incident wave-fronts. This convergence tends to favor a rapid filling of the bay, mainly in estuarine and deltaic environments, where there is a river delivering sediment into the bay. With the bay filling and subsequent change in the coastline orientation, the net longshore drift direction will change again as a consequence of the feedback process.

Keywords: Longshore drift; embayments

A COMPARATIVE STUDY OF SEASONAL CHANGES OF THE SEDIMENTOLOGICAL AND GEOMORPHOLOGICAL CHARACTERISTICS OF MYLOPOTAS AND MANGANARI BEACH IN IOS ISLAND, CYCLADES (GREECE)

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Sedimentological and geomorphological features of Mylopotas and Manganari beaches in Ios Island are investigated in order to determine seasonal changes in the texture of coastal sediments and shoreline position caused by both natural processes and human activities. The fieldwork was conducted in April 2018 and September 2018 including mapping of beach morphology in seasonal scale through topographic monitoring of shoreline, coastline and fixed cross sections in the sites under investigation using a differential GPS. In addition, sediment sampling was carried out along selected cross sections in beaches of Mylopotas (three) and Manganari (two). Grain size analysis and statistical processing were realized to reveal spatial and temporal changes of sediment parameters, such as sorting, skewness, mean and kurtosis. The results indicate a rather homogenous grain size distribution at each study area, with the majority of samples being classified as slightly gravelly sand. DGPS measurements of shoreline position in Manganari Beach indicate changes that vary between 2.50 m and 4.70 m, with the maximum displacement to be observed in the southern part of the beach, where the shoreline is retreated during spring period. Seasonal variations of shoreline position in Mylopotas Beach are up to 4.50 m with the shoreline to be advanced during spring period in the southern and northern part of the beach, while the minimum changes are measured in the central part, where a beachrock formation occurs. Occasional human interferences, such as small-scale beach restoration and nourishment projects, installation of leisure facilities and reshaping of sand dunes, conducted mainly during spring period, alter the coastal sediment budget and transport reinforcing shoreline retreat.

Keywords: Grain size analysis; sedimentology; textural changes; Ios Island

THE ROLE OF THE WAVE REGIME IN BEACH ZONE MORPHOLOGICAL CHANGES: AN EXAMPLE FROM THE NORTHERN COAST OF MESSINIAKOS GULF (IONIAN SEA)

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Wave regime plays a significant role in the morphological evolution of coasts and especially, those consisting of non-cohesive material, i.e. beaches. The present contribution, utilizing field acquired data and data from the EMODnet database, investigates the frequency of occurrence of wave episodes in the inner Messiniakos Gulf, with heights exceeding the average wave height for Greek waters (0.7 m), whereas a comprehensive statistical analysis of the wave characteristics is provided. Furthermore, we examine the influence of such a wave episode on the beach zone along the north coast of the Gulf that took place between 12 and 19 of November 2017. This event was characterized by strong (>6 Beaufort) southerly winds and incoming offshore waves with height of 1.8 m and period of 7.8 s. The impact of this event is associated with morphological changes of the beach zone, which are not equally distributed along the 24 km of the shoreline, exhibiting a maximum retreat of 7-8 m at its westernmost and an accretion (3-7 m) at its easternmost sector (to the east of Kalamata port). These changes are also associated with the pattern of the nearshore sediment transport, that also presents high variability among the 19 control points (shore-normal profiles). Furthermore, in anticipation of future sea level rise of 0.5 m and 1 m and on the basis of static models applied to the shore-normal profiles, the shoreline retreat is estimated at several, up to tens of metres.

Keywords: Nearshore morphodynamics; shoreline changes

DETERMINATION OF TSUNAMI EVACUATION ROUTE BASED ON DETAILED DIGITAL ELEVATION MODEL IN GUNUNGKIDUL COASTAL AREA, JAVA, INDONESIA

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The tsunami evacuation is a short process that must be carried out in minutes. However, this is not always possible because of the short period of early warning in wave arrival time to the coastline. Determining locations for safe areas and evacuation routes is equally important in tsunami evacuation planning. Tsunami Vertical Evacuation (TVE) can be an alternative for coastal communities to minimize the risk. We use the coastal community of Drini, Gunungkidul, Java as a study area in determining tsunami evacuation routes. The study area is located in the tropical coastal karst region with a typical karst cone formation. The topographic condition of the karst cone could be an ideal area as a location for “sheltering-near-place” before being moved to the assembly point. High-resolution Orthomosaic images and DEM generated from Structure for Motion (SfM) process were used as the main data for the Least Cost Distance (LCD) anisotropic model. Land cover Identification from high-scale orthomosaic images shows the variation of Speed Conservation Value (SCVs). The slope value is also used as a surface cost that will affect the travel time to TVE. The tsunami inundation model is calculated based on neighboring operations using the raster calculator from the elevation value in the DEM. The results of the model show that TVE became the main alternative in tsunami evacuation planning. These results provide an evaluation of the location of the assembly point and the evacuation routes provided by the government which considered ineffective because of its inappropriate model. The results of this study provide an overview in determining the locations for a tsunami vertical evacuation shelters. The optimum locations used as shelters can minimize the travel time, have adequate capacity, and safe from inundation. These results provide decision support for tsunami evacuation management in order to minimize the risks in coastal communities.

Keywords: Tsunami; evacuation; DEM; Gunungkidul; Indonesia

IMPACT OF COASTAL STRUCTURES ON SHORELINE BEHAVIOUR – A CASE STUDY FROM SW COAST OF INDIA

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Shoreline stabilization structures such as groins, seawalls, jetties etc. have caused down-coast erosion in many cases in the world. The objectives of this study is to find out the shoreline behaviour of pre and post construction activities of two sandy beaches, namely Ullal and Someshwara of Mangalore coast using Remote Sensing and field based approach. In order to prevent coastal erosion, in 2014 the construction of coastal structures such as inshore berms and offshore reefs were initiated and completed in 2017. Shorelines were extracted from IRS-LISS-IV satellite data for the period 2012 to 2017 using Arc GIS 10.3 software. Shoreline change rate was calculated for pre-construction (2012 to 2014) and post construction periods (2014 to 2017) using Digital Shoreline Analysis System. The result shows that during pre-construction period 86% of the shoreline exhibits erosion with a maximum shoreline displacement of -20.79m. Both beaches show erosion in this period. Whereas; during post construction periods, erosion was reduced to 60% with a maximum displacement of -35.51m. A makeable observation is that, both periods Someshwara beach shows erosion and shoreline is eroding continuously in this beach. In Ullal, after construction of protection structures shoreline is accreting with a maximum value of 28.19m. From this study, it is concluded that coastal protection structures effectively working in Ullal beaches and their performance is satisfactory. Someshwara beach eroding faster way and shore protection structures need to be taken up in this beach.

Keywords: Erosion; shoreline change; GIS; inshore berms

THE COASTAL MORPHOEVOOLUTION OF NAPLES SINCE 6000 YEARS BP: NEW INSIGHTS FOR PIZZOFALCONE PROMONTORY

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The coastal landscape of Naples is characterized by tufaceous high coasts and interposed coastal plains. The knowledge on its Holocene coastal changes has been improved by recent geoarchaeological investigations at Chiaia and Municipio plains and Posillipo promontory. Conversely, no specific study has been still carried out on the morphoevolution of Pizzofalcone promontory, which divides the two coastal plains. In this research, new data about the Naples coastal evolution over the last 6.5 ky were presented, by interpreting morphological, stratigraphic and historical data. Three orders of palaeo-shore platforms provided new constraints useful to reconstruct morphoevolutive scenarios controlled by volcano-tectonic activity in this costal stretch. The first order of platform, at 7 m asl, is located at the footslope of Pizzofalcone and sculptured on Castel dell'Ovo Tuff (OVO, 78.0 ky). Instead, the submerged ones were identified at -5 m bsl both in the Chiaia plain (buried and sculptured into the pyroclastics deposits related to 4.5/4.0 ky BP Campi Flegrei eruptions), and along Posillipo and Pizzofalcone coasts (submerged and sculptured in Neapolitan Yellow tuff, 15 ky BP). The third order of platforms at -3 m bsl were dated to Roman age due to the presence of archaeological remains built on them. The geomorphological interpretation of the emerged platform led to suppose that it formed about 6.5 ky BP and uplifted immediately before the above-mentioned Campi Flegrei eruptions as appended for La Starza marine terrace. Subsequently, the wave action formed the second order of shore platform partially dismantling the raised one. Since that time, a subsiding trend affected the area inducing the formation of the Roman platforms, as resulting of a cliff retreat. Instead, in the plains, a prograding trend prevailed for the sedimentary inputs increase. The natural evolution of the area ended in 1800 with the construction of coastal gardens and streets.

Keywords: Coastal landscape evolution; geomorphological analysis; shore platforms; vertical ground movements; coast of Naples

AGE EVOLUTION AND GEOMORPHIC DEVELOPMENT OF AKROTIRI PROMONTORY SAND DUNES, CYPRUS

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Two well-developed quaternary sand dune fields have been identified on the western and eastern side of Akrotiri promontory (Lemesos, Cyprus). The fields extend immediately from the low level of their source beaches onto higher ground (> 38m amsl). Geomorphic observation supported by OSL dating of multimineral sand horizons demonstrate several phases of sand accumulation in the western field in contrast to the smaller eastern system, where the evidence direct to a relatively recent dune emplacement. The effects of climatic change, relative sea-level change and anthropogenic influence in dune evolution, have been evaluated in both sites in combination with documented evidence of human induced destabilization of the western sand dune field during the 1970s and 1980s. Both fields share similar topographic settings and situated in close proximity but they do not share an entirely similar evolution history. The observations and the data suggest the combination of local and regional control of the development of the sand dunes and the geochronological analysis with luminescence methodology support the ability of the method to reconstruct the evolution of sand dunes fields in the eastern Mediterranean area.

Keywords: Sand dune; Akrotiri peninsula; coastal geomorphology; chronology

NEARSHORE SEDIMENT DYNAMICS IN RELATION TO COASTAL EVOLUTION: SATELLITE RETRIEVALS AND IN-SITU MEASUREMENTS IN THE GULF OF ALEXANDROUPOLIS

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The aim of this study is to investigate the role of suspended sediment in the coastal morphology of the Gulf of Alexandroupolis, by using Satellite imagery. This approach describes both the suspended sediment being reworked under the influence of the coastal hydrodynamic processes in the coastal zone (erosion, resuspension) and the suspended sediment being introduced by the Evros river plume. For the former, nearshore hydrodynamic conditions related to sediment resuspension were examined, while for the latter MODIS images (January 2006- December 2008) and Landsat-8 images (January 2016- December 2018) were gathered and processed to estimate surface suspended sediment distribution. The elaboration of satellite images provided that suspended sediment in the Gulf of Alexandroupolis ranges between 0.02 and 0.5 mg/l and multiplies up to 50 times during flood events (25 mg/l). Suspended sediment in the bottom nepheloid layer of the nearshore zone is among 10 and 15 mg/l, attributed to hydrodynamic activity. Regarding Evros plume, the interannual distribution pattern showed that under normal river discharges Evros' plume core is restricted close to the river mouth (<5m depth), whilst under flood events Evros discharge spreads offshore to Samothraki Plateau. The most frequent NW plume direction is dictated by the prevailing NE winds and Coriolis effect, while combined with Samothraki high anticyclonic circulation develop, occasionally, a secondary SW directed branch of the plume. The long-term influence of E/ NE and North directed winds result in upwelling in the nearshore zone accompanied by a northward longshore movement of riverine waters under the influence of Coriolis Effect. Moreover, plume is restricted close to the coastline under the influence of west directed winds. At the west side of the Gulf increased suspended sediment concentrations within the nearshore zone come as the combined effect of hydrodynamically induced resuspension and the the sediments produced by coastal cliff erosion.

Keywords: Evros plume; suspended sediment; hydrodynamics; LandSat 8+; MODIS

A COMPARATIVE STUDY OF BEACHROCK MECHANISM FOR-MATION FOCUSING ON NATURAL AND ARTIFICIAL BEACHROCKS: CASE OF DIOLKOS, CORINTH, GREECE AND SUMUIDE, OKINAWA, JAPAN

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Beachrocks are a window in the past environmental, geological, sedimentological and geographical conditions that were dominant on the coastal zone. The minerochemical examination of cement and the sedimentological analysis are the most efficient methods for understanding the formation mechanism. However, the examination of beachrock samples have limitations and the evidence of formation mechanism are not enough. This study emphasizes on the beachrock formation mechanism through the comparison of cement characteristics, mineral chemistry and sedimentology of beachrock occurrences from different geological and geographical setting areas Diolkos, Corinth, Greece and Sumuide, Okinawa, Japan. Furthermore, in order to investigate the beachrock formation, artificial beachrock samples were created in-vitro using sand samples and ureolytic bacteria from Okinawa under accelerating conditions. Bulk samples were collected from the study areas in order to analyze their mineralogical (XRD and SEM-EDS) and chemical (XRF) composition. Microscopy studies (optical and SEM-EDS) revealed that the cement agent from Diolkos is mainly composed of High-Magnesian Calcite (HMC) in comparison to the Sumuide beachrock which is characterized by the presence of calcite and aragonite. Additionally, the analysis revealed clastic silicate and aluminosilicate minerals. The grain composition of Diolkos slab consists of quartz, plagioclase, K-feldspar with 20% bioclasts compared to the Sumuide beachrock grains that consist of calcareous residuals from the local coral reef. The artificial beachrock investigation indicated that ureolytic bacteria that reside in the Sumuide beach sediment, are capable to precipitate aragonite coating the sediment grains and filling the pores. The cementation was most active in the top part of the samples than the bottom part. This is an indicator that the beachrock formation might occur in depths where these bacteria can be found. The artificial beachrock analysis included its physicochemical parameters using UCS penetration, pH and Ca²⁺ measurements, X-Ray CT-scanning, petro-graphic polarized microscopy, XRD, and SEM-EDS.

Keywords: Beachrocks; artificial beachrocks; cementation; Corinth; Okinawa

BEACHROCK FORMATION MECHANISM THROUGH MINEROCHEMICAL ANALYSIS AND CEMENT CHARACTERISTICS: CASE STUDY W. AKROTIRI PENINSULA, CYPRUS

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Beachrocks are hard coastal sedimentary formations consisted from various beach sediments, coastal fauna residues and anthropogenic articles. Beachrocks are rapidly cemented through precipitation of carbonate cements typically consisted of High-Magnesian Calcite (HMC), which commonly precipitates in shallow marine environments, (>4 mol % CaCO_3 or 1.2 wt. %) or aragonite (Ar). However, debate still exists concerning the accurate depositional environment of beachrocks and data for the mechanism of their formation are considered necessary. This study aims to contribute to the understanding of the beachrock formation, using mineralogical and geochemical methods, analyzing the cement and the consolidated sediments. Bulk samples were collected from three consecutive beaches located at the West part of Akrotiri Peninsula (Cyprus island). The samples were examined under polarizing microscope for the determination of the cement (HMC as micritic and sparitic crystals), its characteristics (isopachous bladed coating, formation of meniscus etc) and the participation of well-preserved fossil fragments. The mineralogical analysis, with the use of XRD analyzer, indicated a variety of minerals which consisting the beachrock (quartz, carbonates, plagioclase, olivine, biotite, zircon etc). Using SEM-EDS it was possible to accurately determine the cement composition and to observe its crystal characteristics. The cement agent was mainly consisted by High-Magnesian Calcite (HMC) of different crystal sizes and matrix material was present as secondary pores filling. The three studied beachrocks at the west of Akrotiri peninsula, were formed in the middle-low intertidal zone. Evidence of continuous uplift of the beachrock is observed both from geomorphological analysis and through its infrastructure. The beachrocks were highly affected by the nearby Kouris river, which supplied the material derived from the inner Cyprus areas rich in Mg^{2+} rocks (eg. ophiolites) and Ca^{2+} (eg. limestones, marbles).

Keywords: Beachrocks; cement; formation mechanism; geochemistry; Cyprus

BIOTURBATION VIS-À-VIS SEDIMENT DISPERSAL IN A RETROGRADATIONAL DELTA: SAGAR ISLAND, HUGLI ESTUARY, INDIA

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Active grain manipulations by the crab populations were estimated based on the percent surface area bioturbated and quantitative changes in different size fractions of bioturbated and non-bioturbated sediments, in the southern coast of Sagar Island, Hugli estuary. Observations were made on 10 shore normal zones constrained by distinct combination of geomorphology, primary sedimentary structures, textural attributes of the substrate sediment and bioturbation fabric recognizable in the field. Surface area bioturbated varies between 0.08% and 29.92% in these zones. Substantial bioturbation were recorded in the back swamp (6.87% of surface area), upper foreshore (12.33–29.92%) and distal lower foreshore (up to 6.89%). Excavation of burrows (for dwelling) in upper foreshore homogenized the temporal sediment populations inflicting a coarser mode and lower sorting value compared to that of hydrodynamically emplaced substrate sediment. Pelletization (for sediment ingestion) in distinct shore parallel nutrient zones, on the other hand, inflicts better sorting, coarsening and a fine tail truncation in the bioturbated sediments compared to non-bioturbated surface sediments through selective removal of silt and clay fractions during sediment ingestion. Retrogradation of delta in the studied part of basin in the last decade may be supported from the observed gradual straightening of the adjacent creek, probably in response to landward propagation of tidal impact. A fining landward grain-size distribution is common in a retrogradational estuarine delta. Lack of any such trend in the studied part of Sagar coast may be attributed to grain manipulation through bioturbation that obliterated the texture of background substrate sediments, yielding bioturbated sediment populations with no hydrodynamic equivalence. This quantitative estimate of change in sediment attributes through biological interference might help to constrain modelling on sediment dispersal in similar marginal marine set up.

Keywords: Hugli estuary; bioturbation; sediment dispersal; granulometry

COASTAL VULNERABILITY ASSESSMENT ALONG THE NORTH-EASTERN SECTOR OF GOZO ISLAND (MALTA, MEDITERRANEAN SEA)

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The Maltese archipelago is located in the central Mediterranean Sea and comprises the main islands of Malta, Gozo and Comino. Its coastal landscape is largely the result of a long-term evolution under the influence of tectonic activity, geomorphological processes and sea level oscillations. Due to their geological and geomorphological setting, these islands are, as a result, particularly prone to different marine-related and gravity-induced processes, enhanced by ongoing climate change. This study is focused on the assessment of the coastal vulnerability to landslides, coastal erosion, storm water runoff and sea level rise along the NE sector of the Island of Gozo, which is characterized by varied landforms, including landslides, plunging cliffs, sloping coasts, pocket beaches, shore platforms and a large sandy beach partly backed by dunes. Based on a detailed geomorphological investigation, integrated with the analysis of marine geophysical data, coastal dynamics have been characterized identifying this stretch of coast as potentially susceptible to mass movements, coastal flooding and erosion. Furthermore, an index-based approach has been applied for the evaluation of the vulnerability of the exposed elements in the investigated area. In more detail, a set of indicators related to the local land use, the anthropic and natural assets and the presence of economic activities has been proposed with the final aim of producing a coastal vulnerability map by means of GIS tools. The results highlight that the most vulnerable areas are located in Marsalforn Bay, characterized by an extensive urban development, and in Ramla Bay, which is an important tourist attraction hosting the largest sandy beach in Gozo. The research carried out represents a first important step toward risk assessment that also takes into consideration the effects of climate change and sea level rise.

Keywords: Coastal morphodynamics; vulnerability assessment; Gozo; Maltese archipelago

USING SATELLITE IMAGES TO DETECT UNDERWATER FEATURES ALONG DANUBE DELTA UPPER SHOREFACE

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Nearshore sandbars are natural underwater sandy ridges of the upper shoreface with important role in coastal protection against storm impact and, hence, their dynamics and evolution under sea level rise and climate changes are very important for the fate of beaches and dunes. Data availability could be an issue on many coasts worldwide and newly released satellite images and derived products can increase in the future the spatial and temporal resolution, availability and quality of sandbar observations. We present a new methodology for the automatic detection of sandbar crest positions from freely available medium resolution satellite images (Sentinel-2) using a case study of complex waters located on Danube Delta coast (Black Sea). Our methodology fills the gap of automatically obtaining the position of underwater features at medium-term time-scales (weekly) over extensive areas (tens of kilometres). The obtained sandbar locations were validated against 4 in-situ measurements between 2016 and 2018 and the correlation was very good between the two datasets, showing the high potential of these data to reveal underwater morphology of the upper shoreface with relatively high fidelity. The extracted sandbar positions were then integrated into an automatic workflow able to accurately represent the seasonal and multi-annual sandbars dynamics. We further discuss the major advantages, shortcomings and the identified technical problems related to imagery radiometric and geometric corrections in connection with the cloud coverage, the pixel contamination at the sea-land interface and the equalization of the spectral signal over the entire area if high sediment resuspension processes are present. Such a methodology could be applied for sandbar crest extraction along many sites worldwide, providing reliable results along large longshore distances and temporal scales ranging from days to seasons.

Keywords: Sentinel-2; sandbar crest; bar migration

ROCK FALLS AND CLIFF RETREAT RATES IN PYROCLASTIC SLOPES: THE CASE STUDY OF THE PHLEGREAN COAST (SOUTHERN ITALY)

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The coastal area between the towns of Naples and Pozzuoli represents a unique environment in the Italian peninsula, because of the diffuse presence of Greek and Roman archaeological sites in a dynamic landscape. The geomorphological evolution of this area has been strongly influenced by the young (<40 ka) eruptive history of the Phlegrean Fields, the largest active volcanic fields in Italy. The alternation of explosive volcanism, caldera collapse and bradyseism events have shaped the coastline, that is characterized by steep sea cliffs, embayment, sand beaches and coastal lagoon. Regarding sea cliffs, their shape is strongly controlled by rock-type, with the highest cliffs cut in consolidated tuff deposits and the smallest one cut in ash falls and volcanic scoriae units. Geomorphological and structural analysis suggest the occurrence of a dense net of mainly NE-SW trending faults, that causes the diffuse presence of fractures in tuff deposits often acting as critical points from which rock falls originated. In the area, ~100 rock falls were recognized, the largest one being represented by the Capo Miseno fall, with a volume of ~40,000 m³. Here, we carried out a comprehensive analysis consisting in drone surveys, geomorphological analysis and geo-structural measurements that allowed to derive the 3D model of the rockfall and to decipher the mechanism of failure. In addition, the combination of geomorphological and archaeological data along the Phlegrean coastline allowed to estimate cliff retreat rates at different time scales, thus highlighting sea-cliffs more susceptible to rock falls. The presence of human structures and infrastructures and of archaeological sites has been also taken into account allowing to define possible rock-fall risk scenarios.

Keywords: Phlegrean Fields; rock fall; cliff retreat; pyroclastic slope

ASSESSING THE COASTAL VULNERABILITY DERIVED FROM BOTH NATURAL AND ANTHROPOGENIC PROCESSES, ESTIMATING CVI AND TVI AT TOURISM DESTINATIONS: THE CASE OF RHODES ISLAND, GREECE

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Coastal areas are the most delicate systems in environmental changes, caused both by natural and human interference. They are valuable ecosystems and significant as economic resources. This research calculates the useful Coastal Vulnerability Index (CVI) and Tourism Vulnerability Index (TVI) in order to indicate the vulnerability in Rhodes Island both from physical and anthropogenic derivatives, via the estimation and interpretation of various parameters. The coastal areas were depicted through geomorphological and sedimentological-granulometrical parameters according to the CVI requirements. Alike in TVI, physical and tourism parameters were assessed to indicate the most degraded areas caused by tourist saturation. Data processing included geomorphology, sedimentology and topography (i.e., satellite images, geological and topographic maps), supported by fieldwork, laboratory analyses (i.e., sedimentology- granulometry) and detailed literature review. Data analysis was accomplished through GIS platform. The GIS platform effectively contributes to the simultaneous processing of all the aforementioned data as well as the illustration of the spatial distribution of the estimated parameters, highlighting the most vulnerable sectors taking into account their different attributes. The fulfillment of CVI and TVI determination and visualization is absolutely crucial for insular regions, especially those with high tourist value, like Rhodes Island. Thus, the results of the current study will essentially assist the decision-making authorities to select the most appropriate and sustainable solutions for the prominent coastal issues.

Keywords: CVI; TVI; tourism saturation; climate change; sustainable development; Rhodes island

COASTAL EVOLUTION OF THE TWO NATURAL RESERVES OF THE TIDELESS BLACK SEA AND BALTIC SEA: SIMILARITIES, DISCORDANCES AND CYCLIC ALTERNATING EVOLUTIONARY TRENDS

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This study presents a comparative analysis of the multidecadal (1950 – present) coastline evolution of the Danube delta Biosphere Reserve (western Black Sea) and of the Slowinski National Park (southern Baltic coast) which are nowadays largely protected by the direct anthropogenic impact. Both coasts are virtually tideless but highly mobile making them ideally suitable for the analyse of the role played by storminess variability in accordance with the main teleconnection patterns (North Atlantic Oscillation - NAO, East Atlantic/Western Russia – EAWR) on the overall coastline evolution. Storms have been found to exhibit a cyclic pattern with successive periods of 7–9 years of high, moderate and low storminess which determine a fast response of the shoreline and of the adjacent units (shoreface, beach- dune system) trying to adapt to the multi-yearly storm wave energy. Several morphodynamic indices were derived from the comparison of georeferenced maps, aerial and satellite images and field measurements and then analysed comparatively (inter-sites) and in correspondence with the storm climate (including storm severity index – SSI and storm impact potential - SIP) and the computed storm-induced sediment transport (MIKE 21). The peaks in coastal storminess are strongly correlated with especially NAO (negative correlation for the western Black Sea, respectively positive for the southern Baltic Sea) inducing high intensities of erosion and accretion processes, whilst during the calmer periods it occurs a significant decrease of 40-70 % of the shoreline migration rates or a prevalence of accretion. Specific discussion are dedicated either for different features – barrier islands and spits, river mouth bars, sand waves – which are particular sensitive in relation with regional settings (e.g. river flow changes or coastline exposure) or to the antagonistic multidecadal behaviour of the two coastlines.

Keywords: Danube delta; Slowinski National Park; shoreline migration; storminess; NAO

PALEOECOLOGICAL TRACERS OF MARINE-FRESHWATER TRANSITIONS DURING THE EARLY TO MID HOLOCENE DANUBE DELTA BUILD-UP

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The Early to Mid Holocene development of a proto-deltaic morphological system into the low-wave energy upper Danube Bay (formed by drowning of the former Danube valley during the Black Sea reconnection to the planetary sea level, ca. 9.3 ka) was defined by a complex array of sedimentation processes that were controlled, to a large degree, by a shifting contact between the Black Sea waters and the Danube river. In this study, we focus on tracing the marine- freshwater transitions in a series of cores extruded along the terminal floodplain of the Danube River (Brăila – Tulcea), upriver of the present Danube delta. To this end, we use a suite of paleoecological tracers (palynomorphs) including pollen, spores, dinoflagellate cysts, foraminifera test linings, fungal spores, and algal remains to constrain the contact between the paleo-river system and sea water. Our preliminary results indicate that the proximal proto-deltaic complex was largely built by fluvial sedimentation interrupted – at least once- by a marine transgression, which transformed the proto-deltaic front into a ria system.

Keywords: Delta; paleoecological tracers; palynomorphs; marine-freshwater transition

S04. DENUDATION IN THE MEDITERRANEAN ZONE

DRIVERS AND RATES OF DENUDATIONAL PROCESSES AND SOURCE-TO-SINK FLUXES UNDER CHANGING CLIMATE AND ANTHROPOGENIC IMPACTS IN SELECTED MEDITERRANEAN CATCHMENT SYSTEMS IN EASTERN SPAIN

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Climate change, human activities and other perturbations (like, e.g., fires, earthquakes) are likely to influence existing patterns of weathering, erosion, transport and deposition of material across defined landscape components and units. While it is still a challenge to develop an improved understanding of how such changes interact and affect slope and fluvial processes, the connectivity within landscapes and between slope and fluvial systems, as well as contemporary denudation rates, source-to-sink fluxes, and sedimentary budgets, this kind of quantitative analyses promise to be an efficient framework to assess the impact of environmental changes and disturbances to sediment dynamics and to evaluate landscape sensitivity. The current knowledge on drivers and rates of contemporary sediment dynamics and denudation forms the basis for understanding and predicting the consequences of ongoing and accelerated environmental changes. Ongoing GFL research activities on drivers and quantitative rates of contemporary sediment dynamics and chemical and mechanical slope and fluvial denudation in selected catchment systems in eastern Spain are presented. The Pou Roig and Quisi catchment systems in the Calpe region in eastern Spain are located in a Mediterranean, partly mountainous and/or anthropogenically affected environment. Sediment transfers, the intermittent runoff and fluvial transport are almost entirely controlled by pluvial events. Our investigations include geomorphological mapping combined with statistical analyses of existing meteorological high-resolution data and the observation and monitoring of meteorological and runoff events, and of sediment transfers on slopes and in stream channels using a combination of different automatic and manual observation, monitoring and sampling techniques. Our results on controls and the spatiotemporal variability of chemical and mechanical denudation, storage and sedimentary budgets within the two catchment systems contribute to an advanced understanding of key drivers and rates of contemporary sediment dynamics and denudation in this Mediterranean environment, and provide the basis for improved predictions of possible effects of climate change and anthropogenic impacts on contemporary denudation rates in this morphoclimatic region.

Keywords: Denudational processes; catchment systems; morphoclimate; climate change; anthropogenic impacts

THE IAG WORKING GROUP ON DENUDATION AND ENVIRONMENTAL CHANGES IN DIFFERENT MORPHOCLIMATIC ZONES (DENUCHANGE, 2017-2021): OBJECTIVE, ACTIVITIES AND PLANNED OUTCOME

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There is a general agreement that global environmental changes will have significant effects on Earth surface systems. The question on how global environmental changes will affect our landscapes and the way we will interact with it is therefore of the highest importance. Denudation, driven by both chemical and mechanical processes, is of high relevance for Earth surface and landscape development and the transfer of solutes and sediments from headwater systems through main stem of drainage basin systems to the world oceans. Denudation is controlled by a range of environmental drivers and can be significantly affected by human activity. A better understanding of possible effects of ongoing and accelerated environmental changes on present-day denudation systems requires systematic and quantitative studies (including monitoring) on the actual drivers of denudational processes in differentiated landscape controls. Only if we improve our current knowledge of drivers, mechanisms and rates of contemporary denudational processes across a range of different selected climatic environments, possible effects of global environmental changes on denudation can be better assessed. Special focus must be given to selected morphoclimatic zones that react particularly sensitive to ongoing climatic changes and human activities, especially in extreme zones like polar or dry hot ones. A systematic geomorphologic comparison of present-day denudation rates in different defined climatic zones combined with a coordinated analysis and compilation of the respective key controls of denudation that is presently occurring in the different selected morphoclimatic settings is still largely missing and urgently needed. The IAG Working Group on Denudation and Environmental Changes in Different Morphoclimatic Zones (DENUCHANGE) (2017 – 2021) can help to close this still existing key knowledge gap and shall contribute to a better understanding of the possible effects of global environmental changes on contemporary metamorphosis of the Earth surface systems. Detailed information on IAG DENUCHANGE is found at <http://www.geomorph.org/denuchange-working-group/>.

Keywords: Denudation; morphoclimate; environmental drivers; environmental change; IAG Working Group

SOIL EROSION AND DEPOSITION RATE INSIDE AN ARTIFICIAL RESERVOIR IN THE SAN ROCCO WATERSHED, ITALY: BATHYMETRY AGAINST RUSLE

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The study, using different direct and indirect methodologies, wants to evaluate the sedimentation rate within a sample artificial reservoir (Le Grazie lake in central Italy) which, in the period 1952-2015, has caused a strong decreasing of the trap efficiency and a loss of over 70% of the water volume stored. Direct measurements of the lake bottom bathymetry, carried out in 2006 and 2015 (AGEOTEC, GEOMARINE), and 3D reconstructions performed in a GIS environment, made it possible to calculate volume and weight of filling material and, in particular, to verify that the greatest contribution comes from a right tributary of the Chienti river (the San Rocco stream), deepened in a clayey subbasin, and flowing directly into the lake. The values obtained have been then compared with those coming from indirect evaluations carried out using the RUSLE (Revised Universal Soil Loss Equation) Method (Wischmeier and Smith, 1982) performed in the San Rocco subbasin. The comparison between the two approaches made it possible to compensate for errors inherent the methods themselves (uncertainties in the direct measurements or the parameters used in the RUSLE equations) and, above all, to verify an upward trend in the sedimentation rate starting since 2006.

Keywords: Soil erosion; trap efficiency loss; bathymetry; RUSLE method; GIS analysis

OBJECT-BASED MAPPING OF GULLY EROSION IN KARSTIC AREA THROUGH THE USE OF MEDIUM SPATIAL RESOLUTION MORPHOMETRIC PARAMETERS

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The mapping of gully erosion is important for better understanding of erosion spatial distribution and characteristics, as well as various factors associated with its occurrence. Detailed and accurate gully erosion mapping is especially challenging in remote areas, where high spatial resolution data is not available. Aim of this study was evaluation of potential of different morphometric parameters derived from available medium resolution digital elevation model (DEM) for gully erosion mapping. Mapping was based on object-based image analysis (OBIA) approach and application of multi-resolution segmentation algorithm on seven chosen morphometric parameters (slope, mass balance index, topographic position index, vertical distance to channel network, topographic wetness index, stream power index and planar curvature). This approach was tested on Pag island (284 km²), which is known for its bare karstic landscape and numerous active gullies. Classification was performed on segmented objects based on user-defined thresholds for each used morphometric parameter. As a result, 120 active gully erosion zones were detected and mapped within Pag island. Result validation was performed on 12 randomly chosen locations (10 % of all mapped zones). Extracted gully erosion zones were overlapped with reference data, derived by manual vectorisation from high-resolution orthophoto image. Overlap performance was further quantified through following accuracy indicators: Correctness (COR), Completeness (COM), Overall Quality (OQ) and LOC measure (LOC). Validation has shown that proposed medium resolution morphometric parameters and object-based approach can be successfully applied for mapping of gully erosion in karstic areas with limited spatial resolution data available. Mapped gully erosion areas were used for determination of general characteristics and spatial distribution of affected areas and correlated with existing gully erosion susceptibility model of Pag island.

Keywords: OBIA; gully erosion mapping; medium-resolution; morphometric parameters

ASSESSING RIVER'S RELATIVE SEDIMENT DISCHARGE DELIVERY USING MODIS IMAGERY

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The aim of this research was to rank several (17) Greek rivers according to their sediment discharge into the sea, and also to study their seasonal patterns with the use of satellite imagery. The final results have been based on MOD09Q1, an atmospherically corrected 8-day composite, for the whole period that this product is available (2000-2019), but interesting observations and analysis have been also based on Level 1B images (MOD02, MYD02 and MOD35), although for a shorter period of time and fewer images. Equal-area polygons drawn offshore the mouth of the selected rivers ("plume" polygons) were used as regions of interest and the suspended sediment load of each river was assessed with the use of indices, ratios and masks involving all 3 visible channels and near-infrared for Level 1B. For the 8day composite only the available red and NIR bands were used. The results were also cross-checked with the use of BQART, a global sediment yield model with favorable outcome. Thus, we were able to rank the rivers according to their suspended sediment load, to assess the seasonal patterns of sediment discharge from the catchments, to identify the effect of major wildfires and sand and dust storms on sediment productivity and, using (coarse) daily rainfall data over the 17 catchments, to construct a "sediment productivity per square kilometer and mm of rainfall" type of index (which can be seen as a sort of Sediment Delivery Ratio) that we also used to rank the catchments.

Keywords: MODIS; sediment load; Greek rivers; BQART; hydrology

QUATERNARY DENUDATION RATES CALCULATED FROM TUFA DEPOSITS SHELTERED BY INLAND NOTCHES, MT. CARMEL, ISRAEL

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Inland notches are elongated concave-shape indentations that develop on the carbonate rocky cliffs of mountainous zones. These unique features formed as a result of the interaction between specific lithological and weathering factors, emphasizing the importance of climate upon denudation. Inland notches form because 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. Notches are most common in semi-arid and in Mediterranean climates, mainly in areas with annual rainfall of between 400 mm and 850 mm. Occasionally, tufa accumulates within the cavity of the notch, resembling speleothems or developing both along the back wall of the notch and as detached stalagmites. The tufa is more typical of Inland notches that are located on north-aspect slopes. These are characterized by a more hydric environment - that is colder, more humid and has a more stable microclimate, allowing a higher amount of water to percolate in the ground. In the present study we determined minimal ages of notches formation using U-Th dating of tufa deposits developed under the notches' visors or covering notches' cavity beds to determine the relative slope denudation rates on Mt. Carmel. Thirty-one ages were accepted as correct, showing that ages of tufas range between 53 ka and present. Seven corrected ages of samples that have ($^{230}\text{Th}/^{230}\text{Th}$) ratios ranging from 2 to 4 have large uncertainties because non-radiogenic ^{230}Th comprise large fraction of total ^{230}Th . All other 24 corrected ages are younger than 20 ka and older than 2.1 ka, implying that the minimal age of these notches is last glacial period or last deglaciation, showing therefore relatively high slope denudation rates.

Keywords: Inland notch; U-Th dating; tufa; denudation; weathering

S05. GEODIVERSITY OF LANDFORMS IN THE MEDITERRANEAN ZONE

GEOMORPHODIVERSITY, SEDIMENT AND SOIL DYNAMICS, AND RELATED CONTROL FACTORS: MULTISCALE INVESTIGATION IN SELECTED HYDROGRAPHIC BASINS IN THE VEGLIA-DEVERO NATURAL PARK

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The Italian country is N-S stretched, allowing the coexistence of different morphoclimatic conditions. Morphogenetic and geological diversities concur to enrich this complex framework. Due to the ongoing climate change, the climatic features typical of Mediterranean regions are expanding northerly as far as lapping the Alpine regions, where, during the last decade, an increasing of extreme meteorological events occurred. Different responses in climate-related geomorphic processes, including sediment and soil dynamics, are recorded too. Within a specific territory, this variety may be investigated in pilot areas. The Veglia-Devero Natural Park (Central-Western Italian Alps), was formerly analysed for the production of geomorphodiversity maps, obtained integrating existing mapping materials. Considering the results of this preliminary analysis and further fieldworks, two hydrographic basins, characterized by different geomorphic contexts and elevations, were selected for a more detailed characterization of geomorphodiversity at a greater scale, according to local peculiar features. The Rio Buscagna hydrographic basin, elongated WSW-ENE, follows a lithostructural contact, inducing a great diversification of the valleys slopes where currently water and gravity related processes affect ancient glacial landforms. Lithological and morphological contexts influence soil development, as testified by buried surfaces or palaeosols. The Rio Aurna hydrographic basin, is instead characterized by the very distinctive proglacial areas of Aurna and Leone glaciers. In the first case, Little Ice Age moraines disconnect the foreland from the lateral slopes and border a relatively small and flat foreland. In the second case, the Leone Glacier foreland is steeper, presenting an evident rocky glacial step that separates the current glacial snout from a possible rock glacier. Sediment and soil dynamics are evidently diversified in the two hydrographic basins and, considering the relative easy approach to these areas, a thematic itinerary on geomorphodiversity in relation with the analysed dynamics could be proposed.

Keywords: Geomorphodiversity index; sediment connectivity; pedodiversity; Veglia-Devero Natural Park

THE GEODIVERSITY OF MOUNTAIN KARST LANDSCAPES: EXAMPLES FROM THE CENTRAL-SOUTHERN APENNINES

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The Mediterranean zone, and with it the Italian territory, is characterized by an extraordinary variety of landscapes and related landforms referring to a wide range of geomorphic systems (e.g. glacial, fluvial, karst, coastal), sometimes interacting and mostly still active, that have given origin to a great geodiversity. This is especially true for the Apennine chain whose high degree of geodiversity is strongly linked to its actual geological-structural settings, relief features and different climate conditions, as well as to the variations of climate and relief that have occurred since the emersion of the chain. Among the most ancient and typical landforms that characterize the Apennines and the Mediterranean zone in general are those originated by karst processes which are particularly widespread in the carbonate mountain areas of the Central-Southern Apennines. The karst landscape in these mountain areas is characterized by a high variety of karst landforms including both exokarst and endokarst features, from the most ancient evidence of long-term karst corrosion and the complex landforms originated by the interaction of different geomorphological processes (limestone pavements, remnants of paleosurfaces of fluviokarst or glaciokarst origin, etc.) up to typical karst landforms (although frequently structurally controlled) such as dolines, karren fields, poljes, resurgences, karst springs and cave systems. Karst geosites and geodiversity sites are important testimonials of the high geodiversity related to carbonate mountain environments and an excellent basis for illustrating their long-term landscape evolution. In this work we present some selected sites of the Matese and La Montagnola mountain areas (Campania-Molise) to illustrate the variety of landforms that typically characterize the karst landscape of the Central-Southern Apennines. These sites highlight several of the main karst processes active in Mediterranean mountain areas and are excellent examples to explain the complex long-term evolution of the Apennine karst landscape.

Keywords: Karst landforms; long-term evolution; geoheritage; Apennine chain

COASTAL SYSTEMS AND THEIR IMPACT ON MANGROVE ASSEMBLAGES

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Coastal geomorphological processes create and alter habitat, and influence environmental conditions for organisms. Therefore, this study dealt with coastal systems and affected on mangrove. Field study focus on mangrove assemblages in a five-selected area (Um Dhees – Abu Monqar - 17 Km south safaga – Hamraween –Sharm El Bahary). Through fieldwork, we observed three types of mangrove environments including Mangrove environment facing the sea directly, Mangrove environment protected by marine sand spits, and Mangrove environment located in Sharm area. It shows through different environments, varying impact of the coastal systems Study Objectives is studying different effects of coastal system on mangrove, identify the geographical distribution of mangrove and Delineating existing mangroves and siting suitable locations for mangroves plantation using spatial data analysis. This study Using Field, grain size analysis, analyzing spatial data by using GIS (ARC GIS 10.3) techniques and remote sensing Erdas Imagine 2013 (IRI) and Infrared Thermal Sensor for Landsat Global DEM with a spatial resolution of 30 meters, in addition to using Google-Earth-Pro.

Keywords: Mangrove; coastal system; waves; tides; sediments; morphology; bathymetry; satellite image

LANDFORM AND GEODIVERSITY ANALYSIS OF PALE MUNICIPALITY (BOSNIA AND HERZEGOVINA) USING TOPOGRAPHIC POSITION INDEX

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The main objective of this study is to analysis and classification of landforms in area of Pale Municipality in the Bosnia and Herzegovina, by conducting GIS based morphometric analysis. In process of landform classification is used EU- DEM v1.1, DEM resolution 25 m. The whole classification process is based on the calculation of Topographic Position Index (TPI). From DEM, as primary data, we have conduct slope and topographic position index maps, and also geological data. Analise results shows that in analyzed area are presented different categories of landform classification, which are compared with hypsometry, slope and geological maps. Landform classification and analyses indicate on variety and richness of landforms, i.e. high level of geodiversity in analyzed area.

Keywords: Landforms; geodiversity; topographic positioning index; pale municipality, Bosnia and Herzegovina

THE GEODIVERSITY OF SELECTED MEDITERRANEAN ISLANDS

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Spatial geodiversity of selected larger Mediterranean islands is shown on the poster. Based on EU-DEM v1.1 (25x25 m), geodiversity factor maps were created using geomorphometric parameters and map algebra. Factor maps were then transformed into final geodiversity maps for individual islands. Using the Jenks natural break method, five classes of geodiversity were assigned to the final maps. For selected islands of the Mediterranean, the ranking of islands from the highest to the lowest overall assessment of geodiversity is presented.

Keywords: Geodiversity; Mediterranean islands; overall assessment of geodiversity

S06. GEOMORPHOLOGICAL HAZARDS AND RISKS

RISKS OF LANDSLIDES IN SALVADOR, BAHIA (BRAZIL): THE RELATIONSHIP BETWEEN THE ENVIRONMENTAL SUSCEPTIBILITY AND SOCIAL VULNERABILITY

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The population affected by landslides and flood events has increased in the last decades in Brazil, causing many socio-environmental problems. Salvador presents the highest numbers of these events in the Northeastern region of Brazil. Nearly half of the population of the city live in risk areas. Our goal is to relate the occurrence of landslides with the environmental susceptibility and social vulnerability in Salvador, Bahia. We analysed the geological, pedological and geomorphological characteristics of the city to determine the environmental susceptibility to landslides, and the socioeconomic characteristics of the population to evaluate the Social Vulnerability Index (SoVI). We used cartographic bases such as geological, pedological and geomorphological maps, as well as data from the 2010 census. We verified that the greatest social vulnerability occurred at the northwestern region of the city, which is also an area associated with the highest environmental susceptibility due to lithological contacts and faults. Meanwhile, in the southeastern region, the social vulnerability is lower, while the high environmental susceptibility is associated with faults on metamorphic rocks. Finally, the northwestern region presents an increased risk of landslides compared to the southeast.

Keywords: Northeastern Brazil; SoVI; hazards; socio-environmental problems

NEW CONTRIBUTIONS TO THE ANALYSIS OF THE GEOMORPHOLOGICAL AND GEOLOGICAL VULNERABILITY OF THE ROMAN EDIFICE WITH MOSAIC SITE, CONSTANTA

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Touristic and cultural monuments included in the national heritage list are old religious, historical, strategic or civil edifices. The value of these sites comes from a certain combination between their architectural features, notoriety, uniqueness, greatness or legends. Sometimes these sites are affected by different types of degradation through natural hazards. A combination of moisture deposits of foundation, erosional processes and unexisting or poor maintenance, improper reconstructions determined the actual condition of the historical sites. Being a necessary stage in the rehabilitation process of the valuable monuments, this paper continues the idea of a previous research. The main objective is to highlight the presence of the ground water into foundation of The Roman Edifice with Mosaic site, Constanta, Romania during the last decade and the morphological processes connected to this. The natural and anthropogenic geomorphic processes caused by hydrodynamic and gravitational forces have been inventoried and mapped. Also, non-destructive geophysical methods in moisture and depth of cracks in natural – anthropic lithological system of abrasion terrace and front cliffs have been applied. The results emphasize the instability of geomorphological and geological environment on which the Roman mosaic was built. The variation of the humidity of the deposits induced by human activities causes suffusion and slip processes. The study could be useful for future environmental rehabilitation and protection at the initiative of local and central authorities.

Keywords: anthropic and natural hazard; Roman mosaic

A NEW APPROACH FOR THE ANATIONAL-SCALE LANDSLIDE SUSCEPTIBILITY MAP IN ROMANIA IN A EUROPEAN METHODOLOGICAL FRAMEWORK

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Landslide susceptibility maps are considered useful tools in risk analysis, with consistent practical implications since they could provide significant information in terms of improving territorial planning, land use sustainable management or early warning systems. Romania represents one of Europe's most landslide-affected countries. The landslide-prone morphostructural and lithological traits of large mountainous, hilly or plateau regions are enhanced by hydro-meteorological and seismic triggers, resulting in a wide variety of slope processes. Following a first approach conducted in 2010, when Bălțeanu et al. performed a national (undifferentiated) landslide susceptibility assessment, an improved landslide susceptibility zonation at a national scale was prepared for slides and flows, using as predicting factors slope, lithology and land use/cover. The present approach follows a rather different perspective, deriving statistical correlations between landslides and predisposing factors by making use of several landslide inventories with a wide regional or national distribution. The process of combining the statistic (weights expressing the distribution of landslides within different classes of lithology, slope and land use/cover) with the heuristic (expert knowledge) approaches, calibrated and later on validated for distinct homogeneous morpho-lithostructural units allowed the increase of prediction capacity, offering a more robust model at a national scale. A consistent landslide inventory has been built for this purpose, which gathered more than 29,000 landslide cases, separated into slides (94%), flows (4%) and falls (2%). The criteria for establishing the areas for regional zonation were based on a new separation of the national territory into representative units. Following the evaluation of the prediction model performance, a better, improved representation of the general pattern of landslide susceptibility classes' distribution across Romania has been seen. The map outlined large areas ranked as high and very high susceptibility throughout the Subcarpathian chain, as well as in the Moldavian and Transylvanian Plateaus and the Getic Piedmont.

Keywords: Landslides; susceptibility; national scale; Romania

ASSESSMENT OF BANK LINE DYNAMICS OF RIVER GANGA AND ITS IMPACT ON LAND USE PRACTICES USING LANDSCAPE METRICS IN MALDA DISTRICT, WEST BENGAL, INDIA

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The mighty river Ganga is the lifeline of India that drains 10.68 lakh km³ of water and carries 30 lakh metric tons of sediment annually. The lower course of Ganga within the territory of West Bengal flows for about 76 km along the western flank of Malda district. The lower Ganga plain in West Bengal, an early dead flat alluvium tract, is affected by severe bank erosion due to the meandering behaviour of the river. In addition, construction of Farkka Barrage was a shock on such natural system leading to rapid changes in bed form and planform. As a result, the continuous process of aggradation and degradation of the river has enhanced land use instability. In this study an attempted has been made to establish the relationship between spatio-temporal shifting of the river and fragmentation of land use practices within and around the Historical Migration Zone (HMZ) of Ganga during the post Farakka period spanning from 1980 to 2018. The work has been performed through the implementation of Remote Sensing and GIS applications with a multi-temporal approach over the selected time span. The Landsat imageries of five selected years; were used to spawn vectors of the bank lines from the corresponding MNDWI and analysis of landscape fragmentation based on class level matrix. The fragmentation analysis reveals 1980 to 2000 had experienced high fragmentation of land use classes and during 2000 to 2018 the patches were in a process of relative clustering. The HMZ has been studied in terms of land use fragmentation to showcase the direct impact of bank erosion while the multiple buffers were introduced to demonstrate the indirect impact of the geomorphic hazard with increasing distance from HMZ for future management. Alongside, assessment of the genomic condition, aimed at land use practices within the possible Channel Migration Zone (CMZ) in near future has been framed as conducive to the methodology of this study.

Keywords: Bank erosion; channel migration zone; historical migration zone; land use practice; land use fragmentation

LARGE LANDSLIDES AND DEEP-SEATED GRAVITATIONAL SLOPE DEFORMATIONS IN THE CZECH OUTER WESTERN CARPATHIANS

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Czech Flysch Outer Western Carpathians (COWC) represent region with the highest density of large landslides and deep-seated gravitational slope deformations (DSGSDs) in Czechia. The region is internally heterogenous in terms of geology (individual flysch nappes with different lithology) and topography (e.g., high monoclinial ridges in the north-eastern part with local relief > 500 m and subdued hilly landscape in the southwest. The region is diverse in the terms of the landslide types, sizes and recent activity as well. Aim of this study is to describe these differences and decipher driving factors, which cause this varied behaviour of mass movements in the region. We mapped 13,721 landslides and DSGSDs in the area of COWC (~7186 km²). We used LiDAR derived DEM and its derivatives (hillshade maps, slope map) and mapped landslides as polygons incorporating the detachment and accumulation. We classified landslides into five groups (rotational, translational, debris slide and earthflow), the sixth group consist of DSGSDs. We matched the landslides with individual flysch nappes for further analysis. We analysed clustering of the landslides using L-function which showed, that maximal clustering occurs in the radius ~5 km. We calculated kernel density of the different landslide types. This revealed differences in the concentration of different landslide sizes and types. Whereas the lower and more subdued areas in the southern part are hotspot in terms of total number of landslides, the higher and more topographically pronounced areas in the northeast are affected dominantly by large landslides. Discrepancy also exist in the spatial distribution of different types of landslides. Translational and rotational landslides are dominant in the north-east while complex and earthflows are dominant in the lower regions. We examined frequency-area relationship of landslides for individual nappes. The β exponent varies between 2.1 to 3.2 showing different influence of large landslides in the individual nappes.

Keywords: Landslides; deep-seated gravitational slope deformations; flysch; Outer Western Carpathians; Czechia

GEOLOGICAL AND TOPOGRAPHIC CONDITIONING FACTORS OF SHALLOW LANDSLIDES IN SÃO LUÍZ DO PARAÍTINGA COUNTY, BRAZIL

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In December and January 2009-2010, São Luiz do Paraitinga municipality, São Paulo State, was affected by intense rainfall that triggered several landslides, with a total of approximately 625mm in December, the highest value ever recorded. The rainfall continued in January 1st, with a total of approximately 70mm/24h. As a result, new landslides were initiated and the Paraitinga River overflowed, flooding the rural areas and the historical center of the municipality, resulting in casualties and immense economic losses and infrastructure damage. This research focus on the analysis of the lithological, structural and topographic conditioning factors of landslides in São Luiz do Paraitinga county. For this purpose, we used an Areal Frequency (AF), Scar Concentration (SC) and Landslide Potential (LP) index approach to perform an assessment of the influence of lithotypes, fault density and slope on landslide occurrence. Those parameters were obtained from a geological map (1:100.000) and a 12.5m Digital Elevation Model (DEM) (ALOS PALSAR). Results show that although the materials derived from granitoid rocks had greater SC (51.6%), their LP is reduced due to their generalized occurrence (AF=60.8%). Thereby, the materials derived from heterogeneous and homogeneous migmatites, 10.9% and 7.9%, respectively were considered more susceptible to landslides, with the first being twice more prone to landsliding. The micaschists and quartz-micaschists (AF=11.4%) were the least affected lithotype. There is not a clear relationship between fault density and the landslides, because SC and LP indexes are very similar. The slope angle shows a relevant tendency of increase in SC with increments of angle, until a threshold of 30° and > 30° class presented the greatest LP due to its reduced AF (5.5%). Those results can be useful for future landslide susceptibility assessments and to better understand the relations between the analyzed factors and landslide occurrence in the Serra do Mar.

Keywords: Shallow landslides; landslide susceptibility; lithology; morphology; Paraíba do Sul Valley

THE INFLUENCE OF THE GEOMORPHOLOGICAL AND PEDOLOGICAL PROPERTIES ON LANDSLIDES IN THE SERRA DO MAR MOUNTAIN RANGE, BRAZIL

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One of the most affected landscapes by these processes in Brazil is Serra do Mar mountain range, which extends for about 1.500 km, along the southeast coast of Brazil. In January 2014 landslides and debris flows were triggered by intense rainstorms (200 mm/2hours); in only in a basin with an area around 5km² was mapped more than 300 shallow landslides. Thus, the aim of this research was to evaluate the relationship between topographic and pedological parameters and with the shallow landslides distribution. To evaluate the role of the morphological parameters (curvature, elevation, contribution area, slope angles and aspect) we applied a correlation analyses between each map/classes with the scars map. These maps were used to landslides susceptibility assessment using Information Value Model (IV), validated by contingency matrix ratios. After that, we selected one slope where three weathering profiles (between 5.20 and 12.50 m) were excavated to characterize their pedological properties, including permeability and the correlation of Schmidt hammer rebound values and degree of weathering. Regarding the morphological parameters, the results indicated that the most unstable areas are those between 450m and 750m, slope angles between 25° and 40°, hillslopes are mostly towards S and SE, hillslopes are mostly towards SE, S and SW, concave or convex profiles and contribution area between 600m² a 2000m². The success rate of the IV model for shallow landslides was of 73%, the True Positive Rate (TPR) was of 79% and the False Positive Rate (FPR) 44%. In one of these areas, the profiles presented thicknesses between 5 and 6 m, with residual soil up to 2.30 ~ 2.60 m, the predominance of sandy texture and permeability varying between 10⁻⁶ ms⁻¹ and 10⁻⁸ ms⁻¹. As for degrees of weathering, there is a predominance of soft to moderately weathered rocks (NSchmidt between 24 and 48).

Keywords: Information Value Model; degree of weathering; contingency matrix ratios

DEEP SEATED LANDSLIDES ON FLYSCH NAPPE OUTLIERS

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The flysch nappe outliers – an isolated and eroded remnants of nappes – represent a convenient geological-structural background prone to the evolution of deep-seated landslides (DSLs) even in relatively low terrain. The study area of the Podbeskydská pahorkatina upland (PPU) represents sequence of isolated nappe outliers of the Carpathians flysch nappes, Czech Republic. We assume that the complex geological-structural conditions of flysch nappes strongly affect the position and morphology of DSLs and create specific settings in comparison to compact nappe structures. Geomorphological mapping based on interpretation of high-resolution LiDAR data reveals existence of 390 DSLs. With the aim of detection the main controlling factors, position and specific morphological differences between DSLs in flysch nappe outliers and in compact flysch nappes, the comparative statistical analysis of DSL's dimensions and clustering was performed both for study area and reference area of Moravskoslezské Beskydy Mts. (MBM). We find out that the DSLs of PPU are clustered in area of 44 nappe outliers in the central part. We also detect the DSLs of comparable dimension as in MBM even in low terrain of PPU. DSLs in MBM are strongly related to monoclinial structure and are clustered on cataclinal slopes, whereas DSLs in PPU are spread on all slopes. Furthermore, the position of DSLs in PPU is related to existence of key structural-lithological contact of rigid and plastic strata on the base of nappe outliers and isn't so strongly controlled by high-relief and steep slopes as in reference MBM area. We consider the complexity of structural conditions and the existence of key structural-lithological contact in the low nappe outliers to be the main controlling factor of DSLs evolution in PPU, instead of high relief, steep slopes and monoclinial structure in MBM.

Keywords: Deep seated landslide; inventory; statistics; flysch; nappe outlier

THE IMPLICATION OF DEM RESOLUTION ON SLOPE INSTABILITY MODELLING

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Digital Elevation Models (DEMs) are an important source of information to geomorphological studies, the example of slope instability assessment. However, those data can be derived from different sources, such as contour lines or remote sensing Technologies what can implicate in its capability to represent the terrain. Thus, the present work aimed to evaluate the implications of spatial resolution from three DEMs derived from contour lines with 10m, 5m and 1m equidistance, which defined the grid resolution (10, 5 and 1m). For the slope instability modelling it was applied the physically based model SHALSTAB, applying the same soil parameters (c : 0 Pa; Z : 1m; ϕ 31°; ρ : 2.600g/cm³), obtained the class Frequency (F) of the SHALSTAB model and the Scar Concentration (SC) from a watershed affected by shallow landslides. The results showed that the Unconditional Unstable occurred mostly at the medium third part of the slope on three DEMs and the DEM-1m registered a higher value of Unconditional Unstable class Frequency (18%) in relation to DEM-5m and 10 m (16% and 12%). Nevertheless, this percentual increase does not guarantee that the best representation is made by the finest DEM since the increase in the number of cells in this is associated with the largest number of cells present in the whole watershed. Four intermediate classes registered values close to zero in all three scenarios. Considering SC, there was similarity in the indication of instability in DEMs 10 and 5m, registering close to 21% in both cases, for the most unstable class, whereas in DEM-1 the value was significantly higher (33%). In sum, the three simulations were efficient and the highest percentage of SC for the DEM-1m may not attest to the better result since this was due to the greater number of cells in the grid in the basin.

Keywords: Shallow landslides; SHALSTAB; Serra do Mar; Brazil

FLOOD AS AN ANTHROPOGENIC HAZARD: CASE STUDY OF THE 2016 FLOOD OF BIHAR, INDIA

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Bihar is one of the most flood prone states in India. During the August 2016 flood of the Ganga, 15 (out of 38) districts, 3,459 villages and, 8.82 million people of the state were affected. The present study was carried out to investigate the causes of this flood and the role of Farakka Barrage in it, as this structure was widely made responsible for the event. To explore the factors behind the event, we prepared drainage networks of the region by using SRTM elevation data and Landsat-8 OLI images. Inundated area was traced by applying MNDWI on MODIS data of 25 August 2016. Different hydrometeorological parameters employed in the study include percentage departure of monthly rainfall; discharge data of selected dams and barrages: Bansagar Dam (on River Son), Valmikinagar Barrage (Gandak), Birpur Barrage (Kosi), Indrapuri Barrage (Son), & Mohammadganj Barrage (North Koel); and gauge data from six stations along a 526 km stretch of the Ganga: Buxar, Gandhi Ghat (Patna), Hathidah, Munger, Kahalgaon, & Manikchak Ghat. It was found that the flood was mainly caused by rapid release of water from the Bansagar Dam on the Son from 18 to 20 August 2016, as a tropical storm traversed through its upper catchment. Contributions from the Ganga's upstream and the Himalayan tributaries were negligible. The flood peak (50.52 m), recorded at Gandhi Ghat on 21 August 2016, passed downstream, and reached Manikchak Ghat (25.78 m) on 27–28 August 2016. The upstream limit of flooding due to the highest recorded flood level at Farakka Barrage (26.66 m) can only reach up to 9 km below Kahalgaon. Therefore, the extensive flooding of the area between the Son outfall (27 km above Patna) and Kahalgaon cannot be explained by impoundment at the Farakka Barrage.

Keywords: Bihar flood; Ganga flood; dam discharge; Bansagar dam; Farakka Barrage

INHERITED AND MODERN SLOPE PROCESSES IN NUNAVIK: FROM HAZARDS TO RISK SITUATIONS

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Slope processes are active within rolling plateau landscapes of Nunavik, which lies in Northern Québec, Canada. Escarpments are seldom; however snow avalanches and sudden mass movements are obvious from the study of slope deposits. According to the archives and literature, Kangiqsualujjuaq, one of the 14 Inuit villages in Nunavik, has been stricken by a dreadful snow avalanche: nine people died and 25 were injured on the night of December 31st, 1998-January 1st, 1999. At this time, the inhabitants were gathered to celebrate New Year's Eve in the school gymnasium that was located within the deposit zone of a short snow-avalanche track. The memory of this event is locally long-lasting. However the perception of hazard is impeded by the lack of systematic data collection regarding slope activity in locations where hazard could easily shift to risk due to the vulnerability of settlements or short transportation corridors around settlements or within National Parks. At least four snow avalanches have hit Kangiqsualujjuaq before the dreadful avalanche in the 1980s: collective memory have retained none of these events, as they caused limited damage. From the case study of three sites, within the village of Kangiqsualujjuaq, in the surrounding of Umiujaq and in Lac-à- l'Eau-Claire inside National Park Tursujuq, we document the constraints of slope processes at different locations, and the methods developed to monitor changes on slopes all year-round, from the setting of automatic time lapse cameras to morphometric properties slope deposits and natural archives retrieved from peatbogs in the distal parts of slopes.

Keywords: Snow avalanches; cold environment; threat; villages; Inuit

TREE-RING RECONSTRUCTION OF SNOW-AVALANCHE ACTIVITY IN MARAMUREȘ MOUNTAINS (EASTERN CARPATHIANS, ROMANIA)

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Snow avalanches represent a common phenomenon in Maramureș Mountains (Eastern Carpathians) damaging forests and infrastructures, causing fatalities yearly. In remote mountain areas, the snow-avalanche history is poorly documented by historical archives: information regarding snow-avalanche frequency and their spatial extent is unknown. Along the paths, disturbed trees record in their annual rings evidence of past snow-avalanche events and therefore represent a natural archive providing valuable information about past snow-avalanche activity. The main objective of the present study is to reconstruct with tree rings the occurrence and spatial extent of past snow- avalanche events. Disturbed trees growing along the avalanche paths located on forested steep slopes, below the Pop Ivan peak in the vicinity of the Ukrainian border have been investigated. Samples (cores and discs) collected from both coniferous (*Picea abies* (L.) Karst.; *Abies alba* Mill.) and deciduous (*Fagus sylvatica*) trees showing visible signs of damage produced by snow avalanches have been analyzed. Tree-growth anomalies (impact scars and callus tissues, onset sequences of tangential rows of traumatic resin ducts, compression wood and growth suppression sequences) resulting from the mechanical impact on trees of snow avalanches served to reconstruct the avalanche history. The type, amount and intensity of growth disturbances enabled to reconstruct the avalanche history back to the early 20th century. A minimum frequency of reconstructed snow avalanche events was finally used to calculate the return periods along the investigated paths. Further tree-ring reconstructions of snow-avalanche history extended in both Romanian and Ukrainian Eastern Carpathians will allow to better assess the regional pattern of snow-avalanche activity. This study is a contribution to project « *Activité des avalanches des neige dans les Carpates Orientales Roumaines et Ukrainiennes* », funded by Agence Universitaire de la Francophonie (AUF) and Ministère pour la Recherche et l'Innovation de Roumanie (MRI) through Institut Roumain de Physique Atomique (IFA).

Keywords: Snow avalanches frequency; dendrochronology middle mountains; Romania

A MULTIDISCIPLINARY APPROACH FOR INVESTIGATIONS OF THE DYNAMICS OF A BOULDER DEPOSIT ON A LOW-LYING ROCKY PROMONTORY IN THE NORTHERN ADRIATIC SEA

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This study investigates a coastal boulder deposit, which was recently recognized in the North Adriatic coast. Accumulations of large boulders have not previously been reported in the North and central Adriatic Sea, which can be viewed as a semi-enclosed basin. In particular, we devoted our attention to the mechanisms that may be responsible for the detachment and transport of these large limestone rock fragments from the emergent part of the coast and from the seabed towards inland areas. In order to recognize, map and produce an inventory of boulders detached and displaced by storm waves, the research has adopted a multidisciplinary approach. Geomorphic information derived from land surveys was integrated and controlled by aerial photo interpretation obtained by a UAV and submarine surveys. The boulder deposit is composed of hundreds of boulders and lies on a low-lying limestone promontory where the topography, together with the bedding planes and dense joint pattern constitute the predisposing factors for boulder size and detachment. Furthermore, we selected eight boulders, where traditional and innovative monitoring techniques were applied. In particular, we installed a GNSS network and an array of RFID tags. This paper illustrates the different phases of research and the preliminary results from the monitoring network.

Keywords: Boulder deposit; coastal geomorphology; North Adriatic Sea

NATURAL HAZARDS TRIGGERED BY THE INTENSE 2018 MONSOON IN THE KALI GANDAKI VALLEY, NEPAL HIMALAYA

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Geomorphic activity in the central Nepalese Himalaya is naturally driven by tectonics and monsoonal precipitation and, since the last decades, by human activities and intense infrastructure construction. Along the Kali Gandaki valley, the deepest on earth (>5500 m), recent climate trends indicate shifting monsoon intensities and patterns, that might go along with enhanced geomorphic response. This may particularly affect the national road “Kali Gandaki Corridor”, in the context of China’s One Belt and Road Initiative. Here we try to get a better understanding of natural vs. anthropogenically-induced geomorphic hazards, after the dramatic 2018 monsoon season impacting this valley (two severe rainstorms, one in August, followed by another one in September). Comparative interpretations are based on (1) field fieldwork since the last four decades, (2) interpretations of high- resolution Pleiades satellite images of March and October 2018, and (3) field visits in April, September and November 2018 and March 2019. Our results show an increased geomorphic activity along the Kali Gandaki and its tributaries, and along its adjacent banks and mountain slopes (including floods, hyper-concentrated and debris flows, landslides). This activity occurred on both sides of the mountains. On the northern, dry side ($P < 400$ mm/a), local reactivation of earthflow (Khingar- Jharkot), and hyper-concentrated flows have impacted the new road and bridges (Lupra Valley) and the local Tukuche Hydro-power station (Thapa Khola). On the southern side ($P > 1000$ mm/a), large prehistoric rock-slides were reactivated (Chhooya Deorali), whereas many landslides occurred along the river banks and the lower parts of mountain slopes, and debris flows and floods were generated from tributaries (e.g. Bandarjung, Dana), hence causing road blockages. In addition, the new road built with poor consideration of geo-hazards, insufficient safety features or water drainage, and locally inadequate stability measures, caused additional failures, hence more risks to locals and travelers in this highly touristic area.

Keywords: Intense monsoon; geo-hazards; river dynamics; road construction; Nepal Himalaya

CONSTRUCTION OF ROAD AND BRIDGES IN NEPAL HIMALAYA WITH POOR CONSIDERATION OF NATURAL HAZARDS

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Over the past 15 years, there has been a significant construction of motor roads and motor bridges across Nepal Himalaya. Current Nepal's national road construction is fostered by China's One Belt and Road Initiative (Silk Road Annexes, or "corridors"). These road corridors and bridges are being carried out with poor consideration of geo-hazards (rockfall, landslides, debris flow, floods) and of river dynamics (including tributaries) that may threat and/or destroy them, and indirectly impact the economic and touristic fluxes. Our methods include field investigations, diachronic comparisons, local interviews and hydrological modelling. We focus first on the Kali Gandaki corridor road (Myagdi & Mustang Districts) and specifically on the under-construction bridge over Ghatte khola (Myagdi District). This small catchment (7.8 km²) is subject to complex morphological processes (gravitational, hydro-geomorphological) and to extreme events (landslide outburst floods), resulting in bank erosion and debris flow massive aggradation. We questioned the relevance of the selected site (alluvial fan) and size of the bridge, not adapted to our discharge modelling and simulations (water way 2m lower than the highest floods). Similarly, along the Arughat Laarke road (Gorkha), the bridge over Soti khola (confluence with Burigandaki river) has been washed away twice by the flash flood during its construction phase, and ever since the bridge construction is halted. We eventually discuss about other road constructions in terms of their vulnerability to different geo-hazards (e.g. Thulo Bheri river in Dolpa District). Collectively, this presentation emphasizes over the understanding of geo-hazards and geo-disasters to effectively reduce the risks associated with road and bridge construction in Nepal Himalaya. We eventually suggest what better design and construction practices should be implemented in order to support the development process both of rural areas and of the whole country, the mountains of which are highly appreciated by tourism from all over the world.

Keywords: Geo-hazards; river dynamics; road and bridge construction; Nepal Himalaya

ASSESSMENT OF ROLE OF BIG DAMS AND WEATHER EXTREME IN 2017 FLOOD OF SOUTHERN BENGAL, INDIA

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Flood is a serious, common, and costly hazard in southern districts of West Bengal and the state has a long-recorded history of flood. The main objective of this study is to assess the flood hazard scenario in southern districts of West Bengal and the reasons behind the devastating flood. Flood inundated area was delineated by using remote sensing data (MODIS). Flood danger level and warning level was identified by using maximum instantaneous discharge data and gauge height of various gauge stations. Rainfall, river and dam discharge data were analyzed for assessing the flood scenario. Damage related data were collected to assess the spatial variation of hazard intensity. The result shows that 42.4% of the total geographical area of the southern districts of West Bengal was affected by flood. Under the influence of an upper air cyclonic circulation, a low pressure area developed on 16 July 2017 and concentrated into a depression over northwest and adjoining west central Bay of Bengal and in the coastal area. Under its influence, incessant rainfall occurred in various districts of South Bengal during 21 July - 30 July. Rainfall data analysis revealed that south Bengal district received excess rainfall (31% to 118%) during July 2017. Analysis of antecedent rainfall of various rain gauge stations shows that during 22 July - 26 July 2017, Bankura district received 600.40 mm rainfall and only on 23 July 189.20 mm rainfall was recorded. Release of water from the various reservoirs made the flood scenario more detrimental in Hooghly and Howrah districts during last week of July. From 25 July to 8 August, the cumulative discharge from Durgapur barrage was 26,57,750 acre-feet of water with the peak discharge of 2,49,450 cusecs on 27 July which marked the highest discharge since 1978. Excepting the Masanjor dam, all dams show 30% to 120% negative flood moderation capacity during 21 July to 31 July 2017.

Keywords: Flood; hazard; dam; rainfall

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 ^{10}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 susceptible areas 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) ^{10}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⁻¹ and 35.2 m My⁻¹, with an average of 25 m My⁻¹. We observed that the lithological variety and the structural lines explained better the distribution of the rates. Dating by ^{14}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 ^{10}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.

Keywords: Debris flow; ^{10}Be ; long-term exhumation; passive margin escarpment; tropical environment

A DYNAMIC EROSION SUSCEPTIBILITY MODEL USING COMBINED FUZZY SETS AND LOGISTIC REGRESSION

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Susceptibility maps of erosion are fundamental to improve management of areas sensitive to soil loss, which is a huge problem in the Mediterranean area and is highly related to climatic change. Erosion is a very complicated process, occurs after the physical or chemical alteration of rocks, and can be distinguished as surface (sheet erosion), linear (rill and gully erosion) and mass erosion (landslides). This study aims to use Geographic Information Systems (G.I.S.) to model the processes of soil erosion by combining various geomorphological factors and different rainfall intensity inputs. To process the input data fuzzy sets theory is used in order to treat the imprecise relations between data (e.g. slope, vegetation, lithology). After applying fuzzy sets, we obtain the spatial distribution of a vulnerability index. Then we use the values of this index, in combination with rainfall data and the antecedent moisture content, as the input variables for our model to estimate erosion magnitude and by applying the logistic function we obtain the spatial distribution of probabilities of erosion under various rainfall conditions. This model is applied to the drainage basin of Corinth which has experienced the results of extreme rainfall events in the past. The results of this model can be used by stakeholders or other researchers to identify the most vulnerable areas in a watershed, design improved management plans for this area and subsequently mitigate this problem.

Keywords: Erosion; fuzzy sets; geomorphology; logistic regression

STUDY ON THE SEDIMENTARY ENVIRONMENT OF LUOHE FORMATION OF EARLY CRETACEOUS BETWEEN ZHIDAN AND SHENMU COUNTIES IN SHAANXI PROVINCE AND ITS RELATIONSHIP WITH DANXIA LANDFORM IN NORTHERN SHAANXI

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The Luohe Formation of Early Cretaceous in Ordos Basin is an important landscaping layer of Danxia landform. However, it is not enough on the study of the Luohe Formation so that lead to much controversy about the sedimentary environment, especially desert facies and sedimentary system tract. Analysis of the rock assemblage, basic sequence, sedimentary structure and sedimentary events of the Luohe Formation, this research focused on the sedimentary system of desert facies and landscape conditions of Danxia, and then firstly made a preliminary division of sedimentary system tracts. The formation progress of desert sediments from the early stage to the late stage of extinction areas followed: uplifted and denuded by shore-shallow lakes→ small sand dunes-desert lakes (lakeside)→ large sand dunes→ desert denudation and flattening (gobi desert-plain→aeolian plain→uplift and denudation again). Desert extinction and Loess Plateau formation formed a complete desert sedimentary system.

Keywords: Luohe Formation; sedimentary events; division of sedimentary environment systemtract; desert facies; Danxia landform

KINEMATIC ANALYSIS OF SEA CLIFF STABILITY USING UAV PHOTOGRAMMETRY

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Rock-slope instabilities are common processes in steep active slopes and are key agents of landform erosion and evolution. Furthermore, slope failures pose a significant hazard to communities and infrastructure located in coastal and mountain landscapes. As a result, this research presents the application of UAV Photogrammetry to analyse kinematic rock-slope failure mechanisms of chalk sea cliffs, located at Telscombe, UK. Our data were captured from an unmanned aerial vehicle (UAV) and cover a near-vertical cliff face that is about 750 m long and ranges from 20 to 49 m in height. The data collection involved installation of a megapixel full frame digital camera on board an octocopter. Ground control for the survey was conducted using DGPS and total station surveying. Digital Terrain Models with a standard error around the control network of 0.03 m were obtained. Rock-slope discontinuities such as joints, faults and bedding planes were then manually mapped on the DTMs. These data were then used to assess likely mechanisms of slope failure using the kinematic Markland's test over stereographic projections. Our results show that that wedge failure is by far the most likely mode of slope instability, since 39% of the discontinuity intersections are favourable to wedge collapse occurring. Planar sliding is the second probable mode of slope failure, comprising 8% of all mapped joints. In contrast, flexural and direct toppling instability are less likely to occur, comprising less than 5% of the poles and discontinuity intersections. Our results demonstrate that data capture and processed through UAV Photogrammetry can provide a useful basis for rock-slope stability analysis over long slope sections and that this technology offers significant benefits in equipment costs and field time over existing methods. This research shows an innovative approach for future engineering geomorphology applications.

Keywords: UAV photogrammetry; rock slope stability; kinematic analysis; wedge failure

HIKING TRAILS ASSESSMENT USING DENDROGEOMORPHOLOGICAL APPROACH AND TOPOGRAPHIC PARAMETERS. CASE STUDY: BUCEGI MOUNTAINS-SOUTHERN CARPATHIANS, ROMANIAN CARPATHIANS

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Hiking trails are an important component of the touristic infrastructure, represent opportunities for recreation and form together a network with an important role in preventing uncontrolled tourists dispersion. Under the impact of tourists, in the forest area, the erosion processes evolve revealing exposed roots. The aim of our study is to estimate the erosion rate along tourist trails by combining dendrogeomorphological techniques and topographic parameters, with a special emphasis on the slope. Our study was performed along 2 tourist trails in the Bucegi Mountains-Southern Carpathians: Bușteni resort - Urlătoarea Waterfall (Br-UW) and Sinaia resort - Cota 1400 (Sr-C1400). All dendrogeomorphological samples were taken from the tree stem and also from its exposed roots, being encoded afterwards. Through laboratory processing the field data, following tree coordinates were obtained: age, height, circumference, aspect and altitude. The instruments we used during the field stage were a tape measure, a Garmin GPS76CSx., a clinometer and compass (Suunto Tandem). The achieved results are: for the Br-UW trail hiking, erosion was between 0.20-2.50 mm/year, considering that this trail has small and medium slopes (<20° and between 20°-40°); for the Sr-C1400 trail hiking, erosion was between 0.10-1.70 mm/year, alternates small slopes with medium and sometimes large slopes. Our study highlighted that the high mountain environment is sensible to tourist impact. The dendrogeomorphological approach proves to be a very useful tool in the process of assessing the rate of erosion of tourist trails. The obtained results could be validated also by the number of tourists trekking these trails every year, however keeping track of them is extremely difficult.

Keywords: hiking trails; dendrogeomorphological approach; topographic parameters; Bucegi Mountains; Romanian Carpathians

DAM FAILURE AND A CATASTROPHIC FLOOD IN THE MEKONG BASIN (BOLAVEN PLATEAU), LAOS, 2018

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The Mekong basin is home to more than 60 million people, 64 dams were constructed, and more than hundreds are commissioned, but there is no specific regional study to assess the risk of catastrophic floods by dam failure. On July 23rd, 2018 a saddle dams holding the Xe-Namnoy hydroelectric reservoir in Southern Laos, Mekong basin, failed catastrophically and caused severe flash flooding and loss of life and properties. The saddle dam was built on the watershed divide between two river basins to increase the water level in the large reservoir. The breaching transferred water from the Xe-Pian/Xe-Namoy dammed basin toward the neighbouring Vang Ngao River basin. Here, we first address whether it was a natural hazard induced by extreme weather condition, or a mere engineering failure. We reconstructed the reservoir water level time-series and concluded that reservoir water level was lower than the dam crest when the dam collapsed, indicating that the water did not overtop the dam. Second, the saddle dam was an “Earth-fill” dam built with a mixture of loess-like materials, oxisols and saprolite assumed to be impermeable. We consider that a lack of compaction and a overestimation of the clay content by dispersion of mud aggregates contributed to underestimating the risk of piping and seepage susceptibility. Third, the failure of the Saddle dam released ~350 million m³ of water into the adjacent Vang Ngao basin at a peak discharge of 8,500 m³/s, causing catastrophic flash flood downstream and the reservoir level to fall ~23 meters. The number of casualties and impacted people is uncertain, but probably it affected as much as 16,000 people. In conclusion, the disaster was caused collectively by a lack of assessment of impacts and hazards in the receptive basin in case of failure, poor geomorphological-geotechnical engineering, and deficient emergency plan or alerts.

Keywords: Mekong basin, natural hazard, flood, dam failure

EXPERIMENTAL FIELD STUDY ON THE FATIGUE AND FAILURE MECHANISMS OF COASTAL CHALK CLIFFS: IMPLEMENTATION OF A MULTI-PARAMETER MONITORING IN SAINTE-MARGUERITE-SUR-MER (SEINE-MARITIME, FRANCE)

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The major control of structural processes on coastal cliffs erosion is widely recognized, and exogenous factors (marine, continental and anthropogenic) well identified, but the question of their respective contributions in triggering cliff failures remains open. This is mainly due to (1) the difficulty in measuring failure events and underlying processes with sufficient temporal resolution (2) the presence of a structural context and marine weather conditions that are often site-specific (3) the variable time lag between the forcing signature and the failure event. Within the ANR project RICOCHET, we work on the deconvolution of the mechanical response of the cliff (fracturing, micro-displacement, erosion) to marine and continental forcing factors in order to improve the prediction and prevention of cliff failure. The approach developed in this project is mainly based on a 13 months field measurement campaign on the chalk cliff of Sainte-Marguerite-sur-Mer with a large set of instruments. Recent studies have highlighted episodes of micrometric displacement recorded at the top of the cliff, and propose a mechanism of cantilever effect induced by loading of the water column at the foot of the cliff in relation to infragravity waves. One of the objectives of our study is to better characterize the mechanical response of the cliff, including evaluating the cliff movement as a function of height along the wall and investigating the microfracturing that could result from the recorded microdisplacements and thus act as a precursor to cliff failure. Another objective concerns the effect of thermal fluctuations on microdisplacements along existing fracture networks. We present preliminary results on these two questions, based on measurements with a seismometer placed at the cliff top, 8 extensometers located on the cliff face, 25 temperature sensors inserted at a shallow depth in the cliff face, and distributed temperature and deformation measurements acquired using optical fibers installed in a vertical borehole at the cliff top.

Keywords: Coastal cliffs; multi-parameter field monitoring; factors responsible for triggering cliff failure; coastal erosion; Normandy

COMBINING LANDSLIDE SUSCEPTIBILITY WITH POTENTIAL RUNOUT: AN INTEGRATIVE APPROACH COMBINING DATA-DRIVEN METHODS

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Landslide susceptibility maps based on statistical and machine learning (data-driven) methods have been successfully applied to spatially discriminate those areas more likely to initiate landslides from those less likely to be affected by slope instability. Even though such approaches enable to estimate the spatial likelihood for landslide initiation, they usually neglect the potential downslope propagation of the geomorphological process. There are however other models which can be used to assess possible runouts paths for given release areas. This research aims to combine the outcomes of data-driven methods which are able to spatially identify potential landslide release zones, with those that allow approximating the potential runout, informing also the downslope probabilities of an area to be further affected by landslides. A 54km² catchment named Córrego Dantas, situated in the mountainous region of Rio de Janeiro, Brazil, is selected as the study area. After a single heavy rainfall event in 2011, 293 shallow landslides, some of which evolved into hillslope debris flows, were comprehensively mapped and were used as input observation for modelling. First, landslide susceptibility maps based on statistical and machine learning methods are created to explore the spatial likelihood of landslides release. The best performing map is subsequently combined with the conceptual runout model *r.randomwalk* in order to compute the propensity of certain downslope regions to be affected. For doing that, a constrained top-down random walk approach is used. The threshold angle of reach as well as the travel distance determining the extent of the likely runout are derived by back-analysing the probability density functions derived from the observed hillslope debris flows. The presented research aims to contribute towards a better spatial assessment of landslide-prone terrain at regional-scale by not only displaying the spatial likelihood of landslide release, but also by indicating possible downslope paths of future events.

Keywords: Landslide susceptibility; statistical model; landslide runout

A COMBINATION OF NUMERICAL MODELS FOR FALL AND FLOW TO SIMULATE COMPLEX LANDSLIDES

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Landslides can lead to loss of life as well as damages to public infrastructure and private property. Particularly “complex movements”, which include fall and flow processes, often occur with high velocities and energies. Therefore, they are highly dangerous. To reduce the negative consequences of such processes, it is necessary to implement adequate risk management strategies. The results of computer models are often considered in early warning systems, land use planning, and technical protection measures. Computer simulations, which are the main method of this study, are based on knowledge of the initial conditions, the physical characteristics of the movement, and information on previous events. Calculation approaches are often tailored to landslides of a specific type. Many landslides, however, display characteristics of more than one type of movement in space and time. Therefore, process chains and interactions have to be considered in mass flow simulations. But it is not always a priori clear which type of computer models better describes the process of a complex movement since there are, among others, computer models for (i) fall and (ii) flow processes. Unfortunately, very few studies have examined combinations and comparisons of different computer simulation models for “complex movements”. Therefore, the aim of this study is to combine different modelling software, to investigate if a combination can provide a better description of the process and to examine strategies of combining different numerical models. At this point, it is also necessary to develop a criteria set of key parameters which can be used to define the transition from fall to flow. The expected results should then provide a better description and understanding of the process. The chosen method is a comparative back-analysis of well-documented case studies with models designed for flows and falls (WURF, Rockyfor3D, r.avaflow). The plausibility and empirical adequacy of the model outcomes are evaluated.

Keywords: Numerical modelling; complex landslides; computer simulation; process chains; risk management strategies

IMPROVING LANDSLIDE SUSCEPTIBILITY MODEL ACCURACY THROUGH MULTIPLE NESTED MARS ANALYSIS: APPLICATION IN THE ILOPANGO CALDERA AREA (EL SALVADOR, C.A.)

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The goal of this research was to identify a method capable to minimize the prediction errors of landslide susceptibility statistical models. MARS (Multivariate Adaptive Regression Splines)-based susceptibility models were prepared for the Caldera Ilopango area (El Salvador), using a set of physical-environmental predictors and an inventory of 1503 shallow debris flows activated in 2003. Three different model building procedures (mod-A, mod-B and mod-C) were applied, based on the preparation of 100 replicates and in averaging the optimized regression coefficients to obtain a generalized final model, whose predictive performance was evaluated by means of confusion matrixes. For mod-A, each of the 100 replicate included all the positives and a different randomly extracted subset of negatives. By applying a Youden-index based cut-off, the validation indices (TPA-True Positive, FPA-False Positive, FNA-False Negative and TNA-True Negative of mod-A) were obtained. To investigate the false negatives (type-II errors), mod-B was prepared, by including all the FNA (positives) and balanced randomly extracted subsets of TNA (negatives). Finally, to analyze the type-I errors (FPA), mod-C was built including all the TPA (positives) and balanced randomly extracted subsets of FPA (negatives). The validation indices show that the 21% of positives and the 30% of negative are missed by the mod-A, FNA and FPA, respectively. However, Mod-B correctly provides ~90% of FNA, as TN, whilst the ~40% of TNA still was defined as FP. The 10% of FNA and 60% of TNA remain FN and TN in mod-B, respectively. The mod-C allow to correctly define the ~70% of FPA and only the 30% remains FP. The 66% of TPA rests TP in mod-C but the 34% of TP is now predicted as negative. The test suggests preparing sub-models to investigate false prediction as a promising tool for discriminating inside the false cases, future activations from errors.

Keywords: Landslide susceptibility; prediction errors; MARS model

THE LITHOLOGIC CHARACTERISTIC AND PALAEOGEOGRAPHIC SIGNIFICANCE OF ANEMOARENITE OF ORDOS BASIN IN EARLY CRETACEOUS LUOHE FORMATION

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Abstract: Since 2016, Shaanxi Institute of Geological Survey has found a 30773 km²-Danxia landscape belt of about 770 km long from north to south and 5-100 km long from east to west in southeastern Ordos basin, there are over 90 landscape in the belt. The bedrock were mainly made of brick red- purplish red, thick layer-bulk anemoarenite of early cretaceous Luohe formation, it is fragile, mature and able to develop large incline bedding, cross bedding and pore. Its formation has everything to do with paleoclimate and paleoenvironment in cretaceous system. By means of mechanical properties determination of rock, thin section Identification, X-ray diffraction analysis, electron microscopescanning and rare earth microelement analysis, focuses on the gross feature of lithology, stratum, structure and landform, the paper studies the distribution, physical property, material composition, lithology and lithofacies, provenance and depositional environment of Luohe formation stratum. Beyond that, it discusses the sedimentary record of paleo sand sea and evolutionary history of paleoclimate and paleoenvironment.

Keywords: Luohe formation; lithologic characteristic; stratigraphic distribution; paleogeography; Danxia landform

USE OF MULTI-TEMPORAL SAR AMPLITUDE IMAGES FOR RAPID LANDSLIDES DETECTION

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Despite landslides impact the society worldwide every day, landslide information is inhomogeneous and lacking. When landslides occur in remote areas or where the availability of optical images is rare due to cloud persistence, they might remain unknown, or unnoticed for long time, preventing studies and hampering civil protection operations. The SAR ability to work in all weather conditions makes it particularly valuable in frequently cloudy areas. Furthermore, the SAR C-band Sentinel-1 high revisit time, relative high spatial resolution, global coverage mission is enhancing the perspective in the use of SAR for landslide event disasters capturing in particular for rain induced processes. This work sums up some of the experiences carried out in the framework of the NERC-SHEAR funded Landslip project to test and validate methods to detect rapid landslides using multi-temporal series of synthetic aperture radar (SAR) amplitude images. Detection of landslides is based on the assumption that landslide occurrence changes the local land cover and some of its properties including dielectric constant and roughness. Changes can be intercepted using photo-interpretative methods, by following the temporal behavior of some SAR backscattering indexes, and/or the spatial autocorrelation which emerges from random speckling when landslides occur. These methods applied to Sentinel-1 images promise to increase the availability of information about landslide occurrence in peculiar situations, useful for different scopes including validation of operational landslide Early Warning Systems or worldwide climate changes impact.

Keywords: Landslide; detection; SAR amplitude

PALEO-TSUNAMI ALONG THE WEST COAST OF SUMBAWA, INDONESIA: A PRELIMINARY STUDY

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Volcanic materials from the 1257 CE eruption of Samalas volcano reached the sea and may have caused a pyroclastic density current-triggered tsunami since one of these crossed the Alas Strait and deposited its pumice fragments on the western coast of Sumbawa Island, Indonesia. However, the study of tsunami deposits following this eruption remains unknown, whereas the geomorphological impacts of this eruption on the island of Lombok are now better understood. The main goal of this study is, therefore, to investigate whether a tsunami had been triggered by the 1257 CE eruption of Samalas volcano. We collected and analyzed several samples of coral and seashells from tsunami deposits along the west coast of Sumbawa, i.e., in Belang Island and abandoned fishponds in Kiantar Village, in order to identify the tsunami sources and the occurrence period of these events. Based on radiocarbon dating of coral and seashell samples, we conclude that the 1257 CE eruption of Samalas volcano triggered a minor tsunami that hit Belang Island. Other tsunami deposits located in abandoned fishponds are dated 4th century CE and 9th century CE. We also conclude that a large earthquake triggered these tsunamis since no volcanic eruption occurred near the Alas Strait at that time that may trigger a tsunami.

Keywords: Volcanic eruption; tsunami; radiocarbon dating; Samalas 1257; Sumbawa

GEOMORPHOLOGICAL CHARACTERISTICS AND THE IMPACT OF GEOLOGICAL HAZARDS OF LOESS PLATEAU IN NORTHERN SHAANXI, CHINA

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The loess area is one of the important areas for human survival. There are hundreds of millions of population living on Chinese Loess Plateau which is distributed in about 630,000km². The geological hazards resulted by special geological and geomorphological conditions in the Loess Plateau of northern Shaanxi seriously threatens the safety of people's lives and property. The geomorphological characteristics of Loess Plateau of northern Shaanxi were presented here. The main types of geological hazards of Loess Plateau of northern Shaanxi was researched, and the relationship between different geomorphic types such as plateau, beam, moat and terrace and geological hazards was analyzed, based on the survey data of geological hazards from China Geological Survey and Department of Natural Resources of Shaanxi Provincial. Finally, the countermeasures for preventing and reducing geological hazards in loess area are briefly put forward.

Keywords: Loess; geological hazards; disaster prevention; mitigation

GEOMORPHOLOGICAL APPLICATIONS TO NATURAL HAZARDS IN JAPAN AND TAIWAN

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Japan and Taiwan are located along major plate subduction zones and have similar natural environments including steep mountains caused by rapid tectonic uplift. These areas are also characterized by rapid erosion and high sediment yields due to heavy rainfall caused by typhoons and frontal activities. Another common aspect is the existence of many populated places not only in lowlands but also in piedmont areas and even within mountains. Therefore, various natural disasters repeatedly occur leading to casualties and huge economic losses. In Japan and Taiwan, geomorphology and related scientific disciplines play a significant role in analyzing and coping with natural disasters especially those due to heavy rainfall and earthquakes. It is important for Japanese and Taiwanese geomorphologists to share information and conduct collaborative research for effective geomorphological applications to hazards. In this presentation, we introduce some recent case studies from such collaborations focusing mainly on landslides and rainfall conditions. These studies in East Asia have some global implications because they represent the most active geomorphic changes and processes in the world. Some social applications of such geomorphological studies including contributions to high school education are also introduced.

Keywords: Hazard; geomorphology; Japan; Taiwan

LOCATIONS OF HISTORICAL AND ARCHAEOLOGICAL MONUMENTS IN JAPAN AND CHINA IN RELATION TO GEOMORPHOLOGY AND NATURAL HAZARDS

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Locations of historical and archaeological monuments reflect activities and thinking of ancient people who built them as well as related environmental factors such as topography, water availability, and proneness to natural hazards. Such relationships are expected to be stronger in the past when human control on nature was limited, and their analysis is useful to understand how ancient people interact with the environment. Nevertheless, scientific research from such viewpoints has been limited because it requires interdisciplinary approaches encompassing physical geography, human geography, history and archaeology. Recently, some relevant books for common people have been published in Japan, including those discussing relationships between ancient castles and topography. However, these books are based on qualitative or speculative reasoning, and not so scientific. In contrast, some studies tried to investigate these issues more quantitatively and statistically using DEMs (Digital Elevation Models) and GIS (Geographic Information Systems), although there are few comprehensive studies based on recent advanced spatial technology and higher resolution data. This research tries to conduct such analysis using DEMs and GIS to analyze topography in relation to historical and archaeological monuments located in Japan and China. The locational and attribute data of the monuments are collected using existing publications and databases. Morphometric parameters are extracted from DEMs and other environmental data are also utilized. Statistical and geospatial analyses are conducted to understand the relationship between the locations of ancient monuments and their environmental settings especially topographic factors and related natural hazards such as flooding and debris flows. The results suggest that topographic factors and related hydrological conditions affected social aspects including the accessibility and defensive capability of each location, controlling the allocation of historical and archaeological monuments.

Keywords: Monument; geomorphology, hazards; Japan; China

GULLY-LANDSLIDE EVOLUTION FROM 2009 TO PRESENT: A CASE STUDY FROM SOUTHEAST NIGERIA

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Gully erosion and landsliding are geomorphic processes that shape the Earth's surface, yet, they pose significant hazards when they interact with human activities. The aim of this project is to generate understanding of gully- landslide evolution in southeast Nigeria in order to inform hazard and risk mitigation. Five local Government Areas – Ideato North, Ideato South, Isu, Njaba and Orlu with a total area of 534 km² in Imo State, southeast Nigeria were studied. Gully mapping was carried out with 2009 and 2018 RapidEye-5, WorldView-2 and SAS Planet imagery of the study areas. 30 m ASTER DTM was used to generate elevation and slope values. Multivariate statistics were used to test the relationship between gully count/gully area density and slope angle, population density, nearness to rivers and roads. Three stages of gully evolution were identified: active, declining and static gullies. Number of gullies increased from 40 in 2009 to 77 in 2018, a 92.5% increase, while total gullied area increased from 0.35 km² to 0.71 km², an increase of 103%. There was no clear relationship between population density and number of gullies or gully area density. This result shows that population density as a single factor may not be the chief human element responsible for gully erosion as previously thought. Due to the small sizes of landslides in the study area, they cannot effectively be differentiated from gullies in the satellite images, hence, field-based mapping will be used to identify and map landslides within the gullies.

Keywords: Gully erosion; landslides; geomorphic hazard; risk

GIANT LANDSLIDES AND FALL OF GLACIAL LAKES IN THE FORELAND OF THE PATAGONIAN ICE SHEET

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Although spectacular large glacial lakes, staircases of moraine ridges, and extensive outwash plains have inspired generations of scientists to reconstruct the ice sheet history of the Patagonian Ice Sheet (PIS), few of these studies noticed many dozens of giant ($\geq 108 \text{ m}^3$) mass-wasting deposits which originated after the post-LGM ice retreat. More than 283 large landslides detached some $164 \pm 56 \text{ km}^3$ of material along the former Lago Buenos Aires and Lago Puyeredón glacier lobes and lakes in Argentina. In this study, we focus on some of the world's largest hitherto documented landslides in moraines situated in the southern area of the large Late Glacial to Early Holocene "glacial lake PIS". We performed multidisciplinary research based on the geomorphic mapping aided by the high resolution UAV survey, radiocarbon dating and numerical slope stability modeling. Our results suggest that giant slope failures cross-cutting shorelines of the "glacial lake PIS" likely occurred during successive lake-level drop between $\sim 11.5\text{--}8 \text{ ka}$. Exceptional runout ($>5 \text{ km}$) of these landslides is explained by low-friction conditions, as they entered water saturated deposits or moved under the water. Preliminary results of the limit equilibrium and finite element modeling suggest that giant landslides along the low-gradient banks of former glacial lake emerged as a response of fast lake level drawdown, with potential contribution of strong earthquake related to post-glacial rebound. However, radiocarbon dating suggests that mass movement activity in deep gorges incising dried bed of former "glacial lake PIS" continued until the Late Holocene. We conclude that 1) large portions of terminal moraines can fail catastrophically several thousand years after emplacement; 2) slopes formed by weak bedrock or unconsolidated glacial deposits bordering glacial lakes can release extremely large landslides; and 3) landslides still occur in the piedmont, particularly along postglacial gorges cut in response to falling lake levels.

Keywords: Giant landslides; moraines; glacial lake drawdown; glacial-interglacial transition; Patagonian Ice Sheet

OLD BUT STILL ACTIVE: >18 KA HISTORY OF ROCK-SLOPE FAILURES AFFECTING FLYSCH ANTICLINE

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Czech part of the Outer Western Carpathians (COWC) formed by flysch rocks belongs to the global landslide spots, and some of the most landslide-prone areas in the Europe. Although mass movements represent crucial geomorphic agents in COWC, their timing and especially lifespan remain elusive. In this study we focused on rockslides affecting flanks of anticline developed within the Paleogene sandstones. The area ("Pulčín-Hradisko" ridge) is well known as the most extensive rock city in the COWC. Structural-geological investigation, kinematic analysis and the application of near-surface geophysics (ERT, GPR, and refraction seismics) suggests that rockslides accompanied by toppling and lateral spreads are predisposed by the architecture of bedding planes and inherited faults cross-cutting the anticlinal ridge. Based on the ¹⁰Be exposure dating of five scarps and rockslide boulders (together 25 cosmogenic-dated samples), we were able to reconstruct the long-term history of rock slope failures. Although the obtained ages of headscarp exposures reveal consistent pattern suggesting major mass movement phases around ~18 ka and ~12 ka, interpretation of boulder exposure ages is ambiguous. The study area has not been affected by catastrophic slope failure in the historic times, but dendrogeomorphic analysis reveals surprisingly strong tree-ring signals of mass movements within the last 150 years. It might suggest that progressive failure is developing within some parts of rockslide and/or slope portions above the major scarp. We conclude that 1) some rockslide spots within the COWC might express very long history, encompassing full Late Glacial-Holocene period; 2) major mass movement activity in the study site temporally coincided with the major climatic changes; and 3) rockslides with very long history still represent potential hazard, despite that evidence of their active movement is not detected by standard geomorphic mapping techniques.

Keywords: Rock-slope failures; anticlinal ridge; dating; geophysics; Flysch Carpathians

RELATIONSHIPS BETWEEN LAND-USE LEGACIES AND LANDSLIDE OCCURRENCE

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Landslides are recorded especially when economic damage has been caused, which is mostly the case in settled areas, along transportation infrastructure, or on agricultural land. However, recent LiDAR-derived inventories often show a surprisingly high landslide density particularly in forested areas. This apparent contradiction underlines the need to better understand the factors explaining landslide occurrence in cultural landscapes. We hypothesize that land-use legacies may be a previously-neglected explanatory factor for landslide occurrence. The objective of this study was to assess relationships between landslide occurrence and land-use legacies while also accounting for geomorphological and lithological conditions. Therefore, we digitized and classified land-use from the Franciscan Cadastre of 1820, aerial photographs of 1960, and aerial orthophotos combined with InVeKoS data of 2015 in our study areas (the municipalities Waidhofen and Paldau located in Austria). Additionally, yields and livestock information was compiled from archival sources and statistical publications. This information was summarized as socio- ecological variables reflecting plot-level land-use legacies for each study area, providing indicators on cumulative biomass extraction, land-use change and soil compaction. We spatially assessed the landslide occurrence with a semi- parametric generalized additive model (GAM), using a landslide inventory mapped from LiDAR DTMs, the land-use legacy indicators and local geomorphological and geological predictors as input variables. The model performance was computed using the area under the ROC curve (AUROC) estimated by spatial cross-validation. The explanatory power of land-use legacy predictors was evaluated based on their explained deviances and odds ratios. Our results suggest that including land-use legacies in the analysis improves the model fit and that land-use legacies contribute to the explanation of landslide occurrence. Among the land-use legacy indicators, land-use change is the most relevant factor explaining landslide occurrence.

Keywords: Landslide susceptibility modeling; generalized additive model; land use legacy; historical landslide inventory

INTEGRATING PIXEL ANALYSIS INTO SLOPE UNITS LANDSLIDE SUSCEPTIBILITY MAPPING: AN APPLICATION TO THE IMERA RIVER BASIN (NORTHERN SICILY, ITALY)

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In this work, the efficiency of different mapping unit partitioning in the landslide susceptibility assessment was tested. In particular, this test is designed to compare the most commonly used grid cell units (CLUs) and a new type of slope units: LCL_SLU (Landform Classification Slope Units), obtained by intersecting the Slope Units with LCL (Landform Classification) classes. The study area was the Imera basin, in the north sector of Sicily (Italy). A systematic landslide inventory, including 1551 slides was regressed on a set of eleven physical-environmental predictors using MARS (Multivariate Adaptive Regression Splines) method. One-hundred replicates of balanced datasets and random partition were applied for testing the accuracy of the models through ROC-plot analysis and confusion matrices, both in terms of goodness of fit and predictive skill. By averaging the one-hundred MARS regression coefficients, a generalized pixels- based prediction image was obtained, whose scoring was then zoned in the LCL_SLUs, obtaining mean (MN), max (MX) and mean + standard deviation (MS) new scores. These three zoned scores were then assigned to each unit as new predictors for a subsequent MARS LCL_SLU-based modelling. The results show that excellent Area Under Curve (AUC) values were obtained for both models, with higher sensitivity and lower specificity for the LCL_SLUs. This test suggests that by integrating the classical pixel-based analysis on LCL_SLU modelling it is possible to optimize the results of the landslide susceptibility assessment, at the same time preparing much more easy-to-read maps, more suitable for administrations in land management.

Keywords: Landslide susceptibility; slope units; grid cell units; MARS; Imera basin

MORE FREQUENT DEBRIS FLOWS IN SOUTHEAST AUSTRALIA LINKED TO DROUGHT, WILDFIRE, AND THE EL NIÑO–SOUTHERN OSCILLATION

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Between 2003 and 2013, drought, large wildfires, and record-breaking rainfall contributed to debris flows in southeast Australia that appear to be unprecedented in spatial extent and density in historical records. Here, we used a debris-flow inventory from this period of dry and wet extremes to examine the processes and climatic controls underlying the regionwide debris-flow response. Results reveal shallow landslides and surface runoff as two distinct initiation mechanisms, linked to different geologic settings and contrasting hydroclimatic conditions. Landslide-generated debris flows occurred in sandy soils, independent of past fires, and were tightly controlled by extreme rainfall causing saturation and mass failure during La Niña periods. In contrast, runoff-generated debris flows occurred in clay-rich soils from short and intense rainstorms after wildfires in dry conditions, often associated with El Niño. Thus, it appears that both ends of the wet and dry climate extremes produce the same general geomorphic response, debris flows, but in different areas and by different initiation processes. Debris-flow activity is therefore at a maximum when amplitude and frequency of climate oscillations are large. Debris flows in southeast Australia are likely to become more frequent and widespread as wildfire activity and rainfall intensity are predicted to increase.

Keywords: Debris-flows; SE-Australia; climate change; drought; wildfire

VIDEO EDITING AND UAV SURVEY TECHNIQUES USEFUL FOR THE ANALYSES OF BOULDER MOVEMENTS OCCURRED DURING THE STROKE OF MEDICANE “ZORBAS” ON SOUTHEASTERN SICILY

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In the Mediterranean basin, one of the most impressive results of the extreme wave impact on the rocky coasts is represented by the presence of mega-boulders, sparse or accumulated in field or berms. Although the immense number of data derived by the surveys performed all along the coast hit by the Indian Ocean (2004) and the Japan Tsunami (2011) have demonstrated that the wave flow has been able to detach and scatter inland boulders of significant size and weight, the debate about the correlation of these landforms/sediments with the extreme event responsible of their genesis/deposit is still open. In fact, since the absence of eyewitness, at present, no undisputable signatures allow to discriminate between the boulders accumulated by storm from those accumulated by tsunami. The Medicane “Zorbas”, stroke the coasts of southeastern Sicily on winter 2018; its impact was registered along the coasts of Apulia, Basilicata and Calabria with minor energy. The surveillance cameras of the Marine Protected Area of Plemmirio recorded the several boulders movements, present along the Maddalena Peninsula (Siracusa, Italy). In fact, in the same area a boulder field attributed to both tsunami and storm waves was already described. Since 2010, Terrestrial Laser Scanner and UAV photogrammetry techniques have been applied in order to monitor the boulders. Camera recorded distinct movements, most of boulders were detached along the coastline and displaced, as the storm waves impact determines the reduction or nullifies of the friction forces, with subsequent boulders movement in several steps. UAV photogrammetry survey was performed after the event and let us to reconstruct an immersive scenario useful to geometrically analyze all the boulders movements using video editing software. A video analysis was conducted for each movement, to calculate distance, bearing, acceleration of the boulders in combination with wave parameters on the shore platform. A comparison between flow velocity derived by models and flow velocity derived from video analysis was made, in order to observe the discrepancies between the real observation and the model results for sliding, rolling/overturning, saltation/lifting conditions in subaerial/submerged scenario. Model results obtained are bigger than values derived by video analysis, suggesting that model parameters can be overestimated for this coast, so we recalibrated the values of some parameters in order to minimize the error.

Keywords: Boulders; medicane; flow; UAV; waves

UNDERSTANDING THE DESERTIFICATION PROCESSES AND ROLE OF NATURAL AND ANTHROPOGENIC DRIVERS IN AN ARID ECOSYSTEM: A CASE STUDY IN INDIAN ARID LANDS

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Desertification denotes the fragility and stress on land as a source of food to human and livestock population. Indian desert is one of the most thickly populated deserts of the world. The sparse rainfall that falls on the Indian desert is regionally skewed, with eastern margin receiving more rainfall than the western margin and therefore, agriculture is confined to the eastern region where water is available. Understanding the process of desertification within desert environment and causative natural and human factors reflect the real scenario. In this paper, an attempt has been made to examine the role of natural as well as human factors that contribute to desertification and its role in increasing the vulnerability of land. In order to arrive at the findings and result the methodology adopted to understand the desertification process through the impact of the cumulative indices of soil, climate, vegetation and anthropogenic drivers. In order to measure the intensity of vulnerability, weights have been assigned based on selected indicators. The study area clearly demonstrates that most of the western parts of the study area are under severe threat as compared to eastern margins. The study uses satellite derived data in order to assess the intensity of vulnerability of desert ecosystem. Therefore, the paper attempts to find out the level of land production potential in the desert ecosystem and assess the prospects of human occupation dynamics here.

Keywords: Desertification; sustainability; Indian desert; vulnerability; desert ecosystem

GEOMORPHOLOGY AND DISASTER RISK REDUCTION: THE EXPERIENCE OF THE EMTASK ACADEMIC UPGRADING COURSE ON TERRITORIAL, ENVIRONMENTAL AND HEALTH EMERGENCIES

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The aim of this contribution is to show the remarkable attention given to geomorphological risks within the EmTASK academic upgrading course offered since 2017 by the University of Modena and Reggio Emilia (Italy) on Territorial, Environmental and Health Emergencies. The EmTASK course takes advantage of the experience acquired in the management of emergencies due to earthquake, flood and landslide events occurred in Emilia in recent years, which caused severe socio-economic damages and hardly tested the functioning of institutional services, including the Civil Protection. Among the others, the course is organized in co-operation with the Italian Army, environmental and civil protection agencies of the Emilia-Romagna Region and the Regional Fire Corps, with the aim to provide the participants with a sound knowledge and interdisciplinary skills that can foster a holistic approach in forecasting, prevention, management and overcoming of emergencies in the spirit of the Sendai Framework for Disaster Risk Reduction 2015-2030. The training structure of the course comprises (i) lessons regarding the basic knowledge on risk forecasting and prevention and emergency management in different disciplinary and operational contexts; (ii) individual internships – through which practical experience at public institutions or bodies, companies and associations can be achieved – and (iv) field visits. The theoretical part is enriched by training activities in groups referring to scientific-technological, medical-biological-sanitary and legal- economic-social aspects. The course was attended during the first two editions by over 110 students with very different disciplinary backgrounds. Geomorphological hazards and risks have however been one of the main topics of the course, with special focus on Italian landslides (e.g. Vajont) and floods that have caused victims and damages, analyzing their causes and effects from different perspectives, their health and socio-economic implications and finally their legal consequences, when Man was proved to have responsibility in the events occurred.

Keywords: Geomorphological hazard; disaster risk reduction; training, Unimore; Italy

CONSEQUENCES OF MASS MOVEMENTS RELATED TO ANCIENT EXTRACTIVE ACTIVITIES IN THE CITY OF TANDIL, ARGENTINA

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In the city of Tandil, east-central Argentina, mass movements develop affecting different landscape components, part of them closely related to human activities. At the second half of nineteenth century and dawn of the twentieth, underground sand and gravel mining was developed under present-day urban and suburban areas of the city. The aim of this contribution is to analyze relationships between mining, mass movements and their impacts. The distribution of mass movements was analyzed in a GIS environment. Input data was obtained by interpretation of satellite imagery and air photo records, citizen consultations and research in local archives of news stories, technical reports and radio programs. Field work included qualitative evaluation of the impacts and characterization of the geomorphic features and sediments involved. As a result, sediments were identified as fluvial consistent deposits, and parts of an old sub-surficial drainage network were mapped. The ancient extraction of these materials caused substantial changes of natural landscape, due to the creation of underground galleries, known locally as “sand mines”, increasing local instability. As a consequence, several years later, the abandoned state of these mines contributed to the development of aligned subsidence processes: cavity collapses and settlements, affecting houses, roads, campus and a runway. Economic losses identified were cracks in walls, ceilings, lintels and a swimming pool, inclined and compressed doors and windows, inclined walls and detached tiled floors; in some cases, complete or part of houses were demolished because they were irreparable. Illustrating threats to economic activities and persons, a collapse occurred during a construction and three operators had to be rescued. Settlements and collapses were inexistent before the construction of mining galleries, and the recurrence of these processes indicates existing hazards. The expansion of Tandil toward areas with old underground mining galleries and their deterioration, suggests that geomorphological risks are increasing.

Keywords: Cavity collapses; settlements; human activities; underground mining; geomorphological risks

TESTING OF DENDROGEOMORPHIC METHODS ON MONITORED LANDSLIDES: HOW EFFECTIVE IS DENDROGEOMORPHIC DATING FOR THE IDENTIFICATION OF LANDSLIDE ACTIVITY?

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An understanding of past landslide behaviour is crucial for the estimation of future landslide activity. Dendrogeomorphic (tree ring-based) approaches are standard methods for the spatio-temporal reconstruction of landslide activity with annual resolution and timespans of several centuries. Nevertheless, the verification of the effectiveness and sensitivity of these dendrogeomorphic approaches has not been addressed in more detail despite their wide spectrum of limitations. Landslide monitoring, as an accurate tool for assessment of spatio-temporal activity within the landslide body, can help evaluating the effectiveness of dendrogeomorphic methods. To this end, comparative evaluation of both approaches was performed in the Western Carpathians (Central Europe). Dendrogeomorphic methods were tested on (i) active flow-like landslide composed of volcanoclastic rocks and monitored by deviation measurements of stabilized geodetic points, and (ii) deep-seated slope gravitational deformation composed of flysch rocks and monitored by technical levelling and wire extensometer. Event chronologies, recurrence intervals, and spatial variability were evaluated based on dendrogeomorphic analyses of 219 individuals of *P. sylvestris* and 132 individuals of *P. abies*, respectively. In the first case, 30% of the flow-like landslide area showed similar activity based on both approaches. The best fit between the results was observed in areas with mean cumulative surface displacements of approximately 200 mm and mean event recurrence time of 14.5 years. Another parts of landslide body showed differences between both approaches presumably due to different spatial accuracy of used methods and physiology of tree species. In the second case, the formation of compression wood in trees was demonstrated during movements of landslide body in order of millimetres based on extensometer records. The partial lack of correspondence between tree ring records and data from more distant monitoring sites suggests the need for separate dendrogeomorphic analyses of the individual homogenous parts of landslide areas.

Keywords: Landslide; dendrogeomorphology; monitoring; Western Carpathians

MODELLING PEAK DISCHARGE WITH THE USE OF UNMANNED AIRCRAFT SYSTEMS. THE CASE OF MARIOREMA STREAM DURING THE FLASH FLOOD OF 2016 (LAKONIA, GREECE)

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Impacts of climate change related disasters such as flash floods in areas such as the Mediterranean region seem to have been increasing in frequency over time recently. The developments of technology made available in affordable costs enables monitoring and mapping of such phenomena with more accuracy than ever before, like the use of Unmanned Aircraft Systems and Structure from Motion photogrammetry. It is a rapidly developing method of mapping geomorphological and geological features with application to the wider field of geosciences. This work aims at modelling peak discharge during the flash floods of September 2016 in the area of Mariorema stream in Lakonia, Greece, using topography and other data deriving from the use of UAS. Peak discharge estimation followed the slope-conveyance method. Field and aerial work collecting data for flood marks and other features was performed immediately after the flood, and photogrammetry flights were scheduled thereafter. Flight planning and execution used Pix4D capture and a DJI Phantom 4 Pro UAV. Image processing and production of 3D model and derivative orthomosaic and Digital Surface Model were executed with Pix4Dmapper. DSM and floodmarks were processed in GIS to produce cross sections and obtain accurate bed slope data, floodmark elevation and selection of appropriate cross sections for calculations, taking into account a detailed mapping of granulometry, deposition and erosion conditions, bank retreat and flow alternations. Several cross sections were compared regarding flow conditions to select the most appropriate. Manning coefficient (n), bed and energy slope in the cross-section area was calculated. Calculation of wetted surface, wetted perimeter, hydraulic radius, K coefficient, Froude coefficient lead to calculation of minimum, probable and maximum peak velocity and peak discharge at the spot. Results showed a unit peak discharge of $3.17\text{m}^3/\text{s}/\text{km}^2$, for an event of 200mm of daily precipitation over the 200km^2 catchment of Mariorema stream.

Keywords: UAV; peak discharge; flash flood; Lakonia 2016

MASS MOVEMENTS STUDY IN DJOUNDÉ LOCALITY AND VICINITIES (MAROUA II SUB- DIVISION, FAR-NORTH, CAMEROON)

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The mass movements hazards are frequent in several regions in Cameroon. Maroua city, Far North Region, have undergone during the last decades, such natural hazards. The Djoundé locality and vicinities that are located in the Maroua II Sub-division, present significant example of mass movement events. That is why Djoundé locality and vicinities have been chosen for the present study. The study of mass movements hazards is very important for the Cameroon decisions makers to implementing the sustainable management policy of that populated region. The inventory revealed that the most frequent mass movements in the Djoundé locality and vicinities, are rock falls and debris falls. These events are regulated by several predisposing and triggering factors that are from natural and anthropogenic origin. The predisposing factors include inselbergs (basaltic and trachytic boulders), slopes (greater than 65% in some places), vegetation cover dominated by meadow and sporadic trees, rainfall (Total of 747.69 mm annually), temperatures (average of 33.9°C in April), farming and breeding (beefs and sheeps). The triggering factors include the opening of quarries (for building issues), rainfalls (Average 237.71 mm in August) and breeding. In this work, some factors have been mapped through Fields Investigations, Geological and Topographic Maps, Google Earth, ArcGIS, Adobe Illustrator. The combination of these maps permitted to realize the mass movement hazards map of the Djoundé locality and vicinities. It emerges that the probability of occurrence of mass movement hazards in the study area is high (35%) average (40%) and low (25%). These hazards (rock and falls debris falls) are often accompanied by gullying.

Keywords: Djoundé; mass movement; rock and debris fall; gully

S07. GLACIAL AND PERIGLACIAL GEOMORPHOLOGY

THERMOKARST DEGRADATION: LARGE-SCALE LABORATORY SIMULATION

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In Central Yakutia (Eastern Siberia), continuous permafrost undergoes an acceleration of its thermal degradation under the recent global warming. In the Yedoma ice complex, permafrost contains ~70–80% of ice by volume and is characterized by heterogeneous distribution of the ground-ice (syngenetic ice wedges, massive ice ...) which strongly favor thermokarst formation. Retrogressive Thaw Slumping (RTS) mostly occurs along the banks of thermokarst lakes, but the exact RTS dynamic is not fully understood. In order to better understand the relative contribution of parameters (ice content, granulometry, active layer, air and permafrost temperatures ...) to the formation of RTS, a large-scale laboratory simulation of RTS was undertaken at GEOPS cold room (Orsay, France). The RTS experiment corresponds to a 2.5 m x 2.5 m fine sand permafrost saturated with water with regularly spaced artificial ice wedges. The model was instrumented using 10 temperature sensors (platinum resistance thermometers Pt100) to survey the freezing and thawing front and active layer thickness vs time. A morphometric approach together with a slow-motion recording was used to quantify the thermokarst subsidence. We did a hierarchizing of the main parameters involved in the RTS development. Our results demonstrate that air temperature, and ice content all increase the ablation rate, whereas lower permafrost temperature (<-7°C) tends to slow down thermokarst process. The effect of vertical heterogeneity (ice wedges) within the permafrost is predominant and its subsequent thawing increases the vertical subsidence of RTS.

Keywords: Thermokarst; periglacial; permafrost; Siberia; modelling

THE COMPLEX READJUSTMENT OF A PERIGLACIAL RIVER TO ONGOING CLIMATE CHANGE, THE LENA RIVER (EASTERN SIBERIA)

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Draining the coldest region of the Northern Hemisphere, the Lena River is a permafrost-dominated hydrosystem. Siberian rivers are deeply impacted by ongoing climate change which is particularly pronounced in periglacial areas characterized by deep and continuous permafrost. A previous paper highlighted a marked hydrologic change of the Middle Lena River (Gautier et al., 2018): general increase of the water discharge, more frequent high-level events (bank- full, bar-full and high flood discharge), longer duration of floods... Furthermore, the frequency of late hydrologic floods occurring during summer is evidenced. Here, our objective is to better understand interactions between hydrologic functioning, fluvial landform, riparian vegetation of the middle Lena River in Yakutia, at a pluri-decadal time scale (50 years). We examine the fluvial landform of the river on the basis of aerial pictures (Corona images 1967, 1980), satellite images (Landsat: 1992, 2002; Spot 2008, 2010 and Pleiade 2014, 2017). As two main morphometric parameters express the morphological adjustment of the river, they are analyzed in detail for 1967 - 2017: i) fluvial island migration rate and ii) island area. The mean annual rate of island migration strongly varied for the study period (ranging between 11 m and more than 20 m per year), whereas the area slightly fluctuated ($\pm 5\%$). The island head erosion reached a maximal value exceeding 20 m per year between 2002 and 2008, decreasing after. The detailed analysis of the island area reveals a complex evolution, not synchronous with the island erosion: the island area undergoes a decrease since 2008, following a long period of accretion. In order to explain the complex response of the Lena River dynamics, we investigate various factors: presence of permafrost in the island, water discharge and stream temperature, development of pioneer vegetation, destruction of alluvial forest by ice-jams during the spring outburst.

Keywords: Fluvial readjustment; periglacial; permafrost; climate change; Siberia

GLACIAL DECLINE IN THE GRAN PARADISO MASSIF (WESTERN ITALIAN ALPS) SINCE THE LITTLE ICE AGE: QUANTITATIVE ANALYSIS FROM A MULTITEMPORAL DATABASE

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Alpine glaciers are among the most relevant indicators of climate variations as they modify their shape and size in response to changes of 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, here we present a multitemporal analysis of glacier variations occurred in the Gran Paradiso Massif since the Little Ice Age (LIA). Detailed geomorphological and glacial geological field surveys and photointerpretation allowed us to reconstruct LIA glacial limits. Glacier limits outlined from multitemporal datasets (e.g. aerial photographs, historical maps) and all the collected datasets were organized in a multitemporal dynamic glaciological database in GIS environment. The analysis considered about 80 glacial bodies (according to the CGI-CNR glacier inventory, 1957-1958) and provide quantitative data documenting a general glacial decline since the LIA accelerated during the last three decades. Our results highlight a loss of about the 70% of the glacierized surface since the LIA and confirm, for this mountain group too, an areal reduction of over 45% in the last 60 years (1952-2015). We obtained new areal reduction rates that show dramatic variations, in particular they show a strong acceleration from -0,5% y⁻¹ during second half of 19th century to $\approx -1,4\%$ y⁻¹ in the period 1994-2015. Time-Distance curves, based on annual glaciological surveys conducted since the end of the 19th Century by the Italian Glaciological Committee and validated on multitemporal aerial photographs, confirm that these glaciers have been characterized by a general trend of retreat, particularly marked since the '90s. Results underline the strong imbalance of glaciers in the Western Alps and highlight the rapid increase in their reduction rate during the last decades, which is leading to impressive changes and to a relevant increase of the geomorphological hazard in the newly formed paraglacial environment.

Keywords: Glacier variations; time-distance curves; geomorphological mapping; Gran Paradiso Group; Western Italian Alps

**SOILS DYNAMIC, PARENT MATERIAL EFFECT AND
GEOMORPHOLOGICAL PROCESSES IN HIGH MOUNTAIN
ENVIRONMENTS: THE CASE OF RIO BUSCAGNA HYDROGRAPHIC
BASIN (VEGLIA-DEVERO NATURAL PARK, CENTRAL-WESTERN
ITALIAN ALPS)**

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Among the most sensitive environments to climate change and most articulated in term of bedrock features, there are high mountain regions, where climate change, characterizing the Late Holocene, is provoking, the speed up of climate-related geomorphological processes. In this context, soils are a very useful tool to reconstruct past environmental conditions and to infer the variation of the morphodynamic processes in term of space and time. In fact, soil development and evolution are influenced by several environmental factors (i.e., climate, organism, slope or topographic setting, parent material, time). The main aim of this study is the reconstruction of landscape and environmental evolution characterizing the Rio Buscagna hydrographic basin (Veglia-Devero Natural Park, Central-Western Italian Alps) during the Late Holocene. The basin is characterized by an evident asymmetry between the valley slopes in terms of lithology, inducing a great landforms diversification. Hence, 7 soil profiles, selected in different morphological contexts, along two downslope transects, were investigated by means of field and laboratory (of both mineral and organic constituents) characterizations. The investigated soil profiles allow to identify the occurrence of different slope instability phases, which are recorded in the soil profiles as buried surfaces. Moreover, the presence of different pedological units, and their correlation along the slope, underlines the occurrence of separate events of pedogenesis, linked to recognizable stability phases. In particular, on the slope characterized by the calcshists parent material, the biostasy phases should have been particularly pronounced, allowing the development and preservation of podzolic features. In addition, the presence in the area of cover beds influences pedogenesis, modifying chemical and physical effect of parent materials. Therefore, this research underlines the role of soil as useful archive for retracing the geomorphological processes responsible for high altitude areas landscape evolution.

Keywords: Central-Western Italian Alps; soil; climate change buried surfaces; geomorphological processes

GEOMORPHIC PARAMETERS OF SEDIMENT SOURCES INFLUENCING THE MONOLITH AND KELLER STREAMS, JAMES ROSS ISLAND, ANTARCTICA

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Proglacial gravel-bed streams in polar regions are very sensitive to progressing climate change together with a glacier melting. The sediment sources highly influenced the activity of fluvial processes in there vegetation uncovered areas. During the Czech Antarctic expedition 2017–2018 carried out on Czech Antarctic station of Johan Gregor Mendel, James Ross Island, Antarctica we started with fluvial geomorphological research. We tried to identify the sediment transport sources and their impact on bedload changes of proglacial braided streams. The Monolith Stream catchment area (31 km²) is located in the James Ross Island, close to Antarctic Peninsula and it is created by the Monolith (5.4 km long) and Keller streams (6.2 km long). Main petrological types are basalt, palagonite form hyaloclastite breccia, and sandstone according to the field survey and geological map. The main goal was to identify the controlling sediment sources in this catchment. Before the intensive fieldwork, we used various orthophoto images and DEM for the catchment area detection. After that, the unique subcatchments of each tributary was delimited. The results show the categorized 8 sediment sources as a morainic complex of Whisky Glacier, debris-flow dominated fans and fluvial-flow dominated fans. We also create a geomorphological map of these catchments and we collected bedload sediment from selected sources in two fractions (8–16 mm; 64–256 mm) for determination clast size, shape, roundness and petrology to understanding the transport characteristics and short-term fluvial changes.

Keywords: Gravel-bed rivers; proglacial; sediment sources; James Ross island; Antarctica

QUATERNARY GLACIAL LANDFORMS ON PERISTERI AND TZOUMERKA MASSIFS (PINDOS CHAIN, NORTHWESTERN GREECE)

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This study deals with the Quaternary glaciation highly affected and shaped the morphology of the Peristeri and Tzoumerka massifs in northern Pindos mountain chain, NW Greece. The glacial geomorphic features found in an altitude range between 2,200 and 1,500m have been recognized, studied and mapped. The glacial action by alpine glaciers created many impressive glacial landforms, such as Glacial circus, lateral, central and frontal morainic deposits. The field survey showed a difference in moraine preservation from erosion. The morenic deposits located on the eastern mountain slopes are more well preserved comparing with those on the western slopes due to local climatic and hydrological differentiation. All the obtained results enable us an estimation that all the morenic deposits seem to be referable to the Wurmian glaciation. Three inter glacial retreat stages during and after the glacier retreat has been recognized. In particular, the last and more recent moraine seems to be referable to the late Wurmian inter glacial. Also, the ELA of the maximum glacial expansion for Peristeri and Tzoumerka massifs has been estimated at an elevation close to 1,600m using the “average elevation” method.

Keywords: Wurmian glaciation; morenic deposits; ELA; Pindos chain; Greece

THE ROCK GLACIERS ON THE BULGARIAN HIGHEST MOUNTAINS (RILA & PIRIN) AND RETEZAT MOUNTAINS, ROMANIA: A COMPARATIVE ANALYSIS

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Considered as a mantle of rock and ice mixture bodies, widespread in the alpine environment, rock glaciers (RG) are the most visible morphological indicators of the mountain permafrost occurrence. The level of knowledge of these periglacial landforms differ widely at a global level. In the Balkan Peninsula the evolution and current state of rock glaciers and other periglacial landforms is at its infancy. Specific for the mountain discontinuous permafrost belt, rock glaciers have a good paleoclimatical significance, which raises our interest in researching this phenomenon. In this study we performed a comparative analysis of the geomorphological characteristics and the distribution of rock glaciers on highest Bulgarian Mountain, Rila and Pirin and from Retezat Mountains (Romania). In total, we analyzed 216 rock glaciers, 122 located in the Bulgarian highest mountains and 94 in the Retezat Mountains (Romania). The morphometric parameters were extracted using ArcGIS from a 30m resolution DEM and the statistical analysis (correlations, t test) were performed using the software R. The results revealed differences but also some similarities between the two mountain regions. In both mountain regions most of the RG were formed on the same type of rock, granite (over 80%), occur on the northern slopes and have a mean area of approximately 6 ha. RGs in Rila and Pirin have a significantly higher mean altitude (2390 m vs. 2036 m) and a lower mean slope (17° vs. 21°) than those in the Retezat Mountains. The tongue-shaped rock glaciers dominate (89%) the Bulgarian highest mountains compared to the 38% situated in the Retezat Mountains. In the Southern Carpathians more than half, 63%, of the rock glaciers have Nordic exposures, here being concentrated 77% of the inactive/active stone glaciers, and in Rila and Pirin Mountains 77%, and 72% respectively, have Nordic orientations. In the Southern Carpathians 49% of the total rock glaciers are located on granites and granodiorites, and in Rila and Pirin Mountains 82% are present on granites. The average surface area of the rock glaciers in the Southern Carpathians is 4.1 ha, and in the Rila and Pirin Mountains it is 5.8 ha. The relationships between the morphometric parameters of the source area and the size of the rock glaciers suggest that the area of the rock glaciers in the Southern Carpathians is strongly influenced by the width of the source area, with an $R^2 = 0.57$, the size of the source area, with an $R^2 = 0.51$ and only slightly below the height of the source area ($R^2 = 0.34$). In contrast, the area of Bulgarian glaciers is strongly influenced by the size ($R^2 = 0.68$) and the width ($R^2 = 0.63$) of the source area. Although the Retezat Mountains are not the highest in Romania and the Rila and Pirin are situated at a southern latitude, there is a high number of rock glaciers in both areas. Their distribution is highly influenced by topography, lithology and local climatic conditions.

Keywords: Rock glaciers; comparative analysis; Rila & Pirin (Bulgaria); Retezat Mts.; (Romania)

DISTRIBUTION AND TIMING OF LAST GLACIAL PATTERNED GROUND IN THE CZECH REPUBLIC

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Harsh climate conditions prevailed in unglaciated areas of Central Europe throughout most of the last glacial period and led to the expansion of areas underlain by permafrost and formation of associated landforms. Periglacial polygonal patterns, such as ice or sand wedges and sorted polygons, are among the most common permafrost-related features that have survived in both lowland and upland regions up to the present time and may provide a valuable record of climate and permafrost evolution in the past. The evidence from the Czech Republic has, however, been very scattered before now. Here, we describe the distribution patterns and provide first dating of polygonal patterned ground in the Czech Republic. In the Czech Republic, ice-wedge pseudomorphs and sand-wedge casts concentrate into the lowlands of the Bohemian Cretaceous Basin, Moravian Basins, and South Bohemian Basins up to altitudes of 400 m asl where their extensive networks frequently occur, while more patchy occurrences of sorted patterned ground prevail in treeless upland planation surfaces of the Krkonoše Mts., Králický Sněžník Mts., and Hrubý Jeseník Mts. between 1250–1550 m asl. The lowland ice- and sand-wedge polygons are usually between 2 and 32 m in width, while the upland sorted patterns range between 1 and 5 m, but both types tend to mostly have five to six sides. OSL and ¹⁰Be exposure dating indicate multiple phases of patterned-ground activity during the last glacial period that roughly coincide in lowlands and uplands. The patterns mostly emerged around the transitions of the marine isotope stages 4/3 and 3/2, and their final activity took place during the Last Permafrost Maximum (25–17 ka). The presented data bring new insights into the Late Pleistocene permafrost extent and its temporal evolution in Central Europe and provide new perspectives on its environmental history. The Czech Science Foundation, project number 17-21612S, supported this research.

Keywords: Periglacial environment; permafrost; palaeo-climatic indicators; Quaternary; Central Europe

THE LATE PLEISTOCENE GLACIAL HISTORY OF THE ALTA BADIA VALLEY (DOLOMITES, ITALY)

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This paper presents new data for the reconstruction of Late Pleistocene glacial fluctuations at high elevations in the Alta Badia valley (Eastern Dolomites). According to literature data, during the Last Glacial Maximum (LGM) the Alta Badia valley was covered by an extensive ice mass whose primary feeding area was possibly located to the north, as witnessed by the finding of exotic clasts within glacial deposits whose provenance was identified from the Pusteria valley. From recent dating of a charcoal sample retrieved from an excavation wall made on a plateau, the Pralongià (ca. 2000 m a.s.l.), in the central part of the investigated area, it was inferred that the plateau was ice-free since at least 16 ka cal BP. Despite the intense post-glacial slope dynamics, glacial landforms are rather well preserved within the investigated area and provide evidence of glaciers' fluctuations. This research enabled the first absolute dating of glacial deposits in the high valleys of the Dolomites providing clues for the chronological interpretation of LGM and Lateglacial deposits that were earlier mapped on the basis of geomorphological evidence. In particular, ³⁶Cl-based Cosmic Ray Exposure (CRE) dating was applied to moraine boulders. The obtained exposure ages are in rather good agreement with geomorphological evidence and ¹⁴C dating and enabled to constrain the minimum age of LGM ice retreat in the area (ca. 18 ka BP) as well as Lateglacial ice advances (ca. 16-11 ka BP). The definition of former glacier physical parameters (e.g. equilibrium line altitudes) occurred during the Late Pleistocene and derived from the reconstruction of former glacier surfaces and volumes will be fundamental for estimating the related past climatic conditions in the region.

Keywords: Dolomites; cosmic ray exposure dating; Italy; glacial evolution

S08. HUMAN IMPACTS ON GEOMORPHIC SYSTEMS

IMPACT OF HUMAN INTERVENTION ON AGGRAVATING FLUVIAL HAZARDS: A CASE STUDY ALONG A PART OF NAGAVALI RIVER IN RAYAGADA DISTRICT, ORISSA

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The Nagavali River along the Rayagada District is presently flowing through a pediment-pediplain geomorphic complex, which is formed by combining several transverse alluvial cones carried down from the western ridge. Earlier the river used to flow along the boundary of the cones and also along the Piedmont slope of the eastern ridge by forming a small waterfall locally known as Hatipahar. In the year 2006, a narrow canal had been dug along the alluvial cone from the main channel to construct a dam for a hydrel power project. On 3rd July, 2006, torrential rainfall occurred at the upper catchment of the river, both in Kalahandi and Rayagada Districts, causing huge discharge and thereby plenty amount of erosion of the softer alluvium across the canal. Because of this flash flood the Nagavali River started to flow through this canal leaving the earlier course abandoned. After that single event that river has shifted about 550 meters westward and tolled about 0.54 km² loss of land. The newly formed course has established itself over the bed rock along the Hatipahar Region and still possessing very active head-ward erosion and valley incision. This change is actively noticed upto 9.84 Km upstream of the river. A same kind of river oscillation is also observed at 17 km upstream of the study area and it seems that the change occurred during the early part of Holocene. Google Earth and SRTM DEM have been used for demarcating location and spatio-temporal changes along the river. Intensive field survey has been carried out in order to prepare a micro level elevation model and to understand stratigraphic -lithological scenario of the area. The aim of the present study is to analyse the role of geology as well as human intervention on aggravating fluvial hazards along the Nagavali River and also to predict the future risk of such a vulnerable river that receives high discharge almost every year.

Keywords: Pediment cone; flash flood; human impact; fluvial hazards

MOVING FROM LAND DEGRADATION ASSESSMENT DATA TO INFORMED DECISION MAKING AT COUNTRY LEVEL: A CASE STUDY FROM SOUTH AFRICA

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Protecting ecosystems against land degradation and the rehabilitation of degraded areas requires spatial assessment data on the state, causes and impacts of land degradation on ecosystem services. Too often these kinds of assessments and the assessment data are under-utilized by decision makers. This leads to poorly informed decisions, not attending to the real priorities for intervention; not addressing the real causes of land degradation and eventually having little to no impact in protecting and rehabilitating both land cover and ecosystem services at a realistic scale. Without interventions that improve the use and application potential of land degradation assessment data at the national and regional level, countries are unlikely to be able to meet the targets set to contribute towards Land Degradation Neutrality by 2030. This paper will explain the development and use of three composite indexes, (a Land Degradation Index, a Conservation Index and a Sustainable Priority Index for agro-ecosystems) to demonstrate the move from merely having assessment data to informed decision making. The work also demonstrates the analysis and presentation of data from the last national land degradation assessment data for South Africa to inform decision making at national and sub-national (provincial) level. Informed decision making revolves mainly around the identification of priority areas for intervention, but also focusses on guiding decision-makers towards the design of suitable and sustainable future responses to address the problems of land degradation at country level. The paper illustrates how such priority areas may be determined and identified using the above indices.

Keywords: Land degradation index; rehabilitation; spatial assessment

THE JESSOUR OF SOUTHEAST TUNISIA: AN EFFECTIVE ANCESTRAL HYDRO- AGRICULTURAL SYSTEM IN AN ARID ENVIRONMENT

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Jessour (plural of Jesr) are ancestral and empirical hydroagricultural systems that shape the landscape of the Dahar plateau in Southeastern Tunisia. Located in valleys filled by aeolian fine sand deposited during the Quaternary, the system consists of small dams (Tabia) that bar wadis and gullies to partially retain rainwater and sediments to create cultivable plots. Despite arid climate conditions (annual rainfall average 200-220 mm), Jessour allow the practice arboriculture, essentially olive trees, beyond its ecological limits. A research is conducted by the University of Lausanne and the University of Tunis. The purpose is to quantify the water balance at the scale of agricultural plots and their moisture input. Two stations measuring climatic parameters and soil moisture sensors were installed in soil sections to a maximum depth of 1.25 m in two sites in Zammour: a gully without Jessour and a gully arranged in Jessour, distant from the first about 130 m. The first sensor is at 20 cm depth and seven at 15 cm intervals. Measurements were recorded from 28 September 2017 to 21 September 2018. Data analysis highlights the role of Jessour in increasing soil Available Water Content (AWC) and moisture storage during summer. During the rainy episode of 10-12 November 2017, the region received 123.3 mm. The Jesr retained the equivalent of 410.3 mm/1.25m of soil moisture while the saturated pore depth in the gully without jessour was 224.6 mm/1.25m. Throughout the summer of 2017, the water content in the soil remained above 55 mm in the Jesr and at zero mm in the gully. These results took into consideration the sedimentological characteristics of the soil by laser granulometry and organic matter analysis of samples collected near each moisture sensor. This allowed both interpreting soil moisture results and analyzing sediment transfer from the impluvium towards the agricultural plots. The Jessour system proves to be very suitable to face climatic changes which touch this fragile region, hinge between the semi-arid Mediterranean region and the Sahara.

Keywords: Southeast Tunisia; aridity; Jessour; hydroagricultural system; moisture storage

THE GEOMORPHOLOGIST AS A GEOMORPHOLOGICAL AGENT

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The geomorphologist is the landform expert. Geomorphology has traditionally focused on identifying, describing, analysing, explaining and predicting landforms. This paper explores the role of the geomorphologist in making landforms. Humans are significantly altering landforms across many parts of the earth. Some of these changes are incidental to other activities, such as mining or dam construction, and are considered to be an “impact” of that activity. However, in other instances, landform change is deliberate, such as “river restoration” or the creation of “desirable” landforms to enhance landscape settings for residential development. In this paper, I argue that it is appropriate and indeed important for the geomorphologist to influence and participate in landform change at all levels, and refer to examples from the practice of applied geomorphology in Australia. At the highest level, geomorphologists should be knowledge leaders about landforms and contribute to shaping society’s understanding and aspirations in this regard. If we remain silent, others with less knowledge of landforms will determine how altered landforms should look and function, with potentially unrealistic expectations and incongruous outcomes. The geomorphologist has a critical role in landform planning, with both reactive and proactive roles. The reactive planning role is exemplified by geomorphological impact assessment, which can provide the opportunity to modify predicted landform changes resulting from proposed developments by applying mitigation measures. The proactive planning role is illustrated by the contribution of the geomorphologist to new urban developments, including the nature and form of water features and other constructed landforms. At a more detailed level, there is a close interface between geomorphology and engineering. For example, the geomorphologist’s understanding of natural analogues from three-dimensional and temporal viewpoints can inform the specification of requirements for constructed features that mimic natural landforms.

Keywords: Applied geomorphology; planning; impact assessment; engineering geomorphology

ANTHROPOGEOMORPHOLOGY OF THE LOWER DELTAIC WEST BENGAL, INDIA

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The 20,954 km² Lower Deltaic West Bengal (LDWB) region of India is one of the most densely populated regions of the world. The tide-dominated Hugli River, a distributary of the Ganga, is the most important fluvial system of the LDWB and flows south through middle of the region into the Bay of Bengal. It receives five tributaries on its western bank and two on its eastern bank. The Hugli is flanked in the west by the coastal rivers of the Medinipur and the macro-tidal channel systems of the Sundarban in the east. The Kolkata metropolis, and two industrial regions—the Haora and Haldia—are developed on the banks of the Hugli, along with the two largest riverine ports of India—Kolkata and Haldia. Presence of ancient towns and ports in the LDWB bear historical evidences of human alterations in landscape. Alongside industrialization and urban growth, the LDWB is traditionally known for farming activities as recurring floods deposit fertile silts. In this work, anthropic modifications of geomorphic system in the LDWB during ancient times are traced from old literature. Human impact and landscape modification are analysed by using drainage and topographical maps, digital elevation models, multi-dated satellite images, tidal data, and information from Census of India. The index of potential anthropic intervention is derived, and a human impact map of the LDWB is prepared, denoting the hazard susceptibility of the Kolkata region and Hugli industrial belt. Potential anthropogeomorphology is particularly high in 9.2% area of the LDWB. Whereas, 85% of the LDWB comes under direct influence of human activities. The types of human interventions on natural landscape are marked and different anthropic landforms are recognised as excavated, planated, and accumulated. Modifications of natural landscape significantly affected the LDWB and made it vulnerable to hazards like quasi-natural floods, waterlogging, and embankment breaching by storm surges.

Keywords: Delta; tide; anthropogeomorphology; anthropic landforms

IMPACT OF HUMAN ACTIVITIES ON THE DYNAMICS OF BRAIDING IN THE LOWER COURSE OF THE BALASAN RIVER, WEST BENGAL, INDIA

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Balasan, an important right bank tributary of Mahananda River, is noteworthy for its dynamic fluvial characteristics, sometimes causing devastating floods, erosion and sedimentation. All these processes are responsible for the formation of braiding patterns at the lower course of the river and abrupt changes in channel gradient where the channel adjusts. This braiding is highly fluctuating in the present study area. The present study is an attempt to find out the influence of human activities on such dynamic character of braiding. The Soil Water Analysis Tool (SWAT) model has been used to estimate the basic geomorphological and hydrological responses, like runoff, soil erosion and so on. Survey of India (SOI) Topographical maps of 1961-71, satellite images of IRS LISS III and Landsat series have been used to demarcate the nature of braiding and its temporal variation in different segments of the lower course of the river. Braiding patterns have been digitized from high resolution world view II images (provided by Google map) and corrected using IRS LISS III dataset. Braiding morphology has been determined on the basis of Braiding and Planform Index of Brice (1964). High intensity rains accelerate landslides and surface runoff in the upper catchment of the Balasan River and supply huge amounts of sediment to the lower course. Considering the fluvio-geomorphological process, the River Balasan is incapable of transporting these bed-loads efficiently under the existing hydrological conditions, especially in its lower reaches. Moreover, uneven sediment mining from the river bed from the debouching point till the confluence of the river with the Mahanada River disrupts the natural flow of river and thereby and is considered to be the most important cause of such dynamicity of the braiding.

Keywords: Dynamics of braiding; human activities; SWAT

THE INFLUENCE OF FORESTRY ON RELIEF TRANSFORMATIONS IN THE WESTERN TATRA MOUNTAINS (POLAND)

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Forestry in mountainous areas can contribute to significant relief transformations, especially through the formation of roads and their intensive use. Forest roads in mountain areas can influence the modeling of the water outflow and contribute to the development of numerous erosive and accumulation landforms. The main aim of the study was to determine the relief transformations caused by forest roads in selected valleys in the Western Tatra Mountains (Poland). In order to determine the extent of relief transformations 24 km of forest roads were studied. 144 distinct road sections were identified using geomorphological mapping on the basis of the number of erosional dissections. Various other information about the road sections was collected as part of the geomorphological mapping, among others the width of the road, the depth of cuttings, surface resistance, the morphological location and the number of outflows within the roads, as well as information about erosive and accumulative landforms. The research showed a significant diversity in the various features of forest roads, especially in relation to the resistance of their geological substrate. Within the roads deep, local erosive cuts developed. This intensive development caused such zones to be excluded from use. The identification of flow cones within the selected roads allowed us to observe the directions of material movement, which is transported locally to the valley bottom. Differences in the functioning of the roads may also be a result of natural conditions in a given area, especially of the location of roads in convergence zones. In order to minimize the negative impact on the natural environment the planning and formation of new forest roads should be preceded by an analysis of natural conditions. This is particularly important in protection areas where the use of roads can contribute to irreversible relief changes.

Keywords: Forest management; forest roads; relief transformations; erosive cuts; western Tatra Mountains

FLUVIAL CHANGES CAUSED BY HYDRAULIC MINING IN CALIFORNIA: AN EXTREME EXAMPLE OF ANTHROPOGENIC SEDIMENTATION

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Hydraulic mining, the use of water under pressure to extract ore, was invented in California in 1853 and practiced with little regard for environmental impacts. Sedimentation of rivers below the mines was so extreme that in 1884 a federal court banned further hydraulic mining in catchments feeding navigable rivers. Over the 31-year period of mining, more than 109 m³ of sediment was produced, which deeply buried river channels downstream. The constraints of this geomorphic event in space and time and the relatively recent age and distinct character of the deposits provide a rare opportunity to study a massive semi-controlled experiment in anthropogenic sedimentation at a catastrophic scale over centennial time. Several classic geomorphic concepts have been derived from study of the sediment produced by hydraulic mining, including sediment waves and sediment budgets. Additional concepts, such as sediment delivery ratios, sediment connectivity, preservation potential, and anthropogenic denudation rates can be quantified by study of the behavior of hydraulic mining sediment. Sediment budgets were developed for a small tributary in the upper Bear River, one of the most intensively mined catchments in the region. Airborne LiDAR one-meter topographic data were used to interpolate digital elevation models (DEMs) of mine pits and valley bottoms for two periods: the peak period of mining (ca. 1884) associated with high alluvial terraces and 2014 when the LiDAR data were acquired. Differencing the DEMs indicates (1) changes in volume in the mine pits that represent sediment production, and (2) changes in volume of valley-bottoms that indicate sedimentation and removal of sediment between periods. The budgets indicate that earlier concepts of sediment waves and delivery ratios should be revised to reflect longer residence times and protracted periods of sediment remobilization in small mountainous catchments than was previously expected.

Keywords: Human impacts; fluvial geomorphology; mining; sedimentation

ANALYSIS OF POPULATION VULNERABILITY TO DEBRIS FLOW AND FLASH FLOODS IN SÃO PAULO – BRAZIL USING THE SPATIAL APPROACH TO VULNERABILITY ASSESSMENT (SAVE) METHOD

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In environments with frequent and dangerous natural processes, critical scenarios have been observed, especially in reducing risk assessment studies; thus, there are adopted methods able to respond in a uniform way, to the analysis of the interaction between vulnerability and hazard. According to this, we evaluated the vulnerability of a population in the interior of São Paulo to the events of debris flows and flash floods. These events deserve to be highlighted because they result in generally more catastrophic risk scenarios, although their occurrence is less frequent when compared to landslides. Thus, the municipalities selected are Itaoca and Apiaí because they were directly affected by these processes in January 2014, besides Ribeira, a neighboring municipality, not reached but included for comparative purposes. All of them are located in Ribeira's Valley, southeast coast of the state of São Paulo. The applied method corresponds to the Spatial Approach to Vulnerability Assessment (SAVE) and was used in two ways; in the first one the three dimensions of analysis were considered: Sensitivity, Lack of Resilience and Exposition; in the second, only the Sensitivity and Lack of Resilience were examined. For this reason, vulnerability indexes were created for each dimension described as follows: 1) Sensitivity: a) Density; b) Female population; c) Infant Population; d) Old population (From 65 years in Brazil) and e) Illiterate population. 2) Lack of Resilience: a) Poverty level; b) Situation of Households and c) Situation of the environment. 3) Exposure: a) Debris flows and flash floods Mapping; b) Absolute Population; c) Temporary Exposition of People. Regarding the results, we highlight the different amplitudes of the final vulnerability, according to the applications I and II respectively. In the first, the values presented 0.69 (minimum) and 0.97 (Maximum), varying approximately 30%. In the second, the values were 0.17 (minimum) and 0.76 (maximum), reaching almost 60% of amplitude. In the latter case, there is a need for better accuracy in vulnerability values, requiring more studies focused on exposure variables analysis.

Keywords: Resilience; spatial method (SAVE); Serra do Mar; flash floods; Ribeira's Valley

RECENT DISTURBANCES IN THE COASTAL STABILITY DUE TO HUMAN INTERVENTIONS ALONG WEST COAST OF INDIA

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Coastal areas are known as cradles of civilization from the beginning of human settlements and the coastal belts in tropics experience high density of population all over the world. Indian coastal region is one of the most populated coastal belts of the world. Kerala coastal region of South West Peninsular India hosts 2931 person per sq. km. Stability of coastal zone helps to prevent the intensity of coastal hazards like extreme waves, coastal flooding and coastal erosion, which is quite noticeable in the northern part of Kerala state, when compared to the southern coastal region. The paleo-shoreline of Kozhikode coast in northern Kerala is identified as 2.5 to 5 km landward from the modern shoreline in the Beypur – Kozhikode sector, 1 to 2 km in the Kozhikode – Elathur Sector and 1 to 2.5 km in the Kappad – Quilandi Sector. This proves that the area is an accreting one. The sediment discharge of Chaliyar, Korapuzha, Kadalundi and Kallayi rivers along with micro morphology leads to the evolution and development of this coastal plain for last few centuries. Paleo channels of this area changed its direction in many places during Holocene – Pleistocene period under the tidal influence. Nearshore bottom features of the area got diversified with parallel and transverse bars, reefs, exposed and buried rocks. The major nearshore features are demarcated as Kadalur Cape, Thoovappara, Elathur Cape, Thikkodi reef, Kadalur reef, Anchorage reef, Coote reef, Calicut reef, Rocky It, Gilham rocks, Rocky points, Black rock and Puthiyangadi bay. As a fast growing urbanised coastal city of the state, the Kozhikkode coast line is subjected to intense human interventions and thereby adversely affect sustainability of the coastline. Construction of two major fishing harbours, vis. Puthiyappa and Quilandi and Beypur breakwater in 1990s re-defined the coastal morphology and nearshore bottom features of the sector. Shoreline towards the south of Puthiyappa harbour and Beypur breakwater is accreted and vast beach was developed while the Quilandi harbour doesn't have much influence on sediment drift. Rocky coast, sand bed, seasonal sand bar and exposed and buried rocks have been properly documented in the paper. Along with those natural features, the artificial landforms and coastal protection measures have been analysed for understanding the disturbances in the coastal stability of the area. One-meter contour of the bathymetry line runs parallel to the coast except in the near shore of the Elathur and Kadalur headlands. Current investigations show that 48 percent of the total coastline can be considered as stable (Quilandi - Elathur and Elathur – Kallayi sectors), while 36 percent is erosion prone (Kallayi – Beypur Sector) and the rest is accreting.

Keywords: Coastal stability; human interventions along coast; coastal population; Kozhikode coast; coastal protection measures

RECASTING GEOMORPHOLOGY AS LANDSCAPE SCIENCE

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The word geomorphology is known neither to the public at large nor to many members of the academy. By contrast, landscape is imbedded in the vernacular, universally recognized even if not universally understood. We argue that awareness of the discipline would likely increase if it were popularly referred to as landscape science. Geomorphology is unambiguously defined as the science of the form of Earth's surface; landscape on the other hand is a contested word linking the morphology of land with the man-made features that contribute to the roughness of Earth's boundary. Given that human activities are an integral part of the way that geomorphic systems function, studies of pristine geomorphic systems have become less and less relevant to society. There are landscapes that are more threatened than others and critical zones in landscapes that must be managed with greater care than others. Understandings of connectivity and disconnectivity, proximity to thresholds and non-linear change have become focal issues in landscape change. Landscapes can be analyzed as providers of resources; regulators of land use and land cover; sources of cultural services; and supporters of soil formation, for example. In addition, there are fossil landscapes and paraglacial landscapes still adjusting to the legacy of the Pleistocene Epoch. A longer Holocene perspective is necessary to interpret the events of the Anthropocene epoch realistically. Three case studies are provided: (1) permafrost landscapes of Canada: societal implications of warming, especially the expansion of the thermokarst zone; (2) coastal landscapes of the UK low-lying soft sedimentary coasts, societal implications of sea level change, and the role of natural coastal protection; and (3) mountain landscapes of Austria: societal implications of snowfall unpredictability, especially the threats to tourism and the winter sports industry. These examples are important for education of society and for the sustainability of landscape.

Keywords: Landscape; permafrost; coasts; mountains; human activity

LITHOLOGICAL AND GEOCHEMICAL FEATURES OF SEDIMENTS AS THE INDICATORS OF HUMAN IMPACT ON ALLUVIA OF LOWLAND MEANDERING RIVERS - A CASE STUDY OF LIWIEC RIVER, EAST POLAND

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The aim of the study conducted in the Liwiec River valley (East Poland) was to recognize of the Holocene alluvia. The river is 143 km long. Its drainage area (2779 km²) is a typical denudated landscape of the elevation from 86 to 217 m a.s.l., local denivelations reach up to 25 m. The fluvial deposits were described on the basis of drillings and exposures at the river banks. A grain size composition, loss on ignition and trace elements content were analysed. Radiocarbon dating of 8 samples determined the age of alluvia. Climate changes were more clearly recorded in the channel pattern than in sediment features. From the beginning of the Holocene period up to the beginning of the Iron Age, the channel deposits associated with the development of the meanders and the lateral deposition were accumulated in valley bottom. Sorting of alluvial sediments was better at that time. Since the Iron Age, the sedimentation type gradually changed, and fine sediments appeared in the point bars. Since the Middle Ages, accumulation of overbank deposits begins in the bottom of the valley, also the channel alluvia contains more fine grains, and sorting is getting worse. The changes of trace elements in alluvial sediments can be correlated with 4 main phases of settlement expansion: the early Iron Age, the Roman Period, the Middle Ages and the beginning of Modern Times.

Keywords: Meandering river; alluvia; human impact; trace elements; Poland

INTERACTIONS BETWEEN HUMAN ACTIVITIES AND GEOMORPHIC PROCESSES IN A MOUNTAIN AND PIEDMONT FARMING CONTEXT, ARGENTINA

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This contribution deals with land degradation of a human-modified landscape under temperate sub-humid conditions, in the Southern Ranges of the Buenos Aires Province, Argentina. The materials involved and the type and spatial pattern of the geomorphic features developed in dirt roads, cultivated and concentrated livestock areas in piedmonts and hillslopes were analyzed on the basis of remote sensing and field work. Impacts on geomorphology in several subareas with different degrees of human intervention were analyzed and compared. As a result, several relationships between direct and indirect human-induced geomorphic processes and features, and zoogeomorphological, hydrological, gravitational and aeolian processes were found. Distal hillslopes with silty-clay cumulic soils are affected by intense animal trampling in natural springs used as drinking troughs. Consequently, deep soil compaction, vegetation reduction and decrease of water infiltration contribute to earth-flow and sheet erosion. In this sense, earth-flows were only found associated to livestock activity. In piedmonts, hydric erosion on human-induced features comprises: a) concentrated overland flows that affect cattle tracks parallel and adjacent to wire fences, and b) gullying developed radially around artificial drinking troughs or parallel to plow lines and machinery traces. Road cut works on aeolian silty sediments favor the development of topples, falls, slides and collapses, caused by burrowing and pipping in animal hollows and galleries. This kind of processes are natural on barrancas, but road construction increases their influence, accelerating piedmont degradation. Aeolian denudation concentrates around artificial drinking troughs, cattle pens and dirty roads, while in natural slopes and piedmonts is irrelevant because of the climatic conditions. The intensification of erosive processes in the area induced to a large extent by human action, suggests an increase in vulnerability to desertification.

Keywords: Human impact; land degradation; mass movements; erosive processes; zoogeomorphology

OLEĐER SETTLEMENT IMPACT ON MORPHOLOGY OF THE RIVER FLOODPLAINS: THE VICINITY OF WARSAW CASE STUDY

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Due to the high groundwater level and frequent flooding, the bottoms of large river valleys in Central Poland remained mostly unchanged by human activity until the mid-18th century. In 1628, the first Olęders' settlement was established in the Vistula River in Warsaw. The main scope of this study was to recognize the influence of the Olęder settlers river engineering works on the floodplain development – morphology and lithology especially. The floodplain change analysis was performed in two selected sites of the Vistula river valley bottom, located near Warsaw – at the Kępa Kępińska and the Kępa Tarchomińska. The morphological changes of the floodplain were identified using historic topographic maps from 1850 to 1960, and DEM analysis. The changes of the floodplain lithology were recognized with use of the core drilling sampling, up to the 1.5 m in depth. The texture of the sediments was described by grain- size composition and loss of ignition (LOI%) analysis. Since the beginning of the 19th century, each of two study sites underwent significant modification, especially in the Vistula river channel width, floodplain morphology, and land cover. In the first phase of the floodplain modification, the Olęders build mainly transverse dikes, ditches, and embankments. In consequence, dikes forced the accumulation of fine sediments (silts and clay) and the aggradation of the floodplain surface, especially during high flood events. It also caused an increase of fertility of the alluvial soils. Since the beginning of the 19th century, the surface level of both analyzed floodplain areas in the Kępa Kępińska and the Kępa Tarchomińska, have been covered with fine sediments of about several centimeters and locally even up to the 50 centimeters. The Olęders' water management techniques allowed harmonized land use and management of the Vistula river valley bottom. Hence, although partially regulated, the river still could function in conditions close to the nature.

Keywords: Olęders; floodplain; Vistula River valley

ENVIRONMENTAL REHABILITATION OF DISMISSED QUARRY AREAS IN THE EMILIA APENNINES (ITALY) WITHIN A COMMUNITY MASTER PLAN

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Quarry activities can cause considerable long-term on-site and off-site impacts on the environment. By considering different types of quarry rehabilitation schemes, implemented in different parts of the world, it is clear that an effective environmental rehabilitation and requalification plan should consider the territorial context from a multidisciplinary perspective and enhance local territorial resources. This contribution focuses on the rehabilitation of recently dismissed quarry areas within the Rio della Rocca valley (Emilia Apennines, Northern Italy), near the tile making district of Sassuolo, considered the largest in the world. Methods and actions are presented, that have led to the implementation of an environmental rehabilitation scheme within a community Master Plan based on a bottom-up approach considering inputs from the local community at different stages of the rehabilitation process, particularly for the identification of opportunities for and restrictions to territorial development. It should be noted that throughout the past 50 years, quarrying activity has deeply modified the pristine landscape of this valley, which however still holds biotic and abiotic features of great naturalistic interest and scientific value. Once the exploitation ceased, the state of abandonment in which quarries were left made the area degraded and rather unsafe. However, former quarries can be considered as elements of the geological and industrial heritage reflecting the productive/industrial history of the region. As an added value, in several cases, quarries host valuable habitats and constitute important ecological niches. The first step of the Master Plan implementation included the identification, evaluation of geomorphosites in the Rio della Rocca valley and their enhancement within geotourist trails, considering also possible geomorphological hazards threatening the safety of visitors.

Keywords: Rio della Rocca; Master Plan; quarry rehabilitation; geotourism

S09. KARST GEOMORPHOLOGY

CAVES IN GRANITE AND GRANITOID ROCKS – THE CASE OF GOBHOLO CAVES IN ESWATINI (SWAZILAND)

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Caves and cave systems are significant landscape features that have played a vital role in human life as they provided shelter and ancestral sites for mankind through history. In the present day, caves are significant educational and tourist attraction sites across the world. They are a source of knowledge from a geomorphological, cultural and heritage perspective. Different types of caves can be differentiated according to the environments in which they have developed, as well as the processes which are responsible for their development. Karst caves are the most common types of caves found in the world. However, there are other types of caves known as pseudo-karst caves, which form in non-soluble rocks such as sandstone or granite, with totally different morphogenetic processes. Extending some 40 metres below ground and with explored lengths of more than 1,500 m), the Gobholo caves in Eswatini are one of the largest granite cave systems documented on Earth. The caves are found in the Gobholo valley, lying about 10 km east of Mbabane, the capital city of Eswatini (formerly Swaziland). The valley is drained by the Gobholo River, which flows through the cave system for more than 1.8 km. While the cave system is used an adventure site for tourists, very little is known about the genesis and dynamics of this granite heritage system. This ongoing research on the cave system seeks to enhance the scientific understanding of the development of the caves in the context of pseudo-karst caves and to enhance the sustainable management of this site of scientific, educational, and cultural importance. An outstanding feature of this granite cave system, compared with other caves reported in the literature, is that it has elements of both solutional-depositional systems, as well as the typical boulder systems in which the fines have been washed out between large, buried scree-slope boulders. This research focusses on the structure and composition of the granitic bedrock, and compares this with the geochemistry of the water of the Gobholo River.

Keywords: Pseudo-karst caves; solutional-depositional systems; scree slope boulders

CLASTIC SEDIMENTARY DEPOSITS IDENTIFICATION INSIDE CAVES IN CENTRAL BRAZIL

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The clastic sediments in caverns are important paleoenvironmental indicators for the geomorphological reconstruction of the landforms in central Brazilian plateau. The local geology of the Correntes River Basin (3904.3 km²) consists of rocks of the Urucuia Group of Cretaceous elderly are found in the highlands that overlay carbonate rocks of the Neoproterozoic Bambuí Group. There are 164 mapped caves in the basin. The objective of the present work is the identification of cavities with clastic sedimentary deposits having potential for paleoenvironmental studies. In the selected caves ($n = 11$), the deposits are characterized based on thickness, texture, color, contacts, speleothems, sedimentary structures and position of the profile before the water current in the cave. Two deposits in Gruna Tarimba (6th largest in Brazil) are considered for chronostratigraphic characterization using Optically Stimulated Luminescence (LOE) technique. Two main types of deposits are observed: filling of meandering galleries with ephemeral flows of local hydrographic basins that converges to sinkholes and alluvial deposits connected to the fluvio-karstic canal from large catchment areas that converges to sinks. Eleven caves were identified in total: five with active water flow and dynamic deposition/erosion processes and six with recessed fluvio-karstic channels and conduits filled with deposits. In general, the thickness of deposits varies from centimeter to the metric scales, sedimentary structures as cross stratification/parallel plane, contraction cracks and ripple marks. These deposits are found predominantly of sandy contributed by sandstone of Urucuia Group. Preliminary results developed at the Gruna Tarimba show that sediments are older than 50,000 years and are deposited in two stages: (i) an older, preferably clayey with centimetric gravels and (ii) younger essentially sandy.

Keywords: Clastic sediments; cave; central Brazil

THE USE OF UAV DERIVED DEM FOR MAPPING DOLINES IN THE ENVIRONMENTAL PROTECTION AREA OF “NASCENTES DO RIO VERMELHO”, GOIÁS, BRAZIL

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Dolines are characteristic landforms of karst environments. They have great morphodynamic importance, concentrating the surface runoff working as points of high dissolution. From an environmental perspective they represent sites of high intrinsic vulnerability, playing a major role in the transmission of hydrological inputs and trophic resources for the underground sectors, along with the epikarst. This study aims to identify the dolines and other surface features through aid of digital elevation models (DEM) and three-dimensional photomosaics in an extensive karst protected area in the Rio Vermelho headwaters region (176.000 ha), northeast of the state of Goiás, Brazil. This project tested the use of DEM constructed from UAV (<1m) photomosaic and DEM from ALOS-PALSAR (12.5 m), for a small testing area (51.5 ha), using analytic approaches to detect dolines through closed contours. It was observed that from 19 small and medium dolines identified in field, UAV highlighted 17, representing 89.5% accuracy. However, the large number of spurious features observed (128) besides two false negatives indicate the need for adjustments and the adoption of morphometric filters to eliminate small-scale artifacts. Otherwise the ALOS-PALSAR highlighted 11 features (57.9%), ignoring small dolines, indicating it is more useful for analyzes in larger areas. In general it was observed that will be needed filtering, visual checks through photointerpretation and field validation to obtain results that correctly represent the local karst features.

Keywords: Doline; DEM; UAV

CONFINED HYPOGENIC CAVES IN THE SOUTHERN LEVANT: PALEOGEOGRAPHIC IMPLICATIONS

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Maze caves and associated hydrogeology are analyzed at the northern Negev - Judean Desert in Israel, to provide insight on fluid migration and porosity development, with relevance to groundwater and petroleum reservoirs at the Arabian Platform flanks. The caves occur specifically in the arid region of the southern Levant, with no equivalent in the moister climate areas further to the north. The karstified bedrock consists of upper Cretaceous epicontinental carbonates. Caves were formed mainly above deep faults, associated with the Syrian Arc fold system. Hypogenic flow is shown to have formed the maze caves particularly under the confinement of thick chalk and marl caprock. Speleogenesis occurred during the Oligocene – early Miocene when the Afro-Arabian dome was rising and erosionally truncated. Calcite deposits depleted in $\delta^{18}\text{O}$ point to a connection between the caves and recharge over far-field Nubian Sandstone outcrops, north of the Precambrian basement outcrops on the eastern side of the Red Sea. At early-middle Miocene, the Dead Sea rift began dissecting the region, forming a deep endorheic depression at the eastern margin of the study area, and disconnecting the far-field groundwater flow. This was followed by declining groundwater levels and associated dewatering of the caves. Fault escarpments and canyon downcutting have dissected the caves, forming the present entrances. The caves are currently mostly dry, with scarce speleothem occurrences. Gypsum crusts with $\delta^{34}\text{S}_{\text{SO}_4}$ values lower than other sulfate deposits, point at bacterial sulfur reduction, hydrogen sulfide and sulfuric acid being involved in the speleogenesis.

Keywords: Maze caves; desert karst; sulfuric acid speleogenesis; confined caves; Oligocene truncation

ENVIRONMENTAL KARST GEOMORPHOLOGY: APPROACHES AND GOALS IN GREECE

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Karst landscapes cover about 45% of the surface of Greece with an interwoven presence of carbonate rocks up to 70% of the underground. Karst processes and morphologies vary considerably both within and between 11 geotectonic zones of complex geological structure of Greece. Deep shafts are common in Epirus in the north, while long, shallow underground stream systems occur in the southern Peloponnese. Large depressions known as poljes provide flat floors and thick soils for agriculture in the west, while rocky landscapes suitable for grazing and quarries extend eastward and throughout many of the Greek islands. Environmental Karst Geomorphology is a science that incorporates karstic surface and sub-surface elements as well as resources, hazardous processes and human impacts. These are critical to man and the environment as they directly affect the quality and quantity of drinking water, the stability of surface structures (roads, buildings), the presence and abundance of certain minerals and petroleum deposits, and the diversity of the ecosystems. It is a practical approach whereby the objective concerns covering and connecting the main natural-human issues, creating the basic geographic model for the exploration of karst regions, resulting in the proper management of the karst environment. In other words, the basic model aims at creating the karstic environmental identity of the karst regions. In this way, the karstic environment is directly related to the human environment. The main objective is the identification, understanding, storage, description and management of the natural karst environment as well as the anthropogenic factors in Greece. The parallel review of the results of the karst identity information will form the basis for proper management, protection and exploitation of the karst environment in Greece in the future.

Keywords: karst, resources, environment, review.

COLLAPSE SINKHOLES ATTRIBUTABLE TO EVAPORITE DISSOLUTION IN KOTIDO CRATER, ARABIA TERRA

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The identification of karst sinkholes on Mars may provide evidence of dissolution processes caused by liquid water and information on paleoclimatic and paleohydrological conditions. This work presents a comprehensive cartographic inventory of 513 closed depressions developed on evaporite-bearing Equatorial Layered Deposits (ELDs) within Kotido crater, Arabia Terra. Detailed mapping, morphometric analyses and spatial distribution relationships reveal a number of features supporting that the depressions correspond to collapse sinkholes related to evaporite dissolution: (1) suitable topographic and lito-structural conditions for the development of a fracture-controlled epigene evaporite karst; (2) presence of open fissures at the foot of the scarped margins; (3) dimensions and frequency-size distributions comparable with those reported on Earth; (4) spatial association with high-permeability zones (i.e., fractures). Some characteristics of the depressions indicate that they have been re-shaped and enlarged by wind erosion: (1) dominant orientation consistent with the prevalent one-directional winds; (2) differing morphological characteristics on the downwind- and upwind-sides; and (3) nested depressions associated with the upwind sector. The relatively fresh appearance of the depressions and the lack of impact craters suggest a poorly constrained Amazonian karstification phase in the region.

Keywords: Sinkholes; evaporite karst; eolian erosion; frequency-size relationships

HOLOCENE CLIMATIC VARIABILITY IN THE EASTERN ADRIATIC RECORDED IN CROATIAN STALAGMITES

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We present results of stable isotope analyses ($\delta^{18}\text{O}$ and $\delta^{13}\text{C}$) of four U-Th-dated stalagmites from the Eastern Adriatic caves. Two stalagmites (SPD-1 and SPD-2) were collected from Strašna peć Cave, situated on Dugi otok Island in the northern part, and other two from Mala špilja and Velika špilja caves, located in Mljet Island in the southern part of the Croatian Adriatic. All caves formed in well-stratified Cretaceous limestones and stalagmites were deposited in isotopic equilibrium. The growth interval of the speleothems based on U-Th dating covers the period from 9.8 ka to 1.5 ka. In order to reconstruct the Holocene climatic conditions in the Eastern Adriatic, the speleothem isotopic record is discussed and compared with other Holocene records. The Holocene in the eastern Adriatic was characterized by numerous isotopic fluctuations that reflect many and sudden environmental changes. These changes coincide well with the other records, thus revealing regional events along the Eastern Adriatic. Despite these fluctuations, there is an increase of isotopic values ($\delta^{18}\text{O}$ and $\delta^{13}\text{C}$) from early to late Holocene, which primarily record drier conditions in the Eastern Adriatic, which were occasionally interrupted by wet stages. Humid conditions are particularly pronounced between 7.3 and 6 ka, as a reflection of increased precipitation and low temperatures. The transition to today's Mediterranean climate (Cs) occurred between 6 ka and 5 ka. Periods of drought occurred around 4.7 at 4.3-4 ka and around 3.5 ka, with relatively wet phases in between. From 3 ka, there is a general trend towards dry conditions. Moreover, the data indicate a distinct drying trend during the Roman Warm Period and later towards the Dark Age Cold Period (DACP) with shorter periods of wetter conditions.

Keywords: Holocene; stalagmite; stable isotopes; Eastern Adriatic; Croatia

ORIGIN OF KARST DEVELOPMENT IN THE BOUKADIR REGION (CHLEF-ALGERIA)

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Around the Mediterranean basin, limestones are prevalent. In northwestern Algeria, in Boukadir these formations since their deposition have been affected by weathering revealing different forms of karstic dissolutions outcropping along the northern foot of the Ouarsenis Mt composed of lithothamnium limestones of the Messinien, which rest upon blue marls (Upper Miocene). To the south, the Chlef Basin is filled by Plio-Quaternary sediments. Boukadir is crossed along its southern edge by the Relizane strike-slip fault. About 1400m north of the Ouarsenis front, a large collapse sinkhole occurred on June 1988. It broke the national road. Despite this event and visible karstic forms, Boukadir has never been classified as a karstic area. In this study, to unravel the origin of this karst, we combine different methods. First, we analyse the geological and structural context, using geological maps, stratigraphic sections and geological cross-sections. The structural data shows that the carbonate platform is affected by faulting. The major left-lateral Relizane Strike-slip Fault that runs parallel to the piedmont offsets vertically the platform. Then, we look at aerial photos, DEM and satellite images, by making an inventory of dissolution forms and mapping of a network of fractures. This inventory reveals the absence of sinkholes. Finally, field work, on samples and petrographic thin section shows that these carbonate are composed of alternating limestone and bioconstructions rich beds. The formation of this calcrete top layer, is a common feature in the Mediterranean area and can be related to Quaternary climate. We also observe a network of large fractures. Petrographic analysis reveal large heterogeneity. Dissolution characteristics documented, cannot explain the size of the 1988 sinkhole. It must be related to the fault network of Relizane Fault. In conclusion, the karst risk is limited to the covered.

Keywords: Algeria, inventory, karst, faulting, sinkhole, weathering

SOIL MAPPING IN APA NASCENTES DO RIO VERMELHO, THROUGH THE ASSOCIATION BETWEEN DIRECT AND INDIRECT TECHNIQUES

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The present study aimed to perform a soil mapping in the Environmental Protection Area (Apa), Rio Vermelho Springs, in order to integrate direct and indirect techniques. The direct techniques involved two collection campaigns, the first one being along the Rio Vermelho basin, in the depths of 0-20cm, 40-60cm, 60-80cm, in 22 points, and in the second, superficial samples (0-20cm) at 94 Apa points, the samples were air dried, disaggregated, and separated into fractions > 2mm, > 1mm and <1mm. From the samples were made spectroradiometry tests, to be compared to Landsat and Aster images, because the soil reflectance is a property derived from the sum of several factors that will show the behavior or spectral signature, the mentioned factors include a heterogeneous combination of components as particle size, soil structure, surface roughness, moisture content, organic matter content, carbonated mineral content, presence of quartz and Fe oxides. GPR profiles were executed as soil depth on slopes, for spreading the model in the whole Apa area, as accurate soil depth information is essential to improve the way we evaluate the quality and management of soil resources. contribute to the sustainable management of agricultural land. The indirect methods of mapping have evolved to the point of generating maps with the same level of detail of the mappings made through direct techniques.

Keywords: Soil; direct and indirect techniques mapping; GPR

GLACIAL AND PERIGLACIAL PROCESSES IN CAVES

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Caves hosting perennial ice deposits (ice caves) have been investigated for more than a century, with the aim of understanding their climate, the mechanisms of ice genesis, accumulation and dynamics, as well as of recovering paleoclimatic information recorded by the various proxies in ice (stable isotopes of oxygen and calcite, pollen, microbial assemblages). Little effort has been directed, however, towards studying the role played by these underground glaciers on the morphology of the caves in which they have formed. We present here an overview of the glacial and periglacial processes in caves hosting perennial ice deposits and of the resulting morphological changes in rock walls and cave sediments. We argue for a dual designation of cave ice deposits, both as speleothems - as a result of their genetic mechanism(s) and glaciers – as a result of their role in shaping underground landscapes. We further propose a classification of cave glaciers and resulting morphologies, both mirroring and contrasting those at the surface.

Keywords: Ice caves; glaciers; speleothems; morphology; moraine

THE ROLE OF ENDOLITHIC AND EPILITHIC BIOCRUSTS ON KARSTIFICATION IN COASTAL ZONE OF CASPIAN SEA

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Karst landforms are one of the dominant facies in Iran where more than 50% of areas covered by carbonated rocks particularly in arid and semi-arid areas. Apart from the role of atmospheric parameters on dissolution and geochemical reactions in karst developments, microbial communities play an important role to create karst features, at least in a micro-scale at the first actions. In this research, the influence of Endolithic biocrusts on development of Karst cracks and dissolution processes was studied along an evaporated soluble formation at the coastal zone of Mazandaran, Caspian Sea. Also, the role of Epilithic communities on creating Karren-Lapies was studied in the studied area. Microscopic analysis and scanning electronic microscope (SEM) were used for recognition of biocrusts and activities. The results indicated that Endolithic species by accelerate rock decomposition, and chemical denudation of rocks developed the dissolution of carbonate rocks, while Epilithic increases the dissolution and bio-weathering processes due to microbial respiration which provides the environment for other biological crusts and develop Lapiez.

Keywords: Karst; epilithic; endolithic; Caspian coastal zone

CHARACTERIZING AND MONITORING A DAMAGING SINKHOLE IN AN URBAN AREA USING NON-INVASIVE TECHNIQUES: HIGH-PRECISION LEVELING AND GPR. MANTLED EVAPORITE KARST OF ZARAGOZA CITY, SPAIN

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Active sinkholes in urban areas may pose severe hazard and risk situations with significant economic and societal implications. These sinkholes require comprehensive site investigations aimed at resolving critical hazard elements such as the limits of the subsidence area, the kinematic behavior (progressive versus catastrophic), and the subsidence rates as well as their spatial-temporal patterns. However, built-up areas commonly impose significant constraints for the application of some techniques, especially intrusive methods. This work illustrates the advantages of combining high-precision leveling and Ground Penetrating Radar (GPR) through the investigation of a large and highly active sinkhole located in Zaragoza city, NE Spain. Several structures were constructed on this previously known sinkhole. These include a multi-storey building with 100 flats and pad foundation that is experiencing rapid subsidence and has led to a lawsuit involving ca. 25 Meuro. The leveling data has provided the basis for defining the area affected by currently active subsidence and for resolving subsidence rates and their spatial variations. Interestingly, this highly accurate technique reveals subtle uplift and bulging at the margins of the sinkhole attributable to some rigidity in the hardened alluvial cover. GPR profiles acquired with shielded antennas (200 MHz and 100 MHz) allow identifying subsurface structural and stratigraphic features developed over geological time periods, providing information on the subsidence mechanisms. Some profiles show subsidence structures (tilted and laterally truncated reflections) located beyond the currently active subsidence area, suggesting changes over time of its limits. The integration of the data obtained with these methods, together with detailed deformation maps, strain measurements in dilation joints and borehole extensometers will provide the technical basis for managing the risk situation.

Keywords: Subsidence monitoring; high-precision leveling; GPR; urban area

DID THE LAST GLACIATION DEEPEN THE VALLEYS IN THE TATRA MTS.? IMPLICATIONS FROM U-TH-DATING OF (EPI)PHREATIC CAVES

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Glaciers are acknowledged as efficient erosive agents producing discernible relief. Considerable geomorphological output was proven via chronological data, which showed abrupt valley incision during the Quaternary. Valley overdeepening was linked with glaciation/deglaciation cycles. In the Carpathians, however, there is a gap in chronological data between the Miocene exhumation and Last Glacial Maximum deglaciation, therefore in incision/ uplift chronology is lacking. Thanks to karst caves and their relation with the base level, we are able to establish a minimum age of the valley bottom. When water-table drops due to valley incision, phreatic cave passages dry out, and speleothem deposition starts. By dating the oldest speleothems in the youngest, dried (epi)phreatic passage, we can obtain a minimum age of the water-table lowering. We studied the highest mountain range in the Carpathian Arc - Tatra Mts. Last glaciation eroded direct evidence for the presumed seven previous glaciations in Tatra Mts. The information hidden in caves allows us to determine the age of the recent relief and hence the estimate the impact of the glaciations on base level lowering. So far, we have studied nine caves in five valleys where extensive karstic drainage occurs, connected with proglacial water. The oldest stalagmite in active epiphreatic cave, which age we were able to determine, is 327 (+15/-14) kyrs old. The obtained results showed that the phreatic passages in the lowest cave level in the Tatra Mts. shifted to the vadose zone not later than 325 ka. This lead us to the conclusion that that two last glaciations did not cause incision in at least in the Bystra valley. Although glacial erosion formed a significant vertical relief (narrow ridges, hanging valley, cirques, bare-rock faces, broad valleys), the valley deepening is rather controlled by local tectonic uplift (crustal or relative). The work is a result of the research projects no. NCN2016/21/B/ST10/01483, funded by the Polish National Science Center.

Keywords: Landscape age; valley incision; cave; Th/U dating; Tatra Mts

GEOMORPHIC UNITS MAPPING OF FLUVIOKARST LANDSCAPES IN CENTRAL BRAZILIAN HIGHLANDS

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The karst terrains of Brazilian central highlands are under growing agricultural impacts. The present work is part of a greater research project aiming at creating knowledge for the management plans for the protection of caves heritage in an environmentally protected area of the River Vermelho (1762,4,3km²), within the Correntes Basin (3904,3km²) situated in central Brazil. The area consists of limestones from the Proterozoic Bambui Group under Cretaceous sandstones from Urucuia Group. A GIS-based relief compartments mapping of the area is done using satellite images (ALOSPALSAR), geological map (SIEG), cave location map (CANIE BRASIL) combined with several field trips. We identified four Geomorphic units. 1-Lowlands (282,9km²): base-level in siltites and carbonates, with an average slope of 5%, 0,32% covered by concavities, and drainage density in 0.21 d/km². 2- karst terrains (994,6km²): developed in carbonates trapped by siltstone lenses, the average slope of 9.5%, 0.23% of concavities, and drainage density is 0.22 d/km². 3-talus (1483km²): with colluvial and alluvial deposits formed by the Urucuia escarpment retreat, the average slope of 7%, 0.10% of concavities, and drainage density is 0.26 d/km². 4- Highlands (1143,7km²): formed over the sandstone of Urucuia Group with an average slope of 3%, 0.12% of concavities, and drainage density is 0.30%. We also identified two abrupt contacts, the first lowland-karst terrain and second a talus-highlands resulted in canyons and escarpments, respectively. We identified two types of caves: as superior, vadose that collect floods from hillslopes (ducts are often filled with paleosediments, with signs of paragenesis), and deep epigenic fluviokarst. The underlying hypothesis is that the sandstone aquifer and nearby siltstone are the sources of water and silty sediments for the caves, respectively. That is the reason we are applying integrated analysis based on hydrology, geochemistry, sedimentology, geochronology and geophysics. The results of the present project will help in designing better future management plans for the area.

Keywords: Fluviokarst; relief compartments

INFERRING THE GEOMORPHOLOGICAL DYNAMICS FROM THE STUDY OF PALEOCHANNELS: A CASE STUDY OF CENTRAL BRAZILIAN CERRADO

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The north-eastern portions of the Brazilian Cerrado are rich in karstic landscapes, geologically composed of Neoproterozoic Pelito-Carbonate rocks of Lagoa do Jacaré formation of the Bambuí group. The paleochannels in the area have resulted from the drowning of surficial drainage networks into the Karstic features (e.g., sinks) that make underground flow systems in the area. These paleochannels protect the sediments from the period prior to collapse. The present research is carried out for reconstruction paleoenvironmental of the karstic landscapes through studying of fluvial sediments trapped in these paleovalleys. To that end, nine paleovalleys were studied in the area of approximately 176,000 ha, using an integrated approach (e.g., geoprocessing techniques, remote sensing, and fieldworks). The characterization and stratigraphies of the selected profiles were presented in the form of cross-sections. In addition, the soil samples were also taken for geochronological analysis by radiocarbon method. The physical and chemical analyses were also applied. The geochronological analysis of paleochannel deposits at an average thickness of 2.35 meters, showed a range of 400 +/- 30, 2220 +/- 30, 1350 +/- 30 and 11270 +/- 30 cal and BP years of sandy and clayey depositions. The sandy packages consist of gravels with rounded and sub-rounded pebbles of the fluvial environment along with plane-parallel laminations, interspersed with dark sandy layers with the presence of organic matter, which were attributed to periods prior to drainage capture. In spite of the considerable thickness and stratigraphic variations observed on the profiles, the estimated ages correspond to recent periods, which show an active fluvio-karstic system in the area having an estimated sedimentation rate of around 0.26 cm per year. The paleoenvironmental reconstruction makes it possible to obtain the necessary knowledge for the management and protection of these areas of enormous scientific, environmental and cultural values.

Keywords: Brazil; karst; paleovalleys; geochronology

S10. QUANTIFYING LAND SURFACE PROCESSES WITH HIGH-RESOLUTION TOPOGRAPHY AND TERRAIN ANALYSIS

INVESTIGATIONS ON SITE RESPONSE STUDIES FOR SEISMIC URBAN RISK

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The seismic response and local seismic effects are interpreted in terms of spectral accelerations, peak ground acceleration (PGA) and site's oscillation periods for city of Bucharest. These parameters are responsible for the seismic hazard generated over the city area by Vrancea intermediate-depth seismic source. A data set consisting of the available seismic recordings is used for the last strong Vrancea earthquakes ($M_w > 6.4$). Also, the geological description and interpretation of data contained in detailed geological maps is employed as the first and most basic information necessary to perform this study. The existence of down-hole data complements the geological information. The necessity of defining a dominant period-value range corresponding to seismic movements for each site is highlighted, by comparing some terrain characteristics induced by strong events (acceleration, response spectra, oscillation period of the superficial soil deposit) and their changes related to the magnitude of the earthquake. Despite the fact that seismic effects may not be characterized entirely by critical values in the range of the nonlinear effects, the particular features in Bucharest geology may induce various amplifications, as a response to strong earthquakes. These data about soil deposits behavior could be used as input data for seismic risk mitigation. This study brings an important contribution, in a very practical way, for safer buildings on sites affected by high seismicity.

Keywords: Superficial soils; seismic effects; strong motion recordings; risk mitigation

MODERN AND CLASSIC SITE ANALYZES FOR MITIGATION SEISMIC RISK IN BUCHAREST

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The paper will focus upon one of the most exposed regions from Europe to seismic hazard – Bucharest Metropolitan area. In the last century, was affected by four strong earthquakes: November 10, 1940, $M_w = 7.5$ (600 victims); March 4, 1977, $M_w = 7.4$ (1500 victims); August 30, 1986, $M_w = 7.1$ and May 30, 1990, $M_w = 6.9$. The seismic source is from Vrancea region, 160km N-E. For analyzing seismic waves arriving to Bucharest region, exhaustive programs for studying the geology and geotechnical characteristics of the city were carried out. Most recently in Bucharest area, advanced InSAR interferometric techniques help locate certain regional or local anomalies exemplified by ground uplifting or subsidence. On city maps were overlapped soils deformations, seismic intensities and accelerations which characterize Bucharest. These draw attention to endangered areas during earthquakes. Persistent Scatterer Interferometry technique gave us the possibility to find out about ground settlements. This is an important factor for integrity of buildings, because settlement could occur on soft soil or other reasons in soil deposits. Classic geotechnical tests, along the years, were done for analyzing the role of the subsoil, beneath the capital for a correct interpretation of the hazard due to strong earthquakes. In the paper will be presented the last results of the 21-st century, NATO SfP Project No.981882, with a lot of practical results: 10 drills in the most critical zones of the city, with hundreds of samples on which were done dynamic tests (resonant column, dynamic triaxial), static ones (CU triaxial, edometric, angle of repose tests, etc.) and 10 downhole measurements for v_p and v_s profiles. The paper will emphasize the importance of the accumulated data for understanding the non-linear dynamic behaviour of the soil under Bucharest and how it will influence the impact of future seismic hazards.

Keywords: Persistent Scatterer Interferometry; geotechnical tests; soil settlement; dynamic soil tests

TESTING HIGH RESOLUTION TOPOGRAPHY FROM AERIAL LIDAR AND SFM PHOTOGRAMMETRY TO DETECT AND MONITOR PIPE COLLAPSES

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Soil piping is a widespread land degradation process that occurs in almost all morphoclimatic zones. Although it leads to the soil loss, it is not considered in any soil erosion model. The data on erosion rates due to piping are limited and there is no information on regional significance of this process. The main problem lies on the detection and monitoring of this subsurface process. Soil piping is mainly studied thorough the surface indicators, i.e., pipe collapses (PCs). However, mapping PCs remains a challenging and time-consuming task. Thus, there is a high need to find a tool to facilitate and enhance the PCs's mapping.

Recently, high resolution topography from different sources such as LiDAR or Structure-from-Motion photogrammetry (SfM) has been increasingly used. This study aims to evaluate the suitability of these data to detect and monitor PCs. The study area is located in the Bieszczady Mts. (SE Poland), where pipes develop in Cambisols. We use DEM produced from the airborne LiDAR data (obtained from the Head Office of Geodesy and Cartography in Poland), and those produced using SfM technique based on images taken by an Unmanned Aerial Vehicle (UAV) (DJI Phantom-4 equipped with a 1' camera). The LiDAR-derived DEM has the resolution of 1 m x 1 m (the point density of 4 points per 1 m²), whereas the UAV-derived products (orthophotos and DEM) have the resolution of 0.014 x 0.014 m and point density of 9240 per 1 m². Several DEM derivatives indicating the places of PCs were produced. The advantages and limitation of both data source are presented. UAV mapping can be conducted frequently at lower cost, which allows rapid monitoring, whereas LiDAR data may be used for regional scale mapping of PCs. The important lessons are drawn for future research, i.a., the concern about the form depth. The study is supported by the National Science Centre, Poland within the first author's project SONATINA 1 (2017/24/C/ST10/00114).

Keywords: Soil piping; Unmanned Aerial Vehicle; SfM; LiDAR; soil erosion

MORPHOMETRY AND EVOLUTION OF BADLANDS IN THE EMILIA APENNINES (NORTHERN ITALY)

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Soil erosion is one of the most significant land degradation process within the Mediterranean regions. Badlands characterize a relatively small part of the Mediterranean area, but their erosion rates can be very high causing hazardous processes and rapid soil depletion.

The present study aims at understanding the morphodynamics of badlands and their evolutionary trend within the pilot area of the Modena Province (Emilia Apennines, Northern Italy) where badlands extensively affect Cenozoic clayey bedrock. The investigation was carried out 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 at analysing their evolution.

Detailed geomorphological field surveys, interpretation of aerial photographs dating back up to 1950s and satellite image analysis were carried out in order to map and characterize the areas affected by badlands. The retrieved information was stored in a database by means of a GIS and provided an inventory of badland features within the whole Modena Province (Emilia Apennines).

Multi-temporal morphometric analysis of badlands was performed with the aim of understanding the role of the different factors (e.g. slope aspect, climate conditions, landuse) that contribute to their development and of outlining their evolution since 1950s in a number of hydrographic basins also in relation to meteoroclimatic trends. The preliminary outputs of the research show a progressive reduction of active badlands and progressive stabilization of gully features. It is likely that landuse changes played a major role in this landscape evolution. Further steps of the research include the evaluation of the erosion rate by analysing multi-temporal 3D photogrammetric DEMs.

Keywords: Soil erosion; badlands, morphometry; Emilia Apennines, Italy

GEOMORPHOLOGICAL INVESTIGATION ON THE SIAH-KUH MASS ROCK CREEP DEFORMATION (ZAGROS MTS., IRAN) THROUGH SPACE-BORNE SYNTHETIC APERTURE RADAR (SAR) INTERFEROMETRY AND QUANTITATIVE GEOMORPHIC ANALYSIS

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The Siah-kuh Deep Seated Gravitational Slope Deformation (DSGSD) affected the SE slope of the homonym anticline in its SE periclinal closure in the Ilam region, only 30 km south of the Seymareh landslide, defined as the largest landslide on Earth surface (Zagros Mts., Iran). The deformation is driven by Mass Rock Creep (MRC) process and covers an area of about 6 km². The evolution of the gravity-driven slope deformation is strictly related to the drainage evolution of Dowairij River, since its erosion produced the stress kinematic release at the base of the slope likely starting the deformation process. Such instability is still active, and it has not been evidenced by the scientific community. The geomorphological study of the area was carried out firstly through the analysis and interpretation of remote data (Google Earth satellite optical images), which led to the first detection of possible gravity-induced landforms, such as bulges and lateral releases within the deformed area of the Siah-kuh fold. To confirm the existence of ground displacement due to landsliding, InSAR techniques and quantitative geomorphic analysis were applied to the area. On one hand, we produced a surface velocity map and displacement time series in the Siah-kuh slope and surrounding areas by processing 147 radar images of the Sentinel-1 (A and B) satellite on ascending orbit from 17 October 2014 to 31 March 2019. The software SARscape (ENVI) was used to process the images and measure the surface displacements. On the other hand, a quantitative morphometric evaluation was also performed through the Tu index, to predict the catchment-scale suspended sediment yield on the deformation area produced by the Dowairij River system. We derived the erosion rate of the drainage network, responsible of the kinematic release of the slope and then, the time at which the MRC process could have started.

Keywords: Mass Rock Creep; SAR Interferometry; Quantitative Geomorphic Analysis; Siah-kuh fold; Iran

THE NATURE AND HYDROLOGY OF LARGE, FLAT WETLANDS IN THE MURRAY- DARLING BASIN, AUSTRALIA

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Australia is known for being large, flat, hot and dry. In the inland, many rivers show downstream decreases in stream power that in some cases leads to the creation of large, semi-terminal inland deltas. In the Murray-Darling Basin these inland deltas are characterised by very low gradient environments with multiple very small channels, broad floodplains and networks of closed depressions. They are significant wetland environments for a range of plants and animals and include multiple Ramsar wetland sites. Very small flows from the main channel or channels cause inundation and very small landscape changes such as altered reedy vegetation density can significantly alter the pattern and extent of wetting. These wetland areas are priority targets for the delivery of environmental water and understanding their complex hydrology is critical for effective water delivery. The Long-Term Intervention Monitoring (LTIM) project was established in 2014 by the Australian Government to monitor the outcomes of environmental watering on ecologically important indicators in the Murray-Darling Basin including several inland deltas. This paper characterises the Warrego River Western Floodplain, Gwydir River Watercourse and Lowbidgee Wetlands and assesses a range of hydrological monitoring tools used to describe their hydrology. Assessment tools include: high resolution DTMs with hydrodynamic models, multi-temporal satellite imagery from various sensors, traditional channel gauges, in-situ depth logger networks and land holder observations. For less vegetated areas high resolution DTMs and hydrodynamic modelling has proven effective for understanding system hydrology. However, where significant and long lasting emergent wetland vegetation has prevented capture of accurate elevation models and can strongly influence overland flow, multi-temporal satellite imagery combined with multiple gauge and depth observations provides the best understanding of inundation extent and duration.

Keywords: Wetland hydrology; floodplain; inundation monitoring

GEOMORPHOLOGY OF ELBE SANDSTONE MOUNTAINS IN LIGHT OF HIGH- RESOLUTION DIGITAL ELEVATION MODEL

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The area of Elbe Sandstone Mountains (Czech: Labské pískovce, German: Elbsandsteingebirge) is located partly in south-eastern Saxony (Germany) and partly in the northern Ústecký Region (Czechia), being cut through by the canyon of Elbe river. It represents a fine example of a distinct, structurally-controlled landscape evolved within the flat- lying Cretaceous sedimentary rocks. The part north of the Elbe canyon is mainly a dissected plateau, with a labyrinth of minor canyons and gorges. The landscape of the southern part is different due to predominance of numerous isolated tabular hills – mesas and buttes. Beside the major landforms there are many minor, yet geomorphologically interesting forms such as caves, overhangs, clefts and boulders. While being a well-known area of touristic interest in the past and present, the Elbsandsteingebirge was surprisingly paid very little attention in the context of geomorphological research, especially its geomorphometric aspect. The first LiDAR-based digital elevation model of the German part (DGM2 of 2x2 metres resolution) was released in late 2000s. Since then, the potential of morphometric analysis of such data have not been fully utilized; the result were few publications which explored the concept of tracing landform evolution through geoheritage interpretation and the gradual decay of mesas using space-for-time substitution. In 2017, a new LiDAR-based elevation dataset DGM1 (1x1 m resolution) became available, thus giving an insight into morphometric features of such details as narrow clefts cutting mesas and plateaus rims and block covers on cliffed escarpments. The poster presents selected aspects of characteristic morphologies of Elbsandsteingebirge such as morphometric variety of mesas, areas of strongest plateau dissection and patterns of structurally-controlled valley systems. Presentation is based on recently available high- resolution LiDAR elevation dataset DGM1 and creates a background of more complex research concerning interaction between morphometric features and geological setting of sandstone landforms.

Keywords: Sandstone geomorphology; LiDAR DEM; geomorphometry; Elbe Sandstone Mountains; mesas

OBJECT-BASED CHARACTERIZATION OF LANDSLIDE PHENOMENA USING UAV PHOTOGRAMMETRY

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Detection and mapping of landslide and rockfall events using remote sensing products has been proved to be an effective approach to provide landslide inventories. However, most of the studies are lacking valuable semantic information about landslide elements and how they react with the surrounding environment; natural and man-made primitives. In addition, post classification object-based approaches have been proved to result in better accuracy compared with the pixel-based. Lately, innovative close-range remote sensing technology such as Unmanned Aerial Vehicle (UAV) photogrammetry and Terrestrial Laser Scanning (TLS) are widely applied in the field of geoscience due to their efficiency in collecting data about terrain morphology rapidly. This research aims to demonstrate the applicability of UAV technology for automated semantic labeling in managing landslide and rockfall hazard in mountainous environments during emergency situations. SfM photogrammetry in addition to high accuracy RTK-GNSS ground control point establishment, is used to provide detailed 3D point clouds describing the surface morphology of the landslide and rockfall elements. The proposed methodology was divided in five main working phases. The first phase includes designing and execution of an optimal UAV flight planning to collect accurate 3D data. During the second phase, the pre-processing and raw data preparation such as point cloud filtering and elimination of ambiguities is taking place, while at the next phase an image segmentation using the 3D point cloud RGB information is created. The main task was focused on identifying the specific landslide elements by using an object-based approach. Based on Object-Based Image Analysis (OBIA), a sequence of image-based processes was applied, including multi-scale object segmentation, spectral, morphometric and contextual information extraction aiming to detect the landslide among other features. The next phase was set up for object classification in meaningful and homogeneous landslide classes (e.g. scarp, depletion zone, accumulation zone) which are spatially connected by introducing contextual information in the ruleset. The proposed methodology presents the effectiveness and efficiency of UAV platforms to acquire accurate photogrammetric datasets from intense relief environments and complex surface topographies by providing a holistic assessment and characterization of the failure site based on semantic classification of the landslide and rockfall objects. Results have demonstrated the capabilities of combining UAV platforms with computer-based methods for rapid and accurate identification of valuable semantic information subjectively and even from inaccessible areas of the landslide and rockfall body.

Keywords: Landslide; OBIA; hazard assessment; UAV photogrammetry; engineering geology

MORPHOLOGICAL ANALYSIS OF KARST FEATURES BASED ON VERY HIGH-DENSITY POINT CLOUDS

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The generation of rock cavities and especially of those created under karstic procedures is a matter of research for the last decades. A high-resolution subsurface morphology could be produced after scanning the entire cave with state-of-the-art equipment based on Light Detection and Range technology. A handheld laser scanner was used for acquiring points with projected coordinate information (X, Y, Z) covering the entire show cave of Koutouki (Athens, Greece), including its hidden passages and dark corners. The point cloud covers the floor, the walls and the roof of the cave, as well as the stalactites, stalagmites and the connected columns that constitute the decoration of the cave. The absolute and exact placement of the point cloud within a geographic reference frame gives us the opportunity for three-dimensional measurements and detailed visualization of the subsurface structures. Using open – source software we managed to make a quantification analysis of the terrain and generate morphological and geometric features of the speleothems. We identified 55 columns by using digital terrain analysis and processed them statistically in order to correlate them in the frame of the cave development. The parameters that were derived are the contours, each column height, the speleothem geometry and volume as well as the volume of the open space cavity. We argue that with the demonstrated methodology it is possible to identify with high accuracy and detail the geomorphological features of a cave, estimate the speleogenesis and monitor the evolution of a karstic system.

Keywords: Koutouki - Peania Cave; GeoSLAM; handheld laser scanner; speleology; 3D representation

UAV PHOTOGRAMMETRY VS. HIGH RESOLUTION LIDAR DATA – THE USEFULNESS FOR THE GEOMORPHIC MAPPING AND INTERPRETATION OF TOR AREAS, WEST SUDETES (SW POLAND)

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Tors are mesoscale bedrock landforms of different and complex genesis rising from the slope and summit surfaces. They may occur as singular prominent landforms or clusters of closely spaced many rock forms spread over several hundred meters. The identification and geomorphic mapping of large clusters of tors can be supported by the analysis of digital terrain model (DTM) generated from high resolution (1 x 1 m) LiDAR data and UAV/SfM photogrammetry. The former approach enables for the analysis of general spatial distribution of tor assemblages and identification of smaller forms (e.g. blocks, rock steps) with dimensions more than 1 m. However, examples show multiple inaccuracies and lacks in point clouds of elevation LiDAR-based data, so that even the sizeable rock forms are missing from the dataset. The second method using digital terrain model derived from UAV photogrammetry and Structure from Motion procedure can recognize in details a rock surface picturing the minor structures less than 0.5 m long. The aim of the study is to compare these two methods in terms of their accuracy, usefulness and limitations for geomorphic mapping and interpretation of areas dominated by bedrock outcrops (tors). This study is based on different cases of tors in the West Sudetes, SW Poland.

Keywords: Unmanned Aerial Vehicle; LiDAR data; tors; Sudetes

USE OF COMMERCIAL DRONE FOR THE PRODUCTION OF HIGH-RESOLUTION DEMS BY USING DIFFERENT ACQUISITION APPROACHES

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The technological evolution of aerial drones and their wide diffusion allowed in a short time to transfer the photogrammetric approaches to these versatile devices replacing often very expensive classical aerial surveys. In this study, we tested the Phantom 3 drone suitability for obtaining different high-resolution digital surface models (DSMs), by using different flight altitude (5, 15 and 30 m), types of camera (Phantom and Olympus VG 120) and acquisition modes (video or photo). We aimed to perform morphometric and volumetric analyses useful for assessing the distribution and extent of surface water erosion along cultivated slopes. The results show that with a flight height of 30 m the acquisition times are similar between the two acquisition modes for a fixed area of 0.54 hectares, while the DSM resolution varies between 2 cm of the Phantom in photo mode and 6 cm of the Olympus in video mode. With a flight altitude of 15 m, the acquisition time varies from 9' to 3'30" between these two modes, while the DSM resolution varies from 1.4 cm to 3 cm. Finally, flying at an altitude of 5 m, the times vary considerably between 18' and 4'30" between the two modes, while the difference of DSM pixel resolution is approximately 1 cm (from 0.9 to 2 cm). Results highlight that the photo mode is recommended for acquisition at high altitude, while it is possible to consider the video mode for lower altitudes due to smaller acquisition times and good resolution of the final DSM. DSMs obtained at altitudes of 5 and 15 m are useful for morphometric analyses and the assessment of rill and gully erosion, while DSMs obtained at 30 meters are preferable for the study of mass movements and water erosion in wide gully areas.

Keywords: Surface mapping; morphometric analysis; low-cost drone; high-resolution DEMs; photogrammetry

MONITORING IMPERCEPTIBLE VERTICAL MOTIONS NEAR THESSALONIKI, GREECE, WITH REMOTE SENSING, GNSS AND VERY HIGH PRECISION LEVELLING METHODS

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Subsidence phenomena have been observed and confirmed for several decades in the broader coastal area of Sindos- Kalohori, located at the west of the city of Thessaloniki, Greece. The area is part of a 2500-year old plain, occupying about 2000 square kilometers that are drained by four rivers, two of which form extensive deltas. The reasons for the occurrence of subsidence lie in both natural and anthropogenic processes, related to the compaction of sediments and over-exploitation of aquifers. The consequences include intrusion of seawater, coastal floods and risk for population and infrastructure. Today, there are areas in the vicinity of Kalohori with elevations down to a few meters below Mean Sea Level (MSL), some of which were flooded in the past and have never been reclaimed. According to previous studies, mainly based on satellite Synthetic Aperture Radar (SAR) Interferometry (InSAR), the rate of subsidence has been gradually decreasing from between 2 and 5 cm per year in the late 20th century to less than 2 cm per year in the beginning of the 21st century. More recently, there have been studies utilizing InSAR or Global Positioning System (GPS) measurements that have yielded contradictory or no results, indicating that the vertical motions, if any, in the study area are currently in the order of a few mm per year. In fact, some scientists argue for uplift instead of subsidence, as a result of rebound phenomena due to the partial recovery of aquifers. In this context, the purpose of this study to resolve the aforementioned ambiguity, by applying a systematic observation scenario of ground-based and satellite methods. To this end, we employ tens of kilometers of very high precision - in the order of a fraction a mm - digital levelling measurements, combined with Global Navigation Satellite Systems (GNSS) during extensive field work, as well as InSAR processing for monitoring the vertical motions on a yearly basis and identifying the short and long-term trends of subsidence or uplift phenomena. In this paper we present the results of the first two years of high and very high precision measurements with GNSS and digital levelling respectively, as well as our strategy for establishing a reliable and periodic monitoring of the area, also taking into account potential seasonal effects, such as changes in the groundwater level.

Keywords: Thessaloniki; subsidence; InSAR; GNSS; levelling

UAVS (UNMANNED AERIAL VEHICLES) FOR LANDSLIDE MONITORING AND EMERGENCY MANAGEMENT

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On January 2019, a landslide occurred in Pomarico (Southern Italy), destroying and damaging several buildings and making an urban street collapse and slide down the slope. UAVs (Unmanned Aerial Vehicles) have been used to map the area, overcoming difficulties which affect traditional techniques, such as large areas or highly risky environments investigation, bad points of observation, and overcoming limits due to field conformation and study area accessibility, which makes the traditional techniques more expensive, time consuming and less accurate. High-resolution aerial images have been collected to create updated maps, making them available for emergency management. Also, a monitoring campaign was set up to assess landslide dynamics. The data processing was based on an entirely open source workflow. Structure from Motion (SfM) was applied to create accurate Digital Surface Models (DSMs) of the landslide surface, to generate detailed orthophotos of the landslide area and to create 3D models of the damaged buildings, making possible measurements such as landslide surface movement tracking and volumetric change detection. The study has demonstrated the cost-effectiveness and time-efficiency of these new technologies, and is part of a project which is developing a new multisensorial remote sensing system to safely evaluate the stability of natural and anthropic landscape elements affected by paroxysmal events, which would represent a useful and safe tool for the ordinary monitoring activities and for the post-event emergency management.

Keywords: Landslides; remote sensing; UAV; structure from motion

INTEGRATING PREDICTING GULLY EROSION BY INTEGRATED APPROACHES: A TEST IN CENTRAL-WESTERN SICILY

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Gully erosion causes land degradation in a wide range of environmental conditions. The development of gullies in agricultural watersheds may induce high soil loss and reduction of water availability, leading to a significant decrease of soil quality and crop yield. In this study, a set of topographic indices was employed to predict the spatial distribution of gullies across cultivated catchments in Sicily, Italy. These indices are given by different combinations of primary topographic attributes, including catchment area, slope angle, plan curvature and convergence index. The latter were derived from 2-m grid digital elevation models. The location of gullies was also predicted by exploiting data mining techniques such as logistic regression (LR) and multivariate adaptive regression splines (MARS). LR and MARS models were prepared by using as predictors the same attributes included in the topographic indices. These models were calibrated and validated by using 100 random samples of grid cells extracted from each catchment. Validation was performed both internally, by using k-fold cross-validation, and externally, by transferring the models trained in one catchment to another catchment. The predictive performance of both topographic indices and data mining techniques was evaluated by preparing receiver operating characteristic (ROC) curves and by calculating the area under the ROC curve (AUROC). Furthermore, optimal cut-off values of gully occurrence probability were identified to discriminate between stable and gully-prone locations. Thus, cut-off dependent performance statistics such as Cohen's kappa index κ , sensitivity and specificity were also calculated to further evaluate the ability of topographic indices and data mining techniques to predict the locations of gullies in the studied catchments. The results show that the two techniques are suitable for producing high performing gully erosion susceptibility maps.

Keywords: Gully erosion; susceptibility maps; BLR; MARS; Sicily

AN INVESTIGATION OF SOIL GEOMORPHOLOGICAL CHARACTER OF AJODHYA HILL AREA AND ITS INFLUENCE ON LAND USE AND LAND COVER

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Attribute of LULC are dependent on soil and geomorphological character of the area. Objectives are to find out different attributes of soil and geomorphology and their interrelationship. Another objective is to find out relationship between character of soil geomorphology and attribute of land use and land cover. SRTM and ALOS data are used to prepare accurate DEM for analysis of morphology and topography of this region. LULC map is prepared from Landsat 8 satellite imagery through remote sensing software. Ajodhya Hill is situated in the Purulia district of the state of West Bengal. Maximum elevation of the hill is about 698 m from the MSL. Ajodhya hill is composed of older Archaean rock. Granite is principal rock type. Ajodhyay hill is associated with five residual hill, with undulating surface, having the maximum slope in the northern side but its southern side is experiencing relatively gentle slope. Foot hill area of Ajodhya hill has gentle slope varying between 0° - 5° with moderately thick soil layer. Much of the hill area is covered by healthy forest. Scattered vegetation, fallow land and agricultural activity are found in the foothill pediment area. Sandy loam is the principal soil texture. Soil pH is neutral in character mostly. Majority of soil samples having salinity level of 32-95 $\mu\text{S}/\text{cm}$. Surface soils are dry in character having about .1-3 percent of soil moisture. Percentage of organic matter in to the soil remains very low. Concentration of nitrate nitrogen is very high, while ammonical nitrogen is about medium to low. Elevation of foothill pediment region is less than 300 meter. This area is very dry and only feeded by the rain fall during monsoon season. Local people stores water by creating artificial reservoir for use of agriculture and household purpose. Sustainable management of resource is very useful for that region.

Keywords: Agriculture; soil; geomorphology; scattered; forest

LANDSLIDE SUSCEPTIBILITY MAPPING FROM LASER DATA IN NITERÓI (RJ) – BRAZIL

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The landslides are the most recurrent natural disasters in tropical environments. Precipitation and topography are essential factors in shallow landslides. Predictive models can help identify areas of risk and allow for the adoption of preventive actions. SHALSTAB model is one of the most used for combining the hydrological and slope stability models to determine the ratio between the daily rainfall and soil transmissivity for the occurrence of the landslide. This research aims to identify the most susceptible areas to the occurrence of shallow landslides in the city of Niterói (RJ), Brazil. The methodology is subdivided into the following steps: (a) elaboration of digital surface model (DSM) and digital terrain model (DTM) from the airborne laser scanner (LIDAR) data; (b) mapping the landslide scars that occurred before 2014, (c) acquisition of the historical data of daily precipitation; (d) SHALSTAB model application; and (e) analysis of the model efficiency. The results show that the landslides simulations using DTM have a better mapping accuracy than the DSM simulations, which presented a higher amount of unstable class in the study area.

Keywords: Digital surface model; digital terrain model; natural disaster; shallow landslides

S11. SEISMIC GEOMORPHOLOGY

SALT TECTONICS AND THIN-SKINNED CONTRACTIONAL DEFORMATION IN THE LEVANT BASIN: INSIGHTS FROM SEISMIC INTERPRETATION AND PHYSICAL EXPERIMENTS

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The apprehension of salt tectonics is the key to a better understanding of the structural evolution of sedimentary basins occupied by a mobile layer. Unlike most salt basins that have experienced long-lasting deformation, the Messinian evaporites in the Levant Basin have been moderately deformed, giving the opportunity of studying the initial stage of salt tectonics. Despite the availability of 2-D and 3-D seismic reflection data, some uncertainties still exist about the mechanisms responsible for the deformation and structural features observed in the deep-water Levant Basin. Our study combines the interpretation of 2-D and 3-D seismic datasets offshore central Israel together with the conduction of physical analogue experiments. We designed our experiments based on our systematic seismic analysis and interpretation and on the existing literature. We conducted a series of physical experiments taking into consideration the driving parameters that affected our sedimentary basin, testing the influence of gravity gliding and spreading from the Levant margin, gravity spreading from the Nile Deep-Sea Fan, and the influence of the passive buttress of the Eratosthenes Seamount. Deformation was imposed by depositing successive sand lobes and/or by tilting the deformation table. The regional driving forces are the onshore uplift, the sediments derived from the Nile Cone and the Levant margin, and the buttressing effect of Eratosthenes Seamount. All models included a thick viscous layer, analogue of the Messinian evaporitic sequence, overlain by several successive sand layers or one PVC layer, simulating the brittle clastic post-Messinian succession. Results showed that the prominent driving force is the gravity spreading from the Nile cone, whereas gravity spreading and gliding from the Levant and Egyptian margins have a limited effect on the deformation pattern of the deep water basin. Additionally, the buttressing effect of the Eratosthenes Seamount and the location of the salt pinch-out in the basin played an important role in the final deformation pattern.

Keywords: Salt tectonic; gravity spreading; contractional deformation; Messinian; physical experiments

ORIGIN OF WAVE-LIKE SEDIMENTARY STRUCTURES IN THE NORTHERN DEAD SEA, ISRAEL - TURBIDITY CURRENTS OR EARTHQUAKE TRIGGERED SEDIMENT FAILURE?

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Preliminary analysis of recently acquired bathymetric and seismic reflection data from the slope of the Northern Dead Sea reveals what appears to be sediment waves in an area confined from -660 to -720 bmsl. A previous study suggested these features are slump deposits arising from sediment failure triggered by a large historic-earthquake that occurred in the Dead Sea. However, the new dataset portrays unprecedented evidence of wave-like features characterised by similar geometry and internal architecture as classical sediment waves described in lacustrine and marine environments. On the bathymetry data, these sediment waves are nearly parallel and display a linear to sinuous trend and approximately oriented W-E. Seismic stratigraphy of the uppermost lake infill, show that these deposits are characterised by undulating sub-parallel seismic reflectors migrating upslope. Age constraints from distal sediment cores indicate that these depositional features began to develop in the mid-Holocene. The location of the sediment waves along the northern slope of the lake supports an origin related to changes in water inflow from the Jordan River.

Keywords: Sediment waves; bathymetry; seismic reflection; Jordan river; Dead Sea

SEAFLOOR STRUCTURE OF ARGOSTOLI BAY

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In order to investigate the formation processes of the seafloor of Argostoli bay (Cephalonia Island, Ionian Sea), an extended geological survey was conducted to gather details about the near-surface geological framework. Methods used for the survey include high resolution subbottom seismic profiles (29.4 line kilometers; EdgetechCHIRP system at frequencies 2- 16 kHz) side-scan sonar backscatter surveys of the seafloor (approximately 67 line-km, Starfish 450F), single-beam bathymetry (approx. 67 line-km, Lowrance LCX-15MT Sonar system), and bottom sampling including bottom sediment grab samples (van veen grab sampler) and short sediment cores. The survey was focused at both ends of Argostoli Bay (i.e., Argostoli and Livadi inlets). Preliminary analysis of the sub-bottom profiles in the upper 12-20 m reveals a clear pattern of sediment layers, in both ends of the bay. The uppermost layers been deposited horizontally with small differences in their orientation in the area of Argostoli inlet, while the presence of gas is more pronounced in Livadi inlet. Moreover, in Argostoli inlet a palaeo-surface is visible (probably the base of Holocene sedimentary cover) with minor channel features, likely indicating a shallow river valley. Side- scan mapping in combination with sediment samples and cores showed that the surface sediment consists mostly of fine-grained material, rich in organic matter over a gravel-lag deposit that may represent the transgressive surface in the area.

Keywords: Seabed sedimentology; acoustic topography; subaqueous morphology

S12. SUBMARINE GEOMORPHOLOGY

SPATIAL QUANTITATIVE MAPPING OF POLYMETALLIC NODULES BASED ON AUV DATA AND MACHINE LEARNING

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The fine-scale quantitative predictive mapping of polymetallic nodules (PMNs) has increased value for a wide range of scientific fields such as marine geology, geochemistry, and ecology. It is also of interest to the deep-sea mining industry due to increasing global demand in metals (Ni, Co, Cu). In this study, high-resolution multibeam bathymetric and optical image data were obtained within the Clarion-Clipperton Zone (Eastern Central Pacific Ocean), both, with the use of the Autonomous Underwater Vehicle (AUV) Abyss. The analysis of the AUV acoustic data and the calculation of bathymetric derivatives such as slope, curvature, and ruggedness, revealed an uneven microrelief, in which PMNs have a heterogeneous and spatially clustered pattern. Optical AUV imagery, analyzed by the CoMoNoD algorithm provided quantitative information regarding the distribution (number and size) of PMNs. The information derived from the acoustic and optical data was combined with the Random Forest machine learning algorithm, achieving high accuracy at low computational cost. Comprehensive statistical analysis of the results - including ground truth nodule measurements (number and size) from box coring – validated the method. It provides a useful, semi-automated spatial mapping of the PMNs' distribution at regional scale.

Keywords: Polymetallic nodules; AUV; random forest

ELLIPTICITY OF MEGA-POCKMARKS IN THE PATAGONIAN CONTINENTAL MARGIN: AN INTERPLAY BETWEEN TECTONIC STRUCTURE AND OCEAN CURRENTS

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Analysis of high-resolution multi-beam bathymetry and seismic data revealed the presence of widespread fluid escape features in the middle slope of the Patagonian Continental Margin (Western South-Atlantic). On the sea-bottom these features correspond to elliptical mega-pockmarks, while in the sub-surface are represented in the seismic records by several gas related acoustic anomalies. The objective of this work is to discuss the controls on the distribution and ellipticity of the mega-pockmarks in relation to the geological structures and bottom currents circulation. Most of the mega-pockmarks are located above a re-activated and inversed Mesozoic graben controlled by NW-SE and NE-SW striking faults. The morphometrical analysis of pockmarks revealed two preferential directions of elongation which are coincident with the strike of the graben's faults, suggesting that faults and fractures might have acted as pathways for upwards migration of fluids. We also infer that these faults and fractures control the asymmetry of pockmarks. A swarm of fractures would provide a weaker rheological behavior in preferential directions on which the erosive agents, such as ocean currents, will elongate the pockmarks. Regarding pockmarks distribution, we observed that even though acoustic evidence of fluid flow occurs in all the study area, the incidence of pockmarks is constrained just to depths shallower than 1200 m. We hypothesize that the rheological behavior of the superficial deposits in deeper areas where Eocene rocks outcrops or subcrops did not allow the genesis of pockmarks. We conclude that the distribution of pockmarks in the study area was likely controlled by the presence of a source for fluid/gas and soft sediments on the seafloor, while their asymmetry is consequence of the enhanced erosion of bottom currents on weak directions associated with faults and fractures.

Keywords: Mega-pockmarks; Western South-Atlantic; structural control; ocean currents

GEOLOGICAL AND GEOPHYSICAL INVESTIGATIONS OF THE MAIN MORPHOSEDIMENTARY FEATURES OF THE PATAGONIAN CONTINENTAL MARGIN: NEW DATA ACQUIRED ON BOARD OF THE AUSTRAL R/V

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The Patagonian Continental Margin (PCM) corresponds to the portion of the Argentine continental margin located southwards the outlet of the Río Colorado and its continuation along the Colorado Fracture Zone; it includes the northern Scotia Ridge, and the shelf and continental slope adjacent to continental Patagonia, Tierra del Fuego, and Malvinas Islands. Just a small part of this huge territory has been surveyed with high resolution multi-beam bathymetry, and most of its morphology remains unknown. In the years 2017 and 2018 three cruises were performed on board of the R/V Austral - framed on collaboration between PAMPA AZUL, CONICET, Y-TEC and YPF - where three key areas of the PCM were surveyed: Tierra del Fuego, Malvinas shelf, and the slope adjacent to continental Patagonia. During these cruises, hydro-acoustic data was acquired with the hull-mounded systems: multi-beam echo-sounders Kongsberg EM 122 and EM Kongsberg 2040, and parametric sub-bottom profiler PARASOUND P70. Along with the hydro-acoustic data, 33 sediment cores were obtained in water depths spanning from 130 m to 3480 m. This new set of data revealed the geomorphology of the surveyed areas with unprecedented detail, and a plethora of seafloor features -such as sub-marine canyons, ploughmarks and pockmarks- were imaged for the first time. This contribution aims to introduce the main discoveries of these cruises as well as to discuss the influence that the different processes had in shaping each of the areas. The morphometrical study of the bathymetric data, along with the shallow seismic structure and the sedimentological analysis of the cores provides evidence of a dynamic interplay between gravitational and contouritic processes.

Keywords: Patagonian Continental Margin; high-resolution seabed mapping; high-resolution acoustic profiling; contourites; sub-marine canyons

THE RETROGRESSIVE DYNAMIC OF SUBMARINE LANDSLIDES OFF THE ISRAELI SHORES ANALYZED USING HIGH RESOLUTION SEISMIC

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Retrogressive slope failure defines as a successive landsliding event, in which the first landslide triggers a series of upslope migrating secondary landslides. Though this type of landsliding is abundant, a comprehensive understanding of the controls on its spatial and temporal nature is still missing. A better understanding of its mechanism has significant implications on understanding of mass wasting processes and on submarine landslide hazards assessment. Here we study, using high resolution 2D-seismic and multibeam data, the surficial geometry and subsurface structure of a retrogressive landslide complex in eastern Mediterranean. Head-scar and toe of the studied landslide are located at 300 m.b.s.l and 500 m.b.s.l, respectively, where its area is 3 sq-km. Bathymetry reveals a succession of at least three generations of slope failure events, where the secondary events are triggered in the steep scars of the primary ones. In the subsurface the landslide-complex is ca. 70m thick and consists of two major events, identified by the disturbed seismic stratigraphy of the failed slope-material lobes and the discontinuous nature of the failure plane forming the scar. The failure plane of the later event truncates the scar of the earlier one in spatial-accordance to the bathymetric observations. A sequence of 3 minor failure events is observed within the scar of the earlier major event. Failure-events are separated by thick (>10m) sequence of continuous seismic-stratigraphy, interpreted as hemipelagic sedimentation at stable-slope conditions. The last slope failure event is overlaying by >10m of continuous sedimentation. The above observations suggest that the sequence of slope failure events comprising the studied retrogressive landslide are separated in time, apparently up to a few thousand years using the known sedimentation rates for the area. In addition, the last major failure event is not recent. These novel-findings are crucial for geo-hazard assessment of the studied area.

Keywords: Retrogressive landslide; submarine; mass wasting; marine geo-hazard; Levant

DETAILED BATHYMETRY AROUND METHANA PENINSULA, SARONIC GULF

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The new highly detailed bathymetric map (5m cell size) around Methana peninsula, Saronic Gulf, revealed the complexity of the submarine morphology. The Epidavros basin has maximum depth of 420m, while the flat bottom area lying eastwards of Methana is comparatively shallower, reaching a maximum depth of 280m. Our new results show that the Paphsanias volcanic field, representing the northwestern edge of the volcanic arc, consists of 6 volcanic edifices, that their base level ranges from 300m up to 170m water depth. The cones can be divided into two groups based on their morphology. The round pointy edifices are located close to the shore, whereas the elongated-eroded ones to greater water depth. The latter, based on the ROV imagery, consist of lava flows with angular rocks, large debris fields and dispersed large boulders embedded into fine sediment. Between Methana peninsula and Agkistri Island a hummocky area extends with scattered and aligned blocks clustered into three main groups. The linear hummocky area trends NW-SE and is presumably attributed to intrusive volcanism. The western slope of the Epidavros Basin is carved by three major landslides. The most prominent is a complex landslide forming a 5 km along-slope and 3.5 km across-slope indentation in the margin. The main headwall scarp lies at 120 m water depth, while the secondary headwall is situated at 240m water depth. Narrow erosional gullies, confined to the main headwall area, dissect the shelf and open up a flat-bottom basin. Several fault scarps cut the seafloor around Methana peninsula trending mainly NW-SE, E-W, SW-NE. The most distinctive feature is the one extending along the southern margin of Agkistri. This scarp is approximately 100 m high, forming an almost vertical steep cliff.

Keywords: Submarine morphology; volcanic edifice; landslides

SUBMARINE CANYONS ALONG THE SOUTHWESTERN CRETE

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The detailed bathymetry along the Southwestern Crete revealed a rather complex morphology. One of the most dominant geomorphological structures is the submarine Samaria Canyon (Western Cretan Trough) which is characterised by high relief steep walls and V-shaped cross sections. Although, the trough trends predominantly northeastward, with a central axis oriented from east to west, the head displays a north-trending hook termination on the continental shelf. Moreover the canyon shows a convex-up longitudinal profile, suggesting substantial uplift. The depth of thalweg ranges from 1500 to 3500m. Numerous gullies, N-S oriented, dissect the continental slope and then bend to join the main axis. Three main canyon types have been recognized: a) Type 1, shelf-incising canyon heads with a clear bathymetric connection to a major river system. b) Type 2, shelf-incising canyon with no clear connection to a major river system and c) Type 3, blind canyons incised into the continental slope. Type 1 is related to downward processes constituting mostly erosional features, while Type 2 is related to retrogressive erosion and mass failure processes. On the other hand, within Gavdos Rise two intraslope basins can be distinguished at the southwestern part, at depths 1100 and 2000 m respectively. The gentler slopes of the Rise are relatively channel-free with lower morphological values. The overall canyon system is considered tectonically controlled reflecting the offshore active tectonics and faulting of the seafloor and the overall deformation since Middle Miocene.

Keywords: Crete; submarine morphology; canyons

A GIS-BASED METHODOLOGY FOR THE DEFINITION OF SEAFLOOR BIOLOGICAL ZONES: THE MEDITERRANEAN AND BLACK SEAS EXAMPLE

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Sea bottom geomorphology is widely considered a research field of interdisciplinary interest, since understanding the general structure of the ocean terrain can promote knowledge in several scientific fields (e.g. Geology, Biology, Physics etc). Hence, identifying submarine landforms is of significant importance, as morphology, principal amongst other factors, affects considerably the distribution of benthic species on the sea bottom. In this paper we present a new methodology for the quantitative definition of the boundaries between the three major biological zones (circalittoral, bathyal and abyssal) of the Mediterranean and the Black Seas, realised for the purposes of the EMODnet Seabed Habitats Lot. Two different GIS models have been developed in a ESRI platform environment in order to facilitate an automated delineation of the circalittoral-bathyal and bathyal-abyssal zones. For each model the latest 2018 DTM data products provided by the EMODnet Bathymetry Lot have been used as initial inputs. In addition, slope and depth thresholds from the existing literature along with expert judgment have been used as model parameters. According to the output of the models, in the Black Sea the three zones are well defined while transition between them is smooth. On the contrary, the Mediterranean Sea displays a complicate pattern. Abyssal plains are large in the West Mediterranean, but small and sparse in the East. The greater part of the Mediterranean Sea belongs to the bathyal zone, including steep to moderate slopes, flat areas at depths shallower than 3000 m, ridges and seamounts. In addition, the width of the circalittoral zone varies considerably when sweeping even between adjacent areas of the same region. These rapid changes in the morphology of the seafloor trigger further discussion regarding the underlying relief forming processes, especially if considered under the prism of long-term and recent tectonic activity.

Keywords: Seafloor morphology; biological zones; GIS analysis; Mediterranean Sea; Black Sea

VERTICAL VOLCANO-TECTONIC DEFORMATION RECONSTRUCTION BASED ON GEOMORPHOLOGICAL SEA-LEVEL MARKERS: A CASE STUDY OF THE CAMPI FLEGREI OFFSHORE CALDERA

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Seismo-stratigraphic analysis of very high-resolution seismic reflection profiles provides insights into the last ~12 ky vertical deformation pattern in the submerged part of the Campi Flegrei resurgent caldera, in the Pozzuoli Bay (Southern Italy). The collapse of the central part of the Campi Flegrei is associated with the eruption of the Neapolitan Yellow Tuff (NYT) at ~15 ky BP and was followed by discrete phases of intra-caldera volcanic activity associated to central dome resurgence and ensuing subsidence. A detailed study of the depositional architecture of the basin infill highlights a close link to both the post-LGM sea level rise and the post-caldera resurgent dome system. The analysis has revealed the occurrence during the last ~12 ky of several generations of Infralittoral Prograding Wedges (IPWs), whose stratal pattern provides evidence of alternating phases of seafloor uplift and subsidence. The inflection point of these wedges represents a marker of the position of the wave-base level and is useful to reconstruct the vertical volcano-tectonic displacements. Correction of the observed depth of each IPW for the paleo-bathymetric estimate and for the sea-level change allowed us to reconstruct differential RSL (Relative Sea-Level) curves. Periods of relative sea-level and accommodation space stability that allowed the onset of IPWs were attained when uplift occurred at a rate comparable to the rate of sea-level rise. Based on our seismostratigraphic calibration, we found significant seafloor uplift between ~12-9 ky and ~5.5-3.9 ky. These periods broadly correspond to known phases of volcanic activity and unrests, suggesting that not only volcanism but also ground deformation were clustered. In contrast, an aggradational fill pattern prevails between periods of uplift, and allow to document two major subsidence phases between ~9 and ~5.5 ky and after ~3.9 ky. These subsidence periods are temporally correlated to intervals of volcanic quiescence or minor activity.

Keywords: Campi Flegrei; caldera resurgence; sea-level markers; volcano-tectonics; seismo-stratigraphy

TESTING SUBMARINE APPLICATION OF PLANETARY GEOLOGIC MAPPING METHODOLOGIES: INTERSECTING REFLECTION SEISMIC PROFILES WITH GEOMORPHOLOGIC MAPPING OF THE SEAFLOOR IN THE SANTORINI VOLCANIC GROUP

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The most volcanically active region within the Hellenic Volcanic Arc of the Aegean Sea is the Santorini Volcanic Group (SVG) composed of the southwest-northeast trending series of volcanic centers Christiana, Santorini, and Kolumbo. The SVG is geologically diverse and has present day seismic, mass-wasting, volcanic, and hydrothermal activities that are concentrated on the seafloor. In order to properly analyze risks associated with the SVG, assessments must include both subaerial and submarine evaluations, which specifically requires the collection and analysis of high-resolution swath data. We have compiled a preliminary onshore-offshore 1:100,000-scale geomorphologic map of the SVG group using methods developed by the Planetary Geologic Map Coordination Group at the United States Geological Survey (USGS) Astrogeology Science Center. Planetary geologic mapping uses elevation, surface morphology, and previous scientific investigations to geomorphologically map a study area. We generated a synthetic hillshade from a 20 m/pixel resolution digital elevation model (DEM) to be used as the base map, with a supplemental EMODnet 107 m/pixel resolution DEM for areas outside the high-resolution DEM footprint. We mapped 9 linear features and 16 geomorphologic units. In order to test this methodology, we are incorporating published reflection seismic profiles of the seafloor surrounding SVG. We are generating bathymetric profiles matching published and interpreted reflection seismic profiles and comparing the geology outcropping at the seafloor with the mapped submarine geomorphology. We expect the geology from seismic campaigns to validate the geomorphologic mapping and allow for extrapolation of the subsurface geology across the seafloor. The ability to geomorphologically map the seafloor accurately would strengthen investigations of both study areas that do not have extensive seismic studies or drill cores and study areas that have no data, as well as reducing costs of research campaigns by requiring less seismic lines and drill cores to be collected to understand the seafloor.

Keywords: Santorini volcano; planetary geological mapping

ADVANCED MAPPING OF KOLUMBO SUBMARINE VOLCANO (SANTORINI) USING AUV “ABYSS”

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Kolumbo submarine volcano has a 3 km diameter cone with a 1700 m wide crater, a rim as shallow as 18 m below sea level, a flat crater floor 505 m below sea level and lies just off the northeast coast of Santorini. It is currently the most active and dangerous submarine volcano in the Mediterranean Sea and its crater floor hosts a high-temperature hydrothermal field with active massive sulphide deposition of potential economic significance. The AD 1650 eruption killed 70 people and thousands of animals on Santorini due to toxic gas release and tsunami inundation. For the first time, high resolution AUV data were collected in 7 missions of “Abyss” (GEOMAR), under the framework of the project “ANYDROS: Rifting and Hydrothermal Activity in the Cyclades Back-arc Basin”. The goal of this project was to understand the initiation of arc rifting and associated back-arc hydrothermal activity. The focus was on the CSK rift system and Santorini-Kolumbo volcanic line, one of the few places in today’s oceans where submarine rifting of a continental margin arc can be studied in its earliest stages. We present a new bathymetric map of Kolumbo volcano based on AUV bathymetry with 2m resolution which helps to map: a) the abrupt inner slopes of Kolumbo caldera, b) the active vent field at the northern part of the crater floor (485m depth), c) the lava dykes in the inner slopes, d) the mass wasting deposits in the inner slopes, e) the curvilinear scarps with inward dipping faces at the W-NW base of Kolumbo’s flanks (faults and/or remnant crater rims). Using developed AUVs with capabilities to map the seafloor with higher resolution than is possible with hull-mounted or towed sonar systems so as to identify seafloor geomorphological characteristics and produce detailed morphotectonic and hazard maps of active volcanic areas.

Keywords: AUV mapping; Kolumbo volcano; offshore geohazards

MORPHOSEDIMENTARY ANALYSIS OF THE SLOGGETT SUBMARINE CANYON AND ITS REGIONAL IMPLICATIONS. NW SCOTIA SEA

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The south Argentine Continental Margin (ACM) is incised by deep and large canyons that belong to the canyon's system of Tierra del Fuego. The Sloggett Canyon, located in northwestern Scotia Sea, is the longest with a total length of 142 km along the thalweg, cutting the continental platform, slope and abyssal plain. In this work we present a morphosedimentary and structural analysis of the canyon revealed from recently data obtained on board the R/V Austral in the YTEC-GTGM0 cruise in September 2017. It consists in the first complete very-high resolution imaging (up to 20 meters) of the canyon from its upper part down to its distalmost reach. Swath bathymetry with the echosounder EM-122 and sub-bottom profiler with Parasound P70 were used for distinguish morphologies made by processes of erosion, transport and deposition. The head is affected by tributaries channels that range in size, direction and depth and act as a conduit for gravity flows and turbidity currents. They have a wide expression in the east flank regarding the western flank where predominate wall slumping, gullies and scar. The canyon was studied considering three parts of the thalweg, where the direction changes abruptly two times from NW-SE to SW-NE in an angle of approximately 90 degrees. This was associated with the NW-SE lineaments of the West Scotia Ridge, where could be acted as a path for the canyon and the Beagle Channel Fault System that has a W-E direction affecting the slope. Additionally, along- processes related to the strong oceanic currents form contourites drifts and erode the margin to form contourites terraces along canyon depth. The canyon has a connection with the Sloggett Bay (10 km north) and can be considered as a continuation of the Sloggett Continental Tectonic Lineament.

Keywords: Canyon; geomorphology; multibeam bathymetry; sub-bottom profiler; Scotia sea

SURFACE AND SUB-SURFACE FEATURES OF AN ACTIVE GAS SEEP IN MALVINAS BASIN (SW ATLANTIC OCEAN)

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Methane gas seeps are widely distributed, however, only a small fraction of the seeps from the seabed have been discovered as indicated by the fact that new findings are reported every year. Gas seep studies in the deep sea of Argentina are scarce, and do not characterize geological and biological features. This work is part of a multidisciplinary study intended to establish the trophic contribution of methane seepages in the Malvinas Basin. To that end, we analyzed a superficial and sub-superficial analysis of 2D multi-channel seismic data provided by the Argentine Secretary of Energy and selected an area characterized by chimneys and pockmarks to target in an exhaustive survey onboard the Austral oceanographic vessel. This survey was carried out using multibeam (EM122) and single beam echo sounders (EK80) to obtain detailed bathymetric data, as well as a sub-bottom profiler to obtain ultra-high resolution seismic data from the shallow sediment column. The results identified a pockmark-like field. From these, a pockmark with active gas seepage (evidenced by gas plumes in the water column) was selected for seafloor sampling. This pockmark has an elliptical shape and is located at 450 m water depth. Its diameter is 400 m and its depth varies between 2 and 6 m with a slope of 3°. Acoustic turbidity in contact with the surface of the seabed of the pockmark indicates that the seeping gas is mainly methane. This gas would come from a deep source, since it was observed associated with a chimney having an enhanced reflector in the multi-channel 2D records. These results allow, with a high margin of certainty, the sampling of the benthic communities associated with gas seepage.

Keywords: Methane seep; pockmarks; multibeam bathymetry; multi-channel seismic; sub-bottom profiler

SEISMIC IMAGING OF SLOPE INSTABILITY ON THE NORTH-EASTERN IONIAN MARGIN (MEDITERRANEAN SEA)

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Our work focused on the characterization of the Plio-Quaternary sequence along 22 seismic lines collected offshore of Cape of Santa Maria di Leuca (south eastern Italy, northeastern Ionian margin), within an area of almost 10.000 km², on the Apulian ridge. Seismic data have been obtained through an agreement established between the SPECTRUM GEO Ltd and the University of Milano-Bicocca for the development of “3D reconstruction of a Quaternary normal fault network in the Apulian ridge (Ionian Sea)” project. The Apulian ridge (North-eastern Ionian Sea), represents the foreland system of both the Southern Apennines to the west and the Hellenic arc to the east, and is formed by a thick Cretaceous carbonate sequence and discontinuous tertiary deposits, crosscut by a NNW-SSE penetrative normal fault system at places marked by relay zones. The margin shows also evidence of buried and exposed mass-transport deposits sourced from the shelf edge (which is shaped by a number of slide scar, from 2 up to 6 km wide), and extended over an area of more than 1000km², from roughly 200 m down to 1400 m of water depth. Analysis of the regional-scale 2D seismic lines, integrated with high-resolution seismic and multi-beam echo sounder bathymetry and sedimentological and geo-chronological analysis of sediment samples available from the study area, produced reliable stratigraphic correlations and evidence that fault scarps on the seabed are likely coeval with late Pleistocene submarine mass- wasting deposits; suggesting that fault activity lasted at least as far as the Holocene-Pleistocene boundary and that the NNW-SSE normal fault network in the Apulian ridge can be considered active. The morphometric characterization of the fault system and associated relay zones produced an updated tectonic/geodynamic model, which clarifies the recent evolution and kinematics of the margin and gives evidence of small areas still prone to failure.

Keywords: Submarine slide; seafloor imaging; reflection seismic; tectonic geomorphology; Apulian ridge

MACHINE LEARNING SPATIAL PREDICTIVE MODELING IN TISLER REEF (NORWAY)

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Cold-water coral (CWC) reefs are important marine benthic ecosystems, affected by several seabed geomorphological characteristics and environmental variables. These factors increase the complexity of spatial habitat mapping, demanding a wide variety of data and advanced modeling techniques. In this project, high-resolution ship-based multibeam bathymetric data were acquired from the Tisler reef (Skagerrak, Norway) together with video footage from TV-CTDs tows. The bathymetric analysis revealed a diverse seafloor terrain regarding the distribution of bathymetric derivatives such as curvature and rugosity. The optic data (as extracted and annotated still image frames), provided coral and sediment spatial distribution. These two different sources of information, supplemented with other environmental variables derived from CTD and ADCP data, were analysed by machine learning methods (RandomForests). The modeling results showed that the combined use and analysis of such multidisciplinary data can positively contribute to fine-scale habitat mapping of the Tisler cold-water coral reef.

Keywords: Bathymetry; images; machine learning

THE EVOLUTION OF THE ISRAELI CONTINENTAL SHELF SINCE THE MIDDLE PLEISTOCENE: A SEISMIC GEOMORPHOLOGICAL PERCEPTION

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The continental shelf of Israel experienced major geomorphological changes during the past 250,000 years as a consequence of global sea level changes and oscillating sedimentation patterns of the Nile River. This study aims to provide insights into the geomorphological evolution of the Israeli continental shelf through time in relation to sea level oscillations. This research is based on geophysical interpretation of high resolution seismic surveys acquired along the Israeli continental shelf, complemented by statistical analysis of the interpretation picks. The main task included the identification of unconformities, erosional truncations and similar surfaces in the seismic profiles; and their chronological assemblage according to their stratigraphic order and ages obtained by previous studies. Seismic stratigraphy analysis of the geophysical dataset allowed dividing the shelf into four main seismic units (SU1 to SU4) bounded by distinctive four horizons. Two units (SU1 and SU3) represent transgression periods, probably during Marine Isotope Stages MIS1 and MIS5; and the two other units (SU2 and SU4) show morphologies suggesting marine regressive conditions, probably during MIS2 and MIS6. Overall the seismic units represent two major sedimentary cycles, which occurred presumably since MIS7 (ages according to previous studies) and correlate with the Hefer Formation stratigraphy (Tel Aviv and Ashdod members). Moreover, high resolution seismic interpretation reveals a distinctive morphology of some of the bounding surfaces in the form of depth-controlled terraces. Geomorphological and statistical analyses of these features, and their correlation with past sea level curves, suggest that their genesis is related to paleo-shoreline environments that probably occurred during MIS2 and MIS6. Particularly, the presumed MIS6 terrace serves as a prominent regional marker that was further used for estimating the average subsidence rates of the Israeli continental shelf to 0.18 mm/y since 136,000 ka. This study suggests the utilization of a novel statistical approach to unravel the mechanisms controlling the geomorphological evolution of the Israeli continental shelf, which can be applied to other shelf environments worldwide.

Keywords: Seismic geomorphology; sea level; LGM; Pleistocene; statistical analysis; passive margin

S13. TECTONIC GEOMORPHOLOGY

TECTONIC AND LITHOLOGICAL CONTROLS ON THE VARIABILITY OF FLUVIAL LANDSCAPE IN CHOTANAGPUR PLATEAU, EASTERN INDIA

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Understanding the linkages between tectonics, lithology and topography is important to enumerate the role of external controls on the evolution of an ancient landscape over long timescales. The Chotanagpur Plateau is considered to be one of the ancient Precambrian terrains of Indian Peninsular Shield where the role of tectonic land sculpting is strongly indicated by the presence of youthful topography and historical seismic activity. It is the easternmost continuation of the Indian Peninsula which consists of crystalline basement rocks partially covered by Gondwana and Quaternary sedimentary successions. The plateau is covering an area of ~75000 km² with an average elevation of 600-800 m except over its northern margin where the Hazaribagh range of hills rises to >1000 m. It exhibits a mix of characteristic features from both tectonically active settings and ancient cratonic landscapes. A regional scale topographic metrics analyses is undertaken using Advanced Land Observing Satellite (ALOS) PALSAR digital elevation model (DEM) of 12.5 m resolution. This is supplemented by detailed field surveys, lithological and structural mapping in order to examine the variability in landscape and to ascertain its primary driver. The North Koel, the Subarnarekha and the Damodar river basins have been selected for relief and river profile analyses. The chi plots were generated for the main stream as well as for its tributaries to narrate the geological and/or tectonics controls on fluvial landscape. The results show the range of concavity is low compared to the standard concavity of the drainage basins in steady state (0.35 - 0.65). The hypsometric integral values further suggest that the erosional efficiency of the drainages is higher and the drainage basins reflect the erosional stage. On the contrary, due to lithological control, it cannot be easily eroded hence generally giving low concavity.

Keywords: Tectonics; lithology; erosion; river longitudinal profile; landscape development

LANDSCAPES OF TECTONICALLY SENSITIVE EASTERN HIMALAYAN FOOTHILLS: CASE STUDIES BETWEEN RIVER BALASON TO RIVER TEESTA AND RIVER GISH TO RIVER JALDHAKA

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Geomorphic processes and landform of an area are the result of tectonics, lithology, climate and time. It is accepted universally that tectonics and lithology play the most important role. The tectonic setting of the Himalayas between Indian and Asian plates with a very long tectonic history presents spectacular relief features. The foothills of the Himalayas are the results of Pleistocene and post Pleistocene tectonic and climatic changes and are dotted with features of geomorphic significance. These features are formed by the activity of the rivers linking the mountains and the plains; their adjustment to structure and response to base level changes. Two blocks one between the river Balason and the river Teesta; the other between the river Gish and the river Jaldhaka have been selected by the author to study the fluvial processes and features at the Himalayan foothill. The study areas show entrenched alluvial fans, terraces, lineament guided rivers and a general trend of east ward shift of drainage pattern. The paper is an attempt to reveal the genesis and characteristics of above-mentioned features in the light of recent tectonic changes with the help of satellite imageries, SRTM DEM, past maps and records, extensive field observations and survey.

Keywords: Tectonics; lineament; fluvial processes; entrenched alluvial fans; terraces

GUMTI RIVER, TRIPURA: A CASE STUDY ON CHANNEL PLANFORM CHANGE BETWEEN 1930 AND 2017

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The Indian state of Tripura is characterised by six N–S aligned westerly convex anticlines and their intervening synclines belonging to the Chittagong–Tripura Fold Belt (CTFB). The west-flowing Gumti (226 km in 2017) originates from eastern side of the Atharamura range at the confluence of the Raima and the Sarama rivers. After crossing the Atharamura and Baramura ranges, it falls into the Meghna river in Bangladesh. Topographical sheets, 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 planform of the Gumti is digitised from 1932–33 Survey of India topographical maps, 1962 Corona images, 1975 Landsat-1 MSS data, and 2017 Resoucesat-2 L4fmx images. Based on curvature of the meander belts and change in the river course, this river is divided into 22 reaches – 15 of them alluvial. The sinuosity index of each reach is calculated for the three survey/imaging years to determine the extent of change. Results show that changes in channel length and sinuosity are mostly confined to the alluvial reaches of the Gumti. Notably, from Chhanban to Kakraban (Reach–9), the channel length decreased from 21 km (1932–33) to 16 km (2017) and the sinuosity decreased from 1.8 to 1.4. In the stretch (Reach–14) between Durgapur and Rampal, the channel length decreased from 21 km to 17 km and the sinuosity decreased from 1.5 to 1.2. From Bajehora to Binarpur (Reach–16), length decreased from 42 km to 25 km with decrease in sinuosity from 2.2 to 1.4. The probable reasons behind the changes might be a recent spurt in tectonic uplift of the CTFB. Other possible causes include increase in discharge, and augmentation in sediment load due to landuse change and/or landslides.

Keywords: Chittagong–Tripura fold belt; channel sinuosity change

QUATERNARY MORPHOTECTONIC EVOLUTION OF THE WESTERN PO PLAIN (NORTH- WESTERN ITALY)

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This study focuses on the Quaternary morphotectonic evolution of westernmost part of the Po Plain (Piemonte region, NW Italy), where the principal Po and Tanaro river catchments underwent strong variation in dimension and direction: the main scope is to define changes of drainage basin asymmetries and related drainage pattern, still a matter of discussion in the literature. The investigated region is encircled to the west by the Alpine reliefs and is characterized by elevations of pre-Pliocene rocks that separate large alluvial plains. The tectonic framework of this region is quite complex: it identifies the present juxtaposition on a crustal scale between Alps and Apennines, leading since the Oligocene the development of several subsiding depocenter zones. A morphometric analysis using DEM (5m resolution) at a regional scale was carried out to individuate current stream direction flows: the drainage network of the entire region has been hierarchized using Q-GIS plug-ins, and relief energy was calculated to estimate local uplift and different erosion rates. On the basis of morphometric analysis, detailed geological and geomorphological field studies were performed in selected areas. All the collected data were then integrated into the regional kinematics scenario. Preliminary results show that the general pattern of the Pleistocene drainage network is characterized by a strong variation in direction among the first, second and third stream segment orders. The change of drainage pattern seems to be led by interaction of tectonically-induced topographic growth and erosion/deposition phases. As further purpose of the present study, the results of the morphotectonic analysis and the regional tectonic framework has been integrated with an improvement of the historical seismicity reported in the DBMI 15 -Italian Macroseismic Database v.2015, and an analysis of microseismicity of the last 35 years in order to obtain fundamental constraints on the poorly-known seismic hazard of the investigated region.

Keywords: Tectonic geomorphology; GIS; river pattern; morphometric analysis; seismicity

REVEALING QUATERNARY TECTONIC ACTIVITY IN NORTHERN ABRUZZO PERI-ADRIATIC SECTOR (CENTRAL ITALY) BY DRAINAGE SYSTEM QUANTITATIVE ANALYSIS

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The southern Marche-northern Abruzzo peri-Adriatic region records the most recent effects of the compressive tectonics caused by the NE migration of the Apennine front. Seismic lines analysis revealed the presence of buried anticlines covered by the Pliocene-lower Pleistocene marine units. The evidences of the recent activity of these structures has been suggested by several authors, by stratigraphical analysis and field survey. A valid instrument to investigate the activity of deep-seated structures is the quantitative analysis of the direction, gradient and long-profiles of the rivers. In this research we applied these methodologies in the peri-Adriatic sector in front of Montagna dei Fiori, between Vomano and Salinello Rivers, where buried structures and Quaternary tectonic has been well studied. In order to understand their effects on the landscape, we performed quantitative analysis on the drainage system in MATLAB® and GIS environment. The 10m/px TINITALY DEM was used to extract the stream pattern and calculate numerical indexes. In particular, we focus our analysis on the Normalized Steepness Index and χ , usually used to investigate the effects of tectonics on drainage systems. Our results reveal anomalous variations in gradient values and stream directions, suggesting how the blind compressive structures have influenced the drainage setting in recent times and confirming the presence of buried anticlines and the related recent activity.

Keywords: Peri-adriatic; active compression; quantitative geomorphology; MATLAB; GIS

LATE PLEISTOCENE ELEVATED WAVE-CUT PLATFORMS ALONG THE TYRRHENIAN COAST OF SOUTHERN APENNINES, ITALY

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A geomorphological study on the identification and characterization of Late Quaternary sea-level indicators has been carried out along the Tyrrhenian coast of southern Apennines to find out a well age-constrain reconstruction of the stratigraphical and tectonic framework of the Tyrrhenian coast of Calabro-Lucano boundary. A morpho-stratigraphic study has been performed to shed light on the Late Quaternary vertical movements of the coastal region spanning from Scalea, northern Calabria, to Maratea, southern Basilicata. Past sea-level indicators, eg. wave-cut platforms, lithophaga borings and shallow-water deposits crop out up to 170 m above sea level (a.s.l.), are widespread in the study area. The age of the highest marine terraces is still unknown, whereas new chronological constraints have been produced for the shorelines standing up to a few tens of m a.s.l. Dated marine terraces consist of wave-cut platforms carved into the Triassic to Miocene bedrock, which are covered by a few metres thick succession of biocalcarene bearing shore-face fauna. Age dating of biocalcarene deposits has been constrained by U-series measurements on *Cladocora caespitosa* corals and speleothems. Based on morphostratigraphic position of analysed marine terraces, uplift until, at least, the latest stage of the Last Interglacial has been reconstructed. Field work has evidenced the presence of fractures and faults, some of which with offset of a few metres, affecting the marine terraces. The first results along the Tyrrhenian coastal zone of the Basilicata-Calabria boundary provide new constraints for the understanding of the Late Quaternary stratigraphic and tectonic evolution of the area, with specific reference to the vertical movements on the Tyrrhenian coast-side of the southern Apennines.

Keywords: Paleoshorelines; surface uplift; Late Quaternary; sea-level indicators; southern Apennines

DEFORMATION OF QUATERNARY SEDIMENTS IN ALAKNANDA RIVER OF SRINAGAR VALLEY (GARHWAL HIMALAYA), INDIA

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This paper describes the results of a continuing investigation of tectonic control on channel pattern and morphology of Alaknanda River in Lesser Garhwal Himalaya, Uttarakhand, India. The present aims to identify recent deformation (uplift/displacement) along North Almora Thrust (NAT) in the central segment of Alaknanda River valley in the Lesser Garhwal Himalaya. The valley has preserved unpaired fluvial strath terraces that provide signatures of neo-tectonic activity. Uplift the NAT and associated N-S trending transverse faults are considered to be controlling the deformation pattern of terrace sediment in the area. The results of the study show that there are significant evidences of neo- tectonic activities and associated landforms along the NAT which are reported for the first time. The geomorphic landform in the valley has been physically examined to explain tectonic activity during the Holocene. Unpaired fluvial terraces, tilting of terraces, triangular fault facets, fault scarp, drainage offset, and formation of gorges are the significant geomorphic features observed within the valley. Furthermore, we identified several sediment deformational features such as folding, warping, faulting, thrusting have been identified within the fault/thrust zone. The displaced fluvial terraces (T2 and T3) and offset of drainage provides evidence of strike slip fault in the area. The final results of the study indicate that the neo-tectonic movements along NAT was more active during 11.1-4.5ka. It is concluded that NAT and faults in Srinagar section has been reactivated during early Holocene period.

Keywords: Neo-tectonics; tectonic geomorphology; Alaknanda river; central Himalaya

DEEP-SEATED GRAVITATIONAL SLOPE DEFORMATION DISPLACEMENT IN CENTRAL SARDINIA (ITALY, WESTERN MEDITERRANEAN)

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In east center Sardinia (Italy) deep-seated gravitational slope deformations (DSGSDs) and catastrophic rock-slope failures are present. DSGSDs are common phenomena in the central Mediterranean regions reliefs, but this subject has never been faced in Sardinia. Compound landslides with lateral spreading and sackung characteristics, which involve giant carbonate blocks and the underlying foliated metamorphites were analyzed. The area is characterized by a wide plateau with a prominent Jurassic limestone scarp overlying Palaeozoic metamorphites. The uplift, linked to Plio-Pleistocene tectonic activity, leads high slopes. This litho-structural setting is prone to the development of deep-seated gravitational slope deformations. We have analysed correlations between DSGSDs dynamics and geomorphological evolution of the area, characterized by fault slopes and river captures. The use of high resolution UAV (Unmanned Aerial Vehicle) photogrammetry, and geological, structural, geomorphological large scale surveys allowed a depth morphometric analysis and the creation of interpretative 3D geological models. A set of ridge-top trenches with width up to 50 m, length of hundreds of meters and depth greater than 50 meters, were detected, and interpreted as decompression processes of the rock mass. Shear surfaces were found at depths about 100 m. In order to understand the temporal behaviour of the DSGSD surfaces, we applied the Differential SAR interferometry technique using ESA- Sentinel 1 Data. The data indicate slow movements in the areas previously identified with geomorphological indicators. This high-resolution data show a slow active deformation and allowed the formulation of new hypotheses about evolution and kinematics. The results indicate a high correlation between DSGSD, fluvial erosional and active tectonic processes. Geo-structural setting, high relief energy associated with active tectonic uplift seem to be the main control factors.

Keywords: Deep-seated gravitational slope deformation; differential SAR interferometry; UAV photogrammetry; geomorphological analysis; uplift processes

MORPHOMETRIC ANALYSIS OF THE SOUTHERN BORDER OF THE MITIDJA BASIN (ALGERIA)

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The emerged area of the Algerian margin is formed from folds and thrust nappes of the Tellian Atlas interspersed by Neogene basins (e.g. Cheliff and Mitidja basins). It is located at the diffuse plate boundary between Eurasia and Africa, presently reactivated in compression. In this boundary, the deformation dominated by NE-SW trending shortening structures corresponding to active thrusts and folds, is distributed both on land and offshore. It corresponds to the most seismically active area of the Western Mediterranean where moderate to large earthquakes occurred (e.g. El- Asnam 1980, M 7.3; Bouterdes 2003, M 6.8). Mitidja basin is an E-W elongated graben bordered by ascending reliefs. An asymmetric fold growing from West to East representing the Sahel ridge characterized its northern part. While its southern boundary is dominated by the mountainous relief of the Blida Atlas consisting of Cretaceous deposits. A discontinuous contact that shows signs of recent tectonic deformations, underlines this border. Historic earthquakes (eg, Blida, 1825, Mouzaia, 1867) destroyed villages located along this contact. Recently, moderate events such as Hammam Melouane 2013 (Mw: 5.0) and Oued Djer, 2018 (Mw: 5.1) located at the southern edge of this Basin have been recorded. In this work, we apply for the first time a morphometric analysis along the contact Blida Atlas-Mitidja basin. For this purpose, we extracted morphometric indices of 14 watersheds and analyzed the longitudinal profiles of 6 rivers. Extracted indices include the normalized steepness index (K_{sn}), (SLi), hypsometric integral, drainage area, Elongated ratio, and river profiles. This approach allowed us to identify the most relevant morphometric indices for tectonic analysis of this area whose uplift rate is unknown. We found that some indices such as K_{sn} are more appropriate than others, and that the uplift is more pronounced Eastern this area.

Keywords: Mitidja basin; earthquake; morphometry; uplift; Algeria

MORPHO-TECTONIC APPRAISAL OF PENINSULAR INDIA BY COMPREHENSIVE MORPHOMETRIC INVESTIGATIONS

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The Peninsular India was presumed to be tectonically stable. This long term held belief was challenged by the recent earthquake events at Koyna and Killari. The Western Ghat Escarpment has been the subject of morphological study and debate for over a century. The planation surfaces at different elevations of the Ghat is the manifestation of polycyclic landscape evolution. These movements were presumed to be epeirogenic in nature leading to vertical uplift of rigid continental mass as a whole. There are geomorphic signatures, scattered along the Ghat margins that point toward tectonic activity, although it is generally viewed with disbelief. Recent investigations commissioned after Killari earthquake contemplate tectonic activity even in the central part of peninsula, traditionally considered as the least tectonically active zone in the subcontinent. However few site-specific studies on morpho-tectonics have come out with conflicting observations. These studies were based on morphometric analysis using commonly used geomorphic indices of active tectonics. Although these indices are traditionally used to understand contextual tectonic setup, their efficacy is subjective and variant as per the areal extent of the feature under investigation and regional tectonic setup. The comprehensive morphometric appraisal of Peninsular India at regional scale presented here is carried out to understand regional tectonics and its morphometric expression. 'Viz-Morphotec', a set of software application programs for morphometry were developed as per well-documented algorithms and procedures and used for computation of indices over twenty-six basinal as well as non-basinal morphometric parameters. The results for morphometric analysis were further scrutinized in GIS environment to elucidate link between established or adduced tectonics frame and its morphometric manifestation which shows a statistically significant correlation between morphometric indices and tectonic setup of Peninsular India.

Keywords: Peninsular India; morpho-tectonics; polycyclic landscape; Western Ghats

ASSESSMENT OF RELATIVE TECTONIC ACTIVITY IN THE TRICHONIS LAKE GRABEN (WESTERN GREECE) USING GEOMORPHOMETRY AND ARTIFICIAL INTELLIGENCE

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This study aims at assessing the relative tectonic activity around the Trichonis Lake graben coupling quantitative morphometric analysis and self-organizing maps (SOM). Trichonis Lake graben is located in western continental Greece and strikes WNW-ESE for a distance of about 32 km and cuts across the early Tertiary NW-SE fold and thrust structures of the Pindos Mountains. The depression at north and south flanks is bounded by E-W and NW-SE trending faults. Two segmented E-W trending antithetic normal faults, buried locally by Pleistocene deposits and thick alluvial fans, have been mapped along the margins of the lake: An E-W trending and south-dipping low-angle normal fault, related to the major Agrinio Fault Zone, parallel to the northern bank of the lake and a E-W striking and north-dipping normal fault (Trichonis Fault Zone), located south of the lake. The southeastern bank of the lake is bounded by a NW-SE striking normal fault that dips to the NE (Kato Makrinou Fault), while a conjugate NW-SE striking and SW-dipping marginal fault exists along the northeastern flanks of the lake (Petrochorion Fault). We analyzed 35 catchments around the lake using nine morphometric variables. To assess the spatial distribution of relative tectonic activity in the study area, we then combined six of these indices to evaluate a single index (named *lat*). Additionally, the combination of five of the individual morphometric variables yielded a new combined index of relative tectonic activity (named *lrta*). To evaluate the landscape around Lake Trichonis in terms of potential tectonic activity we identified clusters of drainage networks and catchments according to their geomorphic characteristics (expressed by morphometric indices) using SOM, which is a special type of Artificial Neural Networks. The analysis led to the conclusion that the Trichonis fault and the eastern segment of the Agrinio fault show relatively higher tectonic activity.

Keywords: morphotectonics; geomorphometry; artificial intelligence; Trichonis; Greece

GEOMORPHOLOGICAL AND MORPHOTECTONIC FEATURES IN CHINGAZA NATURAL NATIONAL PARK (LA PLAYA RIVER BASIN) AND MOCOA, COLOMBIA, SOUTH AMERICA

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From the analysis of aerial photographs, satellite images and digital elevation models, and by using some geomorphological indexes, several geomorphological and morphotectonic features were found, evidencing neotectonics in the study areas. In La Playa river basin, it was observed a braided drainage pattern, which is atypical for a mountain river. Basin area / fluvial valley area ratio was calculated finding out that La Playa river basin was unique and should be considered as a geomorphosite that should be protected. By identifying lineaments on a digital elevation model, and by identifying slickenside kinematic indicators on newformed minerals in fieldwork and the analysis of stress configuration based on focal mechanisms, it was possible to establish shear zones with flower structures that can work as groundwater recharge. When analyzing river sinuosity and asymmetry factor, the results agreed with the presence of those shear zones evidencing neotectonics in La Playa river basin. Besides, in some areas La Playa river was carving rock. In Mocoa, ancient alluvial fans (20 meters thick) originated by torrential events were carved by the Mocoa River producing unpaired terraces. Also, there are water courses that, despite traveling on deposits, are controlled and in some occasions are carving rock. Finally, Fan area (Fa) / Basin Area (Ba) ratio of the Taruca stream and the Mulato River are 1.56 (7.4km²/4.7km²) and 0.46 (7.0km²/15.1km²) respectively. The Taruca value is anomalous, and its origin can be related to a geomorphological reconfiguration where its alluvial fan was originated by a larger basin similar in size to Mulato River Basin. As a result, all geomorphological and morphotectonic features found indicates some sort of neotectonics activity, however it is necessary to carry out new research projects that include detailed studies of Quaternary geology, structural geology, and tectonics, among others to be able to unravel their formation history.

Keywords: Fluvial geomorphology; tectonic geomorphology; morphometry; geomorphosite; neotectonics

ACTIVE TECTONICS AND PALEOSEISMICITY OF A TRANSVERSE LINEAMENT IN THE RIVER VALLEY (UMBRIA-MARCHE APENNINE, CENTRAL ITALY)

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A case surface faulting affecting a fluvial terrace and slope deposits in the neighbouring of the town of Fabriano (Marche, Italy), is here reported. The observed ruptures trend transversally with respect to the Apennine thrust structures and belong to the “Fossato di Vico-Valle dell’Esino line”, a regional tectonic lineament that has shown persistent activity since the late Miocene in various tectonic regimes, suggesting that this structure may reach considerable crustal depths and are able of reappearing at the surface even after the sedimentary cover of the basement has been shortened by compressive tectonics such as that responsible for the formation of the Apennine chain. The observed surface faulting has been associated to the M=6.2 earthquake that struck the town of Fabriano (Marche, Italy) on April 24, 1741 with a very wide distribution of damages extending along the Esino River Valley to the Adriatic coast, over a distance of more than 50 km. The paleosismological analysis of faulted river terraces and slope deposits, ranging in age from the late Middle Pleistocene to the recent Holocene allowed to define the evolutionary steps of the fault and estimate a dip slip rate of about 0.3 mm/yr.

Keywords: Active tectonics; paleoseismology; transverse lineament; Umbria-Marche Apennine; Italy

GEOMORPHOLOGICAL EVIDENCE OF SURFACE EFFECTS INDUCED BY THE AUGUST- OCTOBER 2016 EARTHQUAKE SEQUENCE ALONG THE MT. VETTORE-MT. BOVE FAULT (UMBRIA-MARCHE, CENTRAL ITALY)

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On August 24th, 2016, an Mw=6.0 earthquake gave rise to a seismic sequence that, after around three years, is still active. The first main shock was followed on October 26th, 2016 by another one (Mw=5.9) located 25 km to the northwest to culminate on October 30th, 2016, with the most significant shock of the sequence (Mw=6.5) near the town of Norcia. Other events occurred in the southern sector of the sequence on January 18th, 2017, with a maximum Mw of 5.5. Field surveys started immediately after the first shock and continued throughout the following winter, highlighted more than 7000 surface geomorphological effects (mostly surface ruptures and faults, gravitational phenomena and sinkholes). In particular, along the Mt. Vettore-Mt. Bove fault, open fractures along the ridges, enlargement of trenches, bulging at the slope foot and, locally, interferometric data, testify the co-seismic evolution of large-scale landslides and deep-seated gravitational slope deformations. These latter phenomena, some of which have been defined for the first time in terms of evolutionary geological and geomorphological models, represent heavy hazard elements also for the presence of built-up areas and infrastructures.

Keywords: 2016 Central Italy Earthquake; Mt. Vettore- Mt; Bove fault; seismic induced mass movements; Umbria- Marche Apennine; Italy

GEOMORPHOMETRY-BASED APPROACH TO MORPHOTECTONIC SUBDIVISION AND REGIONALIZATION, THE SUDETES, CENTRAL EUROPE

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The Sudetes mountain range in Central Europe is a Palaeozoic orogen, rejuvenated in the Cenozoic and subject to differential uplift and subsidence. Its present-day topography consists of a mosaic of elevated massifs, intermediate uplands and intramontane basins. They are locally separated by clear mountain fronts, considered as fault-generated, but wider transitional zones between lower and higher ground are also common. An additional factor complicating morphotectonic interpretation is considerable lithological variability, including all main types of igneous, metamorphic and sedimentary rocks. As a consequence, morphotectonic subdivision of the range is yet to be attempted. Here we use geomorphometry-based approach and look at the spatial distribution of specific geomorphometric features potentially indicative of the pattern of uplift and subsidence. Both simple parameters/characteristics such as steep slopes and planar surfaces, as well as complex measures of the intensity of erosional dissection are used to identify areas likely subject to most uplift and to examine differences and similarities between different parts of the Sudetes range. While interpreting morphometric indices, lithological diversity is taken into account and rock strength is found to be a factor modulating erosional response to uplift. In the final step, the Sudetes are tentatively divided into a number of spatial units which likely behaved as separate morphotectonic entities, with their specific rates of uplift, erosion and potential to both retain pre-uplift topographic features and preserve tectonic landforms.

Keywords: Tectonic geomorphology; geomorphometry; erosion; rock strength; Sudetes

INITIAL STAGES AND EVOLUTION OF EARTH-SURFACE PROCESSES IN AOOS, ARACHTHOS, KALAMAS, LOUROS, AND ACHERONTAS RIVERS (GREECE)

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This study proposes a new method to determine the stages of tectonic geomorphological evolution. Morphology, geology, tectonics and drainage networks are the definitive factors to help us understand landscape and drainage network evolution. Morphology is affected by existing tectonic structures, and has a significant impact on the development of the drainage network as it reacts to tectonic changes by altering the trend and/or inclination of its branches. Considering the aforementioned, conceptual models of the stages of evolution can be developed that highlight the definitive role of tectonic structures (e.g. faults and folds) on a rivers' route. The analyses demonstrate that different tectonic events have a unique influence on different stream orders of the drainage network, which enables the association between the drainage network and specific tectonic structures, comparison of individual areas and the grouping of rivers. The applied methodology consists of processing and synthesizing faults, thrusts, and overthrusts, axes of synclinal and anticlinal structures, and Aoos, Arachthos, Kalamas, Louros, and Acherontas drainage networks, using quantitative and qualitative techniques. The validity of this method is based on the verification of data produced by proven techniques, such as the calculation of the asymmetry factor AF and the composition of rose diagrams, which is a widely-used technique for representing orientations with field observations. The method constitutes a template and tool for the investigation of tectonic geomorphological evolution through time.

Keywords: Tectonic geomorphological evolution; tectonic event; drainage network patterns; asymmetry factor; Strahler order; GIS analysis techniques

COMPARISON OF GROWTH AND DEVELOPMENT OF A DRAINAGE NETWORK AND ITS RELEVANT BASINS

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This work attempts to identify the stage of growth and development of a drainage network and its respective basins. Numerous geomorphologists and geoscientists have formulated various mathematical expressions - equations that can quantitatively describe different parameters of a drainage network or a basin using mainly their geometrical characteristics - features. Through studying and analyzing significant morphometric indices, i.e. Asymmetry factor AF, Tectonic uplift - erosion index ϵ , Hypsometric Integral HI, Slope-gradient factor S, Relief ratio RH, Elongation ratio E, Circularity ratio C, 1st Horton's Law of Stream Numbers RB, and 2nd Horton's Law of Stream Lengths RL, the indices referring to features of the drainage network were compared to the ones that respectively describe these basins. Based on the aforementioned indices, it was observed that the Hypsometric integral is able to describe the stage of evolution of the basin areas according to Strahler's classification, while the Horton Laws describe the stage development of the drainage network. The result of this comparison was the identification of lithology's significance in the evolution of the drainage network of branches length and also the effect on non-primary geometric characteristics of the basin as the area and perimeter. Northwestern Greece was defined as an observation and analysis area and a total of 209 drainage basins and 5 drainage networks were analyzed. Choosing this area requires an extensive tectonic and geomorphological analysis beforehand. The overall assessment and proposal of this paper is the introduction of a lithological factor in the morphotectonic indices to allow for more accurate calculations of all the factors that determine the development of a river.

Keywords: Morphotectonic index; lithology - geology; Strahler order; GIS analysis techniques; Northwestern Greece

DEFORMATION AND UPLIFT OF A RELICT COASTAL LANDSCAPE, COMBINING GEOLOGICAL, GEOMORPHOLOGICAL AND GEODETIC SAR INTERFEROMETRY (INSAR) MEASUREMENTS: EVIDENCE ALONG THE CARBONATE PLATFORM OF DAGMAR-DIBAB, NE OMAN

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The preservation of relict landscapes and landforms in the north-eastern Arabian Peninsula are the result of the crustal deformation due to ongoing convergence between Arabia and Eurasia which is recorded in the tectonic deformation in the Makran subduction zone and the uplift of the Oman Mountains. We investigate the vertical deformation/uplift history of the carbonate platform of the Dagmar-Dibab area of northeastern Oman by combining geological and geomorphological data along with geodetic SAR Interferometry (InSAR) measurements. The study area between Dagmar and Dibab was uplifted up to 200 m due to tectonic processes, that are detected on different elevations of the cascading coastal terraces. The marine terraces formed due to Neogene to Quaternary tectonics, which continued into the Upper Pleistocene and were active also during the Holocene. Data processing included methods such as geodatabase creation, multi-criteria analysis of the landforms through Digital Elevation Model (DEM) analysis, interferometry (InSAR) analysis, fieldwork (topographic survey) and laboratory analysis (XRF, thin sections, dating by ¹⁴C and OSL). The results of the multiproxy and interdisciplinary methodological approach are used as tools for understanding the geomorphological evolution of the Neogene to Quaternary landscape, where landforms are presented as indicators of the area's evolution and define the processes that formed the current relief. At least three tectonic terraces at different elevations were detected. A dolomitized karstified planation surface of Eocene rocks is well developed at an elevation of 160-135m. At least three marine terraces are attached on the seaward side of the planation surface. The mapped terraces (depending on the locations) are at altitudes of about 120- 90 m. (T3), 75-45 m. (T2) and 35-20 m. (T1) with its cliffs varies at elevations from 15 to 30 m. Quaternary deposits have been identified in the marine terraces indicating shallow sea and coastline environment.

Keywords: Relict landscapes; Quaternary tectonic; Oman; InSAR

TECTONIC VERSUS FLUVIAL SHAPING OF THE LANDSCAPE OF THE WESTERN PO PLAIN AND THE POIRINO PLATEAU BOUNDARY, NW ITALY

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The Poirino Plateau is separated from the Po Plain by a S-N oriented scarp in its western margin. The morphological origin of this scarp is still debated, giving that no important river is flowing in the area and the known local tectonic deformation rate is not compatible with the dimension of the element. To investigate the origin of the scarp a double paths method was followed to investigate both options. A reconstruction of historical seismicity of the area, starting from DBMI catalogue, was performed verifying the presence of unknown seismic events, such as to justify a tectonic origin. Alongside, was analysed the current fluvial network, with geostatistical techniques, under the framework of the Holocene river capture, indicated by several authors in the last century, that involved the so-called Paleo-Tanaro River. This process, that gave the origin to the present setting of Po and Tanaro rivers, drastically changed the hydrological network of this part of Piemonte, including erosion rate and basins flow orientation. The results from the historical research do not give evidences of high magnitude seismic events capable to generate surface ruptures and confirm a substantial uniformity with the present micro- seismic behaviour of the area, even if reports of unknown events were founded. The analysis of the setting of the river network, considering also paleoclimatic trend, gave evidences of a pre- capture hydrographic landscape and of its evolution through time strictly connected with progressive accumulation in Po Valley of fluvio-glacial deposit from Alps in a general tectonic subsidence context. The related deposition induced a migration toward east of the river producing lateral erosion along the Poirino plateau. Concluding, the detected scarp can be attributed to the Paleo-Tanaro River erosion activity before capture, while the tectonic activity can be only responsible of the hydrological pattern of the present western Po Plain.

Keywords: Tectonic; fluvial erosion; paleoclimate; historic seismology; capture

RECOGNITION OF AREAS OF ENHANCED EROSION – LITHOLOGICAL VERSUS TECTONIC CONTROLS DECIPHERED FROM GEOMORPHOMETRIC AND STATISTICAL APPROACH (ORLICKIE- BYSTRZYCKIE MOUNTAINS BLOCK, SUDETES, CENTRAL EUROPE)

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Strong erosional dissection at a regional scale may indicate both the higher rate and magnitude of tectonic uplift (as uplift drives erosion) as well as possibly the lower resistance of bedrock to erosional agents. A great challenge in morphotectonic studies is to make a distinction between these two, so to recognize the complex interactions between uplift, erosion and other controlling variables. The great majority of morphometric indices of tectonic activity enable one to obtain discrete information as they are related to some specific locations such as mountain-piedmont junctions (e.g. sinuosity index), river valley cross sections (e.g. valley floor width to height ratio) or points along river courses (SL index). Basing on the fact that uplift drives erosion we aimed at identification of highly dissected terrains in the Orlickie-Bystrzyckie Mountains Block via morphometric approach and the use of spatially continuous dataset. A set of primary and secondary LiDAR-based DEM derivatives served the purpose. The influence of lithological diversity on the occurrence of erosional 'hotspots' was addressed in more detail. The differences in the values of the parameters used to detect areas of enhanced erosion for different lithologies were also examined from statistical perspective.

Keywords: Erosion; morphotectonics; geomorphometry

CHANNEL RESPONSE TO QUATERNARY TECTONICS AND PHYSIOGRAPHIC ATTRIBUTES ON THE HIMALAYAN FORELAND BASIN IN WEST BENGAL, INDIA; A STUDY ON TORSIA RIVER

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The study has been an endeavour to assess the controls implemented by the neotectonic (surface deformation and structural entity) and physiographic attributes (surface slope and topography) on the Torsa River courses (both the present and palaeo-courses) flowing through the Quaternary deposits of the Himalayan foreland basin in West Bengal, India. Extraction of structural attributes, analysis of topographic properties derived from DEM (SRTM), application of morphotectonic and planform indices have been the major operational attributes in this study. The Himalayan foreland basin where imprints of Neotectonism have been precisely preserved the nature of Quaternary deposits, surface deformation due to neotectonic events and association of both the surface and sub-surface structural attributes have resulted into confined river valleys, sharp turns in the flow direction, confined river courses along the lineaments and intense meandering. The morphotectonic indices; Mountain front sinuosity (Smf), Stream length Gradient Index (SL), Channel gradient, Sinuosity character (Regional and Topographic), Channel parallelism to Lineaments (Cp), major flow turn angles and planform attributes; Meander Shape Index (MSI), orientation of meander bends have showcased facets of intense controls of tectonic and topographic on the courses of Torsa River. The domains of spatial diversity of channel response to topographic and structural attributes were delineated based on the changes in channel morphology and channel orientation. Analysis at much smaller spatial windows on different physiographic zones had showcased detail and varied particulars of channel response to both the physiographic and tectonic restraint. An eastward shift of the Torsa River under the guidance of physiography, regional slope characteristics and surface tilting is well accompanied by striking changes in channel morphometry and flow direction due to structural influences and surface deformation at comparatively smaller spatial extent. The topographic confinement has lessened the impact of structure to a concerned extent that the structural control on both the channel orientation and morphology has been more dominant on the low lying alluvial plains than the piedmont plain with higher surface gradient.

Keywords: Himalayan foreland basin; lineaments; morphotectonic; physiography; Torsa River

GEOMORPHOLOGICAL ANALYSIS OF THE SEAFLOOR AND IMPLICATIONS FOR OFFSHORE ACTIVE AND RECENT GEOLOGICAL PROCESSES AND GEO-HAZARDS IN THE AEGEAN AND THE HELLENIC TRENCH

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The seafloor of the Aegean Region displays a complicated geomorphological pattern, which reflects the complicated Plio-Quaternary deformation. We use the 100 m DTM (EMODnet Bathymetry) and swath bathymetry to describe the offshore geomorphology and highlight its relationship with active geological processes and sea-level fluctuation. With the exception of the North Aegean Trough (1600 m) and the SE Aegean basins (2000-2500 m), most of the basins are <1000 m deep and display rhomboid, elliptical or spindle shape. They are a few tens of kilometers long and aligned in NE-SW to ENE-WSW and in NW-SE to WNW-ESE directions. They are bounded by steep slopes delineating active faults, which separate them from shallow ridges, seamounts, plateaus and islands. Volcanic seamounts are circular, while ridges and other seamounts derive from structural movements. Wide shelves occur off the mouths of major rivers with their edges at roughly 115-125 m bpsl. The slopes off the shelf edges are incised by amphitheatrical scars created by frequent failures, and by gullies further downslope. Small failures occur on most of the slopes. The roughness of their relief is associated with the age of the failures. The Hellenic Trench displays three sectors. The Kephallinia Valley, a 3000-3500 m deep trough, has developed along the steep escarpment of the Kephallinia Fault. It marks the deeper part of a roughly 200 km long canyon valley, which starts from Otranto Strait and runs along the western margin of the Ionian Islands. The Ionian Trench consists of a series of isolated depressions with depths exceeding 4000-5000 m, aligned in NW-SE direction. The NE-SW trending Ptolemy, Pliny & Strabo Trenches consist of smaller troughs and basins, separated from each other by ridges and structural highs. The morphological configuration of the Ionian and Pliny & Strabo Trenches bears evidence of horizontal shearing along overlapping fault segments.

Keywords: Seafloor geomorphology; tectonic processes; geohazards; Aegean region

DIFFERENTIAL UPLIFT OF THE EASTWARD MOUNTAIN FRONT OF OLYMPUS MT (GREECE) BASED ON TECTONIC GEOMORPHOLOGY OBSERVATIONS

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The study of the east dipping N-S mountain front of Olympus Mt that is presented in this work, was based on the interpretation of high-resolution digital elevation model (DEM), as the main dataset for calculating various tectonic geomorphology indices, through quantitative techniques. Since the fluvial network maintains its connection to the tectonic forcing and therefore contains potentially useful information about variations in rock uplift rates across the landscape, we used a highly detailed one generated from the DEM in order to calculate various indices and extract quantitative information. Calculations were made in a GIS platform by using the Ks index, the drainage basin asymmetry index and the geometry of the triangular facets on the front of the mountain, alongside the fault zone delineating the mountain. The results extracted by combining the previous methodologies are in agreement with the observations which were made during the fieldwork, that there is no uniform uplift along the main Olympus fault zone.

Keywords: Triangular facets; morphotectonic indices; longitudinal river profiles; channel steepness index

AGE ESTIMATIVE OF EROSIONS PROCESS IN SHOUTERN PORTION OF BAURU SEDIMENTARY BASIN (BRAZIL)

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The southern portion of the Bauru sedimentary basin (Brazil) has erosive features that appears after the beginning of the deforestation process (1950) and the installation of cities in the region. In contrast to these features, there are others observed in the aerial photos of the first flight realized in 1953 with possibly different characteristics and genesis. Measurements with ¹⁰Be showed a difference of up to eight times in the denudation rate of these erosive features in comparison to the Ivaí river sub basins measured in the Northwest region of the Paraná State (Couto, 2015). Thus, the subject of this work was to estimate the approximate the beginning age of the formation of these erosive features as a subsidy to its genesis understanding. Initially the highest points were extracted from the edges of each analyzed area, erosive and sub basins features, in a vector file. Subsequently, these points served to interpolate each paleosurface. The last step was the calculation of the volume of sediments lost and the time required for each feature to reach the current stage. The average values of 42,67 m/my for denudation rates and 1,19 my for the age of the erosive features, when compared to the values obtained in the sub basins measured, 8,50 m/my for denudation rates and 4,14my for the average age, this accord with the hypothesis that the sub basins began their formation process in the Miocene/Pliocene, while the erosive features date from the Pleistocene. This is consistent with the literature regarding the action of drier and cooler paleoclimates, such as those that operated during the last Pleistocene glaciation.

Keywords: Erosive features; erosion process age; paleosurface; Bauru sedimentary basin

RELIEF RESPONSE OF TWO “TWIN” MOUNTAIN RANGES TO ASYMMETRICAL UPLIFT INFERRED FROM MORPHOMETRIC ANALYSIS (CENTRAL WESTERN CARPATHIAN)

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Tatra Mts. and Low Tatra Mts. are geologically very similar mountain ranges. Both are composed of Paleozoic crystalline core, covered by Mesozoic autochthonous sediments and series of nappes. Also both were asymmetrically uplifted mainly along faults bounding their southern edge, i.e. tilted toward N. Moreover, both massifs were shaped by glaciers and partly, in their northern slopes, also by karst processes. However, these two mountain ranges differ in the time range in which they were uplifted. Exhumation of the Tatra Mts. began in the middle Miocene, while Low Tatra exhumation start at the Late Oligocene. It is also assumed that Low Tatra as a mountains appear earlier within the Carpathians morphology. The data from dating of post-exhumation processes are poor so far. Hence, we attempt to test the thesis of a higher maturity of Low Tatra in comparison to Tatra Mts. by employing morphometric analysis. Similar geological and climatic conditions in which both ridges were formed favorite the assessment of tectonic activity using morphometric indices. We analyzed 25 drainage basins in Tatra Mts. and 25 in Low Tatra. For each of the selected basin the following morphometric indicators has been calculated: minimum bulk erosion, hypsometric integral, elongation ratio, circularity ratio, asymmetry factor, concavity ratio. Longitudinal and normalized river profiles, stream-length gradient index, ratio of valley width to height were computed along trunk rivers. Additionally, swath profiles across and ridge profiles along Tatra Mts. and Low Tatra Mts. were produced. Obtained results show spatial variations in relief as a result of asymmetrical uplift of studied massifs, with generally steeper southern slopes, and gentler and longer northern ones. Generally higher values of indices related to tectonic activity computed for Tatra Mts. suggest higher maturity of Low Tatra Mts. This research was funded by a grant from the Polish National Science Center (NCN2016/21/B/ST10/01483).

Keywords: Relative uplift; relief; geomorphic index; drainage network; Tatra Mts

THE TAIL DOESN'T WAG THE DOG: ASYMMETRY OF THE ANDES OROGEN DRIVEN BY THE GEOMETRY OF THE SUBDUCTING NAZCA SLAB

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Coupled deformation-surface process models predict that the asymmetry of orogenic wedges is mostly explained by the sense of subduction but may be further modified (enhanced or subdued) by superimposition of dominant wind direction and erosion. These models provide a numerical basis to attribute changes in orogenic asymmetries to the formation of orographic rainfall gradients across strike. In such models, the divide migrates laterally toward the prevailing wind direction, therefore changing the position of the arc (i.e. topographic divide) with respect to the trench. These models broadly agree with empirical data in that observations of seismic tomography reveal a correlation between crustal thickness (orogenic wedge development) and the position of the arc. However, the dynamics of the subducting slabs are not considered in such models even though a correlation between slab-dip and arc position exists. The latter suggests that just as the arc position changes with slab dip, the asymmetry of an orogenic wedge may consequently change as a function of it as well. Here, we test the hypothesis that arc position changes with slab dip, driving the asymmetry of an orogenic wedge in the Andes mountains irrespective of strong orographic rainfall gradients across and along strike. Observations of the radius of curvature of the subducting Nazca slab from previous studies were compiled and compared with orogenic wedge widths and the position of the volcanic arc (topographic divide). Orogenic asymmetry is calculated as the ratio of trench-to-crest distance and trench-to-backarc deformation front distance. The data reveals a positive correlation between radius of curvature and orogen asymmetry confirming that the slab geometry must be accounted for when assessing the climatic influences on orogenic asymmetry given that erosion rates do not always mirror disparate precipitation rates across the range.

Keywords: Orogenic wedge; subduction zone; slab geometry; orographic rainfall; orogen asymmetry

CONSTRAINING MOUNTAIN FRONT ACTIVITY IN ACTIVE EXTENSIONAL SETTING BY TECTONIC GEOMORPHOLOGY: CASE STUDIES FROM THE SOUTHERN APENNINES (ITALY)

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The southern Apennines is a fold-and-thrust belt, which was formed during the late Cenozoic convergence between the African and Eurasian plates. Late Quaternary and active tectonics are dominated by extensional faulting mainly acting in both the inner and the axial belts of the mountain belt. Since the Early-Middle Pleistocene, activity of high-angle normal faults caused the formation of large coastal grabens and intramountain basins that are often limited by mountain fronts, up to 2000 high, formed in carbonate rocks. Late Quaternary activity of some of these high-angle normal faults, that mainly trend NW-SE and E-W, has been proved through field geomorphological and/ or stratigraphical and structural data and could be inferred by quantitative investigation of landforms. To test the suitability of the quantitative analysis approach to assess the state of activity of faults placed at the boundaries between mountain fronts and alluvial basins, and to verify the limits of applicability of this method, we have carried out a comprehensive analysis of some mountain fronts in the Southern Apennines. We have compared the following indexes: mountain front sinuosity, swath profile, river long profile, slope/area data, alluvial fan and drainage basin metrics. Overall data point to variable geomorphic features of different mountain fronts and along-strike variability of some parameters at the mountain front scale in response to either rock-type resistance or fault behaviour. This study highlights the importance of the tectonic geomorphology approach in active orogens and suggest that this method is suitable to application worldwide to compare mountain front maturity.

Keywords: Mountain front; tectonic geomorphology; river long profile; Southern Apennines

S14. UNESCO GLOBAL GEOPARKS: GEOHERITAGE ASSESSMENT AND MANAGEMENT - GEO-TOURISM DEVELOPMENT

GEOMORPHOLOGICAL MAPPING AS ENRICHMENT OF CULTURAL HERITAGE: THE CASE STUDY OF QUARRY DUMP DEPOSITS OF THE APUAN ALPS (TUSCANY, ITALY)

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The Apuan Alps (northern Tuscany) are renowned for the marble extraction since the Roman Period. This area, recognized as “Unesco Global Geopark” since 2015, holds naturalistic, geomorphological and geological elements including many geosites also of international interest. The peculiar topographic and morphologic context is strictly related to the human activity which represents one of the most active processes in shaping the landscape. The pluri- millennial quarrying activity composes a dynamic and outstanding anthropogenic landscape that is unique for its aesthetic appearance. Over the millennia, different marble extractive techniques produced not only erosional features such as quarries but also depositional landforms retaining quarry dump deposits, referred as to ravaneti. These latter are very common in the Apuan landscape and represent geomorphosites retaining relevant information on quarrying technologies and methods through time as well as on the timing of different phases of marble extraction. Purpose of this work is to enrich our knowledge of historic sites related to quarrying activity started from 1st millennium BC, and form part of the cultural heritage. This allows to better understand and appreciate the value belonging to such unique and unrepeatable historical sites and it also may contribute to their management and conservation. To reach this goal we applied a multitemporal landscape analysis using aerial photographs integrated with field surveys. Data on ravaneti also refer to size and surface oxidation of marble clasts, debris and vegetation cover, were digitized using a GIS, collected into a properly created geomorphological database of the Apuan Alps and shown in a geomorphological map. The geomorphological characterization of the Apuan extractive areas, with particular regards to ravaneti, represents an important tool for a correct land management and contributes to enrich the cultural heritage allowing the historical reconstruction of extractive areas and suggesting ravaneti worthy of geoconservation and insight for geotourism development.

Keywords: Geomorphological mapping; quarry dump deposit; cultural heritage; geopark; Apuan Alps

GEO-BIODIVERSITY AND CULTURAL ENVIRONMENT OF THE REGIONS SURROUNDING THE CORINTH GULF (GREECE)

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Story maps are widespread as an interactive tool used for science and spatial data communication, information and dissemination. A web-based application using story mapping technology is here presented to highlight places of interest around Corinth Gulf, Greece. A tailored story map that combines thematic webmaps, scenes (3D webmaps), narrative text and multimedia content was created to highlight the geological and cultural environment of the area around Corinth Gulf. The webmaps and scenes were entirely created by a Geographic Information System (GIS) having a great impact on web-based visual presentations. The major part of the central Gulf is an 800-870 m deep, 40km long, 9-12km wide, WNW-ESE elongate flat area between Central Greece and Peloponnese, starting from the Ionian Sea and ending at the Isthmus of Corinth, representing one of Europe's most seismic areas. In the presented application, the aim was to highlight the geodiversity, the cultural and touristic environment and the biodiversity (unique flora and fauna) on both sides of the Gulf. Using Story Maps, this relatively new geographical approach, having open source code, provides many possibilities, as it is easy to be used both from the developer and from the end user. It allows integration of new functions combining many scientific fields to disseminate and understand scientific findings for broader non-technical audiences. Furthermore, it is responsive, and it can be also as interactive as the developer wishes. The developed application can be an ideal way for presenting the geological, geomorphological and cultural contents of other places, especially places which can be characterized as geotopes or protected areas worldwide. Finally, as Corinth Gulf portrays a Natura 2000 area, this application provides a quick access of all useful data to a wide audience, developing the interest and possibly motivating people to learn more and visit the area.

Keywords: Story maps; Natura 2000; Corinth Gulf; geotope

THE VALUE OF HANZHONG TIANKENG GROUP APPLYING FOR UNESCO WORLD GEOPARK

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As the karst landscape mainly on Tiankeng, Hanzhong Tiankeng Group is the transition zone between Yangtze Plate and Qinling Mountains orogenic belt. Through systematic survey and comparative study, it can be concluded that: Developed on karst plateau of Micang mountain that is falling to pieces, Hanzhong Tiankeng Group is of typical autogenic water fenestral karst evolution model with systematic evidences from broad valley of land surface to canyons, corridors, lobbies and Tiankeng underground. The geological remains in Hanzhong Tiankeng Group are well preserved, with scarce plant and animal resources and distinctive habitat system on the bottom of Tiankeng, which provides plots for biodiversity research in Qinba Mountain areas. Found in the northernmost tropical-subtropical karst area of China, Hanzhong Tiankeng Group has abundant resources that a World Geopark should have, it is also a Tiankeng group with the largest number of Tiankeng in karst plateau in China. Hanzhong Tiankeng Group area is not only the birthplace of Han nationality but also a land of plenty, applying for UNESCO World Geopark is of practical significance in poverty alleviation and sustainable development of economy.

Keywords: Hanzhong China; Tiankeng; autogenic water fenestral; karst plateau; UNESCO World Geopark

FROM GEOMORPHOLOGICAL MAPPING TO GEOTOURIST MAPPING. CASE STUDY IN SOUTHEAST TUNISIA

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Tunisia is a tourist destination whose offer has developed around two axes: sea tourism and Sahara tourism. In recent years, the government has been trying to develop a third approach based on cultural tourism. This represents a niche for the development of geotourism. As part of a collaboration between the universities of Tunis and Lausanne, a mapping project oriented towards geotourism has been set up. It has two objectives: (i) the development of a geomorphological mapping legend specific to the Tunisian context; (ii) the elaboration of a methodology to simplify a geomorphological map for a non-specialist audience. This work aims to contribute to the development of an authentic tourism offer in Dahar (Destination Dahar) and is in line with the creation of a geopark in the region. This poster presents a series of maps made in the Oued K'hil region. The area is located on the Dahar plateau (cuesta). It presents a variety of typical structural landforms and runoff erosion landforms (glacis, alluvial fans, slope deposits, gullies...). It is also characterized by relatively mobile forms of erosion and wind accumulation (Barchans, nebkas, micronebkas...). Landforms of anthropogenic origin are also important, including the presence of traces of Roman Limes, as well as hydro-agricultural river damming, known as Jessour. Two 1:50,000 geomorphological maps were produced using a legend developed at the University of Lausanne, used for geomorphological mapping in the mountains and adapted here for arid environments, and a legend developed in Tunisia, inspired by the French legend R.C.P. 77. Three cartographic zooms were performed at 1:10.000 and 1:25.000 scale to capture certain geomorphological details. Finally, a geotourism map of the region is proposed, together with a methodology specifying the processes for simplifying the geomorphological map for geotourism purpose.

Keywords: Geomorphological mapping; geotourism; southeast Tunisia

INVESTIGATING THE GEOTOURISTIC POTENTIALITIES RELATED TO THE INSUBRIC LINE ALONG THE “TRAVERSATA DELLA VAL GRANDE” IN THE SESIA-VAL GRANDE GEOPARK

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Among the aim of geotouristic itineraries, there is the giving value to already existing trails in a region. Within a Geopark, the opportunities and the topics related to Earth Sciences could be several. In the UNESCO Sesia-Val Grande Geopark (Central-Western Italian Alps), one of the most relevant feature is represented by the Insubric Line. This is a tectonic line, or more precisely a deformation belt, related to the Alpine orogeny and crossing the whole Alpine range. The line passes through the Geopark territory from SW to NE. It is considered the most important tectonic line of the Alps due to its spatial extension and to the surficial effects related to deformation, evident at regional scale. In this research the attention was focused on the Insubric Line portion interesting the area of the Sesia-Val Grande Geopark named Val Grande National Park. Between the Premosello Chiovenda (SW) and the Malesco (NE) municipalities, two of the most famous hiking trails of the Alps overlap along the Insubric Line, and are conditioned by its structural conditioning on the relief: the “Traversata della Val Grande” and the “Geoalpine Route”. The first one is a challenging hiking path attracting people from all over Europe and beyond. The second one is the geotouristic version of the “Alpine Route” that goes across the entire Alpine range (<http://www.viageoalpina.eu/>). This proposal aims at emphasizing the scientific and cultural value of a portion of the mentioned itineraries in relation with the Insubric Line. This potential geotrail acquires an even more significance in relation with the cultural (i.e., Comunitour 2019) and geotouristic initiatives (i.e., the “Geoalpine” equipped traits of Pogallo and Mt. Zeda; the “Geotouristic ring of the Loana Valley”; the “Vogogna Geological path”) already present within the Val Grande National Park area of the Sesia-Val Grande Geopark.

Keywords: Insubric Line; geotrail, cultural itinerary; Sesia-Val Grande Geopark

PROPOSAL FOR A DECLARATION OF A GEOPARK IN THE VALLEYS OF SOBA, ASÓN AND MIERA (CANTABRIA, SPAIN)

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The Atlantic Geoparks project, funded by the Interreg Atlantic Area programme, aims to highlight the Geoparks of the Atlantic area. The proposal of the Spanish candidacy for the declaration of a geopark in northern Spain. The territory covered is about 800 km², including 20 municipalities. A database consisting of 66 geosites, natural elements and cultural points of interest has been constructed. This geosites are based on criteria as type of interest, intrinsic or scientific value, potential of use, presence of other complementary values or existence of protection figures. Among others, coastal and aeolian, karst and glaciers landscapes can be found, as well as other stratigraphic, tectonic, and paleontological features. The coastal area of the geopark concentrates a high diversity of environments highly representative of littoral zones of medium latitudes. Barjan and longitudinal dunes in an orthogonal framework climbing the mountainside constitute the relevant dune system of Sonabia. There are also numerous peat bogs with ages ranging from 10,000 years B.P. and 2,000-5,000 years B.P. The fossil forest of Trengandín beach indicates that between 2,890-4,070 years B.P. the sea level was at least 2 m below the current one. The Asón area is internationally recognized for its varied and rich underground heritage with more than 4,000 caves explored. Some of these caves have been used as shelters, at least, during the last 45,000 years (remains paintings of Covalanas cave, World Heritage of UNESCO, have been dated in about 20,000 years). The maximum glacial development of this area occurred between 44,000 and 29,000 years B.P. Glacial remains appear at levels around 600 a.s.l., the lowest of the Iberian Peninsula. The declaration of a geopark constitutes a great opportunity to promote the tourism and development of the territory.

Keywords: UNESCO geopark; sites of geological interest (Geosites); geoheritage; soba; Asón and Miera valleys

THE NATURAL RESERVE OF THE SECCHIA RIVER FLOW REGULATION SYSTEM: A PLACE FOR FLOOD MITIGATION AND PEOPLE AMUSEMENT (PO PLAIN, ITALY)

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This work illustrates the Landscape Map of the Natural Reserve of the Secchia River which is located in the area of the flow regulation system of this river in the Po Plain. The Secchia River is a right tributary of the Po River which collect water from the Emilian Apennines and it flows through the west outskirts of Modena. Where it flows on to the plain, it formed a large alluvial fan, during the Quaternary; the Natural Reserve is located in the north - western margin of the fan. The waters of the Secchia R. have periodically caused floods which occurred mainly between 1960 and 1973 and were determined by changes in the flow and transfer velocity of the volume of water in the bed; the more recent flood occurred in 2014. Flow regulation system was constructed in 1979, in natural depressed areas adjacent to the course of the river, in order to control this hydrological hazard. The structure consists principally of a regulating dam built across the river bed and a storage basin bordered by embankments. This area on time have acquired naturalistic values so that Region Emilia-Romagna established the natural reserve in 1996 (area of 260 hectares), that acts as a real green lung within the highly populated and intensely productive territory. In the area various tourist structures have been built such as places of refreshment and sports facilities; some of them are flooded during the exceptional floods of the river. The Landscape map represents a document of knowledge for the establishment of a project on hydraulic safety, re-naturalization of abandoned quarrying areas, promotion of sustainable tourism and improvement of the use of the area. In the Landscape Map are mapped the hydrographic network, the fluvial landforms and deposits, the anthropogenic landforms, the vegetation and tourist information.

Keywords: natural reserve; flow regulation system; geomorphological mapping; landscape map; Secchia river

ASSESSING GEODIVERSITY IN TIERRA DEL FUEGO (SOUTHERN PATAGONIA, ARGENTINA). A STRATEGY TO PROMOTE GEOTOURISM

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This contribution aims to present three hierarchized areas in central and northern Tierra del Fuego (Argentina) whose geodiversity may be used for educational purposes to encourage the Earth Sciences and to design of geotourism strategies. In comparison with south Tierra del Fuego, tourism development in both areas is still low. After applying a specific methodology, 163 georesources were identified, described, mapped and classified. 123 of them represent enclaves –i.e. geological or geomorphological sites of scientific or didactic interest- and the other 40 refer to views –i.e. panoramic points to appreciate landscape as a whole-. For enclaves assessment, three values were considered as a first approach: aesthetic, use and intrinsic. As a second approach, enclaves were assessed considering level of conservation, singularity, diversity of elements, present activities and accessibility. The enclaves were hierarchically organized around the Fuegian localities: Tolhuin, Río Grande and San Sebastian. The first includes: three coastal lakes, a stock, cliffs made on till, a river mouth, a delta, a lake formed by pull-apart basins on a transform plate boundary and its storm berm. The second includes: abrasion platform, paleocliff, estuary, spit and capes; the third includes: erratic boulder field, receding cliffs, inclined sedimentary strata, an 11-meter-tidal-range bay, Holocene marshes and a cape. The hierarchized area around Tolhuin could develop a geotourism strategy treasuring the singular geographic position regarding the two tectonic plates involved in its geology as well as glacial processes. The georesources around Río Grande offer an opportunity to interpret current exogenous processes, past sea level fluctuations and climate changes. The hierarchized area around San Sebastian has georesources that allow the interpretation of coastal processes in a place affected by glaciations and the postglacial marine transgression. The methodology applied and the georesources analysed proved to be useful as tools to outline a geotourism strategy.

Keywords: Geodiversity; geotourism; Tierra del Fuego

GEOMORPHOSITES AS ENVIRONMENTAL HERITAGE IN THE PROPOSAL OF GEOPARK CAMINHOS DOS CANIONS DO SUL – SC/RS – BRAZIL

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The states of Santa Catarina and Rio Grande do Sul, south of Brazil, are strived in the proposition of the Geopark “Caminhos dos Canions do Sul” to UNESCO. Thus, it is constructing the inventory of geosites, which highlights the scientific, educational and landscape potential of geological, geomorphological, paleontological sites of interests in the territory. In geomorphology, the work seeks to identify from the scientific, cultural, socioeconomic and scenic relevance of the geomorphosites. These consist in significant geomorphological attributes of the landforms, that qualify them as components of the heritage. Here are displayed examples of various values in the geopark assigned to geomorphosites. From the scientific point of view, the landform aspects are considered a geomorphosite when are covered of meaning. These landforms can have value from the evolutionary point of view, as paleogeomorphological testimony or by the multiplicity of active geomorphological processes. As an example, it has scarps and deep valleys in shapes of canyons. The geomorphological asset can compose or be testimony of one artistic representation or cultural tradition. In the first case, it can have relevant artwork that represents landscapes, and, in the second case, locations described by writers or part of religious or traditions iconography. Inside the territory, the “taipas” (walls) of rocks are located on the upland areas of Santa Catarina or the trails of the “tropeiros” on the scarp link the coastal plain to the upland areas. One geomorphological asset can have socioeconomic value if used for touristic or sportive purposes, as well as landscape value like a component of grandeur or like attraction that, from the sensibilization, contributes for understanding the landscape dynamics. It is believed that geomorphology has an essential role in the geomorphosites designation by its value as environmental heritage, mainly when refers to aspects from the scientific point of view.

Keywords: Geomorphosites; geodiversity values; geoparks; Brazil

CULTURAL VALUES OF GEOMORPHOSITES AND ABIOTIC ECOSYSTEM SERVICES

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Cultural values of geodiversity have been already recognized and reflected in numerous approaches and methods. Regarding the concept of geomorphosites, cultural values are usually assessed within the group of “added values” and they refer e.g. to historical, archaeological, religious, spiritual, artistic, geohistorical and architectonical aspects. In some cases, cultural values are linked to educational and tourist use of the geomorphosites. During the last decades, a considerable number of case studies has been presented, however, these studies mainly focused on the natural or rural areas with limited influence of human activities. In urban areas and on the sites that are strongly influenced by human activities, some methods may cause ambiguities and negatively influence the objectivity of results. Other possibility of assessing the cultural values (respectively cultural benefits) is to use the concept of ecosystem services. In 2018, the abiotic ecosystem services were added to the Common International Classification of Ecosystem Services and the cultural services were also included. These values refer to natural, abiotic characteristics of nature that enable active or passive physical and experimental interactions that enable intellectual activities, that have symbolic or spiritual importance or that may be considered a part of heritage. This approach has not been examined yet in many studies. On several examples from the Czech Republic (Bohemian Paradise UNESCO Global Geopark and Brno city), both approaches are applied on the assessment of cultural values and benefits of particular geomorphosites. Based on this, the possible pitfalls and problems are identified and the suitability of the methods is discussed.

Keywords: Cultural value; geomorphosite assessment; abiotic ecosystem services

COMPARISON OF AERIAL AND TERRESTRIAL PHOTOGRAMMETRY FOR 3D MAPPING OF PETRIFIED TREES, LESVOS GEOPARK

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New technologies in data acquisition led to an increasing interest in capturing high-resolution images using Small Unmanned Aerial Systems (SUAS) and terrestrial means for geological research. The purpose of this study is to compare two different data acquisition methods in order to create accurate and precise cartographic products. Three dimensional (3D) models generated from images with ground sampling distance 0.1cm-0.3cm acquired by SUAS and a DSLR camera were used to map a group of petrified tree trunks at Sigri, Lesvos island, Greece. The methodology involves two different workflows: aerial and terrestrial survey carefully planned in order to serve photogrammetric specifications to map the location accurately, precisely and rapidly. In total, mapped 12 petrified tree trunks of each method separately. Then 3D surface models and the equivalent 3D models were generated using the “structure from motion” (SfM) algorithm. Location, geometric characteristics and volume of the petrified trees are extracted and calculated from this information acquired by 3D models. The comparison made among, the 3D cartographic products which acquired by SUAS, 3D cartographic products acquired by DSLR camera and measurements acquired by conventional methods. The results of the survey, illustrates how aerial and terrestrial remote sensing techniques can offer accurate 3D spatial information of location, orientation and geological position of the petrified trees.

Keywords: Lesvos geopark; petrified trees; SUAS; terrestrial photogrammetry

PRELIMINARY GEOHERITAGE ANALYSIS FOR THE CREATION OF A GEOPARK IN THE DAHAR REGION, SOUTHEAST TUNISIA

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The Dahar is a mountainous massif (maximum altitude 713 m a.s.l.), formed by plateaus slightly inclined to the west (cuestas) until the first dunes of the Sahara, incised by valleys and depressions partially filled with Pleistocene wind deposits (loess), overhanging a coastal plain to the east, the Jeffara plain. At the request of the National Mines Office of Tunisia and the Swisscontact Foundation, a preliminary analysis for the creation of a geopark in the Dahar region in southeastern Tunisia was carried out. This work contributes both to the development of a regional cultural tourism offer (Destination Dahar) and to the creation of a geopark to protect and enhance geoheritage. The following work has been carried out: (i) the geological, geomorphological and geographical characterization of the region; (ii) the delimitation of the potential geopark based on the selection of 29 geosites (geomorphological, sedimentological, paleontological, landscape); (iii) characterization of the selected geosites, including a description of the site, analysis of access, level of protection and potential threats, and their classification according to primary and secondary geological interest; (iv) classification of the geosites into four categories of value (universal, regional (Mediterranean region), national, local); (v) analysis of geotourism potential and their classification into four forms of tourism (ecotourism, integrated geotourism, geocultural tourism, geological tourism) adapted to different audience profiles; (vi) production of several synthesis maps at the geopark level; (vi) analysis of possible forms of governance of the geopark based on the experience of European geoparks; (vii) detailed geomorphological analysis of selected geomorphosites and their characterization using the geomorphosite evaluation method of the University of Lausanne.

Keywords: Southeast Tunisia; Dahar; geoheritage; geotourism; geopark

QUANTITATIVE ASSESSMENT OF GEOHERITAGE IN MALTA (CENTRAL MEDITERRANEAN)

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The recognition, quantitative assessment and selection of the most important sites of geological and geomorphological interest are fundamental steps in any geoconservation strategy. The Maltese archipelago, located in central Mediterranean Sea, still conserves a myriad of geological and geomorphological features, notwithstanding the increasing pressures from population growth and mass tourism investment over recent decades. The islands' geoheritage is of great relevance and interest both in terms of their contribution to the understanding of the geological processes acting through time on landscape and also for their aesthetic importance. For this reason, based on several methodologies previously proposed by various authors, the current work presents the results of a quantitative assessment of geosites that have the potential to be recognised as both natural heritage and tourist resources with potential economic benefits. In particular, the methodology applied combines sites of geological interest with landscape cultural components, which are partly determined by the geomorphological context in which they are situated. It considers both their scientific value and additional value. The scientific value is assessed using a set of criteria as representativeness, integrity, rarity, geological diversity and scientific knowledge. The additional value is assessed considering different categories that show the links existing between geoheritage and other aspects of nature and culture, as educational, ecological, historical, aesthetical and use values of the sites. The research focused on the northern part of Malta, where the interplay between geological features and geomorphological processes provides a striking example of a landscape with strong scientific and aesthetic interest and value. The results provide useful knowledge for the definition of strategies aimed at the development of a sustainable and responsible tourism and a contribution to its possible nomination as UNESCO Global Geopark.

Keywords: Geoheritage assessment; geosites; Malta

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