Proceedings of

The 11th Workshop of the IAG/AIG SEDIBUD

(Sediment Budgets in Cold Environments) Working Group

"Relationships between climate change, vegetation cover and sediment fluxes in high latitude/high altitude cold environments"

Research Station of the Babeş-Bolyai University,

Baru (Hunedoara County, Romania)

September 5 – 8, 2017

PROGRAMME

Tuesday, September 5th, 2017

17:00 Opening of the registration desk

19:00 Welcome cocktail, dinner & icebreaker

Wednesday, September 6th, 2017

8:00 Breakfast

9:00 Chair's welcome and opening remarks

Oral presentations

Session 1, chaired by Olimpiu Pop

9:15 Jasper Knight & Stephan Harrison

The role of rock glaciers in the paraglacial history of deglacierizing mountains.

9:35 Adrian Cristian Ardelean, Alexandru Onaca, Petru Urdea, Florina Ardelean

Monitoring rockwall retreat and rockfall supply within the Căldarea Pietroasă glacial cirque (Făgăraș Mountains).

09:55 Ahinora Baltakova, Rossitza Kenderova, Georgi Rachev, Dimitar Krenchev, Sonya Stoyanova, Petko Bozhkov

Results from ground surface temperature measurements used as indication of possible permafrost occurrence in the Pirin Mountains.

10:15 Răzvan Popescu, Alfred Vespremeanu-Stroe, Mirela Vasile, Nicolae Cruceru

Rock glaciers debris characteristics and dynamics in Southern Carpathians.

10:35 Coffee break

Session 2, chaired by Ahinora Baltakova

11:00 Katja Laute & Achim Alfred Beylich

Potential effects of climate change on future snow avalanche activity in western Norway deduced from meteorological data.

11:20 Patrick Chiroiu, Alexandru Onaca, Petru Urdea, Adrian Cristian Ardelean

Unraveling the snow avalanche regime of the last century in the Făgăraș Mountains, Southern Carpathians: an integrative dendrogeomorphic approach.

11:40 Olimpiu Pop, Flaviu Meseşan, Mircea Alexe, Ionela-Georgiana Gavrilă, Stefan Buimagă-Iarinca, Iulian Holobâcă, Liviu Buzilă, Ioan-Aurel Irimuş, George Rus, Cosmin Timofte

Assessment of the sedimentary fluxes and morphological changes in mining areas from Călimani Mountains (Eastern Carpathians, Romania) based on topographic surveys and dendrogeomorphology.

12:00 Lunch

Poster presentations

Session 3, chaired by Alexandru Onaca

14:30 Petko Bozhkov

Application of Sediment Connectivity Index in the Area of Zemen Gorge (West Bulgaria).

Achim Alfred Beylich & Katja Laute

Relationships between morphoclimate, vegetation cover and solute and solid fluxes in the boreal Homla drainage basin in middle Norway.

Waldemar Kociuba & Grzegorz Janicki

Contemporary transformations of a gravel-bed proglacial river under rapid valley glacier recession (SW Spitsbergen).

Meseșan Flaviu, Olimpiu Pop, Ionela-Georgiana Gavrilă

Snow-avalanche activity assessed by dendrogeomorphology and remote sensing in Parâng Mountains.

Irene Bollati

Denudation rates and evolution of landforms in mountain ranges: examples from Alps and Apennines.

Ionela-Georgiana Gavrilă, Olimpiu Pop, Flaviu Meseşan, Cosmin Timofte

Frequency of high-magnitude snow avalanches reconstructed with tree rings in Rodna Mountains (Eastern Carpathians, Romania).

Anuschka Buter, Francesco Comiti, Tobias Heckmann

Linking geomorphological connectivity to sediment transport measurements in an Alpine glaciated basin: present dynamics and future scenarios.

Sonya Stoyanova

Preliminary results from fluvio-morphological and slope wash studies in the headwater of Sinanitsa River, the Pirin Mountains, Southwestern Bulgaria.

David Krause & Marek Křížek

Dynamic slope processes in the mid-mountain area of the Central Europe – an example from the Eastern High Sudetes.

Cosmin Timofte, Flaviu Meseşan, Ionela-Georgiana Gavrilă, Olimpiu Pop

Assessing the snow-avalanche activity in Șureanu Mountains using tree-ring analyses.

Olimpiu Pop, Răzvan Ichim, Andrei Diaconu, Ioan Tanțău, Iulian Holobâcă, Ionela-Georgiana Gavrilă, Flaviu Meseşan, Cosmin Timofte

Exploring the potential of biological indicators from peat bog archives to reveal sediment transfer and deposition by snow avalanches in Şureanu Mountains (Southern Carpathians, Romania).

Armelle Decaulne, Najat Bhiry, Julien Lebrun, Samuel Veilleux , Denis Sarrazin

Slope types, slope processes and talus morphometry in Lac à l'Eau Claire, western Nunavik.

Armelle Decaulne, Þorsteinn Sæmundsson, Achim Alfred Beylich

The I.A.G./A.I.G. Working Group SEDIBUD – a long-lasting effort to enhance scientific research and collaborations in high-latitude and high-altitude cold environments.

Achim Alfred Beylich

Main outcomes and scientific products of the I.A.G./A.I.G. SEDIBUD (Sediment Budgets in Cold Environments) program (2005 – 2017).

16:00 Coffee break

16:30 SEDIBUD business meeting

19:00 Dinner

Thursday, September 7th, 2017: One-day field trip

8:00 Breakfast

9:00 Departure for one-day field trip in the alpine area of Parâng Mountains: Cârja Peak (2405 m a.s.l.), Mija glacial valley and lake. Estimated time for the field trip: 6 - 7h.

18:00 Dinner at the restaurant in Petroşani city (after the field-trip).

Friday, September 8th, 2017

8:00 Breakfast

9:00 Chair`s summary and closing comments

10:00 Departure of the participants

Organizing Committee

Achim A. Beylich, *Geological Survey of Norway (NGU), Trondheim, Norway*

Olimpiu Pop, *Babeş-Bolyai University, Faculty of Geography, Laboratory of Dendrochronology, Cluj-Napoca, Romania*

Ionela-Georgiana Gavrilă, *Babeş-Bolyai University, Faculty of Geography, Laboratory of Dendrochronology, Cluj-Napoca, Romania*

Flaviu Meseşan, *Babeş-Bolyai University, Faculty of Geography, Laboratory of Dendrochronology, Cluj-Napoca, Romania*

Alexandru Onaca, *West University of Timişoara, Faculty of Chemistry, Biology and Geography, Department of Geography, Timişoara, Romania*

Florina Ardelean, *West University of Timişoara, Faculty of Chemistry, Biology and Geography, Department of Geography, Timişoara, Romania*

Dănuț Petrea, *Babeş-Bolyai University, Faculty of Geography, Cluj-Napoca, Romania*

Monitoring rockwall retreat and rockfall supply within the Căldarea Pietroasă glacial cirque (Făgăraș Mountians)

Adrian C. Ardelean[1,2], Alexandru Onaca[1], Petru Urdea[1], Florina Ardelean[1]

[1] *West University of Timișoara, Department of Geography, Timiș, Romania*
[2] *National Museum of Banat, Department of Archeology, Timișoara, Romania*

High mountains systems are known to be susceptible to global climatic changes, having a quick reaction to rises in air temperature (Kääb, et al., 2005). As geomorphologic processes governing sediment transfer and landform evolution within the alpine environment are very sensitive to climate and vegetation cover it is anticipated that global temperature rise will have a major impact on landscape evolution within high-altitude and high-latitude cold environments (Beylich, et al., 2011).

As temporal and spatial interaction between climatic and geomorphic processes have led to the current distribution of the alpine landscape (Schrott, et al., 2003) the study of the production, transport and sediment storage in drainage basins is an essential step for the better understanding of the evolution of the alpine landscape, especially in densely populated mountain areas with a high potential for the occurrence of natural hazards (Taylor and Kite, 2006). Therefore, in order to get an overview of current day sediment input continuous measurement regarding backweathering rates and rockfall supply offer an important prerequisite for an accurate, small scale, sediment budget estimation within high mountain environments.

Quantitative data on rockfall supply and backweathering has been provided for the alpine ranges of Europe by numerous field studies starting with the research of Rapp (1960); thus the current approach present the first results of continuous measurements on two robust construction nets installed at the foot of solid rock faces within the Căldarea Pietroasă hanging valley (Făgăraș Mountains). The present study aims to investigate the multiannual sediment input at two source areas via two small sediment traps of 30 m^2 (installed in the summer of 2015) and 10 m^2 (installed in the summer of 2016). Due to the relatively inclined slopes of the target area the nets were equipped with 60 cm high steel fences in order to prevent rocks from rolling out of the net area. Rock particles that fell onto the nets were later weighted and removed. In order to get a more complete annual assessment of sediment input, 3D models of the rock walls were obtained from terrestrial laser scanner surveys starting with 2017.

At the first site the mean annual input of sediments was 3.5 kg. The clasts weight vary between 50 and 750 g, whereas the largest clast having a length of 17 cm and a width of 14 cm. After one year of measurements the second site revealed a lower sediment input of 4.2 kg of debris, with the largest blocks having around 2800 g.

References:

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Results from ground surface temperature measurements used as indication of possible permafrost occurrence in the Pirin Mountains

Ahinora Baltakova[1], Rossitza Kenderova[1], Georgi Rachev[1], Dimitar Krenchev[1], Sonya Stoyanova[1], Petko Bozhkov[1]

[1]*Sofia University "St. Kliment Ohridski", Faculty of Geology and Geography, Department Climatology, Hydrology and Geomorphology, Sofia, Bulgaria*

Ground surface themperature (GTS) is one of the most common used indicators of permafrost occurrence and a basis for further studies of cryogenic processes out of continues permafrost areas. The Pirin Mountains (Vihren peak, 2914 m, Rila-Rhodopean Massif, SW Bulgaria), the second highest in Bulgaria and third on the Balkans Peninsula, was never an object of permafrost studies, despite of relict and present periglacial landforms presence, until our observations, started in 2012. GTS measurements proved freezing period of 8 to 6 months (depending on slope aspect). Observations of 2-4 years showed serious regime variability every year and suggest that only one year observation is more than insufficient period for adequate conclusions about possibility of permafrost occurrence in this particular case.

Three sites were monitored with different slope aspect– Kazanite Cirque (Banderitsa Valley, N-NE aspect), Begovitsa Cirque (Begovitsa Valley, S-SW aspect) and Sinanitsa Cirque (Sinanitsa Valley, W-NW aspect) on the same elevation – 2200 m, defined as the Alpine boundary in the Bulgarian mountains and. In Kazanite site the exposure control also was taken into account and the monitoring developed on higher altitudes. Thermometer loggers were installed in shallow soil cover at 2-3 cm depth and programmed to record hourly data.

All of the thermometers showed that on 2200 m a.s.l. GTS remained isothermal at 0 ^{o}C under continues snow cover, which indicates absence of permafrost. At the highest altitude monitored in Golyam Kazan Cirque (2461 m, SW aspect) GTS regime is characterized by frequent freeze–thaw cycles during the cold season which indicates strong wind action control. The only site with indication for very low permafrost probability is located in a concave setting, which favours wind-driven snow accumulation and lower incoming solar radiation due to the shading effect of a ridge, inducing the conservation of snow packs. We present first results and further observations on different surfaces and borehole measurements are foreseen. This is the first time that real measurements used for indication of probable permafrost has been reported in the mountains of Bulgaria.

Relationships between morphoclimate, vegetation cover, and solute and solid fluxes in the boreal Homla drainage basin in middle Norway

Achim A. Beylich[1], Katja Laute[2]

[1]*Geological Survey of Norway (NGU), P.O. Box 6315 Torgard, NO-7491 Trondheim, Norway*
[2]*Université de Bretagne Occidentale, IUEM, CNRS, UMR LETG, Technopôle Brest-Iroise, rue Dumont d'Urville, 29280 Plouzané, France*

It is generally accepted that ongoing and future climate change will cause major changes in contemporary Earth surface systems. Changing climate and vegetation cover changes influence sediment dynamics and sedimentary budgets in defined drainage basin systems. Interdisciplinary research efforts for the better understanding of the spatio-temporal patterns of geomorphic processes operating under changing climate and varying vegetation cover conditions are required. From a process-geomorphological point of view it is accordingly of increasing importance to obtain an improved knowledge of the complex relationships between contemporary geomorphological processes, vegetation cover and present-day climatic conditions to achieve more realistic assessments of the possible geomorphological consequences of climate change.

Until recently, the present-day climate of a defined area has often only been characterized by monthly and annual means or sum values of wind speed, air temperature and precipitation. This type of climatic information is in many cases sufficient to explain given vegetation cover conditions and patterns. However, as most geomorphologic surface processes, acting under given vegetation cover conditions, consist of discrete process events which are not or only partly correlated to the meteorological means or sum values, there is an obvious need for an additional approach of statistical analysis of meteorological raw data.

In this study the "morphoclimate" of the Homla drainage basin situated in a boreal environment in Trøndelag in middle Norway is analyzed and presented. The selected Homla drainage basin is with its given catchment characteristics considered to be a typical drainage basin system for middle Norway. "Morphoclimate" according to Ahnert (e.g., 1982) is particularly related to process geomorphological needs and, in this sense, is defined as the totality of those climatic characteristics of a defined area that influence the type, frequency, duration and intensity of the exogenic geomorphologic processes in this area. The statistical method primarily used in this context is the magnitude-frequency analysis. Particular emphasis is on (i) the frequencies or recurrence intervals of meteorological events of given magnitudes, and (ii) the frequencies of geomorphologically important thresholds. Aspects of the current wind, temperature and precipitation regimes that control directly and indirectly (through vegetation cover) the type, frequency, duration and intensity of the contemporary denudational surface processes as well as the sedimentary budget in the selected drainage basin system are presented.

Runoff in the boreal Homla drainage basin is occurring year-round and the contemporary geomorphologic process activity is altogether characterized by a clear dominance of chemical denudation over mechanical fluvial denudation. The general intensity of the denudational surface processes operating under the present-day morphoclimate and vegetation cover conditions is low. Ongoing changes of the

morphoclimate affect, together with human activities (agriculture, forestry, water power), the contemporary pattern of geomorphic process activity both directly and indirectly through changes of the vegetation cover conditions.

Main outcomes and scientific products of the I.A.G. / A.I.G. SEDIBUD (Sediment Budgets in Cold Environments) program (2005 – 2017)

Achim A. Beylich[1] and the SEDIBUD Team

[1]*Geological Survey of Norway (NGU), P.O. Box 6315 Torgard, NO-7491 Trondheim, Norway*

The SEDIBUD (Sediment Budgets in Cold Environments) program, building on the European Science Foundation (ESF) network SEDIFLUX (Sedimentary Source-to-Sink Fluxes in Cold Environments, since 2004) was formed in 2005 as a new program (working group) of the International Association of Geomorphologists (I.A.G./A.I.G.). The major goal of this new program has been to address and close the still existing key knowledge gap on how ongoing and projected climate change in cold regions is affecting and will alter the fluxes of sediments, solutes and nutrients.

Amplified climate change and ecological sensitivity of high-latitude and high-altitude cold climate environments was highlighted as a key global environmental issue. Ongoing and projected climate change in largely undisturbed cold regions is modifying melt-season duration and intensity, along with the number of extreme rainfall events, total annual precipitation and the balance between snowfall and rainfall. Similarly, changes to the thermal balance are reducing the extent of permafrost and seasonal ground frost and increase active-layer depths. These combined effects are changing Earth surface environments in cold regions and alter the fluxes of sediments, solutes and nutrients. There is general agreement on the high importance of this key global environmental issue. However, the absence of quantitative data and coordinated analysis to understand the sensitivity of the Earth surface environment is acute in cold climate regions. Contemporary cold climate environments generally provide the opportunity to identify solute and sedimentary systems where anthropogenic impacts are still less important than the effects of climate change. Accordingly, it is still possible to develop a library of baseline fluvial yields and sedimentary budgets before the natural environment is completely transformed.

SEDIBUD (2005 – 2017) has about 400 members worldwide and the steering committee of this international program is composed of eleven scientists from ten different countries. The central research question of this global program over the past 12 years has been to: *Assess and model the contemporary sedimentary fluxes in cold climates, with emphasis on both particulate and dissolved components*.

Research activities carried out at 56 defined SEDIBUD key test sites (selected catchment systems) by SEDIBUD members have varied by scientific program, logistics and available resources, but have in most cases represented interdisciplinary collaborations of geomorphologists, hydrologists, ecologists, permafrost scientists, quaternary geologists and glaciologists with different levels of detail. SEDIBUD has developed a key set of primary research data requirements intended to incorporate results from these varied projects which has allowed quantitative analyses across the program. Defined SEDIBUD key test sites provide field data on annual climatic conditions, total discharge and particulate and dissolved fluxes and yields as well as information on other relevant denudational Earth surface processes. A number of selected SEDIBUD key test sites are also providing high-resolution data on climatic conditions, runoff

and solute and sedimentary fluxes and yields, which – in addition to the annual data – contribute to the SEDIBUD metadata database.

To support these coordinated and integrative research efforts, the SEDIFLUX manual and a set of framework papers and book chapters have been produced to introduce and establish the new integrative approach and common methods and data standards. Comparable field-datasets from different SEDIBUD key test sites are analyzed and integrated to address key research questions of the SEDIBUD program as defined in the SEDIBUB working group objective.

A key SEDIBUD synthesis book was published by the group in 2016 and a synthesis key paper is currently in preparation. Detailed information on all SEDIBUD activities, outcomes and published scientific products can be found at http://www.geomorph.org/sedibud-working-group/.

Denudation rates and evolution of landforms in mountain ranges: examples from Alps and Apennines

Bollati Irene[1], Pelfini[1], Trombino[1], Del Monte[2], Giovanni Mortara[3], Reynard E.[4]

[1] *Earth Science Department A. Desio, Università degli Studi di Milano, Via Mangiagalli, 34, I-20133, Italy*
[2]*Earth Science Department of Università di Roma La Sapienza*
[3]*National Research Council (CNR – IRPI) Torino*
[4]*Institute of Geography and Sustainability of the University of Lausanne*

Denudation processes linked with water action in mountain environments proceed with proper rates and contribute to produce badlands-like landforms. Denudation rates depend on the typology of substrates, on the structural and tectonic settings and on the climate features of the regions. In specific cases, also human interventions contribute to modify denudation trends. Mountain chains located within the Italian peninsula are characterized by a great variety of morphodynamic and morphoclimatic settings, due to the altitudinal and latitudinal distribution of the territory. A series of sites, located within Alps, on both the Italian and the Swiss sides, and Apennines, characterized by badlands-like landforms, have been investigated by means of different methodologies. The researches has been carried out in collaboration with other research groups* and imply:

i. geomorphological mapping and multi-temporal analysis on changes in the width of the areas characterized by active denudation,
ii. measurements of denudation rates through iron pins monitoring and analysis on tree roots exposed by erosion and
iii. multitemporal analysis of denudation trends through examination of historical iconographic material.

The selection of sites allowed to identify some sample sites different for:

i. substrates (e.g., glacial deposits, marine shales, soluble rocks);
ii. combination of morphodynamic agents (glacial exharation, gravity, running water action);
iii. influence of the structural setting (e.g., presence of Deep Seated Gravitational Slope Deformation);
iv. climate conditions (Alpine vs Mediterranean climate). The choice of the study cases was also influenced by the representativeness of the sites in the framework of geoheritage: quite all of the sites are officially recognized as sites of geological and geomorphological interest and valuable under different perspectives. The importance of understanding their dynamics is fundamental for their proper management in term of conservation and/or divulgation purposes.

Application of Sediment Connectivity Index in the Area of Zemen Gorge (West Bulgaria)

Petko Bozhkov[1]

[1]*Sofia University "St. Kliment Ohridski", Faculty of Geology and Geography, Sofia, Bulgaria*

The efficiency of sediment transfer between hillslopes and a given feature of interest is known as sediment connectivity (coupling). The concept of sediment connectivity originates from sediment budget studies and it is related with USLE-RUSLE models, sediment yield assessment and computation of sediment delivery ratio (SDR) (Borselli et al., 2008; Cavalli et al., 2013). It represents the probability that sediment particles will (or would not) reach local sinks. The degree of sediment connectivity is measured using a geomorphologic index developed by Borselli et al. (2008) and modified by Cavalli et al. (2013, 2016). The index of sediment connectivity (IC) is topography-based and allows quantitative analysis of connectivity pattern that exist in a given area. In this study the area of Zemen Gorge is used as test site for computation of IC values. The area is chosen for its specific morphological characteristics. The results are compared with data from field work and preliminary results from ongoing geomorphological and sedimentological research of weathering and slope processes. IC values can be calculated using the freely available stand-alone application called SedInConnect (current version 2.3) developed by Crema et al., 2015. Only a single shapefile (polygon) and a DEM (with cell size 5x5 m) are used as an input data in order to obtain IC values with respect to the main channels – Stuma River and its tributaries. This allows estimating the probability that sediment eroded from the hillslopes will attain the river bed.

Conclusions about the degree of connectivity and the spatial distribution of the index values are suggested. Large positive values indicate increased level of connectivity, i.e. coupling, while negative values describe the areas with low sediment connectivity (decoupling). The connectivity map shows the linkage between different parts of the terrain. The degree of connectivity is the greatest at places with high drainage density, steep slope, and large local relief. It is possible due to the large number of streams from different orders. However, more studies are needed in order to estimate the rates of erosion and sediment redeposition in the area of interest.

References:

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Linking geomorphological connectivity to sediment transport measurements in an Alpine glaciated basin: present dynamics and future scenarios

Anuschka Buter[1], Francesco Comiti[1], Tobias Heckmann[2]

[1] *Free University of Bozen-Bolzano*
[2] *Catholic University of Eichstätt-Ingolstadt*

There are several recent studies in geomorphology focusing on the topic of sediment connectivity (e.g. Cavalli et al. 2013; Fryirs 2013; Heckmann and Schwanghart 2013; Bracken et al. 2015; Cossart and Fressard 2016). Sediment connectivity describes how and to what extent sediment fluxes are linked between geomorphic zones within the landscape (Cavalli et al. 2013; Bracken et al. 2015). It is widely seen as an important and promising research area, which could help handling sediment and water management issues which affect, for example, river morphology, river ecology, hydropower plants or the likelihood of natural hazard events (Fryirs 2013; Bracken et al. 2015). This is important, for example to responsible authorities or operators of water power plants, especially regarding the fact that mountainous and glaciated mountain environments and hence also the hydrological dynamics and the sediment transport will be sensitively affected by the changing climate conditions (Micheletti & Lane 2016; Lane et al. 2017).

A newly presented and innovative method of analyzing sediment connectivity is the possibility of using the mathematical branch of graph theory (Phillips 2012; Heckmann & Schwanghart 2013; Phillips et al. 2015). Graph theory is scientifically widely used in e.g. computer science, sociology or transport and infrastructure but also in different sectors of geosciences whenever network analysis is conducted, like for example in ecological, hydrological, seismic or meteorological issues (Heckmann et al. 2014; Phillips et al. 2015). It is perfectly applicable to structure, analyze and define network systems, objects within the system and interactions between those objects. Recently its potential in studying and analyzing sediment connectivity quantitatively has been tested (Heckmann & Schwanghart 2013; Phillips et al. 2015; Cossart & Fressard 2016; Heckmann et al. 2016).

In the present PhD research project, which started in November 2016, this method is applied to study the sediment connectivity of an intermediate size (about 150 km² in area), glaciated Alpine catchment in the Vinschgau/Venosta Valley (Sulden/Solda River, Italian Alps).

Nodes in a GIS will represent the relevant determined spatial units of a geomorphological map. Within the software "SAGA GIS" a numerical and spatial explicit modelling approach will be applied to simulate the sediment transfer. Each sediment transport process will be considered by a different model, integrating the respective specific threshold parameters. The resulting sediment transport pathways, the edges of the resulting graphs, will subsequently be registered and will contain information on the start and end node as well as the type of process. The final edge matrix will be processed with the software "R" to statistically analyze the graphs and furthermore define properties of the nodes and edges. The spatial distribution of sediment source, transport and deposition areas and related sediment pathways will be defined for different and contrasting sub-catchments, and related to quantitative measures of the sediment fluxes provided by monitored stations in the basin.

Furthermore, the simulation of extreme meteorological events, implemented in the model, e.g. in form of a higher sediment transport capacity in the river channel or a lower slope threshold for debris flows, will give valuable insights in the complex system of sediment transport in a mountain environment. Potential locations of extreme sediment fluxes, which could affect the population, infrastructure or hydroelectric facilities can be identified in advance and consequently, preventive operations can be planned by the authorities. In addition, consequences of higher or lower sediment transport capacities, induced, for example, due to restorative or protective buildings or dams, can be analyzed within the model. All these parameters will also be subject of the envisaged sensitivity analysis to understand the functioning of the sediment cascades and the respective sediment connectivity in the study area.

Additionally, multi-temporal digital elevation models (DEMs) will be analyzed using DEMs of Difference (DoDs) and flow routing algorithms to determine sediment pathways and to calculate sediment delivery ratios (SDR). The sediment delivery ratio is commonly used as a "performance factor" of sediment connectivity; it is defined by the ratio of sediment yield at the catchment outlet and gross erosion. However, in most cases in the past the SDR was estimated and not calculated. Consequently, this new approach can be seen as a major advancement (Heckmann & Verica 2017).

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Unraveling the snow avalanche regime of the last century in the Făgăraș Mountains, Southern Carpathians: an integrative dendrogeomprhic approach

Patrick Chiroiu[1], Alexandru Onaca[1], Petru Urdea[1], Cristian A. Ardelean[1]

[1] *West University of Timișoara, Department of Geography, V. Pârvan, no. 4, Timișoara 300223, Timiș, Romania*

Snow avalanches represent one of the most frequent and destructive mass movements which occur in mountainous regions all over the world, posing a constant threat to human activities, settlements and infrastructure. Prevention and effective risk management measures are based on specific knowledge obtained by the analysis of past process behavior. Except the major events which caused loss of lives and important material damage, in Romania, quantitative data on the occurrence and characteristics of past snow avalanches is almost completely missing. In these cases, "silent witnesses" such as tree-ring records are employed to reconstruct the regime of past mass movements. Dendrogeomorphology, besides being a well established method used in mass movement analyses, is continuously developing new standard procedures in order to amplify the signal related to geomorphic disturbance and to reduce the "noise" induced by other factors, such as climate extremes or insect outbreaks.

A novel four-step procedure proposed by Favillier et al., (in press) was adapted and applied to reconstruct snow avalanches on 12 forested paths in the Fagaraș Mountains, Southern Carpathians. The approach consists of combining avalanche event detection methods in order to maximize the signal-noise ratio and to exclude the influence of climatic and other exogenous disturbances, other than avalanches, which could affect normal tree growth. Growth disturbances identified in cores extracted sampled from 596 avalanche affected Norway spruce trees (Picea abies (L.) Karst) yielded 130 major snow avalanches which occurred between 1900 and 2012 in the studied area. Using a regional avalanche activity index, 11 years with increased snow avalanche activity were identified: 1923, 1929, 1952, 1962, 1967, 1988, 1992, 1995, 1997, 2002 and 2005. Subsequently, avalanche synchronicity on more than 50% of the studied paths was obtained for six of the above mentioned years. Major snow avalanche return periods between 12,6 and 4,6 years characterize the central part of the Făgăraș Mountains. Accounting the scarcity of archival records regarding past snow avalanches in Romania, the results of our study provide novel quantitative data over an entire mountainous region, enriching the knowledge on process regimes and offering a basis for effective hazard mitigation and risk management measures.

Slope types, slope processes and talus morphometry in Lac à l'Eau Claire, western Nunavik

Armelle Decaulne[1,2], Najat Bhiry[3,4], Julien Lebrun[4], Samuel Veilleux[4], Denis Sarrazin[3]

[1] *CNRS LETG laboratory, Nantes*
[2] *GDR 2012 AREES (Arctique - Enjeux pour l'Environnement et les Sociétés)*
[3] *Centre d'études nordiques, Québec City (Qc), Canada G1K 7P4*
[4] *Département de géographie, Université Laval, Québec City (Qc), Canada G1K 7P4*

Lac à l'Eau-Claire (56°20'N; 76°17'W) is one of the several meteoritic craters on the Ungava peninsula (Nunavik, Canada), located about 115 km east of Hudson Bay. It is composed of two neighboring craters (CL-West and CL-East). CL-West is about 30 km in diameter, with a distinct inner ring of islands. Clearwater Lake is situated within the boundaries of the Tursujuq National Park. The region lies on granite-gneiss rocks of the Precambrian Shield while islands constitute a central uplifted area and are covered with impact melts (breccia). Deglaciation of the region occurred at approximately 6000 yr BP. From this period the reliefs of Clearwater Lake islands were exposed to the cumulative effects of heavy periglacial conditions and gravity processes on 25 to 150 m high slopes.
The aims of this ongoing research are:

- To inventory the range of slope processes (landslides, rockslides, screes, debris flows, snow avalanches, etc.)
- To estimate their degree of activity by examining landforms they created (inherited *versus* active processes through inherited *versus* fresh landforms)
- To date movements on slopes (both relative dating by lichenometry and plant cover, and absolute dating by dendrochronology since *Picea mariana* lives hundreds of years in the area, and ^{14}C in stratigraphic deposits)
- To estimate the runout of the processes and their distance to the lake water in order to document the risk for Cree camps and tourists in case a slope process event generates a wave by entering the outer lake shallow waters.

The preliminary results we present here provide identification and classification of slope types and associated processes on the main northern island of Lac à l'Eau Claire, Lepage Island. From field-based methods, the longitudinal profiles are characterized, and the vegetation cover on the talus is documented. The results show that present-day slope processes are active, despite a limited altitudinal difference from the apical to the distal part and an almost exhaustion of debris supply. The research provides clues on the processes that are remobilizing and redistributing the debris on the talus, and explores perspectives for further work, especially to obtain dating on the stages of development of the talus, before shortly discussing its paraglacial evolution.

The I.A.G./A.I.G. Working Group SEDIBUD – a long-lasting effort to enhance scientific research and collaborations in high-latitude and high-altitude cold environments

Armelle Decaulne[1], Þorsteinn Sæmundsson[2], Achim A. Beylich[3]

[1] *CNRS LETG laboratory, Nantes, France*
[2] *Department of Geography and Tourism, Faculty of Life and Environmental Sciences, University of Iceland, Reykjavík, Iceland*
[3] *Geological Survey of Norway (NGU), Trondheim, Norway*

SEDIBUD (SEDIment BUDgets in cold environments) officially started in 2005, following the approval of the Working Group by the International Association of Geomorphology (I.A.G./A.I.G.) during the 6th International Conference of Geomorphology held in Zaragoza in September 2005.

SEDIBUD really got its roots earlier, as it sprouted from the SEDIFLUX (SEDImentary source-to-sink FLUXes in cold environments) Network, funded by the European Science Foundation (ESF), from 2004 until 2006. The fourth and final workshop of SEDIFLUX was also the first SEDIBUD workshop, held in Trondheim from October 28 to November 2, 2006.

During the past 12 years, SEDIBUD has been aiming at gathering researchers interested in improving the knowledge on earth surface processes in a changing cold climate context, with changing environments adapting to new environmental conditions. SEDIBUD researchers have been focusing on quantitative analyses of solute and sediment transfers in a wide range of high-latitude and high-altitude cold environments, from high arctic/antarctic to subarctic/subantarctic, alpine and upland sites. Researchers from the group have been investigating fluvial and cryospheric systems, glacial, paraglacial and periglacial processe, glaciofluvial, aeolian and marine transfer systems, and relationships between geomorphic surface processes and vegetation cover. Altogether, researchers have been collecting data to perform quantitative analyses of sediment transfers, nutrient fluxes and sediment budgets across a range of key cold environments

In this poster, we provide an overview of the history of the group and its scientific production, proposing a short quantitative analysis on the working group activities since 2005, which includes:

- organization of workshops, most of the time associated with field trips in areas that are investigated by local organizer scientists,
- publication of abstract volumes and proceedings,
- publication of newsletters, minutes and business meeting reports,
- journal publications, as special issues in international supports following each workshop,
- publication of a synthesis book,
- creation of a database on SEDIBUD key test sites
- organization of scientific sessions at international conferences.

All members of the SEDIBUD Working Group, reaching a number of up to 300 and coming from up to 27 countries covering all continents, are deeply thanked for their involvement in the project, contributing to the success of the group and research produced during over a decade.

Frequency of high-magnitude snow avalanches reconstructed with tree rings in Rodna Mountains (Eastern Carpathians, Romania)

Ionela-Georgiana Gavrilă[1], Olimpiu Pop[1], Flaviu Meseşan[1], Cosmin Timofte[1]

[1]Laboratory of Dendrochronology, Faculty of Geography, Babeş-Bolyai University, Cluj-Napoca, Romania

In Rodna Mountains, the forested slopes affected by snow avalanche (SA) process are offering a great potential for dendrogeomorphological investigations. Since the monitoring of SA by other methods is fragmentary or lacking, tree-rings represent a very valuable natural archive on past processes occurrence giving the opportunity to reconstruct the event chronology with annual resolution. Since this geomorphic process is not monitored, some areas are being liable to geomorphological hazards. The present study aim to analyze the tree-ring records in order to reconstruct the frequency of past snow avalanche activity along a path situated on the southern slope of Piatra Albă Peak (2034 m a.s.l). 60 Norway spruce trees (*Picea abies* (L.) Karst.) and *Abies alba*) with visible signs of mechanical impact caused by snow avalanches (stem tilting, uprooting, decapitation, broken branches and stem scars) were sampled along the path. Tree-growth anomalies found in the 70 increment cores and 14 stem discs allowed determination of a minimum 17 SA events which occurred during the 1953-2016 period. Since the dendrogeomorphic methods provide the most consistent avalanche event chronology in this site, further studies are expected to be conducted on other avalanche paths in order to obtain a synthesis of avalanche regime at regional scale which can contribute to an accurate avalanche hazard zonation.

The role of rock glaciers in the paraglacial history of deglacierizing mountains

Jasper Knight[1], Stephan Harrison[2]

[1]*School of Geography, Archaeology & Environmental Studies, University of the Witwatersrand, Johannesburg 2050, South Africa*
[2]*College of Life & Environmental Science, University of Exeter, Penryn TR10 9EZ, UK*

Rock glaciers associated with burial of glacial ice by rock debris can be seen as an important component of paraglacial mountain landscapes. In contrast with ice glaciers, rock glaciers have not been fully mapped globally, and thus there is incomplete understanding of their distribution, controls and ages and importance in regional hydrology. Rock glaciers can form in several different ways, including at glacier ice margins by upward shearing of subglacial sediments followed by ice stagnation; coverage of the ice surface by supraglacial debris derived from valley sides; ice stagnation and downwasting leading to increased sediment concentration within remaining ice; and by mass movement transformation of ice-cored moraines. As such, rock glacier formation may represent a transient stage of the paraglacial evolution of deglaciating mountains. This study considers the properties of rock glaciers, their positions in the landscape, and relationships to other glacial and paraglacial features, using examples from different deglaciating mountains worldwide. We then propose an evolutionary model for the formation of rock glaciers, considering their pivotal role in the evolution of paraglacial mountain landscapes. Under ongoing climate change, it is likely that rock glaciers become more significant as a water and sediment buffer in cascading mountain systems.

Contemporary transformations of a gravel-bed proglacial river under rapid valley glacier recession (SW Spitsbergen)

Waldemar Kociuba[1], Grzegorz Janicki[1]

[1]*Faculty of Earth Sciences and Spatial Management, Maria Curie-Skłodowska University, Lublin, Poland.*

A study into contemporary changes in the morphology of the valley bottom and channel of a gravel-bed river was conducted in the Scott River catchment (NW part of the Wedel Jarlsberg Land, SW Spitsbergen) from 2009 to 2013. Half of the catchment with the area of 10 km^2 is occupied by a valley glacier with strong recession. The diversified development conditions of the glacier-free valley bottom are determined by a number of factors, e.g.: the functioning of the terminoglacial zone, the extent of the glacial terminus, and the eather course or flood-flows occurrence .

Structural factors determined the development of two valley narrowings with a gorge character, and a clear division of the valley floor into 3 varied morphological zones. A gorge in the terminal moraine rampart distinguishes the upper wide (of up to 700 m) section of the valley bottom with an intramarginal outwash plain character. A valley gorge dissecting the elevated marine terrace separates the middle section of the alluvial valley from the mouth section (alluvial fan). At this section, the Scott River develops an extensive braided system fed by small tributaries.

Changes in the discharge rate and bedload transport regime are influenced by the glacial ablation rate, determining the variability of the channel morphology and the contemporary development of the valley bottom. The complex proglacial Scott River system also affects the varied pattern of the development of the Scott River threshold channel. The upper, proximal section of the valley is dominated by a braided channel system fed by sub- and supraglacial waters. In the middle distal section, the development pattern changes from one-channel meandering one, through a multi-channel "wandering" system, to (locally) classic braided system. In the river's mouth section, it returns to the one-channel meandering pattern, through the multi-channel "wandering" system modelling the southern part of the alluvial fan, to a straight channel. The river below the crevasse cutting the coastal berm develops a subaqual prodelta.

Studies on fluvial transport rate, conducted in the Scott River catchment in the period 2009-2013, also document the mixed type of the river's load with relatively low contribution of bedload material. The currently developed alluvial valley is almost entirely occupied by a flood plain and braided river bed. Changes in the channel system are only related to the melting period of the snow cover. After this period, the channels are distinguished by high stability, and their channel pattern is usually transformed during several days of ablation or ablation-precipitation flood-flows.

The study was conducted in the scope of the statutory research of FESSM MCSU "Application of the TLS in the geomorphological research" and the grant of the National Science Centre "Mechanisms of fluvial transport and delivery of sediment to the Arctic river channels with different hydrologic regime (SW Spitsbergen)" No. 2011/01/B/ST10/06996.

Dynamic slope processes in the mid-mountain area of the Central Europe – an example from the Eastern High Sudetes

David Krause[1], Marek Křížek[1]

[1]*Faculty of Science, Charles University, Prague, Czech Republic*

Slope processes like snow avalanches and debris flows are often described in high altitude alpine areas of the world. On the example of Europe, the Alps, Carpathians, Apennines, Pyrenees etc. are most discussed. On the other hand, there are mid-mountain areas, such as the High Sudetes, sharing above mentioned phenomena with the alpine-type ranges. The Eastern High Sudetes laying on the border between the Czech Republic and Poland are perfect example of a mid-mountain zone with presence of some alpine phenomena such as relicts of glaciation, active and relict periglacial landforms, alpine timberline and deep-seated valleys with steep slopes. The mountain range is built of relatively durable variscian metamorphic rock, thus the type and intensity of slope processes affecting the surface morphology is quite different than in less durable flysch mountains (for example the flysch belt of Carpathians, where deep landslides prevail).

In present time, debris flows and snow avalanches are the most dynamic processes affecting the surface of the Eastern High Sudetes. Their activity is influenced by climatological, morphological and lithological conditions, when the average annual precipitation exceed 1000 mm and the steep slopes are covered by thick weathering mantle developed during the Pleistocene glaciation cycles. This is why the debris flow paths and avalanche paths are located predominantly in the upper valley parts, frequently affected by nivation or glaciation in the past. Debris flow and avalanche activity has implications on the surface morphology among thousands of years and designate ecological factor, forest management disturbances and natural hazard even in present times. The vegetation cover of the mountains has changed a lot since the 19th century, when the natural mixed forests have been replaced by the Norway spruce (*Picea abies*) monocultures and non-native dwarf pines (*Pinus mugo*) were planted above the timberline in order to protect the slopes against erosion. During last centuries, the complex assessment of debris flows and avalanches in the Eastern High Sudetes has not been done, even when the debris flows and avalanches are the most dynamic geomorphologic processes in this area at present time. Their activity corresponds to repeating events and shows variability of the environment related to climate change and human activity.

The aim of presented study campaigns constraining on debris flows and avalanches is to get detailed information about past and present activity and magnitude of these processes and their impact on surface. In the presented poster, the methods and results of particular study campaigns are shown. The study is supported by the Grant Agency of Charles University (project GAUK 1072116 – "The Geomorphic Evolution of the Upper Parts of Valleys in the Eastern High Sudetes Mts. in the Holocene") and the terrain research is enabled by the Protected Landscape Area Jeseníky.

Potential effects of climate change on future snow avalanche activity in western Norway deduced from meteorological data

Katja Laute[1], Achim A. Beylich[2]

[1]*Université de Bretagne Occidentale, IUEM, CNRS, UMR LETG, Technopôle Brest-Iroise, rue Dumont d'Urville, 29280 Plouzané, France.*
[2]*Geological Survey of Norway (NGU), P.O. Box 6315 Torgarden, NO-7491 Trondheim, Norway*

Meteorological records for western Norway show the general trend that the last 100 years, and especially the last three decades, have been warmer and wetter than the time periods before. As snow-avalanche formation is mainly governed by meteorological conditions as, e.g., air temperature fluctuations, heavy precipitation and wind conditions, it is likely that the frequency and magnitude of both ordinary and extreme snow-avalanche events is and will be modified through the documented effects of current and future climate change.

This work focuses on recent and possible future effects of climate change on snow-avalanche activity along the western side of the Jostedalsbreen ice cap representing one of the areas with the highest snow-avalanche activity in entire Norway. We have analyzed long-term homogenized meteorological data from seven meteorological stations in different elevations above sea level, three of them with a long-term record of 120 years (1896-2015). Daily precipitation and air temperature data are analyzed from the highest-situated meteorological station (located at 872 m a.s.l.) in order to reveal the percentage share of precipitation which actually occurs as snow within the snow avalanche source areas (generally located at this and/or higher elevations a.s.l.). In addition to the statistical analyses of long-term datasets, gained results and insights from a four-year (2009-2012) high-resolution snow avalanche monitoring study conducted in the same study area are incorporated.

The statistical analyses of mean monthly air temperature and monthly precipitation sums for the core winter period (December – March) showed that there is an increasing trend for both air temperature and precipitation with an accelerated increase for the last 30 years. Further on, a tendency for the causal relationship between a positive NAO index and higher precipitation sums could be detected. Magnitude-frequency analyses conducted for three defined time intervals (120, 60 and 30 years) of monthly precipitation sums for the winter period exhibit an increase of precipitation especially during the last three decades with the tendency that more precipitation is occurring in February and March. An increase of precipitation during the winter period of ca. 23 % (as a mean for three meteorological stations) for the next 10 years is calculated. Combining this result with the correlation of the monitored number of snow avalanches during four years and the actual amount of snow precipitation yields an increase of ca. 20 % for the number of snow avalanches within the succeeding 10 years.

While strong winds, rapid air temperature fluctuations and heavy snow fall events are identified as the main triggering mechanism for snow avalanches along the SW coast of Norway, an increase of the monthly precipitation sums (snow fall) during the winter period may lead to a generally higher snow-avalanche frequency. The detected trend of increasing air temperatures might not necessarily affect the

current and near future snow-avalanche activity as snow avalanches are triggered in higher elevations above sea level where precipitation will still occur as snow fall. Currently, more than 80 % of the winter precipitation falls as snow at these elevations. However, it is possible that with increased "rain on snow" events due to rising air temperatures during the winter periods, the risk of wet snow avalanches and slush flows will increase. Generally, the current snow avalanche peak season might shift forward, leading to a beginning of the peak season already in February.

Snow avalanche activity assessed by dendrogeomorphology and remote sensing in Parâng Mountains

Flaviu Meseșan[1], Olimpiu Pop[1], Ionela Georgiana Gavrilă[1]

[1]*Laboratory of Dendrochronology, Faculty of Geography, Babeș-Bolyai University, Cluj-Napoca, Romania*

The snow avalanches are one of the most important geomorphic processes affecting the treeline in the Romanian Carpathians. In this paper, the snow avalanche activity was reconstructed using standard dendrogeomorphological procedures in two avalanche paths located in the western side of Parâng Mountains. Along other avalanche events, the most severe events were recorded by trees in 1996-1997 and 1985-1986 winters.

Because no Landsat images were available for this area between 1995 and 1998, the 1985-1986 avalanche event was selected as case study for the remote sensing approach. Two Landsat 5 SR images taken before and after this avalanche event, during vegetation season were downloaded. Four vegetation indices were computed on both images (Normalized Burn Ratio (NBR), Normalized Difference Moisture Index (NDMI), Moisture Stress Index (MSI) and Disturbance Index (DI)). In the areas where sampled trees recorded avalanche related disturbances, NBR and NDMI values recorded a decrease in post avalanche image compared with pre-avalanche image, while MSI and DI values increased. In the undisturbed forest areas, the values of all four indices remained relatively constant. Based on these indices variations, the spatial extent of 1985-1986 avalanche event was identified in other 9 avalanche paths distributed along the entire ridge of Parâng Mountains.

A logistic regression analysis confirms that the spectral indices record sudden variations only in the pixels with disturbed trees, but not in the mature forest. The combined use of dendrochronology and remote sensing provided a clear reconstruction of maximum snow avalanche extent in the subalpine area of Parâng Mountains for the 1985-1986 winter snow avalanche.

The combined use of dendrogeomorphology and remote sensing represent a powerful technique for assessing the past snow avalanche extension. It can be further used to reconstruct other avalanche events occurred in Parâng Mountains or other mountain ranges.

This work represents a contribution to the Bilateral Project ZONAGEOTOUR « Zonage des aléas géomorphologiques dans les espaces touristiques des massifs du Parâng (Roumanie) et du Pirin (Bulgarie) » (Geomorphic hazard zonation in tourism areas of Parâng Mts., Romania and Pirin Mts., Bulgaria), financed by the Agence Universitaire de la Francophonie (AUF) and Fonds de Recherche Scientifique (FRS) de Bulgarie.

Assessment of the sedimentary fluxes and morphological changes in mining areas from Călimani Mountains (Eastern Carpathians, Romania) based on topographic surveys and dendrogeomorphology

Olimpiu Pop[1], Flaviu Meseşan[1], Mircea Alexe[1], Ionela-Georgiana Gavrilă[1], Stefan Buimagă-Iarinca[2], Iulian Holobâcă[1], Liviu Buzilă[1], Ioan-Aurel Irimuş[1], George Rus[1], Cosmin Timofte[1]

[1]Laboratory of Dendrochronology, Faculty of Geography, Babeş-Bolyai University, Cluj-Napoca, Romania
[2]Minesa – Institute of Research and Mining Design, Cluj-Napoca

During the second half of 20th century, in the central part of the massif the mining activities for sulphur-rich ore extraction and processing produces significant morphological changes. The impact on sediment transfer across the affected catchment started during the mining period and followed many years after the cessation of mining activities. After the mining cessation in 1997, neither rehabilitation works, nor erosion control measures have been undertaken to stabilize the spoil heap deposits. On the highly unstable spoil heap talus surface, the natural reforestation and the material consolidation is impeded. The talus surface represents the source area of materials travelling along Dumitrelul stream channel. DFs are triggered especially during spring to summer rainstorms, when the water from rainfalls accumulates on the spoil heap platform and flow down the talus following the stream channel. High magnitude DFs are able to mobilize the unconsolidated material and to transport it 4 km downstream, reaching the Dumitrelul sediment retention reservoir. Very little is known about the sediment fluxes and the frequency-magnitude relationships of hillslope processes related to these sediment transfer and the associated morphological changes in these mining areas. Topographic survey and dendrogeomorphic investigations were applied here in order to document the morphological changes and frequency of DF activity. Topographical measurements carried out successively in 2010 and 2017 allowed us to calculate the volume of materials stored behind the dam and to estimate the sedimentation rate for the last 7 years within the Dumitrelul sediment retention reservoir. Along Dumitrelul DF path, 38 disturbed trees located either at the border, or within the stream channel had been sampled. From an adjacent forest stand located upslope, outside the area reached by DFs, another 22 living trees were sampled (2 cores per tree, 44 cores in total), in order to build a local reference chronology which reflects the past local climatic conditions of the site and serves for crossdating with the growth chronology of individual disturbed tree. Only the scars associated with the overgrowing callus tissue, as well as the onset sequences compression wood have been identified and considered as the result of mechanical impact produced by the materials transported by DFs. For the event reconstruction we excluded other growth disturbances found within tree-rings, such as the growth suppression sequences (GS) and the tangential rows of traumatic resin ducts (TRDs), as these could be also associated with other disturbances (e.g. material toxicity). The analysis of growth disturbances occurring simultaneously in different trees allowed the reconstruction of a minimum of 6 major DF events that occurred along Dumitrelul channel since 1970.

Exploring the potential of biological indicators from peat bog archives to reveal sediment transfer and deposition by snow avalanches in Şureanu Mountains (Southern Carpathians, Romania)

Olimpiu Pop[1], Răzvan Ichim[2], Andrei Diaconu[2], Ioan Tanţău[2], Iulian Holobâcă, Ionela-Georgiana Gavrilă, Cosmin Timofte, Flaviu Meseşan

[1]Laboratory of Dendrochronology, Faculty of Geography, Babeş-Bolyai University, Cluj-Napoca, Romania
[2] Faculty of Geology, Babeş-Bolyai University, Cluj-Napoca, Romania

Peat bog archives store various recorders (tree-rings, pollen, plant macrofossils, testate amoebae, microscopic/macroscopic charcoal and stable isotopes), with a great potential for reconstructing the past geomorphic activity. Among these multiproxy bioindicators, tree-ring archives provide the best reconstructions of past snow avalanche activity regarding the temporal precision, accuracy, robustness of proxy influences and widespread distribution in space. In living and subfossil trees, growth anomalies related to past snow avalanche activity can be dated precisely, with annual or even seasonal resolution. However, tree-ring records in living trees are relatively limited in temporal depth and spatial coverage. The investigation of alternative multiproxy archives from peat bogs coupled with dating methods (AMS ^{14}C and ^{210}Pb datings etc.) allow to extend the temporal depth, corroborating tree-ring inferences and adding complementary information at different time and spatial scales about snow-avalanche activity.

Peat geomorphic process activity reconstructed from peat bog archives in Romanian Carpathians has not been previously performed or aimed at until now and could represent a new perspective for further geomorphological studies. The aim of this study was to explore the potential of various bioindicators peat bog to reveal the past snow avalanche activity in Iezerul Şureanu site (Şureanu Mts., Southern Carpathians, Romania). Trees growing on peat bog surface with visible signs of mechanical disturbance related to past geomorphic activity (tilting and uprooting, apex lose, wounding etc.) have been sampled (2 cores per tree) and their growth anomalies dated. Growth chronologies from disturbed trees have been compared with a local reference chronology from trees growing outside the study site in undisturbed area. Tree-ring-based reconstructed events have been correlated with data resulted from sediment analyses and peat stratigraphy coupled with radiochronological dated peat profile. The preliminary results indicate possible causal links between the deposition of mineral sediments layers at different levels within organic peat deposits and periods with snow avalanche activity. In the study area, further investigations based on the combined multiproxy approaches will offer the possibility to obtain synthetic proxy data sets at different spatio-temporal scales and will improve the episodic mass-wasting reconstruction robustness for the Late Holocene.

Rock glaciers debris characteristics and dynamics in Southern Carpathians

Răzvan Popescu[1], Alfred Vespremeanu-Stroe[1], Mirela Vasile[1], Nicolae Cruceru[2]

[1]*University of Bucharest, Faculty of Geography*
[2]*Spiru Haret University, Faculty of Geography*

Rock glaciers from the granitic massifs of Southern Carpathians are quite different in terms of debris characteristics in comparison to those located in the crystalline massifs. The former are made of predominantly large angular blocks with openwork structure while the latter have a lower frequency of large blocks and present a matrix of fine sediments that consolidate the debris. The status of granitic rock glaciers is intact above 2000 m asl on the northern slopes while the crystalline rock glaciers are predominantly relict. This happens in spite of more favorable topoclimatic conditions for perennial ice and rock glaciers development of the crystalline massifs imposed by slightly higher altitudes and more shaded slopes imposed by higher rock walls and narrower valleys. In this context, we aim to verify the hypothesis that the debris characteristics and lithology differences impose such contrast in rock glaciers past and present evolution.

Therefore, the debris texture of 9 rock glaciers was assessed by measuring the dimensions of each clast (*a*-, *b*- and *c*- axis) in sample plots of 4 × 4 m in the field (2 to 9 plots for each rock glacier) and in sample plots of 2 × 3 m in the lab (in GIS-environment) based on vertical photographs made in the field with a standard device; finally, the average volume and surface were computed for each site. The clast-size data were compared with the thermal indices of the rock glaciers based on multi-annual ground surface temperature (GST) measured in situ with miniature digital data loggers (iButtons). The surface offset defined as the difference between mean annual ground surface temperature (MAGST) and mean annual air temperature (MAAT) was used as a synthetic indicator of thermal conditions. In addition, we applied high precision topographical measurements using a total station in 2012, 2013 and 2014 on a granitic rock glacier in order to test the activity of mountain permafrost creep at this site.

The granitic rock deposits present the highest mean clast sizes (0.07 – 0.1 m^3) and a lower heterogeneity (low standard deviation) in comparison with the crystalline schists deposits which have the lowest clasts size values (0.002 – 0.13 m^3) and an increased heterogeneity degree (e.g. higher standard deviation). In comparison, the offset has a higher amplitude in the granitic massifs because of negative thermal anomaly occurrence at some rock glaciers while in the crystalline massifs are homogenous and closer to 0 °C. Only in one schistose rock glacier, the values were found to be comparable to those from the granitic massifs. The higher mean grain size in the granitic rock glaciers and debris deposits in general impose a higher porosity in contrast to the crystalline deposits. Moreover, the lack of fine sediments or at least their scarcity in the former deposits allows for an efficient ground air circulation (cold air funneling and warm air evacuation) at the beginning of the cold season and an efficient thermal barrier during the warm season. The granitic rock glaciers dynamics investigations revealed horizontal movement rates of 1 … 4.3 cm yr^{-1} and vertical movements of 0 … -3.4 cm yr^{-1}. The slow movement in comparison with the values reported in other mountain areas could be related to the lower ice content and the consequently greater internal friction also enhanced by the large dimensions of the clasts.

Preliminary results from fluvio-morphological and slope wash studies in the headwater of Sinanitsa River, the Pirin Mountains, Southwestern Bulgaria

Sonya Stoyanova[1]

[1]*University of Sofia "St. Kliment Ohridski", Sofia, Bulgaria*

The headwater of Sinanitsa River is located above the upper boundary of the forest (2000-2200 m a. s. l.) on the west macro-slope of Pirin Mountains and it is in the catchment of Vlahina River, left tributary in the Struma River's drainage system. The high relief (Gergiiski peak, 2589 m a. s. l.; Sinanitsa peak, 2516 m a. s. l.) and steep slopes (more than 70^o is the maximum value of incline) are an obvious feature of this mountain area. The cold climate is another factor controlling runoff, erosional and slope wash processes.

In this particular study the results of short-term observation (about the period of 2016-2017) of fluvio-morphological processes and slope dynamics are presented.

The character of riverbed usually reflects fluvial processes and the dynamics of sediment transport. Thus, samples are collected from the river bottom in order to track changes in the main deposits' features and to compare them due to flows orders. Differences in fluctuations of the low-ranked flows (1^{st} and 2^{nd}-order) are obtained in 5 cross-sections and the main morphological features across the river valley are measured. Several boreholes on the floodplains are drilled across the valley in attempt to interpret the deposition's dynamic within the temporal and spatial context and, most of all, what is the role of slope wash processes for the plains formation and which slope predominantly delivers sediments along the source-sink path.

Slope wash processes are observed along landforms like talus and ladslip. The talus in point 263 is defined as active and there is an intensive export of material. Sediments have size from middle boulders (to 27 cm) to fine particles (under 2 mm). Because of this intensity it is put a sediment trap to establish the quantity of exported deposits (kg/ year). There are painted lines across the cones in point 264 (landslip) and point 266 (slope with landslip and talus processes) to track the coarse material's downslope movement. Also, there are tree reference marks along a talus in the Sinanitsa cirque.

The study area characterizes typical for Bulgaria high altitude cold environment, where frequent fluctuations around freezing, weathering, low temperatures, seasonal freezing and thawing of regolith and soil tend to encourage particular types of geomorphological processes.

Assessing the snow-avalanche activity in Șureanu Mountains using tree-ring analyses

Cosmin Timofte[1], Flaviu Meseşan[1], Ionela-Georgiana Gavrilă[1], Olimpiu Pop[1]

[1]*Laboratory of Dendrochronology, Faculty of Geography, Babeş-Bolyai University, Cluj-Napoca, Romania*

Snow avalanches affect most of the alpine areas from Romanian Carpathians and represent one of the debris transfer mechanisms in these environments. Understanding the process frequency and magnitude is crucial for a precise hazard zonation in the avalanche prone areas. High resolution hazard maps are needed to reduce the avalanche-related risk, particularly in mountain areas with human activity (e.g. the winter tourism resorts).

In Șureanu Mountains the sky resort is extending in the alpine areas. Here, the past snow avalanche activity is undocumented by archival records. Several avalanche paths developed as a result of repeated avalanche impact. Inside them many trees show growth disturbances related to past avalanche activity (e.g. scars, broken top, tilted stems, broken branches).

The purpose of this study is to reconstruct the snow avalanche activity in an avalanche path with two branches located in the Auşelu valley, close to Șureanu ski resort. 102 heavily disturbed Norway spruces (*Picea abies* (L.) Karst.) were sampled during field campaigns in 2016 and 2017 summers. The samples were air dried, sanded and analyzed according to the standard geomorphological procedures. Resulted avalanche chronology extends back to the beginning of the 20th century. For each reconstructed event the spatial extent was determined. The avalanche frequency and return periods were determined and mapped in different sectors of the investigated path.

The application of dendrogeomorphic methods provided a consistent avalanche event reconstruction that can be further used for a precise avalanche hazard mapping in the area.

List of participants

No.	Name and surname	Host Institution	Country	E-mail adress
1	Alexe Mircea	Babeş-Bolyai University, Faculty of Geography	Romania	mircea.alexe@ubbcluj.ro
2	Ardelean Adrian Cristian	West University of Timişoara, Department of Geography	Romania	cristian86ardelean@gmail.com
3	Ardelean Florina	West University of Timişoara, Department of Geography	Romania	florina.ardelean@e-uvt.ro
4	Baltakova Ahinora	Sofia University "St. Kliment Ohridski", Faculty of Geology and Geography	Bulgaria	abaltakova@gea.uni-sofia.bg
5	Beylich Achim Alfred	Geological Survey of Norway	Norway	achim.beylich@ngu.no
6	Bollati Irene	Università degli Studi di Milano, Earth Science Department	Italy	irene.bollati@unimi.it
7	Bozhkov Petko	Sofia University "St. Kliment Ohridski", Faculty of Geology and Geography	Bulgaria	petko_bozhkov@abv.bg
8	Buimagă-Iarinca Ștefan	Institute of Research and Mining Design - MINESA, Cluj-Napoca	Romania	stefan.buimaga@ymail.com
9	Buter Anuschka	Free University of Bozen-Bolzano	Italy	anuschka.buter@natec.unibz.it
10	Buzila Liviu	Babeş-Bolyai University, Faculty of Geography	Romania	liviu.buzila@ubbcluj.ro
11	Chiroiu Patrick	West University of Timişoara, Department of Geography	Romania	pchiroiu@gmail.com
12	Comiti Francesco	Free University of Bozen-Bolzano	Germany	francesco.comiti@unibz.it
13	Cruceru Nicolae	Spiru Haret University, Faculty of Geography	Romania	cruceru nick@yahoo.com
14	Decaulne Armelle	CNRS LETG Laboratory, Nantes	France	armelle.decaulne@univ-nantes@fr
15	Diaconu Andrei	Babeş-Bolyai University, Faculty of Geology	Romania	andreicosmind@yahoo.com
16	Gavrilă Ionela-Georgiana	Babeş-Bolyai University, Faculty of Geography, Laboratory of Dendrochronology	Romania	ionela.gavrila@ubbcluj.ro
17	Grzegorz Janicki	Maria Curie-Skłodowska University, Faculty of Earth Sciences and Spatial Management	Poland	grzegorz.janicki@umcs.pl

18	Harrison Stephan	University of Exeter, College of Life & Environmental Science, Penryn	UK	stephan.harrison@exeter.ac.uk
19	Heckmann Tobias	Catholic University of Eichstätt-Ingolstadt	Germany	Tobias.Heckmann@ku-eichstaett.de
20	Holobâcă Iulian	Babeş-Bolyai University, Faculty of Geography	Romania	iulian.holobaca@ubbcluj.ro
21	Ichim Răzvan	Babeş-Bolyai University, Faculty of Geology	Romania	
22	Irimuş Ioan-Aurel	Babeş-Bolyai University, Faculty of Geography	Romania	aurel.irimus@ubbcluj.ro
23	Kenderova Rossitza	Sofia University "St. Kliment Ohridski", Faculty of Geology and Geography	Bulgaria	rossica@gea.uni-sofia.bg
24	Knight Jasper	School of Geography, Archaeology & Environmental Studies, University of the Witwatersrand	South Africa	jasper.knight@wits.ac.za
25	Kociuba Waldemar	Faculty of Earth Sciences and Spatial Management, Maria Curie-Skłodowska University	Poland	waldemar.kociuba@umcs.pl
26	Krause David	Faculty of Science, Charles University, Prague	Czech Republic	david.krause@natur.cuni.cz
27	Krenchev Dimitar	Sofia University "St. Kliment Ohridski", Faculty of Geology and Geography	Bulgaria	
28	Laute Katja	Université de Bretagne Occidentale, IUEM, CNRS, UMR LETG	France	katja.laute@univ-brest.fr
29	Lebrun Julien	Université Laval, Département de Géographie	Canada	julien.lebrun.1@ulaval.ca
30	Marek Křížek	Charles University, Faculty of Science	Czech Republic	marek.krizek@natur.cuni.cz
31	Meseşan Flaviu	Babeş-Bolyai University, Faculty of Geography, Laboratory of Dendrochronology	Romania	flaviu.mesesan@ubbcluj.ro
32	Najat Bhiry	Université Laval, Département de Géographie Centre d'études nordiques	Canada	najat.bhiry@cen.ulaval.ca
33	Onaca Alexandru	West University of Timişoara, Department of Geography	Romania	alexandru.onaca@e-uvt.ro
34	Petru Urdea	West University of Timişoara, Department of Geography	Romania	petru.urdea@e-uvt.ro
35	Pop Olimpiu	Babeş-Bolyai University, Faculty of Geography, Laboratory of Dendrochronology	Romania	olimpiu.pop@ubbcluj.ro

36	Răzvan Popescu	University of Bucharest, Faculty of Geography	Romania	razvan.popescu@geo.unibuc.ro
37	Rus George	Babeş-Bolyai University, Faculty of Geography	Romania	george.rus@ubbcluj.ro
38	Sæmundsson Þorsteinn	University of Iceland, Faculty of Life and Environmental Sciences	Iceland	steinis@hi.is
39	Sarrazin Denis	Centre d'études nordiques	Canada	denis.sarrazin@cen.ulaval.ca
40	Stoyanova Sonya	Sofia University "St. Kliment Ohridski", Faculty of Geology and Geography	Bulgaria	sonya.s.stoyanova@gmail.com
41	Tanțău Ioan	Babeş-Bolyai University, Faculty of Geology	Romania	ioan.tanțău@ubbcluj.ro
42	Timofte Cosmin	Babeş-Bolyai University, Faculty of Geography, Laboratory of Dendrochronology	Romania	cosmin.timofte@ubbcluj.ro
43	Vasile Mirela	University of Bucharest, Faculty of Geography	Romania	mirela.vasile@geo.unibuc.ro
44	Veilleux Samuel	Université Laval, Département de Géographie	Canada	samuel.gagnon.9@ulaval.ca
45	Vespremeanu-Stroe Alfred	University of Bucharest, Faculty of Geography	Romania	freddy@geo.unibuc.ro