



Martin-Luther-Universität  
HALLE-WITTENBERG



universität  
wien



**Proceedings of the**  
**9th I.A.G./A.I.G. SEDIBUD**  
**(Sediment Budgets in Cold Environments)**  
**Workshop**  
**“Sediment Dynamics in Cold Climate Environments”**

**Kaunertal, Tyrol/Austria**

**September 7-10, 2015**

edited by David Morche, Sabine Kraushaar, Achim Beylich



The tongue of the Gepatschferner glacier with its lateral moraine and a recently deglaciated rockwall with high rockfall activity (photo: David Morche)

## How to get there ...and back again

### The venue:

The Gepatschhaus (<http://www.gepatschhaus.at>) located in the upper part of the Kaunertal valley catchment in the Ötztal Alps in Tyrol/Austria.

The Gepatschhaus has shared rooms that cost 15.00 € per night/ person.

Breakfast and Dinner is available for 23.50 € and each Lunchpaket for 4.00 €.

### Arrival

If you arrive by train in Landeck-Zams you can use the following bus connection to get to the 'Kaunertal Gepatschhaus', the bus station is right in front of the train station:

Date: 07.09.2015      Starting Point: Landeck-Zams

#### Bus line:

Regionalbus **4236** (Direction: 'Serfaus Seilbahn') to '**Prutz Postamt**', change there to Regionalbus **4232** (Direction: 'Kaunertal Weißseeferner' or 'Feichten Grasse') to '**Kaunertal Gepatschhaus**'

Time of departure: 8:15 / 12:45 / 18:10 (maybe the last one ends up in the village Feichten Gemeindeamt about 17 km downvalley of Gepatschhaus, give us a call and we will pick you up there by car)

After arrival at the bus stop please follow the signs to the 'Gepatschhaus' where we will be waiting for you.

### Departure

Date: 10.09.2015      Starting Point: Kaunertal Gepatschhaus

#### Bus line:

Regionalbus **4232** (Direction: 'Prutz Postamt') to '**Prutz Postamt**', change there to Regionalbus **4218** (Direction: 'Landeck-Zams') to '**Landeck-Zams**'

Time of departure: 16:45

or:

Bus line: Regionalbus **4232** to '**Landeck-Zams**'

Time of departure: 10:40

---

## Program

<b>7th September 2015</b>		
until 19:00	Arrival	
19:00	<b>Dinner at the Gepatschhaus</b>	
open end	Ice Breaker	
<b>8th September 2015</b>		
07:30 - 08:40	<b>Breakfast</b>	
08:45 - 08:55	Achim Beylich	Welcome note by SEDIBUD-Chair
<b>Presentations</b>		
09:00 - 09:55	Sam McColl	Early hillslope response and reworking of landslide sediments: Challenges for quantifying landslide-sediment contributions in glaciated mountain systems
10:00 - 10:25	Daniel Dräbing	Quantification of thermal and mechanical processes and their implications on rock stability in the Steintaelli
10:30 - 10:55	<b>Coffee break</b>	
11:00 - 11:25	Sonya Stoyanova	Slope processes monitoring in Begovitsa SEDIBUD key test site, the Pirin Mts., SW Bulgaria
11:30 - 11:55	Ionela-Georgiana Gavrila	Assessing the frequency and magnitude of large debris-flows in natural and mining areas of Calimani Mountains (Eastern Carpathians, Romania) using dendrogeomorphic methods and numerical modeling
12:00 - 12:25	Mark Allan	Structure from Motion photogrammetry for quantifying the magnitude-frequency of slope failures above and around glaciers in the European Alps
12:30 - 13:55	<b>Lunch break</b>	
14:00 - 14:25	Ricardo Carrillo	Interpreting changes in coarse sediment availability in a glacierized Andean stream by using hysteresis indexes
14:30 - 14:55	Achim Beylich	Environmental controls, spatiotemporal variability and rates of contemporary fluvial suspended sediment transport in the inner Nordfjord in western Norway
15:00 - 15:25	Sandro Rossato	Inferring LGM sedimentary and climatic changes in the southern Eastern Alps foreland through the analysis of a 14C ages database (Brenta megafan, Italy)
15:30 - 15:55	David Morche	Proglacial fluvial sediment dynamics in the Gepatschferner forefield (Tyrol/Austria)

16:00 - 16:25	<b>Coffee break</b>	
16:30 - 18:25	<b>Poster 3 + 1 (3 minutes presentation and 1 question)</b>	
	Achim Beylich	Environmental drivers, spatiotemporal variability and rates of contemporary chemical and mechanical fluvial denudation in selected glacierized and non-glacierized cold climate catchment geosystems: From coordinated field data generation to integration and modeling
	Katja Laute	Reconstruction of postglacial rockfall/rock-slope failure activity in the mountainous fjord landscape of western Norway
	Dimitar Krenchev	Peat and glacial lake sediments in the Pirin Mts., SW Bulgaria
	Verena Czarnowsky	Characterization of perennial springs with stable isotope signatures in the Kaunertal Valley, Austria
	Sarah Kamleitner	Are there still dead ice lenses in 1850 LIA moraines? First results from the Kaunertal, Austria
	Anne Schuchardt	Annual variability of sediment storage on proglacial braid plains using TLS (Tyrol, Austria)
	Matthias Faust	Supraglacial sediment input and glacio-fluvial sediment output of an alpine glacier, the Gepatschferner (Tyrol, Austria)
	Jana Dusik	Seasonality of reworking conditions of proglacial slopes in the upper Kaunertal
19:00	<b>Dinner a la card</b>	
<b>9th September 2015</b>		
07:30 - 08:55	<b>Breakfast</b>	
09:00 - 18:00	<b>Excursion to the Riffital Valley and the glacier Gepatschferner</b>	
19:00	<b>Dinner a la card</b>	
20:30	<b>SEDIBUD business meeting</b>	
<b>10th September 2015</b>		
07:30 - 08:55	<b>Breakfast</b>	
09:00 - 18:00	<b>Departure</b>	

---

## KEYNOTE

### **Early hillslope response and reworking of landslide sediments: Challenges for quantifying landslide-sediment contributions in glaciated mountain systems**

Sam T. McColl

Physical Geography Group, Massey University, New Zealand

Distinguishing and quantifying landslide sediments in glaciated mountains remains a considerable, but worthwhile challenge. Addressing this challenge will provide better knowledge of landslide activity, which is useful to know because alpine landslides present a considerable hazard, they dominate erosion, and their sediments modify the behaviour of glaciers, rivers, and landform development. Models suggest that the activity and geomorphic-roles of alpine landslides are likely to have become amplified during deglaciation when freshly-exposed and glacially-steepened slopes became subjected to new destabilising processes; thus, much effort has been directed at establishing the timing of, and factors influencing, ‘paraglacial’ landslide activity. Empirical data suggest that the peak amplification of post-glacial landslide activity was 1000s of years after, rather than immediately following, the commencement of deglaciation. These observations have provoked suggestions that enhanced seismic activity, stress-changes, or climate changes may be important drivers of post-glacial landslide activity. While this may stand, it is argued here that early deglaciation, particularly during the initial thinning of glaciers, may also be a significant period of enhanced landslide activity and that this activity is not well-captured by existing models and data due to re-working of the landslide deposits. In particular, landslides emplaced on to the surface of glaciers or those that ‘fall’ slowly into the sides of glaciers, may constitute an under-recognised proportion of sediment input to mountain systems. This hypothesis is based on three observations and modelling exercises presented here:

- (1) The ductile behaviour of ice at low strain rates allows movement of rock slopes buttressed by ice. Field evidence and force models demonstrate that landslides, still partially ‘buttressed’ by glaciers, can push into glacial-ice at rates of  $10^{-2}$  to  $10^2$   $\text{myr}^{-1}$ .
  - (2) The elastic strength of ice at high strain rates enables glaciers to dampen the seismic response of surrounding hillslopes. Numerical modelling experiments show that
-

this effect can dampen seismic-shaking by 50% but this is rapidly diminished during early deglaciation. Glacially-modified mountain peaks protruding above ice during the early stages of deglaciation are thus more likely to co-seismically fail early;

- (3) Recent observations show that landslides emplaced onto glacier accumulation zones are rapidly entrained, becoming englacial or basal sediment load. It will be difficult to recognise the origin of this sediment once it emerges down valley, but landslides that fall on to glaciers, particularly those that fall onto accumulation zones, are probably contained within sedimentary records (e.g. moraine, outwash, proglacial lake sediments), but have gone unrecognised as such.

Consequently, it is argued that enhanced landslide activity is likely to occur during early deglaciation, but presently these landslides are largely-unaccounted for and more is yet to be learnt of their effect on glacial and proglacial systems. Testing this hypothesis may require searching for and dating landslide sources areas in addition to applying new techniques for tracing and finger-printing landslide-derived sediments.

## **Quantification of thermal and mechanical processes and their implications on rock stability in the Steintaelli**

Daniel Draebing<sup>1</sup> and Michael Krautblatter<sup>2</sup>

<sup>1</sup> without current affiliation, former Department of Geography, University of Bonn, Bonn, Germany

<sup>2</sup> Chair of Landslide Research, Technische Universität München, Munich, Germany

Besides glacial and geological factors, climatic factors such as water, permafrost and weathering are supposed to be preparatory and triggering factors of paraglacial rock slope failures. The involvement of permafrost in rock stability is supported by field evidences such as ice in rock scarps or talus slopes or increased rockfall activity linked to warmer summers or decades. However, the influence of permafrost on rock stability and linkages to hydrostatic pressure or weathering are poorly understood. Here, we use (1) laboratory-calibrated time lapse Seismic Refraction Tomography (SRT) to quantify spatial variation of active layer thawing, (2) continuous crackmeter measurements to identify and quantify mechanical processes and (3) derive implications for seasonal and long-term rock stability of the Steintaelli rockwall.

The Steintaelli is a north-west to south-east oriented ridge, located on the crestline between the Matter- and Turtmann valleys (3050 – 3150 m a.s.l.) and consists of schisty and slaty paragneis rock dissected by 30 cm ice-filled fractures. Currently only remnants of the Rothorn NE glacier remain which covered the entire catchment during the Little Ice Age.

(1) The active-layer thaw was quantified by using SRT (Krautblatter and Draebing, 2014). In 2012, the active layer thawed to depths of 5-12 m on the NE slope and crestline while the SW slope was permafrost-free. Snow isolation prevented or delayed thawing and active layer extended to depths of 0-4 m in 2013 and 0-5 m in 2014, respectively. Time-lapse SRT shows an overall annual (2012-13) and 2-year (2012-14) cooling effect due to snow cover (Draebing et al., in prep. a).

(2) Movements of ice-filled fractures were continuously monitored by crackmeters between 2012 and 2014. We identified high-frequent thermal expansion and contraction processes with thermo-mechanical-induced fracture opening and closing up to 1.0 cm during snow-free conditions.

---

Volumetric expansion and ice erosion occur in the freeze-thaw window of  $-0.7^{\circ}\text{C}$ . Due to insufficient water saturation of fractures volumetric expansion occurs rarely, however, refreezing during snowmelt periods results in fracture dilation up to 0.2 cm. Advected heat transported by snow meltwater erodes ice and decreases ice pressure with coincident fracture closing. During snow-covered conditions, temperature remains between  $-1.5$  and  $-6^{\circ}\text{C}$  and ice segregation occurs with coincident fracture opening up to 0.9 cm (Draebing et al., in prep. a, b).

(3) On seasonal scale, rock movements are expected in early summer due to snowmelt and hydrostatic pressure increase and in autumn resulting from reduced shear resistance due to active-layer thaw in combination with cryostatic pressure increase due to freezing (Draebing et al., 2014). The crackmeter data demonstrate that fractures close in early summer suggesting that hydrostatic pressure increase is incapable to counter cryostatic pressure decrease. In autumn, fracture opening due to freezing was monitored, however, the opening persisted only short-term due to ice pressure decrease. Annual fracture movements are low indicating stable conditions, however, high-frequent thermal stress and repetitive occurrence of high-magnitude ice segregation can lead to thermal fatigue and shear plane development, respectively. Thus, weathering processes have the potential to decrease rock stability on the long-term scale.

## References

- Draebing, D., Haberkorn, A., Kenner, R., Krautblatter, M. and Phillips, M. (in prep. a): Identification of spatial and temporal snow cover variability and resulting thermal and mechanical response in a steep permafrost rockwall.
- Draebing, D., Krautblatter, M. and Dikau, R. (2014): Interaction of thermal and mechanical processes in steep permafrost rock walls: A conceptual approach. *Geomorphology*, 226, 226-235.
- Draebing, D., Krautblatter, M. and Hoffmann, T. (in prep. b): Identification of weathering processes and their temporal occurrence in permafrost rockwalls.
- Krautblatter, M. and Draebing, D. (2014): Pseudo 3D - P-wave refraction seismic monitoring of permafrost in steep unstable bedrock. *Journal of Geophysical Research: Earth Surface*, 287-299.
-

---

## **Slope processes monitoring in key site Begovitsa, the Pirin Mountains, Southwest Bulgaria**

Rossitza Kenderova, Ahinora Baltakova, Sonya Stoyanova,

Petko Bozhkov, Georgi Rachev, and Dimitar Krenchev

University of Sofia “St. Kliment Ohridski”, Department of Climatology, Hydrology and Geomorphology, Sofia, Bulgaria

Begovitsa is a U-shaped relict glacial valley on the South-West slope of the highest part of the Pirin Mountains (above 1800 m a.s.l.) in the catchment of Sandanska Bistritsa River, left tributary in the Struma River’s drainage system. Geomorphological and sedimentological study is in progress in this site for denudative processes, lake and talus cones storage and fluvial transport since 2011.

In this current study we represent the results from slope processes dynamics within the period of our observations. The research covers weathering processes on rock outcrops, cracks measurement, products of wedging and soil formation; monitoring of creep and solifluxion and deposits related to their forms; slope erosion, river bed and terrace material characteristics within the Begovitsa catchment. Samples for grain-size analysis are collected from seven boreholes and three soil profiles. Four year period data is used to describe changes in the area. We used morphographic and sedimentological analyses (grain size and lithomineralogical analyses) and also field measurements.

The studied area characterize typical for Bulgaria high altitude cold environment in which geomorphologic processes are intensive due to temperature changes. This intensity is marked by changes in slope morphology and the velocity of creep and solifluxion. Fluvial deposits are informative about the depositional environment. Soil and peat bog profile data provides new information about past and recent fluctuations in climate and their impact on weathering, fluvial and slope processes. More data is required in order to understand the evolution of slope erosion and sediments redeposition in the high mountainous area.

---

**Assessing the frequency and magnitude of extreme debris-flow events in natural and mining areas of Călimani Massif (Eastern Carpathians, Romania) using dendrogeomorphic methods and numerical modeling**

Olimpiu Pop, Ionela-Georgiana Gavrilă, Ștefan Buimaga-Iarinca, and Flaviu Mesesan  
Faculty of Geography, Babeș-Bolyai University, Cluj-Napoca, Romania

The Călimani Massif is formed by the highest stratovolcano of the Carpathian volcanic chain (Pietrosul peak, 2100 m a.s.l.). An opencast sulphur mine has been here operational between 1966 and 1997, resulting in spoil heaps piled up on the steep slopes next to the pit. Sulphur ore exploitation resulted in the progressive formation of the spoil heaps, with granulometry ranging from silt to blocks of up to 5 m in diameter. Mobilization of the poorly consolidated spoil heap deposits typically occurs during heavy rainfalls, when the debris flows propagate downstream along gullies and river beds, affecting the riparian forest composed of Norway spruce (*Picea abies* (L.) Karst.) trees. From a different natural source area located below the main crest, debris flow initiates and follows a deep-incised gully. Sediments combine at the confluence point with Dumitreleul river with those originating from spoil heap areas. *P. abies* trees growing along the gully border and on the cone surface in this natural area are also heavily affected during extreme debris flow events. The affected trees growing along the gully and river borders register in their ring structure the past debris flow events with an annual or even seasonal resolution. It gives the opportunity to reconstruct debris flow extreme events that occurred in the past in this remote mountain area. This study aims at estimating the frequency of extreme debris flow events in both natural and human-influenced areas based upon dendrogeomorphic analyses and numerical modeling. In this regard, 51 heavily disturbed trees were sampled and the growth anomalies formed within their rings related to mechanical impact of debris flow were identified. It served to reconstruct extreme events in different sectors of channels with natural and human-influenced debris flow activity. The numerical modeling of flow has been done using a back analysis approach and the Voellmy flow law. The Voellmy rheology is described by the dry Coulomb friction  $\mu$  and a turbulence parameter  $\xi$ . The rheological parameters and topographical features were computed from field data and for the validation of this approach, the model results have been distributed over the dendrogeomorphological reconstructed event maps. Further research on growth anomalies formation in affected trees and numerical modeling is needed, to better understand the frequency and magnitude of natural and human-induced debris flows in the area.

---

---

## **Structure from Motion photogrammetry for quantifying the magnitude-frequency of slope failures above and around glaciers in the European Alps**

Mark Allan, Stuart Dunning, and Michael Lim

Department of Geography, Northumbria University, Newcastle upon Tyne, NE1 8ST, UK

As valley glaciers retreat and thin, they expose stores of sediment that are particularly prone to failure and rapid reworking through a range of mass movement processes. These newly exposed slopes are thought to undergo a period of more intense or more frequent failure before returning to the background norm. The magnitude-frequency and spatial relationships to previous ice extents of slope failures are poorly constrained owing to a lack of substantial monitoring data at a great enough resolution. Structure from Motion (SfM) photogrammetry holds the potential to create accurate high resolution 3D models of the environment with relatively low-cost equipment and highly automated processing workflows. Here we utilise imagery from repeat helicopter, UAV and ground based surveys to resolve complex topographical features from slopes above and around glaciers in the European Alps in high resolution. Sites selected from the Mt Blanc massif, and the Rhone glacier have well-documented histories of ice retreat, thinning and permafrost degradation. Initial data cover the slopes of Argentière, Mer de Glace, Aiguille du Midi, Bossons, Bionnassay, Miage, Pré de Bard and Rhone. The quality and alignment of SfM-derived 3D models are tested and change detection is performed using a multi-scale cloud-to-cloud comparison technique. Our results demonstrate the SfM derived slope and slope change models can add key data on spatial patterns of slope behaviour, when due care and consideration is given throughout the processing, alignment and change-detection phases.

---

---

## **Interpreting changes in coarse sediment availability in a glacierized Andean stream by using hysteresis indexes**

Ricardo Carrillo and Luca Mao

Department of Ecosystems and Environments, Pontificia Universidad Católica de Chile,  
Santiago, Chile

Quantifying bedload transport in mountain stream is of the highest importance for predicting morphodynamics and risks during flood events, and for planning river management practices. At the scale of single flood event, the relationship between water discharge and bedload transport rate often reveals hysteretic loops. When sediment transport peaks before water discharge the hysteresis is clockwise. If the peak of sediment transport occurs before the peak of flow discharge, the resulting hysteresis is clockwise, and this has been related to early rupture of the static armour layer, or to the loose surface bed material left by previous high-magnitude floods, so generally to unlimited sediment supply conditions. On the contrary, counterclockwise hysteresis has also been observed and mainly related to bed form development lagging changes in flow, the time necessary to destroy a well-established armour layer, or the consolidation of grains in the bed during intra-flood periods. Bedload hysteresis observed in the field is thus most often due to different sediment availability conditions between the rising and falling limb of hydrographs. Understanding the direction and magnitude of hysteresis at the single flood event can this reveal the sediment availability, and temporal trend of hysteresis could be used to infer the dynamic of sediment sources. This work is focused in the temporal trend of hysteresis pattern of bedload transport in a small (27 km<sup>2</sup>) glacierized catchment in the Andes of central Chile (Estero Morales) during the ablation season from October 2014 to March 2015. Runoff is dominated by snowmelt during spring and glacier melt in summer and late summer. Calibration was carried out using a 0.5 m long Japanese acoustic pipe sensor fixed on the channel bed. This sensor detects the acoustic vibrations induced by particles hitting the device. Vibrations are amplified and then transmitted to a converter, which generates a voltage processed then through a 6-channel band-path filter. Direct bedload samplings were taken using a Bunte-type trap. A preliminary analysis of the collected data reveals that hysteresis of single floods due to snow- and glacier-melting index follow patterns according to the season. Clockwise hysteresis is typical in events occurring in late spring and early summer, while counterclockwise appears mostly in the summer season.

---

The hysteresis index tends to decrease from spring to late summer, indicating a progressive shift from clockwise to counterclockwise loops. This pattern suggests that sediment availability decreases overtime probably due to the progressive exhaustion of sediments stored in the channel bed.

This research is being developed within the framework of Project FONDECYT 1130378.

---

## **Environmental controls, spatiotemporal variability and rates of contemporary fluvial suspended sediment transport in the inner Nordfjord in western Norway**

Achim A. Beylich and Katja Laute

Geological Survey of Norway (NGU), Geo-Environment Division,  
P.O. Box 6315 Sluppen, NO-7491 Trondheim, Norway

There is the general opinion that fluvial suspended sediment transport is of significant importance within the sedimentary budgets of glacierized or partly glacierized drainage basin systems. In this study, contemporary suspended sediment transport has been monitored and analyzed since 2004 in selected partly glacierized drainage basins in the steep fjord landscape of the inner Nordfjord in western Norway. The size of the selected drainage basins ranges from 60.1 km<sup>2</sup> to 79.5 km<sup>2</sup>, with the share of drainage basin areas being covered by glaciers ranging from 38% to 18%. Our data indicate that there are significant intra- and inter-annual variations with respect to fluvial suspended sediment transport rates and suspended sediment yields. Three different periods with an increased frequency of major discharge events can be identified over the year, with these periods showing a significant inter-annual variability. High runoff in spring (April – June) is mainly caused by snowmelt whereas major discharge events in summer (July – August) are mostly due to thermally determined glacier melt. In autumn (September – November), major runoff events are associated with long-lasting and/or heavy rainfall events. Autumn and summer are with respect to fluvial suspended sediment transport more important periods than spring. The intensity of fluvial suspended sediment transport in autumn depends strongly on the number of heavy rainfall events that can trigger transfers of sediments from slope systems into main stream channels through saturation overland flow and connected slope wash and debris flow events. The computed mean annual suspended sediment yields show a significant spatial variability and range from 16 t km<sup>-2</sup>yr<sup>-1</sup> to 31 t km<sup>-2</sup>yr<sup>-1</sup>. Main environmental controls of the detected spatial variability of mean annual and drainage basin wide suspended sediment yields are (i) the share of the drainage basin area being covered by glaciers, (ii) the efficiency of small proglacial lakes in trapping part of the suspended sediments delivered by defined outlet glaciers, and (iii) the steepness and the degree of vegetation cover of ice-free drainage basin areas with sedimentary covers.

---

The calculated annual suspended sediment yields in the inner Nordfjord are altogether lower than annual suspended sediment yields found in many other glacierized drainage basin systems worldwide, and the fluvial sediment transport in the selected drainage basins of the inner Nordfjord is supply-limited.

---

## **Inferring LGM sedimentary and climatic changes in the southern Eastern Alps foreland through the analysis of a 14C ages database (Brenta megafan, Italy)**

Sandro Rossato and Paolo Mozzi

Department of Geosciences, University of Padua, Padua, Italy

The evolution of climate, environment and depositional settings during the LGM has long since been deeply investigated, being the youngest and best preserved glacial period. The European Alps and their foreland have been highly investigated with a wide range of techniques in order to discern the evolution of the LGM and its internal fluctuations. We suggest the analysis of radiocarbon ages databases to be a useful technique to infer information on the evolution of major glaciofluvial systems in the Alpine foreland, in relation to glaciers dynamics and climatic fluctuations during the LGM. The Brenta megafan (NE Italy) has the dual advantage of being located in a well-studied area (the Venetian-Friulian plain), where many key sites are located (e.g. the Tagliamento morainic amphitheater and the Lake Fimon), and to have been extensively radiocarbon dated. By means of statistical methods and meta-analysis of the whole database and some sub-datasets (i.e. ages obtained from peat layers and dates with a reference depth in respect to the top of the depositional surface of the LGM), we were able to infer some useful insights on the LGM evolution of this alluvial systems. In particular, the Brenta megafan proved to have aggraded with remarkably different rates during three different LGM sub-intervals (pre-27, 28-23 and 24-17.5 kyears cal BP), meaning that erosive and transport processes were more effective (sedimentation rates are 25 to 60% higher) during the central part of the LGM.

The statistical regressions highlight the same fluctuations in the sedimentation rates that were recognized also with the calculation along single cores, even if the obtained values vary according to the adopted methodology. Indeed, the younger interval shows smaller sedimentation rates ( $\approx 1.3$  m/kyears with every technique) than the middle one ( $\approx 2.2$  m/kyears with linear and nonlinear regression and  $\approx 1.65$  m/kyears with the Least Median of Square - LMS - regression), resulting in at least 28% (LMS values; 64% with linear and nonlinear estimates) higher values in the second group, compared to the first one. The older population is composed by few, poorly-correlated data, hence carefulness should be adopted to not mis- or over-interpret the results. Nevertheless, it's remarkable that all the regression modules gave

---

very similar results ( $\approx 1$  m/kyears), that are at least 25% and 60% (LMS values) less than those from the younger and the middle population, respectively.

Climatic signals proved to be difficult to detect. The good correspondence of regional events with the data deriving from our analyses shows that the Brenta glaciofluvial system evolved coherently with the neighboring glaciers and connected sedimentary systems in the southeastern Alps (e.g., Tagliamento and Astico glaciers). The boundary between the two younger sub-intervals at 23.5 kyears cal BP is in good correspondence with a climatic amelioration event recognized in the whole southeastern Alpine region and displays some similarities with the evolution of the alluvial - lacustrine system of Lake Albano in a fully Mediterranean realm.

Peat layers production in the floodplain fens proved to increase significantly in correspondence of the intra-LGM climate amelioration corresponding to the second half of Heinrich event 2, peaking at around 23.5 k years cal BP.

## **Proglacial fluvial sediment dynamics in the Gepatschferner forefield (Tyrol/Austria)**

David Morche<sup>1,2</sup>, Matthias Faust<sup>1</sup>, Henning Baewert<sup>1</sup> and Anne Schuchardt<sup>1</sup>

<sup>1</sup> Institute of Geosciences and Geography, Martin-Luther-University Halle-Wittenberg, 06120 Halle/Saale, Germany

<sup>2</sup> Catholic University of Eichstätt-Ingolstadt, Chair of Physical Geography, Ostenstr.18, D-85072 Eichstätt, Germany

Glaciers in the European Alps are retreating since the end of the Little Ice Age around 1850. Where the glaciers shrink, they leave unconsolidated sediment stores (moraines, till, glacialfluvial deposits). These sediment stores are highly vulnerable for being subsequently eroded and are thus a key variable (source) in the fluvial sediment budget of proglacial areas. The fluvial system in proglacial areas is more or less continuously fed with (fine) sediment by glacial melt water (glacial milk) during the ablation period and infrequently (e.g. during rainstorm events) supplied with sediment by landslides, debris flows, rock fall or fluvial transport from the slopes. A part of the sediment input is temporary stored in intermitted sinks, such as the river bed, bars or braid plains. These storages can be reworked and then become sources for fluvial sediment transport mainly during floods. These sediment transporting processes are highly variable in both, the temporal and spatial scale. Following this high variability, knowledge of sediment fluxes and the interrelated geomorphological processes in proglacial areas, based on field-data was found to be lacking. Therefore, a research project has been set up in the Kaunertal valley, Austrian Alps. The presented part of this joint project is focused on the quantification of recent fluvial sediment dynamics. Suspended sediment load and bed load are measured on different locations in the proglacial Fagge River below the Gepatschferner, one of the largest glaciers in the Alps. The main aim of the presented part of the joint project is the investigation of the interrelations of the sediment transport rates in the proglacial Fagge River in the Kaunertal valley.

---

---

**Environmental drivers, spatiotemporal variability and rates of contemporary chemical and mechanical fluvial denudation in selected glacierized and non-glacierized cold climate catchment geosystems: From coordinated field data generation to integration and modeling**

Achim A. Beylich

Geological Survey of Norway (NGU), Geo-Environment Division,  
P.O. Box 6315 Sluppen, NO-7491 Trondheim, Norway

There is, by today, an impressive number of quantitative process geomorphic studies presenting contemporary chemical or mechanical fluvial denudation rates from a wide range of cold climate catchment systems around the globe. However, the number of quantitative studies that actually considers and includes all three main components of fluvial transport, i.e. solute transport, suspended sediment transport and bedload transport, is actually rather small. Most of the existing studies include only one or, at best, two of these components. It is generally accepted that a knowledge of the quantitative shares of fluvial solute, suspended sediment and bedload transport of the total fluvial transport, together with detailed information on sediment sources and sediment storage, is needed for the reliable construction and understanding of sedimentary budgets.

In this contribution results from longer-term process geomorphic work carried out in selected glacierized and non-glacierized high-latitude and high-altitude cold climate catchment geosystems in Iceland, Norway, Sweden and Finland are compared. The size of the six studied catchment systems ranges from 7.0 km<sup>2</sup> to 79.5 km<sup>2</sup>. Contemporary chemical and mechanical fluvial denudation rates measured in the defined catchment systems with different cold climates, different degrees of glacier coverage, different lithologies and general sediment availabilities, different catchment morphometries, and varying degrees of vegetation cover are presented. The geomorphic process monitoring and analysis includes fluvial solute, suspended sediment and bedload transport. By direct comparisons among the different catchments environmental controls of the computed annual denudation rates are detected and the spatial variability of the contemporary chemical and mechanical fluvial denudation rates found across the different cold climate catchment systems is explained. Annual fluvial denudation rates generally increase with increasing topographic relief, increasing mean slope angles, increasing annual precipitation and increasing glacier coverage, and generally decrease with

---

---

increasing vegetation cover in areas with sedimentary covers. Lithologies with low weathering resistance lead to clearly higher fluvial denudation rates than lithologies with high weathering resistance. The presented approach of analyzing and integrating comparable datasets on fluvial solute and sediment transport collected from different defined cold climate catchment geosystems with varying environmental conditions and characteristics is found to be useful for the quantitative analysis of environmental drivers and the spatiotemporal variability of contemporary solute and sedimentary fluxes, yields and denudation rates in cold climate environments. This approach can also serve to improve possibilities of modeling possible effects of climate change by applying space-for-time substitution.

---

## **Reconstruction of postglacial rockfall/rock-slope failure activity in the mountainous fjord landscape of western Norway**

Katja Laute<sup>1</sup>, Achim A. Beylich<sup>2</sup>, and Stefan Winkler<sup>3</sup>

<sup>1</sup> Trondheim, Norway

<sup>2</sup> Geological Survey of Norway (NGU), Geo-Environment Division, Trondheim, Norway,

<sup>3</sup> University of Canterbury, Department of Geological Sciences, Christchurch, New Zealand

Large areas of formerly-glaciated mountain landscapes exhibit a high spatial density of postglacial rockfalls and rock-slope failures. However, the temporal patterns of rock-slope failure frequencies after Deglaciation are still fairly unknown. The mountainous fjord landscape in western Norway represents a suitable study area as it exhibits a high number of rockfalls and rock-slope failures within a defined region with a well known Deglaciation history. In detail, the inner parts of the Nord- and Sognefjord systems located closely to the Jostedalbreen ice cap in western Norway are selected as study areas.

The focus of this study is on (i) the temporal reconstruction of rockfalls and rock-slope failures within the two defined and nearly lithologically homogenous study areas (Nord- and Sognefjord) and (ii) the identification and explanation of the triggering and controlling factors of the investigated rock-slope failures.

First investigations have been started by applying Schmidt-hammer exposure-age dating (SHD) at seven larger rockfall deposits as well as at five moraines of known age within two steep, parabolic-shaped and glacier-connected neighbouring drainage basins, Erdalen (79.5 km<sup>2</sup>) and Bødalen (60.1 km<sup>2</sup>), located in the inner Nordfjord. During the sampling 50 to 100 impacts using a mechanical Proceq N-type instrument were taken from the surface of 5 to 50 single rockfall boulders located at the outer margin of the rockfall deposits. In order to avoid sampling of more recent rockfalls or redistributed debris material the sampling strategy selected preferred a larger number of individual boulders sampled with few impacts rather than sampling just a small number of boulders with a high number of multiple impacts. First results show that the mean rebound (R-) values measured at the seven rockfall deposits fall into recognizably different age categories. Based on the SHD measurements obtained from the moraines of known age, the determined rockfall age categories are situated between the Preboreal with Schmidt-hammer rebound (R-) value means and 95% confidence intervals

---

ranging from  $39.7 \pm 2.0$  to  $45.2 \pm 1.4$  and the so-called Little Ice Age period with R-values ranging from  $54.0 \pm 1.8$  to  $60.0 \pm 1.8$ .

To establish a chronology of postglacial rock-slope failures a combination of different relative and numerical dating techniques will be applied. The controls of selected postglacial rock-slope failures will be explored using detailed geomorphological mapping combined with hillslope morphometry analyses and investigations of lithological and structural rock properties. A sound understanding of controls is essential in order to understand the temporal pattern of rock-slope failure activity.

Results of this study will contribute to improved geomorphic hazard assessments and new insights on the anticipated geomorphic consequences of global climate change.

## Peats and lake sediments in the Pirin Mountains, Southwestern Bulgaria

Dimitar Krenchev

University of Sofia “St. Kliment Ohridski”, Department of Climatology, Hydrology and Geomorphology, Sofia, Bulgaria

The Pirin (2914 m a.s.l) Mts. are part of a horst-blocked upland and have a NW-SE extension in Southwestern Bulgaria. The mountains have typical alpine landscape, especially in the northern part, dominated by large cirques, U-shaped valleys and moraine ridges, which have been preserved since the last Pleistocene glaciation. Most of the cirque depressions are situated at a height between 2000 and 2500 m a.s.l., occupied by lakes and peat bogs. There are about 160 lakes in the Pirin Mountains and 120 of them have stable water regime. The other lakes have an area smaller than 0.1 ha and dry in the summer. There are available data on physical, chemical and biological parameters for most of the lakes and also the region is well studied in regard to the vegetation and climate variability. Over the past 30 years palynological studies with around 60 radiocarbon dating of pollen and macrofossils of more than 20 different glacial lakes and peat bogs were carried out.

The main aim of this study is to analyze peats and lakes sediments and their sequences by grain-size and mineralogy in order to do correlation with the available data. This would allow clarifying the intensity and conditions of sedimentation in the past periods, the origins of deposits and the rate of their accumulation.

For the purpose of the study four sections with available palynological data and radiocarbon dating were selected and drilled - Lake Bezbog and peat bogs Gundova Mochara, Mozgovitsa and Begovitsa. Samples from the drilling of another lake (Okadensko) were provided by the Biological faculty of the Sofia University. The depth of the drilling ranges from 80 to 160 cm and have 3 to 7 different layers. Grain-size analysis was done and for Lake Bezbog, Okadensko and Gundova Mochara mineralogical analysis was carried out.

In all sections the deposits show uniformity without abrupt changes. The percentage of the fractions in the different sequences is almost equally. There are some differences between the various samples regarding the sorting and size of the sediments. For example the prevailing fraction at Lake Bezbog is sand as a percentage participation in depth ranges between 68 % and 73 %, while in Lake Okadensko silts dominate, which reach to 78 %. In

---

peat bogs Gundova Mochara and Mozgovitsa there are two prevailing fractions - silts and sands and both vary around 40 - 50%.

Mineralogical analysis also shows some differences in regard to origin and transportation of the sediments. Multiple changes of the source were observed in the various sequences as well as the formation of new minerals which indicates a chemical weathering.

For more detailed results other lakes and peats in the Pirin Mountains should be studied. This would lead to a more detailed data for ongoing geomorphological processes in the past and paleoenvironmental reconstruction.

---

---

## Characterization of perennial and episodic springs with stable isotope signatures in the Kaunertal Valley, Austria

Verena Czarnowsky<sup>1</sup>, Sarah Kamleitner<sup>2</sup>, Kay Knöller<sup>3</sup>, Jürgen Heinrich<sup>1</sup>, David Morche<sup>4</sup>, and Sabine Kraushaar<sup>2</sup>

<sup>1</sup> Leipzig University, Institute of Geography, Leipzig, Germany

<sup>2</sup> University of Vienna, Department of Geography and Regional Research, Vienna, Austria

<sup>3</sup> Helmholtz Centre for Environmental Research – UFZ, Halle, Germany

<sup>4</sup> Martin Luther University Halle-Wittenberg, Institute of Geosciences and Geography, Halle, Germany

Since the end of the Little Ice Age in 1850, the maximum extent of the glaciers in the European Alps, including the Gepatschferner Glacier in the Kaunertal Valley (Western Tyrol, Austria), has been decreasing. In the proglacial system of the Kaunertal Valley, uncovered and easily erodible sediments on steep slopes constitute a high geomorphic active area. As a part of the PROSA project (PROglacial Systems of the Alps), a significant volume reduction of sediments on lateral moraines has been calculated using terrestrial laser scans (TLS) of consecutive years, as well as water and sediment discharge measurements in the Fagge River. However, the lack of the corresponding amount of correlative sediments downstream, and the detection of perennial and episodic springs on the lateral moraines foster the assumption that melting dead ice could be part of the calculated volume reduction on steep slopes in the Kaunertal Valley. Hence, this ongoing research project aims to clarify the origin of springs on the lateral moraines using the stable isotopes  $\delta^2\text{H}$  and  $\delta^{18}\text{O}$ , and tracer experiments with Brilliant Blue FCF to prove the hydrological connectivity between runoff on the moraine ridge and the springs.

Between May and August 2015, 44 spring water, ice and precipitation samples were collected monthly and stable isotope signatures of  $\delta^2\text{H}$  and  $\delta^{18}\text{O}$  were analysed. 26 of perennial and episodic springs on the lateral moraines display a corresponding isotope signature to ice. The monthly results of this current research project are compared to the single investigations by Kraushaar et al. (2014) in September 2013 and July 2014 and to the monthly precipitation averages of 30 years measurements in the Villacher Alp, derived from the Global Network for Isotopes in Precipitation. Furthermore, several discharge measurements of the springs on the lateral moraines contribute to characterize the springs.

---

## References

Kraushaar, S., Blöthe, J., Baewert, H., Dubberke, K., Culha, C., Knöller, K., Morche, D. (2014): Supportive methods for sediment budgeting: Stable isotope measurements of perennial springs in the Kaunertal valley. IN: Morche, D., Krautblatter, M., Beylich, A., Heckmann, T. (2014): Proceedings of the 8th I.A.G./A.I.G. working group SEDIBUD (Sediment Budgets in Cold Environments) “Sediment Cascades in Cold Climate Geosystems”. Zugspitze/Reintal, Bavaria/Germany, September 1 - 3/4, 2014.

---

## **Implications of long- lived radionuclide $^{129}\text{I}$ for Geomorphology – first attempts from Kaunertal**

Sarah Kamleitner<sup>1</sup>, Verena Czarnowsky<sup>2</sup>, Ronald Pöppl<sup>1</sup>, Johannes Lachner<sup>3</sup>, Peter Steier<sup>3</sup>, David Morche<sup>4</sup> and Sabine Kraushaar<sup>1</sup>

<sup>1</sup> University of Vienna, Department of Geography and Regional Research, Vienna, Austria,

<sup>2</sup> Universität Leipzig, Leipzig, Institute of Geography, Leipzig, Germany

<sup>3</sup> University of Vienna, Isotope Research and Nuclear Physics, Vienna, Austria

<sup>4</sup> Martin Luther University Halle – Wittenberg, Institute of Geoscience and Geography, Germany

High resolution LiDAR time series are useful tools allowing the quantification of relief changes in proglacial areas and the establishment of sediment budgets in morphological highly active Alpine catchments. Estimated sediment volume loss is often exclusively associated with different processes of mass movement, slope wash, and fluvial erosion, whereas the melt out of dead ice bodies, as potential contributor to morphological changes, remains unnoticed. Yet, the melting alone could account for a volume reduction in the sediment matrix of up to 13 %, the additional leaching of the water to a further unknown amount. Thus, the potential presence of dead ice lenses in the lateral moraines could lead to uncertainties in sediment erosion calculation using DEMS from the glacier forefield.

Previous investigations of springs evolving from the Little Ice Age (LIA) lateral moraine were showing light isotope signatures comparable to those of the glacier ice, and led to first assumption about the presence of ice lenses within the moraines (Kraushaar et al. 2014). In order to verify this hypothesis and clarify the relative age of the potential ice a multi – method approach is being applied. It consists of  $^{129}\text{I}$  analysis of selected spring samples, as well as geophysical measurements.

The environmental abundance of the long- lived radionuclide  $^{129}\text{I}$  has been enriched by human activity such as nuclear weapon tests, nuclear energy production, and reprocessing plants by several orders of magnitudes. Iodine's high solubility in water and its potential to pass between different media allows a statement on the relative age of the spring waters - being either pre- nuclear melt water from ice lenses within the moraine or recent ice, runoff, and/or precipitation percolating through it.

---

The use of iodine for relative age estimations and to identify the origin of springs in proglacial areas has not been well established to this day. Therefore further information about subsurface conditions, inner structure of the moraines and existence and position of possible ice lenses are going to be gained by several ERT (Electrical Resistivity Tomography) profiles in different morphological positions on the moraines as well as thermal images.

Sarah Kamleitner is supported by DAAD-IAESTE (Az. DE-2015-1321-1-A) and by the University of Vienna (grant to Sabine Kraushaar).

## References

Kraushaar, S., Blöthe, J., Baewert, H., Dubberke, K., Culha, C., Knöller, K., Morche, D. (2014): Supportive methods for sediment budgeting: Stable isotope measurements of perennial springs in the Kaunertal valley. IN: Morche, D., Krautblatter, M., Beylich, A., Heckmann, T. (2014): Proceedings of the 8th I.A.G./A.I.G. working group SEDIBUD (Sediment Budgets in Cold Environments) "Sediment Cascades in Cold Climate Geosystems". Zugspitze/Reintal, Bavaria/Germany, September 1 - 3/4, 2014.

---

**Annual variability of sediment storage on proglacial braid plains  
using TLS (Tyrol, Austria)**

Anne Schuchardt<sup>1</sup>, Matthias Faust<sup>1</sup>, Henning Baewert<sup>1</sup>, and David Morche<sup>1,2</sup>

1 Institute of Geosciences and Geography, Martin-Luther-University Halle-Wittenberg, 06120  
Halle/Saale, Germany

2 Catholic University of Eichstätt-Ingolstadt, Chair of Physical Geography, Ostenstr.18, D-  
85072 Eichstätt, Germany

Fluvial systems of proglacial areas are influenced by spatial and temporal variability of discharge and sediment transport. While the discharge in proglacial areas is predominantly influenced by glacial melt water, the sediment transport is characterized by mainly unconsolidated and unvegetated sediment sources and stores. The most important sediment stores in high mountain areas are braid plains. They develop in alluvial channel reaches or upstream of barriers and can switch their role from sediment sinks, when more sediment is deposited than eroded, to sediment sources and vice versa.

Due to glacial retreat, higher discharges and higher rates of sediment transport are expected in the near future. Understanding the influence of sediment stores in the proglacial sediment transport in summit regions is important for regional planning and natural hazard management. The interdisciplinary research project PROSA (High-resolution measurements of morphodynamics in rapidly changing PROglacial Systems of the Alps) investigates the sediment budget of a proglacial system in the European Alps combining various methods for measuring different geomorphological processes.

In this context the so called Fernergries and Zwischengries braid plains are observed by terrestrial laserscanning in order to quantify sediment erosion and deposition. They are located in the Kaunertal in the Eastern European Alps. The valley is drained by the Fagge River originating from the glacier Gepatschferner. The Gepatschferner is located at the south end of the Kaunertal. It is the second largest glacier in Austria.

The braid plains Fernergries and Zwischengries were scanned biannually from 2012 to 2015.

---

Scans were carried out in June and then repeated in September to detect changes after the high summer discharges. Results show that the smaller braid plain Zwischengries started initially as a sediment source, until September 2013, when it switched to a sediment sink.

However, in June 2014 the braid plain reverted back to a sediment source. The braid plain Fernergries is recently acting as a sediment source after a great sediment input in August 2012 during an extreme discharge event.

---

## **Supraglacial sediment input and glacio-fluvial sediment output of an alpine glacier, the Gepatschferner (Tyrol, Austria)**

Matthias Faust<sup>1</sup>, Henning Baewert<sup>1</sup>, and David Morche<sup>1,2</sup>

<sup>1</sup> Institute of Geosciences and Geography, Martin-Luther-University Halle-Wittenberg, 06120 Halle/Saale, Germany

<sup>2</sup> Catholic University of Eichstätt-Ingolstadt, Chair of Physical Geography, Ostenstr.18, D-85072 Eichstätt, Germany

During the years 2012 to 2014 the Gepatschferner, Austria's second largest glacier, has shown an accelerated glacial retreat leading to the exposure of unconsolidated sediments as well as bedrock areas. The glacier is located in the Eastern European Alps at the south end of the Kaunertal valley covering an area of 15.7 km<sup>2</sup> (2012) and is drained by the Fagge River.

To get a first impression of the sediment budget of the Gepatschferner, we looked into the sediment delivery by surrounding rock walls and the sediment output of the glacial meltwater stream. This study is part of the PROSA project ("High-resolution measurements of morphodynamics in rapidly changing Proglacial Systems of the Alps").

The supraglacial sediment input is determined by identifying the contributing rock walls and applying measured back weathering rates on them as well as using DoDs created from TLS data for a small and very active rock wall. For the identification of contributing rock walls an energy line angle approach is used on the DEM of 2012.

The sediment output of the glacial meltwater stream, the Fagge River, was measured during the ablation periods from 2012 to 2014 at a gauging station installed in front of the glacier outlet. Water level was recorded every 15 minutes and discharge measurements were made at different stages. Using the derived stage-discharge relationships, a hydrograph was computed for each season. Additionally suspended sediment concentration (SSC) and bedload transport were measured; the first by several hundred water samples, the second with a portable Helly-Smith sampler. The solid sediment output was then estimated using the discharge data as well as SSC and bedload data.

The results show that the recent supraglacial sediment input is much bigger than the glacio-fluvial sediment output. It was found that a small but very active rock wall delivers more than 85 % of the total sediment input.

---

## **Seasonality of reworking conditions of proglacial slopes in the upper Kaunertal**

Jana-Marie Dusik, Fabian Neugirg, Tobias Heckmann, Ludwig Hilger, Florian Haas, and Michael Becht

Department of Physical Geography, Catholic University of Eichstaett-Ingolstadt, Eichstaett, Germany

Glacier retreat since the end of the Little Ice Age (LIA) has exposed, large areas of loose glacial sediments to reworking by non-glacial processes like rill erosion, gullying, slope wash and mass movements. Seasonal meteorological parameters have great influence on frequency and magnitude of erosional events. With this study we investigate the differences between typical seasonal climatic phenomena and corresponding sediment flux rates on steep proglacial moraines. The combination of freeze and thaw processes, insolation, snowmelt, and precipitation in different thermal conditions (snow and rain) due to highly variable temperatures leads to very dynamic slope processes in late winter/springtime and at the beginning of the winter. Unlike with summer conditions, when moraine slopes use to dry out and densify, the moraines are waterlogged and sediments are easily transportable without need for high magnitude rainfall events. In the summer months the hardened surface of moraine slopes has a very low infiltration capacity and most of the rainfall water occurs as surface runoff. Only after some time with steady rainfall of medium magnitude the slope surface is opened for infiltration and the sediments are loosened for transport processes triggered by e.g. summerly thunderstorms with high magnitude rainfall events.

The investigated area is situated in the Upper Kaunertal, Central Austrian Alps (64 km<sup>2</sup>), and forms part of the joint project PROSA (High-resolution measurement of morphodynamics in rapidly changing proglacial systems of the Alps). We use high-resolution surveying techniques like airborne and terrestrial LiDAR and digital photogrammetry to monitor surface changes effected by different geomorphic processes on steep moraines and drift-mantled slopes that have been deglaciated since the end of the LIA.

Multitemporal airborne images dating back to 1953 are used to derive digital elevation models (DEMs) for long-term analysis of surface changes and the corresponding sediment transfer.

---

---

Recent developments are measured by DEMs of Difference (DoD) based on multitemporal airborne (2006, July 2012, September 2012) and terrestrial (July 2010, September 2011, September 2012, September 2013, September 2014) LiDAR surveys. Short-term changes are investigated by Structure from motion (Sfm) data based on terrestrial photogrammetry since May 2015 in weekly to monthly recording cycles. High resolution meteo data (precipitation, temperature and soil moisture) are cross-correlated and compared to according sediment flux rates.

---

**List of participants**

<b>Name</b>	<b>First name</b>	<b>Address</b>	<b>e-mail</b>
Allan	Mark	Northumbria University School of Engineering and Environment Department of Geography Ellison Building A221 Newcastle upon Tyne NE1 8ST	<a href="mailto:mark.allan@northumbria.ac.uk">mark.allan@northumbria.ac.uk</a>
Beylich	Achim	Geological Survey of Norway (NGU) Geo-Environment Division P.O. Box 6315 Sluppen Leiv Eirikssons vei 39 NO-7491 Trondheim, Norway	<a href="mailto:achim.beylich@ngu.no">achim.beylich@ngu.no</a>
Bozhkov	Petko	University of Sofia "St. Kliment Ohridski" Faculty of Geology and Geography Department Climatology, Hydrology and Geomorphology 1504 Sofia, 15 Tsar Osoboditel	<a href="mailto:petko_bozhkov@abv.bg">petko_bozhkov@abv.bg</a>
Carrillo	Ricardo	Department of Ecosystems and Environments, Pontificia Universidad Católica de Chile, Santiago, Chile	<a href="mailto:rcarril@uc.cl">rcarril@uc.cl</a>
Czarnowsky	Verena	Leipzig University, Institute of Geography	<a href="mailto:czarnowsky.v@gmx.de">czarnowsky.v@gmx.de</a>
Dräbing	Dräbing	Bonn	<a href="mailto:daniel.draebing@gmx.de">daniel.draebing@gmx.de</a>
Dusik	Jana	Physical Geography Catholic University of Eichstaett-Ingolstadt Ostenstraße 18 85072 Eichstätt Germany	<a href="mailto:jana.dusik@ku.de">jana.dusik@ku.de</a>
Faust	Matthias	Martin-Luther-University Halle-Wittenberg Institute of Geosciences and Geography Von-Seckendorff-Platz 4 06120 Halle (Saale) Germany	<a href="mailto:MatthiasFaust@gmx.de">MatthiasFaust@gmx.de</a>
Gavrila	Ionela-Georgiana	Babes-Bolyai University, Faculty of Geography, Cluj-Napoca, Romania	
Kamleitner	Sarah	University of Vienna	<a href="mailto:Sarah.Kamleitner@gmx.net">Sarah.Kamleitner@gmx.net</a>
Kraushaar	Sabine	University of Vienna	<a href="mailto:Sabine.kraushaar@univie.ac.at">Sabine.kraushaar@univie.ac.at</a>
Krenchev	Dimitar	University of Sofia "St. Kliment Ohridski" Faculty of Geology and Geography Department Climatology, Hydrology and Geomorphology 1504 Sofia, 15 Tsar Osoboditel,	<a href="mailto:krenchev@abv.bg">krenchev@abv.bg</a>

		office 281	
Laute	Katja	Trondheim, Norway	<a href="mailto:katja.laute@googlemail.com">katja.laute@googlemail.com</a>
McColl	Sam	Physical Geography Group, Institute of Agriculture and Environment, Massey University Private Bag 11222, Palmerston North 4412	<a href="mailto:s.t.mccoll@massey.ac.nz">s.t.mccoll@massey.ac.nz</a>
Morche	David	Martin-Luther-University Halle-Wittenberg Institute of Geosciences and Geography Von-Seckendorff-Platz 4 06120 Halle (Saale) Germany Physical Geography Catholic University of Eichstaett-Ingolstadt Ostenstraße 18 85072 Eichstätt Germany	<a href="mailto:david.morche@geo.uni-halle.de">david.morche@geo.uni-halle.de</a>
Pop	Olimpiu	Babes-Bolyai University, Faculty of Geography, Cluj-Napoca, Romania	<a href="mailto:olimpiu_p@yahoo.com">olimpiu_p@yahoo.com</a>
Rossato	Sandro	Department of Geosciences – University of Padova	<a href="mailto:sandro.rossato@unipd.it">sandro.rossato@unipd.it</a>
Sarafov	Aleksandar	University of Sofia “St. Kliment Ohridski” Faculty of Geology and Geography Department Climatology, Hydrology and Geomorphology 1504 Sofia, 15 Tsar Osoboditel	
Schuchardt	Anne	Martin-Luther-University Halle-Wittenberg Institute of Geosciences and Geography Von-Seckendorff-Platz 4 06120 Halle (Saale) Germany	<a href="mailto:anneschuchardt@googlemail.com">anneschuchardt@googlemail.com</a>
Stoyanova	Sonya	University of Sofia “St. Kliment Ohridski” Faculty of Geology and Geography Department Climatology, Hydrology and Geomorphology 1504 Sofia, 15 Tsar Osoboditel	<a href="mailto:sonya.s.stoyanova@gmail.com">sonya.s.stoyanova@gmail.com</a>

Get your radiocarbon results  
before your research fossilizes

**BETA**

**Beta Analytic**  
Radiocarbon Dating  
Since 1979

- Results in as little as 2-3 days
- Queries answered within 24 hours
- Results available online

**Australia Brazil China India Japan Korea UK USA**

[www.radiocarbon.com](http://www.radiocarbon.com)