NÁTTÚRUSTOFA
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5th I.A.G./A.I.G. SEDIBUD Workshop Sediment Budgets in Cold Environments

"Qualitative and Quantitative Analysis of Sedimentary Fluxes and Budgets in Changing Cold Climate Environments: Field-Based Approaches and Monitoring".

Sauðárkrókur, Iceland
September 19th – 25th, 2010

Extended Abstracts Contributions

Editors: Þ. Sæmundsson. A. Decaulne &
A.A. Beylich

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I.A.G./A.I.G. SEDIBUD

Sediment Budgets in Cold Environments

http://www.geomorph.org/wg/wgsb.html

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Preface

Following the workshops in Trondheim, Norway (2006), Abisko, Sweden (2007), Boulder, U.S.A. (2008) and Kingston, Canada (2009), the I.A.G./A.I.G. Working Group SEDIBUD (SEDIment BUDgets in cold environments) continues on its renewed period of activity (2009-2013) in Sauðárkrókur, Iceland, with the fifth workshop of the group.

The topic of this Scientific Meeting is *Qualitative and Quantitative Analysis of Sedimentary Fluxes and Budgets in Changing Cold Climate Environments: Field-Based Approaches and Monitoring".* The workshop is focussed on the crucial aspect of relying on strong present-day observations of geomorphic processes and related landforms in high latitude and high altitude fragile environments, presently recording significant climate change related perturbations. Only field-based routines and monitoring, carried out at high resolution, hourly, daily, seasonal or yearly time scales, can describe and analyse the various ways thermal and precipitation regimes affect the Earth surface. Such an integrated approach provides significant information on sediment fluxes and budgets from source to sink in catchments, from the slope systems to the fluvial ones. Also, the understanding of landforms resulting from previous geomorphic activity, associated to accurate isochrones and time series analyses, is a key to understand future landscape modifications. Such robust field-based observations and measures allow the definition and adjustment of appropriate modelling approaches.

During the meeting, the group will get the opportunity to visit selected SEDIBUD Key Test Sites in Northern and North-eastern Iceland, where projects using several time-scale proxies are ongoing.

This year, the I.A.G./A.I.G. Working Group SEDIBUD is also supporting young scientists presenting there PhD projects and results on sediment budgets and fluxes in different cold environments.

We welcome you all to Sauðárkrókur!

Þorsteinn Sæmundsson
Armelle Decaulne
Achim A. Beylich

Programme

Sunday, September 19th, 2010

Arrival of participants in the late afternoon and dinner

Monday, September 20th, 2010

08:00 Departure from Sauðárkrókur for the excursion in Skagafjörður.

Visit of the SEDIBUD Key Test Site Reykjaströnd, just North of Sauðárkrókur; of the Almenninga landslide area in the Northeastern part of the fjord; lunch in the town of Siglufjörður; stop in Hofsós (close look at the local use of geothermy, and visit of the basaltic pillars exposed along the coastline); visit of the "Beer Institute" on the Hólar University campus in the valley of Hjaltadalur.

Tuesday, September 21st, 2010

08:00 - 09:00 Opening of the 5th SEDIBUD Science Meeting around the natural geothermical properties of the area… Meeting at 08:00 in front of the Sauðárkrókur swimming pool.

09:30 - 10:30 Welcome by Þorsteinn Sæmundsson, director of the Natural Research Centre of Northwestern Iceland and by the mayor of Sauðárkrókur; the SEDIBUD framework by Achim A. Beylich

10:30 - 10:50 Coffee break… or tea

Session 1 - Chair Scott F. Lamoureux

10:50 - 11:10 Þorsteinn Sæmundsson - *The Morsárjökull rock avalanche, in the southern part of the Vatnajökull ice cap, and its effect on the Morsárjökull outlet glacier from 2007-2010*

11:10 - 11:30 David Morche - *Karst hydrology and dissolved load of the upper Partnach River, Reintal/Zugspitze*

11:30 - 11:50 Isabelle Gärtner-Roer - *Kinematics and sediment transfer rates of active rockglaciers*

11:50 - 13:00 Lunch

Session 2 - Chair Þorsteinn Sæmundsson

13:00 - 13:30 Sigurdur Reynir Gislason (Invited Speaker) - *Direct evidence of the feedback between climate and weathering*

13:30 - 13:50 Achim A. Beylich - *Spatio-temporal variability of mechanical and chemical denudation rates in glacier-fed valley-fjord systems in the inner Nordfjord, western Norway*

13:50 - 14:10 Matt Strzelecki - *Quantifying cold coast sediment budgets: recent advances from High Arctic fjords in Svalbard*

14:10 - 14:30 Susan Liermann - *Variability of contemporary sedimentation rates in a small proglacial lake, Nordfjord area, Western Norway*

14:30 - 14:50 John C. Dixon - *Inorganic nitrogen in the geochemical budget of Kärkevagge, Swedish Lapland*

14:50 - 15:10 Katja Laute - *Influences of the Little Ice Age glacier advance on hillslope development in the headwater areas of two tributary valleys of the Nordfjord, Western Norway*

15:10 - 15:20 Coffee break… or tea

Session 3 - Chair John Dixon

15:20 - 15:40 Halldór G. Pétursson - *Landslides in Iceland, a short review*

15:40 - 16:00 Ola Magne Sæther - *Metals in water and foams from NOM-rich sub-Alpine streams*

16:30 - 17:30 Young Scientists Meeting (*chair*: Matt Strzelecki)

18:30 Poster session around a cocktail in the Natural Research Centre of Northwestern Iceland lecture hall

19:30 SEDIBUD Workshop dinner

Wednesday September 22nd, 2010

08:00 - 09:00 Some more investigations regarding the local geothermy…

Session 4 - Chair Achim A. Beylich

09:30 - 09:50 Wolfgang Fister - *Erosion by wind, windless rain, and wind-driven rain --- Experimental in situ measurements with a portable simulator*

09:50 - 10:10 Grzegorz Rachlewicz - *Sediment fluxes in glacierized valley systems of central Spitsbergen (Svalbard)*

10:10 - 10:30 Karianne S. Lilleøren - *A regional inventory of glacial and periglacial landforms indicating alpine permafrost in Norway*

10:30 - 11:00 Coffee break… or tea

Session 5 - Chair Armelle Decaulne

11:00 - 11:20 Skafti Brynjólfsson - *Morphological and sedimentological land system model for surging glacier at Tröllaskagi, North Iceland*

11:20 - 11:40 Scott F. Lamoureux - *High Arctic sediment fluxes associated with summer rainfall*

11:40 - 12:00 Bernd Etzelmüller - *7 years of permafrost monitoring in Iceland - updated results and geomorphological implications*

12:00 - 13:00 Lunch

Session 6 - Chair Þorsteinn Sæmundsson

13:00 - 13:30 Ólafur Arnalds (Invited Speaker) - *The continuous volcanic dust emissions and loess deposition in Iceland*

13:30 - 13:50 *Maciej Dluzewski* - Sediment supply from side valleys as a factor influencing the river channel pattern in the High Atlas; a case study from the Upper Dades valley

13:50 - 14:10 Armelle Decaulne - *The Höfðahólar rock avalanche in Skagafjörður, Northern Iceland: geomorphological characteristics and relative dating*

14:10 - 14:30 Coffee break… or tea

14:30 - 16:30 SEDIBUD Business Meeting

18:00 Visit to Verið - Vísindagarðar, refreshments from Fisk Seafood

19:30 Dinner

List of posters (displayed in the Natural Research Centre Lecture Hall)

Achim A. Beylich - *The global I.A.G. / A.I.G. Sediment Budgets in Cold Environments (SEDIBUD) Programme: Coordinated analysis and quantification of sedimentary fluxes and budgets in changing cold environments*

Skafti Brynjólfsson - *A collective database on landslides and snow avalanches in Iceland*

David Morche - *Modeling sediment transport in an alpine river reach with HEC-RAS 4.0*

Katarzyna Wasak - *Properties of initial soils developing on Fláajökull foreland*

September 23 - 25, 2010

Post-conference field-excursion

Accepted abstracts

The continuous volcanic dust emissions and loess deposition in Iceland

Ólafur Arnalds

Agricultural University of Iceland, Hvanneyri, Iceland

Glacio-fluvial activity, volcanic activity, and human ecosystem disturbance has resulted in the formation of large unstable sandy areas in Iceland that are sources of large scale dust emissions and deposition throughout the country. Icelandic sandy deserts are about 22,000 km^2 and they have been classified and mapped in the scale of 1:100 000 (Arnalds *et al.*, 2001ab). Icelandic dust is mostly basaltic volcanic glass, which is rather unique for global dust sources. The dust comes primarily from two types of sources: i) confined plume areas and ii) extensive sandy deserts.

Major plume sources have been identified by field observations and satellite images (Arnalds, 2010) and both a map showing major plume areas and a map showing major areas influenced by each plume area are introduced. The dust plume areas are relatively limited in extent (1-30 km^2); typically flood-plains near major glaciers where glacial rivers with heavy sediment load cause deposition of fine textured sediments during peak flows. These sediments are very susceptible to wind erosion, with saltation fluxes measured in the field commonly > 100 kg m^{-1} per storm. Deflation rates of 1-5 kg^{-2} have postulated for such areas during major storms (see Arnalds, 2010 for flux and deflation rates). Major dust plume areas include Dyngjusandur, north of Vatnajökull (*jökull* means glacier in Icelandic), Leirá and Múlakvísl rivers and Mælifellssandur near Mýrdalsjökull, and Hagavatn south of Langjökull, but 14 such areas are indicated on the map.

Sandy desert areas are less productive dust sources per unit area than the plume areas with fewer storms causing dust emission per year. However, they are much more extensive than the plume areas, or up to 5000 km^2, resulting in significant dust production when storm conditions prevail. A map of areas influenced by deposition from extensive sandy deserts is also introduced.

Information from various sources, including combining the maps showing deposition influence from both plume areas and sandy deserts, and research on soil thickening rates is combined to obtain an overview of aeolian (volcanic loess) deposition in Iceland. Sedimentation rates range from < 25 g m^{-2} yr^{-1} far from aeolian sources to > 500 g m^{-2} yr^{-1} near or within major sandy areas. These numbers are similar to higher than deposition rates reported for other major global dust areas. Global dust emissions are usually associated with arid and semi-arid regions, where geomorphology or other factors lead to the accumulation of relatively fine-textured particles. Iceland is usually not considered among the major dust source areas (e.g. presented by Prospero *et al.*, 2002, Lawrence & Neff, 2009), but is most likely a major source of atmospheric dust in spite of the northerly location and humid climate. The dust production from sandy deserts in Iceland and subsequent deposition is in many ways an analogue for the processes leading to the loess formation during Pleistocene in the northern hemisphere.

References

Arnalds, O., 2010. Dust sources and deposition of aeolian materials in Iceland. *Icelandic Agricultural Sciences* 23, in print.

Arnalds O., Gísladóttir F.O. & Sigurjónsson H., 2001a. Sandy deserts of Iceland: An overview. *Journal of Arid Environments* 47, 359-371.

Arnalds O., Thorarinsdottir E.F., Metusalemsson F., Jonsson Á., Gretarsson E. & Arnason A., 2001b. *Soil Erosion in Iceland.* Soil Conservation Service and Agricultural Research Institute, Reykjavik. Translated from the original 1997 publication, 121 pp.

Lawrence C.R. & Neff J.C., 2009. The contemporary physical and chemical flux of aeolian dust: A synthesis of direct measurements of dust deposition. *Chemical Geology* 267, 46-63.

Prospero J.M., Ginoux P., Torres O., Nicholson S.E. & Gill T.E., 2002. Environmental characterization of global sources of atmospheric soil dust identified with the NIMBUS 7 total ozone mapping spectrometer (TOMS) absorbing aerosol product. *Reviews of Geophysics* 40 (1).

Spatio-temporal variability of mechanical and chemical denudation rates in glacier-fed valley-fjord systems in the inner Nordfjord, western Norway

Achim A. Beylich, Susan Liermann & Katja Laute

Geological Survey of Norway (NGU), Quaternary Geology & Climate group & Norwegian University of Science and Technology (NTNU), Trondheim, Norway

High-resolution surface process monitoring and analysis (including channel discharge, fluvial solute transport, fluvial suspended sediment transport, fluvial bedload transport) in the glacier-fed Erdalen and Bødalen valley-fjord systems, situated in the steep fjord-landscape of western Norway (inner Nordfjord), show that there are significant intra- and inter-annual variations with respect to fluvial sediment transport rates and sediment yields.

Three different periods with a high frequency of major runoff events can be identified over the year, with these periods showing a significant inter-annual variability. High channel discharge in spring (April – June) is mainly caused by snowmelt whereas major discharge events in summer (July – August) are due to thermally driven glacier melt. Runoff in spring is strongly controlled by the total amount of accumulated wintry snow, which can vary significantly between different years. In autumn (September – November), major runoff events are associated with heavy rainfall events.

Autumn is the most important period with respect to fluvial sediment transport.

The intensity of fluvial transport in autumn (and over the entire year) depends in both valley-fjord systems strongly on the annual number of heavy rainfall events that trigger transfers of sediments from slopes into channels via saturation overland flow with connected slope wash and debris flow events. Annual suspended sediment yields are about two times greater than annual solute yields corrected by atmospheric inputs. Chemical denudation is clearly lower than mechanical denudation in the bedrock dominated fjord landscape of the inner Nordfjord. Bedload transport rates appear to be smaller than suspended sediment transport.

Suspended sediment concentrations in glacier melt water during summer show a high spatial variability both between Erdalen and Bødalen and within both valley-fjord systems which is indicating varying sediment delivery rates from different outlet glaciers of the Jostedalsbreen ice field.

Sediment yields during glacier melt in summer as well as total annual sediment yields in Erdalen and Bødalen are lower than in many other glacierized catchments worldwide. Fluvial sediment transport and fluvial sediment yields in the inner Nordfjord are altogether supply-limited.

Despite the high percentage of bare bedrock surfaces in the fjord landscape of the inner Nordfjord, re-working of sediments on slopes seems to be a more important sediment source for the contemporary sediment yields of valley-fjord systems than sediment delivery from present outlet glaciers.

The contemporary fluvial sediment yields are interpreted in combination with the analysis of subrecent (following the Little Ice Age glacier advance) sedimentation rates in lakes in Bødalen and Erdalen.

The global I.A.G. / A.I.G. Sediment Budgets in Cold Environments (SEDIBUD) Programme: Coordinated analysis and quantification of sedimentary fluxes and budgets in changing cold environments

Achim A. Beylich (1, 2) & the SEDIBUD Team

(1) Geological Survey of Norway (NGU), Quaternary Geology & Climate group, Trondheim, Norway

(2) Norwegian University of Science and Technology (NTNU), Trondheim, Norway

Amplified climate change and ecological sensitivity of polar and high-altitude cold climate environments has been highlighted as a key global environmental issue. Projected climate change in cold regions is expected to alter 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 expected to reduce the extent of permafrost and seasonal ground frost and increase active layer depth. These effects will undoubtedly change surface environments in cold environments and alter the fluxes of sediments, nutrients and solutes, but the absence of data and analysis to understand the sensitivity of the surface environment are acute in cold environments.

The ***SEDIBUD (Sediment Budgets in Cold Environments)*** Programme of the International Association of Geomorphologists (I.A.G./A.I.G.) was formed in 2005 to address this key knowledge gap. SEDIBUD has currently about 400 members worldwide and the Steering Committee of this international programme is composed of ten scientists from nine different countries: Achim A. Beylich (*Chair*) (Norway), Armelle Decaulne (*Secretary*) (France), John C. Dixon (USA), Scott F. Lamoureux (*Vice-Chair*) (Canada), John F. Orwin (New Zealand), Jan-Christoph Otto (Austria), Irina Overeem (USA), Þorsteinn Sæmundsson (Iceland), Jeff Warburton (UK), Zbigniew Zwolinski (Poland).

The central research question of this global group of scientists is to

Assess and model the contemporary sedimentary fluxes in cold climates, with emphasis on both particulate and dissolved components.

Initially formed as European Science Foundation (ESF) Network SEDIFLUX (2004-2006), SEDIBUD has further expanded to a global group of researchers with field research sites located in polar and alpine regions in the northern and southern hemisphere. Research carried out at each site varies by programme, logistics and available resources, but typically represent interdisciplinary collaborations of geomorphologists, hydrologists, ecologists, and permafrost scientists and glaciologists with different levels of detail.

SEDIBUD has developed a key set of primary research data requirements intended incorporate results from these varied projects and allow analysis across the programme. SEDIBUD Key Test Sites provide data on annual climate conditions, total discharge and particulate and dissolved fluxes as well as information on other relevant surface processes. A number of selected Key Test Sites are providing high-resolution data on climatic conditions, runoff and fluvial fluxes, which in addition to the annual data contribute to the SEDIBUD Metadata Database. To support these efforts, the SEDIFLUX Manual has been produced to establish common methods and data standards. In addition, a framework paper for characterizing fluvial sediment fluxes from source to sink in cold environments has been published by the group. Comparable datasets from different SEDIBUD key test sites are analysed to address key research questions of the SEDIBUD programme as defined in the SEDIBUD Working Group Objective (available at the SEDIBUD website, see below).

SEDIBUD currently has identified 38 SEDIBUD Key Test Sites worldwide with the goal to further extend this network to about 40-45 sites that cover the widest range of cold environments possible. Additionally, it is expected that collaboration within the group will act as a catalyst to develop new sites in underrepresented regions. The SEDIBUD Key Test Site Database (available at the SEDIBUD website, see below) and the SEDIBUD Fact Sheets Volume provide significant information on SEDIBUD Key Test Sites. SEDIBUD is open for proposals for possible additional SEDIBUD Key Test Sites to be included in the programme. Coordination and collaboration with a number of International Polar Year (IPY) research programmes including: International Tundra Experiment (ITEX), Circumpolar Active Layer Monitoring (CALM), BIPOMAC and Arctic Coastal Dynamics (ACD/ACCO Net) provides further opportunities for collaborative research to address broader polar environmental research issues.

Individual research projects being headed by SEDIBUD Members, using datasets generated at SEDIBUD Key Test Sites and targeting at defined Key Research Questions, using SEDIBUD as umbrella programme, are encouraged by the SEDIBUD Steering Committee.

More detailed information on the I.A.G./A.I.G. SEDIBUD Programme and relevant SEDIBUD documents are available at http://www.geomorph.org/wg/wgsb.html.

A collective database on landslides and snow avalanches in Iceland

Skafti Brynjólfsson [1], Jón Kristinn Helgason [2] & Halldór G. Pétursson [1]

(1) Icelandic Institute of Natural History, Akureyri, Iceland

(2) Icelandic Meteorological Office Avalanche Center, Ísafjörður, Iceland

From the settlement of Iceland in the 9th century, landslides and avalanches have caused many catastrophic events and severe economical losses in Iceland. Research and documentation of present landslides and avalanches, alongside a collection of available information from historical sources of past occurrences are an important part of the work to minimize the effects and danger of this natural hazard in Iceland. Maintaining a database on these natural processes is just one aspect of this work, on which The Icelandic Institute of Natural History (IINH) and The Icelandic Meteorological Office (IMO) are now working.

All work on landslides and avalanches in Iceland is based on Ólafur Jónsson´s pioneering work (Jónsson 1957). Part of this work was an inventory of landslides and avalanches in Iceland based on old annals, narratives in books, information from periodicals and newspapers and manuscripts or oral. Since 1988 the IINH has systematically collected additional information to Ólafur Jónsson´s landslide inventory and documented the landslides that have occurred in Iceland since 1957. The main focus has been on landslides from the 20th century, i.e. the period when the IMO has systematically collected information on the weather and climate of Iceland.

For the past 15 years, the IMO has kept an inventory database on avalanches and from the year 2003 the IINH has kept a similar database on landslides, these databases where created to preserve all the documented information on these natural processes. Recently it was decided to merge these databases into one major database which was given the name OLI to preserve the memory of Ólafur Jónsson. The responsibility of each institute will, however, remain the same, with the IINH in charge of landslides and the IMO in charge of avalanches.

Today the merged database can be searched for landslide information using search criteria such as decades, date, location or keyword search for general description. The database was created in order to store the data in an accessible manner thus creating a strong basis for relevant researches and also to make it accessible for interested parties, such as planning directors, scientists, engineers and the general public. The database can be an important source of information regarding natural hazards in urban and rural areas and has proved to be a useful tool in systematic planning and future land use.

For each landslide a lot of information can be entered in to the database, but the details of each specific entry depends on the scenario at each time. In case of the most recent landslides, date, location, weather condition, damages recorded, and general description of the landslide is always entered. If the landslide is particularly hazardous, e.g. occurs above inhabited areas or is considered to be particularly interesting, for numerous reasons, field observations are carried out and more detailed data obtained and stored in the database.

At present, the database contains 5.564 records of landslides, which include mostly debris flows and rock fall. Such a database is a useful tool for understanding the frequency, possible causes, triggering factors and to identify series of landslides and some of the principal landslide areas in Iceland. The database will in the future be available for public use on the internet. Present debris flows will be revealed on an interactive map where date and quantity of each event is specified.

Morphological and sedimentological land system model for surging glaciers at Tröllaskagi peninsula, North Iceland

Skafti Brynjólfsson (1) & Ólafur Ingólfsson (2)

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(2) Institute of Earth Science, University of Iceland, Reykjavík, Iceland

The characteristics of surging glacier environments have been described by a process-form landsystem model. The surging glacier landsystem model works well for the large outlet glaciers of Vatnajökull, but it does not readily explain patterns of sedimentation and morphology at surging cirque glaciers at Tröllaskagi peninsula in North Iceland. By mapping the geomorphology and sedimentology of two known surging glaciers at Tröllaskagi, Búrfellsjökull and Teigarjökull, a new landsystem model for small surging cirque glaciers has been developed. The new landsystem highlights and explains the uniqueness of the geomorphological environment of small surging cirque glaciers at. It is based on the surging glacier landsystem model of Evans and Rea (2003), but modified in accordance with field observations from Búrfellsjökull and Teigarjökull.

The new landsystem illustrates that landforms such as flutes and crevasse ridges and extended hummocky moraine are usually found in front of the known surging cirque glaciers at Tröllaskagi. Coarse and angular sediments are also prominent while less fine material is found, opposite to the large surging glaciers of Vatnajökull.

A two small cirque glacier have been studied as the first test sites for the new landsystem model. Until now the glacier Grýtudalsjökull has not been considered as a surging glacier but it resembles the known surging glaciers at Tröllaskagi. The non surging glacier Deildarjökull was studied to highlight the surging glaciers uniqueness.

The geomorphology and sediment environment of Grýtudalsjökull is similar to what the new landsystem revealed, i.e. a few end moraines, flutes, crevasse ridges and hummocky moraines composited of rather coarse and angular sediment. The crevasse ridges cross the elongated flutes which indicate that a glacier surge has halted suddenly and crevasse ridges have formed as the glacier tongue settled down in the bottom sediment. Extended hummocky moraines inside the end moraines indicate dead ice melting of a stagnant glacier front after a surge.

The forfield of Deildarjökull is different, small well defined annual moraines have formed as the glacier responded to winter accumulation. End moraines, which in general are bigger than in front of the surging glaciers, are few and probably formed in connection to favourable period where the glacier was in balance with climate. In general the sediment is richer of fine material and the angular sediment is not as prominent in front of Deildarjökull.

Until now only three of about 150 glaciers at Tröllaskagi peninsula have been known as surging glaciers. The first test results indicate existence of more surging glaciers at Tröllaskagi than before assumed. Further studying of the small cirque glaciers at Tröllaskagi can increase the rather limited knowledge of the nature of the surging glaciers.

The Höfðahólar rock avalanche in Skagafjörður, Northern Iceland: geomorphological characteristics and relative dating

Armelle Decaulne (1, 4), Denis Mercier (2, 4, 5), Etienne Cossart (3, 4), Thierry Feuillet (2, 4), Þorsteinn Sæmundsson (6) & Helgi Páll Jónsson (6)

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The Skagafjörður area is amongst the richest, when speaking about large slope mass movements in Iceland. Several landslides are visible especially on the eastern side of the fjord, starting at the top of the rockwall with a more or less developed scar. The morphological characteristics of those debris masses belong to a large range of mass movements, including several examples of translational landslides, rotational rockslides and rock avalanches (according to Dikau *et al.*, 1996). A significant number of those landforms have been described in the early 20th century by Ólafur Jónsson (1957). Jónsson pioneer work interpreted these landforms as resulting from the post-glacial rockwall debuttressing, following the shrinking of the large ice bodies in the early Holocene. However, no attempt of dating has yet been carried out on the debris masses.

The Höfðahólar debris mass is located in the outer Skagafjörður area; the whole complex is 1700 m long and 1450 m large; the topography is hectic, and is characterised by a series of ridges amongst those intact portions of the collapsed rockwall are visible. The lower part of the debris mass is cut in a 15-20 m high sea cliff that exposes large boulders and rockwall sections with a fine rich matrice.

The site proposes four combining dating opportunities:

(i) the dating of a succession raised beaches on which the rock avalanche material lies. The higher beaches, exceeding 65 m a.s.l. are visible on both sides of the fjord and have been dated older than 12000 BP. Beaches between 43 and 50 m a.s.l. have been dated older than 11300 and 9900 BP and beaches at 22-31 m a.s.l. between 9900 and 9600 BP. Regression below the present sea level occurred at 9000 BP (Rundgren *et al.*, 1997). As the rock avalanche deposit does not display visible evidence of being impacted by the glacio-isostatic rebound (no sea cliffs are seen upper from the actual sea-level), we estimate it has occurred later than 9000 BP.

(ii) the tephrochronological dating from the excavations we made in the upper part of the mass, where peat areas developed since the setting of the rock avalanche goes back to 4500 years BP, with the H4 Hekla acid white thick layer found at 140 cm depth. The deposits from Hekla are well known in the area, and the five most common ash layers were discovered in the opened section, providing a significant time marker.

(iii) 14C dating of birches (*Betula* sp.) trunk and branches pieces found 80 cm below the H4 layer. The results are not yet available, but the period around 8000 BP is known to have been warm at those latitudes, favouring tree development.

(iv) basalt samples were collected on the landslide, at various elevations on the deposit, to provide Cosmic Ray Exposure dating. To specify the age of the landslide, we will measure ^{10}Be within olivine and pyroxene in basalt. We will plot the calculated ages to identify whether they are clustered, then defining one or various stages of slope instability. Samples were carefully selected to ensure that targeted boulders did not move since deposition: prominent boulders were chosen. Beryllium isotopic ratios will be measured at the laboratory of cerege by Accelerator Mass Spectrometry. The results are not yet known.

For now, the two first dating possibilities constrain the release of the rock avalanche event between 9000 BP (present-day sea-level) and 4500 BP (tephrochronology oldest dating). The finding of a large amount of wood long before the H4 tephra layer suggests that the occurrence of the rock avalanche was closer to the oldest extremity of this time period (so-called early birch period, just around 9000 BP, according to Einarsson 1991, and Óladóttir *et al.* 2001). Such results comfort the Ólafur Jónsson idea, proposing the occurrence of such landslide as the result of a rapid paraglacial crisis following the deglaciation period, due to the combined effects of rockwall debuttressing and glacio-isostatic uplift. The cosmogenic and ^{14}C results will propose a more accurate dating.

References

Dikau R., Brunsden D., Schrott L. & Ibsen L. (eds.), 1996. *Landslide Recognition: Identification, Movement and Courses.* John Wiley & Sons, London, 251 p.

Einarsson Þ., 1994. *Geology of Iceland, rocks and landscape.* Mál og Menning, Reykjavík, 309 p.

Jónsson Ó., 1957. *Skriðuföll og snjóflóð*, Bókaútgáfan norðri, t. 1, 141 p.

Óladóttir R., Schlyter P. & Haraldsson H., 2001. Simulating Icelandic vegetation cover during the Holocene, implication for long-term land degradation. *Geografiska Annaler* 83, 203-215.

Rundgren M., Ingólfsson Ó., Björk S., Jiang H. & Hafliðason H., 1997. Dynamic sea-level change during the last deglaciation of northern Iceland. *Boreas* 26: 201-215.

Inorganic nitrogen in the geochemical budget of Kärkevagge, Swedish Lapland

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While nitrogen is an essential nutrient for plant growth in the terrestrial environment and generally fixed by biological processes in soils, in Arctic and alpine environments N is a severely limited nutrient because of both climatic and soil constraints. It is widely believed that inorganic nitrogen is such a small component of the nitrogen cycle that this source is generally not viewed as being a significant component of the nitrogen cycle. However, it has been estimated that in fact as much as 20% of the total nitrogen budget may be stored in geological materials and where N is severely limited such as in Arctic and alpine environments inorganic N may in fact be the dominant source of N for biological processes. Nitrogen saturation may therefore have substantial impacts on geochemical cycles involving both soil and water chemistry.

In order to determine the potential for the rocks and soils of Kärkevagge to be significant sources of N samples of the principal rock units of the valley along with soil developed on a variety of rock types were sampled. Ammonia/ammonium contents were determined using ion chromatography. Ammonia/ammonium contents of the sampled rock materials display a wide range of abundances with marble containing a mean NH4 abundance of 4,300mg/Kg, quartz schist 1,600mg/Kg, biotite schist 4,300mg/Kg, and garnet mica schist 4,500 mg/Kg ammonia/ammonium. Soil ammonia/ammonium abundances were found to be 1,600mg/Kg. N-pool abundances range from 2.5 Kgm3 for marble to 8.7 for garnet mica schist. Soil N-pools were found to be 3.0 Kgm3.

The inorganic N present in ammonia/ammonium measured in bedrock represents N-input into the geochemical budget. The N in bedrock originates from organically bound nitrogen associated with sediment or thermal waters representing a mixture of sedimentary, mantle and meteoric sources. Nitrogen in the soil originates from the weathering of N-rich rocks, or the presence of unweathered nitrate minerals or fluid inclusions is released to the soil and ultimately to plants by assimilation by biota or nitrification. Geologic nitrogen in Kärkevagge rocks and soils may represent a large and reactive pool with the potential for considerable impact on the geochemical system.

Sediment supply from side valleys as a factor influencing the river channel pattern in the High Atlas; a case study from the Upper Dades valley

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During last several dozen years there has been a considerable sediment aggradation in floors of main river valleys of the Atlas Mountains. This process is particularly significant in the southern side of the mountain, where vegetation is very sparse due to dry or semidry climate. Numerous human settlements are located relatively high in the mountains where winter air temperature is low, therefore there is a need for fuel supply to the households. This results in vegetation clearance for burning. Recently, human population of this region tripled, thus intensifying destruction of the vegetation cover.

The aim of the study was to: 1) determine human impact on morphology of contemporary river channels in the southern part of the High Atlas (Morocco), and 2) determine the pattern of sediment supply from side valleys. We assumed that majority of the sediment accumulated in the main river channels was supplied by the episodic tributary rivers from the side valleys.

The study was undertaken in years 2006-2010, in the upper Dades valley by geomorphologists from the University of Warsaw and the Jagiellonian University (Poland) in co-operation with the Mohammed V University from Rabat (Morocco). Geomorphological mapping was focused on the river channel landforms and alluvial fans developed at mouths of the side valleys. Precise measurements of the landforms were done with use of GPS RTK. Shape of clasts, accumulated in bars of the main channel and alluvial fans of tributary rivers, was determined according to Zingg (1935). The analysis was done in following fractions: 5-10 cm, 10-15 cm, and 15-20 cm. In selected places along the course of the river, fifty rounded clasts were measured in each fraction and petrography of the clasts was noted.

The Dades river channel was inspected along 132,58 km of its course, from the sources of the river (3150 m a.s.l.) to Boumalne (1526 m a.s.l.). Highly dissected catchment of the selected channel covers 1521 km^2. The main river has a single channel, stable discharge, and coarse grained load (mainly pebbles). There are several dozen episodic tributary rivers along the researched section (each rarely exceeding 20 km in length) with discharge occurring usually in periods: September-October and February-April. Cobbles dominate in beds of the tributary rivers as well as in alluvial fans at mouths of the rivers.

Most of the researched catchment is built of relatively similar rocks: thickly layered limestones, marls and sandstones of upper-Jurassic age (in the upper part of the valley), thickly and medium layered limestones and marls of Lias age (in the middle part), and highly folded conglomerate layers of Neogene age and stony-sandy-clayey Pleistocene sediments (in the lower part). Therefore, the shape of the river bed clasts reflects rather fluvial processes then the rock structure.

We found a significant differentiation of the shape of fluvially transported clasts. There is a very little share of spheres and rods in the smallest fraction (5-10 cm), which can be explained by the fact that such clasts are most easily transported (Illenberger 1991, Hattingh, Illenberger 1995, Schmindt, Gintz 1995), removed from the river channel, and finally deposited at the High Atlas forefield. Discs dominate in this fraction of the Dades river bed deposits. Such clasts are difficult to mobilise by the river flow (Illenberger 1991, Hattingh, Illenberger 1995, Schmindt, Gintz 1995), and only the highest discharge of the Dades river is able to transport the discs.

In the fraction 10-15 cm there is a great differentiation of the shapes. Rods and spheres slightly dominate, but still their share is comparable with a share of discs and blades. High differentiation of the shapes can result from a limited sorting due to sporadic transport of clasts in this fraction by the Dades river. On the other hand, it can be inferred that the differentiation of the shapes results from a significant delivery of clasts in this fraction from side valleys.

Rods and blades clearly dominate in the largest fraction (15-20 cm), which can result from significant delivery of fresh clasts of this size to the river.

Most frequent clasts, found in the alluvial fans developed at mouths of the side valleys, are spheres and discs or discs and rods, in the case of larger clasts. Such high differentiation of the material results from short and episodic transport in the tributary rivers (Illenberger 1991, Hattingh, Illenberger 1995).

Comparison of shapes of the clasts found in the alluvial fans and in the bed of the main river shows a significant delivery of the material from the side valleys. This is supported by the fact that the fans and the bars in the Dades valley floor, developed below the relevant fans, are built with clasts of a similar shape. Only the share of spheres is significantly higher in the fans. This can be explained by fast removal of spheres by the Dades river flow since this shape is most easily transported.

Significant delivery of material from the side valleys results in fast aggradation on the alluvial fans and in the Dades river floor. Rapid floods cause increase in area of the fans which are not confined be any morphological obstacles. Lower parts of the fans gradually encroach on river terraces and finally modify the course of the main river. This process is responsible for intensification of side erosion on the opposite bank of the river. Sediment aggradation in the river causes gradual elevation of the bed. This, in turn, results is frequent flooding of the river terraces which are often cultivated by local farmers. The agricultural land is therefore frequently destroyed by accumulation of coarse material. We observed deposition of 1 m thick layer of such coarse alluvium on growing crops during a single flood event which lasted several days.

Intensified sediment aggradation in beds of main rivers, due to delivery from the side valleys, has a profound significance for the development of the river channels in the High Atlas. It apparently reflects vegetation clearance in the mountains by the local people.

References

Hattingh J. & Illenberger W.K., 1995. Shape sorting of flood-transported synthetic clasts in a gravel bed river. *Sed. Geology.* 96, 181-190.

Illenberger W.K., 1991. Pebble shape (and size!). *J. Sed. Petrol.* 61, 756-767.

Schmindt K.H. & Gintz D., 1995. Results of bedload tracer experiment in a mountain river. *River Geomorphology*. 36-54.

Zingg T., 1935. Beitrag zur Schotteranalyse: *Schweizerische Mineralogische und Petrologische Mitteilungen.* 15, 39-140.

7 years of permafrost monitoring in Iceland - updated results and geomorphological implications

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The distribution of mountain permafrost has been mapped and monitored mainly in locations with relatively continental climates characterized by a stable snow cover and low winter temperatures. In contrast, there is a paucity of systematic ground temperature investigations from maritime mountain areas such as Iceland and transitional areas between the Scandinavian mountain permafrost zone and the continuous permafrost in Svalbard. Knowledge of the present distribution and thermal characteristics is crucial for assessing the response of permafrost to climate change and its geomorphological and geotechnical impact.

Intensive field-based studies on the distribution of permafrost and the dynamics of selected periglacial landforms were carried out in northern (Tröllaskagi peninsula) and eastern Iceland since 2003. For the whole period ground thermal monitoring has continued at four sites. This presentation reviews and synthesises the main results of the 7 years of monitoring, and draws lines to former and future geomorphic process dynamics and landscape development including the influence of frozen ground on sediment budgets.

The presentation demonstrates that permafrost is widespread at elevations above c. 900 m a.s.l. in Iceland, depending on the snow cover regime. At this elevation, permafrost temperatures are close to 0°C, and thus highly vulnerable for climate variability. Modelling exercises show quite rapid responses on snow and temperature changes, depending of ground ice content. Climate variability has been substantial even during the period of instrumental measurement of meteorological variables (start late 18. Century). This is due to the large influence of sea ice, with sea ice close to northern Iceland results normally in lower winter temperatures. During the LIA and parts of the last century (e.g. the 1970ies) permafrost must have been much more widespread than today, mainly because of clearly lower winter temperatures. The presentation outlines some modelling results of former thermal regime in the mountains of Iceland, and possible future development.

Erosion by wind, windless rain, and wind-driven rain - Experimental in situ measurements with a portable simulator

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Natural rain events often occur as rainstorms, adding a driving component to falling raindrops. Laboratory investigations in wind tunnels with the ability of simultaneous rainfall production showed that wind significantly alters drop sizes, drop fall velocities and impact angles of falling raindrops. Leading to higher kinetic energies and increased soil detachment in comparison to falling drops with no wind influence. Unfortunately, in most in situ soil erosion studies this combined effect of wind and water is either not taken into account or deliberately excluded from the system, because of increasing complexity of processes involved. Therefore a portable combined wind and rainfall simulator for in-situ soil erosion studies was developed and used in Spain (Aragón, Andalusia). The main objective was to get first results to compare erosion rates caused by wind, windless rain and wind-driven rain on plot scale.

The working section of the simulator is 4 m long, 0.7 m high, 0.7 m wide and rectangular in shape. A bounded plot of 2.2 m² can be irrigated by four pressure nozzles (Lechler type 460.608) with an intensity of about 90 mm h-1. The spatial drop distribution is very well reproducible and the drop sizes resemble natural rainfall quite well, when compared to Marshal-Palmer distributions of same rainfall intensities. The pre-shaped boundary layer varies from 15-20 cm in height. The airflow within the lower 30 cm of the tunnel is sufficiently homogenous across the tunnel (deviation from mean 0.4-0.55 m s-1) for in situ measurements. The duration of wind simulations is 10 min and 30 min for rainfall simulations. The simulations are performed in four consecutive test runs with following order: (1) Single wind, (2) single rainfall on dry soil conditions, (3) single rainfall on moist soil conditions, and (4) simultaneous wind and rainfall. The interval of runoff collection is 2.5 min and emptying of samplers for wind material takes place at the end of each test run.

The results indicate that wind erosion in Aragón is more or less negligible on undisturbed, crusted soil surfaces, but it can reach high amounts of up to 50 g m-² on rolled and grazed fields. The expected increase of runoff erosion rates from windless rain to wind-driven rain, due to the combined force of wind and water, can be seen in most simulations. The increase varied from 1.5 % up to 226 %.

The results show that this combined wind and rainfall simulator is a valuable tool for soil erosion studies in the field. The good transportability ensures the investigation of diversified research questions even in remote areas.

Kinematics and sediment transfer rates of active rockglaciers

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It is assumed that rockglaciers represent a major sediment storage and transport component of the periglacial system. Since a reactivation of an inactive rockglacier – regardless of whether inactivity was climatically or dynamically induced – has never been observed, these landforms are considered to be sediment traps and are therefore closed coarse debris systems. Remobilisation of the sediment might take place only in a glacier advance. However, only few attempts have been undertaken to quantify the transfer of sediment by creeping rockglaciers and quantitative regional scale studies to determine the contribution of rockglaciers to the sediment budget of entire geosystems do not exist.

During the last decade, an increasing number of studies quantified permafrost creep and investigated spatio-temporal variations thereof, in particular in the European Alps. The main purpose was and still is to better understand the dynamics of rockglaciers and creeping talus slopes, and to investigate how current atmospheric warming influences these landforms.

The study presented here combines calculated volumes and masses of several Alpine rockglaciers with information on kinematics quantified for these landforms - including its spatio-temporal variations. The purpose of the study is to describe sediment transfer rates and to prepare further studies on regional scale relevance of rockglaciers for sediment budgets in a changing climate.

Direct evidence of the feedback between climate and weathering

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Long-term climate moderation is commonly attributed to chemical weathering; the higher the temperature and precipitation the faster the weathering rate. Weathering releases divalent cations to the ocean via riverine transport where they promote the drawdown of CO_2 from the atmosphere by the precipitation and subsequent burial of carbonate minerals. To test this widely-held hypothesis, we performed a field study determining the weathering rates of 8 nearly pristine north-eastern Iceland river catchments with varying glacial cover over 44 years (Gislason *et al.* 2009). The mean annual temperature and annual precipitation of these catchments varied by 3.2 to 4.5 C and 80 to 530%, respectively during the study period. Statistically significant linear positive correlations were found between mean annual temperature and chemical weathering in all 8 catchments and between mean annual temperature and both mechanical weathering and runoff in 7 of the 8 catchments. For each degree of temperature increase, the runoff, mechanical weathering flux, and chemical weathering fluxes in these catchments are found to increase from 6 to 16%, 8 to 30%, and 4 to 14% respectively, depending on the catchment. In contrast, annual precipitation is less related to the measured fluxes; statistically significant correlations between annual precipitation and runoff, mechanical weathering, and chemical weathering were found for 3 of the least glaciated catchments. Mechanical and chemical weathering increased with time in all catchments over the 44 year period. These correlations were statistically significant for only 2 of the 8 catchments due to scatter in corresponding annual runoff and average annual temperature versus time plots. Taken together, these results (i) demonstrate a significant feedback between climate and Earth surface weathering, and (ii) suggest that weathering rates are currently increasing with time due to global warming.

Reference

Gislason S.R., Oelkers E.H., Eiriksdottir E.S., Kardjilov M.I., Gisladottir G., Sigfusson B., Snorrason A., Elefsen S.O., Hardardottir J., Torssander P., Oskarsson N., 2009. Direct evidence of the feedback between climate and weathering. *Earth and Planetary Science Letters* 277, 213–222.

High Arctic sediment fluxes associated with summer rainfall

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Projected climate change is expected to alter the hydrological regime in Arctic regions and to change the relative contributions of snow melt and rainfall to surface runoff. Additionally, increased melt energy is likely to deepen the active layer, resulting in altered soil moisture storage conditions with implications for stream flow. The High Arctic is normally considered to be dominated by nival (snow melt) runoff and sediment transport is typically closely associated with discharge during this interval. The role of rainfall runoff over sediment transport is less well documented, with few examples of long term studies. We report results o f a long term study from the Cape Bounty Arctic Watershed Observatory (CBAWO) located in the Canadian High Arctic. Hydrometric and sediment flux studies from paired watersheds have been carried out at CBAWO since 2003, and results to date provide an opportunity to assess the role of rainfall intensity over suspended sediment fluxes in this environment.

During the 2003-9 melt seasons, nival runoff and sediment transport dominated and resulted in up to 100% of sediment transport in some years. For the most part rainfall events were of low magnitude and resulted in limited discharge responses and low event sediment yields. Rainfall of c. 10 mm/day and 30 mm/day generated substantial suspended sediment fluxes and the latter resulted in exceptionally high suspended sediment concentrations in the rivers and overall event fluxes. Two high intensity rainfall events in July 2009 resulted in 80% of the overall seasonal sediment flux and the highest measured during the period of record. These results indicate that a moderate amount of rainfall delivered in one or two events can dominate seasonal sediment flux and effectively reduce the nival contribution to a minor component. A rainfall-yield relationship curve produced from available data suggests that the relationship is highly non-linear, and further implies a high potential to transport sediment during large rainfall runoff events. This data also suggests a minimum rainfall threshold of c. 10 mm/day is necessary to generate measurable sediment transport, which is consistent with other observations in the Arctic.

Differential 2007 permafrost disturbance between the two river catchments at CBAWO reveals that the increased availability of sediment from slope erosion amplifies the effect of intense rainfall. The highly disturbed West River basin generated approximately 20% greater yield in 2009 than the adjacent East River.

Influences of the Little Ice Age glacier advance on hillslope development in the headwater areas of two tributary valleys of the Nordfjord, Western Norway

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Large areas of the Norwegian fjord landscapes are covered by hillslopes, which are characterized by the influences of their glacial inheritance during the Pleistocene and also the Little Ice Age glacial advances. Hillslopes in glacially formed landscapes are typically composed of talus slopes developed beneath free rock faces. Studying hillslopes as sedimentary source, storage and transfer zones and analyzing surface processes acting on hillslopes since the end of the deglaciation are of importance in order to gain a better understanding of the complex sedimentary source-to-sink fluxes in cold climate environments (paraglacial systems).

This study presents first outcomes of a PhD project, which is part of the NFR funded SedyMONT-Norway project within the ESF TOPO-EUROPE SedyMONT (Timescales of sediment dynamics, climate and topographic change in mountain landscapes) programme.

The focus of this study is on geomorphic influences of the Little Ice Age glacier advance on postglacial hillslope systems in four distinct headwater areas of the Erdalen and Bødalen valleys in the Nordfjord valley-fjord system (inner Nordfjord, Western Norway). Both valleys can be described as steep, U-shaped and glacier-fed, subarctic tributary valleys. Approximately 14% of the 49 km^2 large headwater areas of Erdalen are occupied by hillslope deposits and 41% by rock surfaces; in Bødalen hillslope deposits occupy 12% and rock surfaces occupy 38% of the 42 km^2 large headwater areas. Within each of these headwater areas five hillslope test sites have been selected. In Erdalen two hillslope test sites are located inside of the LIA glacial advance limit and three outside. In Bødalen three hillslope test sites are located inside of the LIA glacial advance limit and two outside of this limit.

The main aims, which are approached within the timeframe of the LIA glacial advance until today are (i) to identify the type, intensity and rates of acting hillslope processes, (ii) to analyse the spatio-temporal variability of hillslope processes as well as (iii) to estimate the mass balance of hillslope systems.

The applied process-based approach includes mainly three components: (i) the process components, (ii) the morphometric and material components and (ii) the mass balance components.

Process components:

Regarding process components, the selected hillslope test sites are instrumented with designed monitoring installations including nets for collecting freshly accumulated rockfall debris, stone tracer lines for measuring surface movements, a combination of wooden sticks and depth integrated measurements for monitoring of slow surface creep movements. In addition, remote site cameras for monitoring rapid mass movement events (avalanches, slush- and debris flows) and slope wash traps for analyzing slope wash denudation are installed as well as continues monitoring and discrete sampling for solute and suspended sediment concentrations at small hillslope drainage creeks are conducted. Temperature loggers are installed both in rock walls and talus slopes for studying rock temperatures and mechanical weathering.

Morphometric and material components:

In order to analyze morphometric and material components geomorphological mapping is performed. In addition, the type of material and the material composition (samplings) is studied and extensive hillslope morphometry field investigations/measurements are carried out.

Mass balance components:

In terms of the mass balance the volumes of loose material within the hillslope systems are estimated using a combination of geophysical measurements (georadar, seismic refraction surveys) and GIS / DEM computing.

First results show a recognizable more complex talus slope morphometry as well as a more complex composition of the loose material within the hillslope systems located inside of the LIA glacial advance limit as compared to hillslopes situated outside of this limit. Steepened lower talus slopes and the more complex composition of slope deposits generate a higher intensity of currently acting slope processes (e.g. avalanches, slush / debris flows, rock and boulder falls, slope wash, chemical denudation) with the consequence of higher sediment delivery rates from hillslopes located inside of the LIA glacial advance limit as compared to slopes situated outside of this limit.

Variability of contemporary sedimentation rates in a small proglacial lake, Nordfjord area, Western Norway

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Lithostratigraphical analyses of lake sediments are applicable to detect changes in the sedimentary regime and provide implications of landscape response to variability in hydrological and climatological sytems within a catchment. Delta and lake sediments from the lake Sætrevatnet are studied to (i) quantify the high contemporary sedimentation rate, (ii) identify and characterize sediment sources, (iii) analyze the temporal variability of sedimentary and geomorphic processes. Lake Sætrevatnet is situated in front of the Bødalsbreen glacier in the steep and U-shaped Bødalen valley in the innermost part of the Nordfjord area, western Norway. The lake was formed after the rapid retreat of the Bødalsbreen glacier at AD 1930. The streamflow to the lake is complex with a high variability and runoff peaks during spring snowmelt, summer glacier melt and heavy rainfall events in fall or a combination of the three variables.

Lake sediments were cored from a Zodiac boat with a modified Livingston piston-corer in August 2009. In addition, short gravity cores and freeze cores were collected from lake ice in February 2010. In total four piston cores, five gravity cores and three freeze cores were retrieved. Until now magnetic susceptibility of the four piston cores were measured and subsamples were taken for grain-size and SEM analysis. A defined grid of wooden sticks on the delta was installed for calculations of current accumulation rates at the inlet of the lake.

First SEM-EDS analysis points out a domination of quartz and mica, followed by feldspar, which clearly reflects the surrounding bedrock (granitic orthogneiss) of the catchment. Besides the elementary composition, the grains are mostly angular and all analyzed samples show a low degree of sorting. Both indicate that the material has been only shortly transported. The lake sediments taken with the piston corer mainly consist of silty to sandy material with an increasing amount of sand in the proximal cores. Clay could not be proved in any analyzed sample (cores, grab-samples, material of the sediment trap). Delta accumulation measurements from May to October 2009 affirm the assumed high sedimentation rate. The mean accumulation rate (May-Oct 2009) at the inlet of the lake Sætrevatnet is 4 cm. The highest accumulation rate is associated with the major inflow, which is also reflected in an increasing silting up on the right side of the lake. All short gravity and freeze cores show a complex and heterogenetic lamination with a fairly high organic content. The complex lamination is caused by the high variability in hydrological regime and the sediment transport to the lake as well as the sedimentation pattern within the lake.

The next step is to discuss the potential yearly pattern of the laminated sediment record. Recent sedimentation rates will be characterized using short live radionuclide 137Cs and 210Pb. Mineralogy evolution of the single layers will be carried out with XRF analysis. ITRAX (XRF) analysis and the interpretation of the potential varve thickness and composition will be enable to identify different sedimentary and geomorphic processes within this subcatchment of the Bødalen valley. Moreover, analysis of grain size composition, density and the organic & total carbon content will be carried out to understand the complexity of the laminated structure and to identify the sediment sources.

A regional inventory of glacial and periglacial landforms indicating alpine permafrost in Norway

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Scope

An inventory of permafrost-related landforms in Norway is compiled using pre-existing maps, aerial photos and field observations. Such a systematic inventory did not previously exist for Norway, and is needed e.g. as an independent validation of numerical permafrost distribution models. Similar work is done by Àgùst Guðmundsson (2000) in northern and eastern Iceland, and permafrost landforms in Iceland and Norway will be compared. In this presentation, the inventory was used for statistical purposes to examine possible relationships between landforms, climate and topography.

Methods

For Norway, the landforms were divided into two major groups; landforms of southern and northern Norway, and internally divided into either 'active/inactive', or 'fossil' landforms. These groups were further classified, sorted by shape (lobate or tongue-shaped), or landform origin (ice-cored moraines, talus-derived rock glaciers, and moraine-derived intermediate landforms). Statistical *t*-tests were applied to examine class-dependent trends in parameters such as area, mean annual air temperature (MAAT), elevation and aspect.

By combining gridded maps of MAATs (© met.no) and DEMs (© Norwegian Mapping Authorities), a down-scaling algorithm was developed, and MAAT was included in the further analyses.

Results and discussion

Activity and origin

In northern Norway, most of the mapped landforms are fossil (155 of 215), while in southern Norway, there is a slight overweight of active/inactive landforms (42 of 73), as a result of higher concentration of ice-cored moraines. Also, the majority of the landforms in northern Norway are talus landforms, which are mainly fossil features.

All together, there are only a few active talus-derived rock glaciers in Norway today, while the intermediate moraine-related landforms show a higher degree of activity. Also, all the landforms in southern Norway are situated inside the traditional interpretation of the Younger Dryas glaciation limit, while the landforms in northern Norway are mainly situated outside the YD limit, but inside the limit of the assumed Weichsel maximum.

The concentration of fossil talus-derived landforms in northern Norway can be interpreted to reflect a former dry, periglacial climate that favored their formation, while no areas today are favorable for the development of these landforms. The intermediate moraine-derived landforms and ice-cored moraines then reflect a more modern climate where glaciers and permafrost co-exist, and at one point during the Holocene, the dominating process creating permafrost landforms must have changed.

Aspects, temperatures and permafrost limits

The active landforms in southern Norway are to a much higher degree dependent on aspects than the fossil, and show a preferred direction towards north (18°). In northern Norway, the fossil landforms are also depending on aspect, and have a preferred orientation towards NW (301°), while the active landforms have shifted slightly towards north (325°).

The mean MAAT of the active permafrost landforms for southern and northern Norway are -4.4 and -1.3 °C, respectively, and the fossil -1.3 and 1.5 °C.

Based on the presence of landforms, the lower limit of permafrost in southern Norway is close to 1600 m a.s.l., and sporadic permafrost down to 12-1500 m a.s.l. depending on aspect. Corresponding values for northern Norway are 650 and 350 m a.s.l. These results correspond well to previous studies.

Conclusions

Permafrost-related landforms in southern Norway are mainly ice-cored moraines and intermediate, moraine-derived landforms, connected to present glacial activity. In northern Norway, the majority of the landforms are fossil talus rock glaciers, related to a different thermal regime than present. The inventory of active landforms indicates a lower limit of mountain permafrost distribution, which largely corresponds to previous studies.

Reference

Guðmundsson, Á., 2000. *Frerafjöll, Urðarbingir á Tröllaskaga.* MSc. thesis, Science Institute, University of Iceland, Reykjavik, 322 pp.

Karst hydrology and dissolved load of the upper Partnach River, Reintal/Zugspitze

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Due to climate warming high altitude geosystems are in a transient state and hydrological studies are of great importance. Especially, karst hydrology processes in alpine environments are still not fully understood. In 1996 and 1997 first investigations were carried out by Wetzel (2004a, b, 2005). Discharge was measured and water level and electrical conductivity were recorded at the spring of the Partnach River, Reintal/Zugspitze. Using graphical and geochemical methods Wetzel (2004a) could show that runoff is produced by different karst water systems with specific velocities of flow in the upper part of the catchment, Zugspitzplatt. Three components of flow have been detected. Flow in karst conduits, flow in fractures and diffuse Darcian flow in fine fractures are reacting with a time lag after heavy rainfall events. Displacement processes for all components of flow can be observed by means of electrical conductivity. Old pre-event water with a high electrical conductivity is pushed out of the aquifer before the new storm water can be detected by a falling electrical conductivity (dilution effect) in the karst spring. Flow velocities in the karst conduits have been calculated during snow-melt. The rhythmic curve of the daily melting hydrographs is connected with a stepwise fall of the electrical conductivity at the karst spring because of dilution processes. New melting water arrives at the Partnach spring when the electrical conductivity is decreasing. By means of the electrical conductivity, mean velocities of flow of about 400 m/h (about 11 m/s) have been calculated. During a dye tracer study (Eosin, Uranine) starting in 2005 Rappl *et al.* (2010) could show that the Zugspitzplatt area is a well developed karst system. And it is only drained by the Partnach River spring.

In terms of fluvial sediment transport and geomorphic effective discharge dissolved load is predominant in karst regions (Morche 2005, Schmidt & Morche 2006, Morche 2010). Since 2002 a gauging station operates again at the outlet of the highest karst plateau of Germany, Zugspitzplatt, Bavarian Alps. Water level, electrical conductivity and water temperature have been recorded. Water-level recordings were transformed into flow duration curves by using high precision level-discharge relations (Morche 2006, Morche *et al.* 2007, Morche 2010). Water samples were analyzed in the laboratory (ion content). Rating-curves were used for the quantification of the solute sediment fluxes in the river. Fluvial sediment transport is highly variable due to the occurrence of floods. But, mean discharge is determined to be the most effective in terms of geomorphic work (Morche 2010). Based on a multiannual record, the mean annual chemical denudation rate measured as dissolved load in the Partnach River is 2529 t including subterranean and subaeriel denudation (Morche 2010).

References:

Morche, D., 2006. Aktuelle hydrologische Untersuchungen am Partnach-Ursprung (Wettersteingebirge). *Wasserwirtschaft* 96 (1-2), 53-58.

Morche, D., 2007. Chemical denudation in an alpine geosystem - A 5 year record. In: Atalay, I., Efe, R. & A. Soykan (eds.) Environment and Culture in the Mediterranean Region. Abstract volume of the "International Symposium on Geography", 5th - 8th June 2007, Kemer/Antalya, Turkey, p. 83.

Morche, D., Schmidt, K.-H., Heckmann, T. & Haas, F., 2007. Hydrology and geomorphic effects of a high magnitude flood in an Alpine river. *Geografiska Annaler* A 89 (1), 5-19. DOI:10.1111/j.1468-0459.2007.00304.x

Morche, D., 2010. Die fluviale Lösungsfracht und ihre Effektivität bei der rezenten geomorphologischen Formung in einem kalkalpinen Hochgebirgstal. *Salzburger Geographische Arbeiten* 46, 93-110

Rappl, A., K.-F. Wetzel, G. Büttner & M. Scholz, 2010. Tracerhydrologische Untersuchungen am Partnach-Ursprung. *Hydrologie und Wasserbewirtschaftung* 54 (4), 220-230

Wetzel, K.-F., 2004a. On the hydrology of the Partnach area in the Wetterstein Mountains (Bavarian Alps). *Erdkunde* 58, 172-186

Wetzel, K.-F., 2004b. Hydrology of an alpine karst area – the example of the Partnach spring (Upper Bavaria). *Landschaftsökologie und Umweltforschung* 47, 429-434

Wetzel, K.-F., 2005. Discharge analysis of an alpine karst spring - the example of the Partnach spring (Bavarian Alps). *Landschaftsökologie und Umweltforschung* 48, 91-98

Modeling sediment transport in an alpine river reach with HEC-RAS 4.0

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Monitoring and modeling of sediment transport processes in cold climate environments (high latitudes and high mountain Geosystems) is a key issue for near future geomorphologic research. Due to enhanced slope morphodynamics caused by global warming more sediment will be supplied to the river systems. Based on monitoring modeling of river sediment loads is possible. The Hydrologic Engineering Centers River Analysis System (HEC-RAS) is a tool for performing one-dimensional hydraulic calculations and analysis on natural and constructed channels or even on a whole network of river beds. The latest version (4.0.0) published in March 2008 was added by methods to calculate sediment transport capacities and to do sediment impact analysis [USACE, 2008a & 2008b; Daly & Vuyovich, 2003; Mengesha, 2008] by entering the three main model components (geometric data, quasi-unsteady-flow data and sediment data) [Yang, 2002].

A lot of data collection and field work have been done on the Vordere Blaue Gumpe (VBG) (Reintal, Bavarian Alps, Germany) [Morche & Schmidt, 2005; Morche *et al.*, 2006; Morche *et al.*, 2008], which will be used to put the skills and accuracy of HEC-RAS in sediment transport analysis to the test.

The three main components that are needed in HEC-RAS, to perform sediment transport simulations are geometric data (basically cross sections, reach lengths and bank locations), the flow data of a specific time period and sediment transport boundary conditions (bed slope, limits of erosion/deposition). A combination of functions (transport formula, sorting method, fall velocity method) have to be chosen in HEC-RAS. While the geometric data and the quasi-unsteady-flow data, that were used, remained unchanged different functions for sediment transport calculations were varied among each other. The transport functions (TF) of Ackers-White, Yang and Wilcock are most suitable for the area under investigation.

Next to the sediment transport analysis different hydraulic parameters can be calculated for each combination of a cross section and a specific point in time. Most of the differences in calculated values become apparent between the TF itself than in between the TF due to the changed sorting method (SM) and fall velocity method (FV). This shows that the choice of the SM and the FV is not as important as the selection of the proper TF. Besides that the combinations with the Wilcock function show more stable results than those with the functions of Ackers-White and Yang, so the SM and the FV have even less impact using Wilcocks TF.

Apparently the SM and the FV have no wide influence on different parameters. For sediment transport analysis two factors (cumulated mass out and cumulated mass bed change) were taken into consideration to recheck this fact. The results for cumulated mass out and cumulated mass bed change for the VBG are shown. The graphs of the same TFs in those figures are in colors alike because the main focus of this research is on the importance of the appropriate TF. It was also recognized that the run of the curves using the TF of Wilcock or Ackers-White are very congruent in each case whereas the graphs using Yangs function are showing a wider distribution. Furthermore the final values for cumulated mass out vary among each other. The results for the function of Ackers-White range between 2446t – 2490t whereas according to Yangs function a cumulated mass out varying from 2333t to 2801t is expectable. If the TF is set to Wilcocks function the results barely differentiate between each other. HEC-RAS predicts a mean cumulated mass out of 676t for the simulation period. The cumulated mass bed change inside the VBG show similar results. Again the run of the curves using Wilcocks or Ackers-Whites function go well together for each of these TF. The graphs from combinations with the Yang function are widespread once more. The differences in size of the cumulated mass bed change can be identified as well. Therefore using Yangs or Ackers-Whites TF the cumulated mass bed change is significantly higher throughout the whole VBG than when the TF of Wilcock is applied.

The further workflow will include measuring the discharge at the VBG, taking new sediment data (bed gradation updates) and making new laser scans to provide a new geometric data base. All that will help to quantify how the VBG works in terms of fluvial sediment transport between sediment sources and sink and how it is coupled to the Partnach River.

References:

Arcement Jr., G.J. & Schneider, V.R., 1989. Guide for selecting Manning`s roughness coefficient for natural channels and flood plains. U.S. Geological Survey Water-Supply Paper 2339. Washington.

Barnes Jr., H., 1967. Roughness characteristics of natural channels. U.S. Geological Survey Water-Supply Paper 1849. Washington.

Bimböse, M., Schmidt, K.-H. & Morche, D., 2010. High resolution quantification of slope-channel coupling in an alpine geosystem. In: *Sediment Dynamics for a Changing Future* (Proceedings of the ICCE/IAHS International Symposium held at Warsaw, Poland, 14–18 June 2010). IAHS Press, Wallingford, IAHS Public. 337: (in press).

Daly, S.F. & Vuyovich, C.M., 2003. Modeling river ice with HEC-RAS. CGU HS Committee on River Ice Processes and the Environment. 12th Workshop on the Hydraulics of Ice Covered Rivers, Edmonton, AB, June 19-20, 2003.

Gomez, B. & Church, M., 1989. An Assessment of Bed Load Sediment Transport Formulae for Gravel Bed Rivers. *Water Resources Research*, Vol. 25/6: 1161-1186.

Mengesha, F., 2008. *Channel Stability Analysis – The Case of Borkena River (Ethiopia)*. Master of Science Thesis. Addis Ababa University. Addis Ababa.

Morche, D., 2002. Granulometrische und morphometrische Differenzierung von Lockermaterial aus Sedimentquellen und –senken im mittleren Reintal, Oberbayern. Diploma thesis, Institute for Geosciences, Martin-Luther-University Halle-Wittenberg, Halle, Germany.

Morche, D. & Schmidt, K.-H., 2005. Particle size and particle shape analysis of unconsolidated material from sediment sources and sinks in a small Alpine catchment (Reintal, Bavarian Alps, Germany). *Z. Geomorp.* N.F., Suppl. Bd. 138: 67-80. Berlin, Stutgart.

Morche, D., Katterfeld, C., Fuchs, S. & Schmidt, K.-H., 2006. The life-span of a small high mountain lake, the Vordere Blaue Gumpe in the Bavarian Alps. IAHS Press, Wallingford, IAHS Public. 306: 72-81.

Morche, D., Witzsche, M. & Schmidt K.-H., 2008. Hydrogeomorphological characteristics and fluvial sediment transport of a high mountain river (Reintal, Bavarian Alps, Germany). *Z. Geomorph.* N.F., Suppl. 1, Bd. 52: 51-77. Berlin, Stuttgart.

Morche, D. & Bryk, A., 2010. Bed load transport in an Alpine river after a high magnitude flood - Results from the 2008 field campaign. In: *Status and Perspectives of Hydrology in Small Basins*, IAHS Press, Wallingford, IAHS Public. 336: 157-164.

US Army Corps of Engineers, 2008a. HEC-RAS River Analysis System. Hydraulic Reference Manual. Version 4.0. U.S. Army Corps of Engineers Hydrologic Engineering Center. Davis, CA.

US Army Corps of Engineers, 2008b. River Analysis System HEC-RAS. Release Notes. Version 4.0. U.S. Army Corps of Engineers Hydrologic Engineering Center. Davis, CA.

US Army Corps of Engineers, 2008c. HEC-RAS River Analysis System. User`s Manual. Version 4.0. U.S. Army Corps of Engineers Hydrologic Engineering Center. Davis, CA.

Wilcock, P. R., 2001. Toward a practical method for estimating sediment-transport rates in gravelbed rivers. Earth Surface Processes and *Landforms*, Vol. 26: 1395-1408.

Yang, C.T., 1996. *Sediment Transport: Theory and Practice*. New York.

Yang, C.T., 2002. Sediment transport modeling – combination of theoretical concepts and practical approach. In: Summer, W. & Walling, D.E. (2002): *Modeling erosion, sediment transport and sediment yield.* International Hydrological Programme. Technical Documents in Hydrology, No. 60. Paris.

Landslides in Iceland, a short review

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The pioneering work of Ólafur Jónsson (1957, 1976) is the foundation for near all work on rapid mass movement in Iceland. In his work from 1957 he documented accounts of landslides and snow avalanches and their descriptions mostly from historical annals and other written sources. In his later work from 1976 the object was primarily the large landslides in Iceland, rockslides and rock avalanches, or berghlaup as Jónsson named them. At present many Icelandic research institutes are involved in studies of rapid mass movements and the research efforts have been greatly intensified from the pioneering days of Jónsson's, mainly due to the catastrophic accidents that snow avalanches caused in the year 1995, and the serious danger and problems mass wasting causes in many communities around Iceland.

Jónsson's work on the landslide inventory of Iceland has been continued at the Icelandic Institute of Natural History where information on landslides has been collected simultaneously as they have occurred. Additional information has also been collected on the landslides reported by Jónsson, with emphasis on information from the 20th century, from the period which the Icelandic Meteorological Office has systematically collected data on the weather and climate of Iceland.

Conditions in Iceland are in many ways favorable for rapid mass movements. The bedrock of the island is made by young volcanic rocks and clastic sediments derived from those and is easily erodible, e.g. by frost shattering, creating a constant supply of new debris on the mountain slopes all over the country. Glaciers of recent glaciations have eroded deep valleys and fjords into the Icelandic lava pile and from the steep and often high slopes surrounding them, both landslides and snow avalanches are common. In the volcanic zones subglacial eruptions have produced hyaloclastic ridges and tuff rich table mountains, both consisting of erodible material and steep slopes, where rock fall is common. Earthquakes are common in Iceland and have often been reported as a triggering factor to rapid mass movements, mostly connected to rock fall but also triggering landslides and snow avalanches. Last but not least the climatic conditions and the geographical position of Iceland are favorable for rapid mass movements. Iceland is situated in the middle of the North Atlantic Ocean where cold and warm air masses meet and is in the middle of one of the most common route of the low pressure systems across the Atlantic. Rapid shifts in weather condition are common, often accompanied by quite an amount of precipitation which often falls in a short time and can often trigger landslides or snow avalanches.

Landslide activity in Iceland has been divided into two main groups. The first consisting of debris flows which have originated in the talus scree or the debris cover on the slopes. If the slopes are still covered with soil these flows are a mixture of soil, debris and water and can in some instances even been classified as soil flows. The second group consists of large and small rock falls from steep slopes and cliffs. As Iceland is made of easily eroded young volcanic bedrock this group of landslides is very common and most of the landslides that occur in Iceland probably belong to this group. This dividing of landslide activity in either debris flows or rock falls has been used in Iceland for decades but it does not cover all landslides types that occur. Other groups of landslides such as slides or topple are common, but more studies are needed for recognition and the exact composition of the different types of landslides found in Iceland. In this context it is right to mention the term berghlaup, which Icelandic geologists have used to describe a group of landslides that occur in bedrock. The largest and most picturesque landslides in Iceland belong to this group and most of them occur in the older bedrock series of Iceland although some have occurred in younger bedrock. A brief survey shows that this group consists of at least three different types of landslides, e.g. rock slides, rock avalanches and large rock falls or rock mass falls. The major part of these landslides appears to be old and date from just after the deglaciation and up to the middle part of the Holocene. It is not clear how frequent this type of landslide activity has been during the last 1000 years, or since the time of settlement of the country. A few of the large rock avalanches, in the older bedrock of Iceland, could date the last 1000 years but most of the recent activity in these areas appears to be rather small rock slides events. Recently rock slides and rock avalanches have been reported to have fallen from steep slopes in the vicinity of the outlet glaciers of some of the large glaciers in southern Iceland, in relative young bedrock.

In Iceland landslides are by far most common in the central north and in the northwestern and eastern parts of the country. In the 20th century landslides have caused considerable damage to the road system of Iceland and also on various types of buildings, such as apartment buildings and industrial sites, both in rural and urban areas. During this period landslides have claimed at least 27 lives in Iceland. Most of these deaths were caused by rock fall.

The most common triggering factor for landslides in Iceland is heavy precipitation usually connected with strong wind. Autumn storms often cause debris flows and rock fall activity in western, northern and eastern parts of the country and often it is possible follow the path of the storm from one part of the county to another by the landslides. The amount of precipitation needed to trigger off landslide activity, or the so-called threshold conditions are somewhat different between different parts of the country, but are best displayed in the eastern fjords. Snowmelt is also an important triggering factor for landslides. During the intensive snowmelt period in the spring months from April to June, rock fall activity is common over the whole island, but debris flows caused by snowmelt are by far most common in central north and northwest part of the country. In the winter months sudden and intensive snowmelt periods are known to occur, when storms from the south suddenly bring much warmer air into the area, often followed by great amount of rain. These sudden weather changes have often been followed by great landslide activity and river flooding over the whole country. Another important triggering factor for landslides in Iceland is earthquakes.

References

Jónsson, Ó. 1957. *Skriðuföll og snjóflóð* I-II. Bókaútgáfan Norðri, Akureyri. 586 + 555 p.

Jónsson, Ó. 1976. *Berghlaup*. Ræktunarfélag Norðurlands, Akureyri. 623 p.

Sediment fluxes in glacierized valley systems of central Spitsbergen (Svalbard)

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Climate and weather variations are main driving factors of sediment transport and deposition processes. It is especially well visible in mountain and high latitude environments that are very sensitive to climate fluctuations. Within the latter, special role is given to processes related to presence and degradation of various forms of ice. Three systems of medium size, valley and outlet glaciers, covering up to 25% of their catchments were investigated in the area of a specific, quasi-continental climate subtype of Spitsbergen interior. To estimate the character and amount of sediments transported in the glacial environment, several depositional conditions were analysed.

Basic factor determining contemporary glacial covers development is connected with a visible negative mass balance of glaciers and their recession, leading to the deposition of vast masses of labile sediments. Majority of sediments is transported in subglacial position as the effect of incorporation in polythermal conditions at glaciers bed. The supply from subglacial position to the surface of glaciers frontal parts, that generate the formation of ice-cored moraines, was stable during about 60 years after the termination of the Little Ice Age (LIA) due to balanced rates of ice movement and ablation in marginal zones. Supraglacial covers generated during that period reach 2 m of thickness, while sediments freshly deposited during last decades of accelerated ablation are only 0.2-0.3 m thick. Seasonal activity of mass movements, discharge of melt-water and permafrost active layer dynamics initiates transport of morainic deposits and their further transformations. The effect of glacier surge was identified in the form of massive till series building front moraines of considerable size. Glaciofluvial deposition is widely recognized in the study area and outwash plains are the most significant within identified landforms. Sandur deposits are coarsest in proximal parts at the contact with LIA moraines. Glaciers decay is responsible for elongation of glaciofluvial transport pathways, outwash plains proximal parts erosion and river channels stabilization.

Inland zones of glacial and glaciofluvial storage are important areas of temporal accumulation during LIA and after its termination. The delivery of sediments to this area from glacial ice covered parts of catchments is estimated at 1.2-2.8 mm y^{-1} depending on glacier type (non-surging/surging). Depending on catchment structure and glacier size the denudation rate, calculated as the function of suspended and dissolved sediments discharged in proglacial rivers was estimated at 0.125-0.799 mm y^{-1}. Chemical denudation is established at constant level while mechanical component is distinctly changeable, depending on local conditions of sediments delivery to the streams.

Quantifying cold coast sediment budgets: recent advances from High Arctic fjords in Svalbard.

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In contrast to mid and low latitude coasts, relatively little is known regarding the potential impacts of climate and sea-level change on high latitude coastal margins. Indeed, many of the existing intellectual paradigms regarding the functioning of polar beaches are now out-dated, based on descriptive geomorphology and a limited process-based understanding. My PhD research project aims to address this deficiency in understanding by quantifying the mechanisms and patterns of recent adjustment of high Arctic coasts in Svalbard following the end of Little Ice Age, an interval of time characterized by abrupt climate warming, rapid deglaciation and rising relative sea-levels.

In this paper, I summarise my PhD research to date by presenting initial results from an analysis of digital aerial photogrammetry, combined with field-based geomorphological mapping. The geographical focus is Petunia Bay, one of the most protected bays of the Svalbard archipelago, which is characterized by a semi-arid, sub-polar climate, limited wave fetch and tidal range, and rapid retreat rate of all surrounding glaciers. Landscape and coastal change is mapped using combination of DEM-s developed over a 70 year period between 1936 and 2009, combined with field-based geomorphological mapping. I also detail the characteristics of beach sediment from several beach settings together with 'Jennings and Shulmeister' beach classification methods to identify potential factors controlling the morphodynamics of these polar beaches. My work highlights the need for a greater understanding of the controls on polar coastal sediment budgets, especially given the potential for accelerated warming and sea-level rise in the coming decades and centuries.

The Morsárjökull rock avalanche, in the southern part of the Vatnajökull ice cap, and its effect on the Morsárjökull outlet glacier from 2007-2010

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A large rock avalanche fell on the Morsárjökull glacier on the southern part of the Vatnajökull ice cap, in south Iceland, on the 20th of March 2007. This rock avalanche is considered to be one of the largest rock avalanches which have occurred in Iceland during the last decades. It fell in two separate stages, the main part on the 20th of March and the second and smaller one, on the 17th of April 2007.

The rock avalanche fell on the eastern side of the uppermost part of the Morsárjökull outlet glacier, which is about 4 km long and surrounded by up to 1,000 m high valley slopes. The rock avalanche covered about 1/5 of the glacier surface, an area of about 720,000 m^2. The scar of the rock avalanche is on the north face of the headwall above the uppermost part of the glacier. It is around 330 m high, reaching from about 620 m up to 950 m. It is estimated that about 4 million m^3 of rock debris fell on the glacier, or about 10 million tons. The accumulation lobe is up to 1.6 km long, reaching from 520 m a.s.l., to about 350 m a.s.l. Its width is from 125 m to 650 m, or on average 480 m. The total area which the lobe covers is around 720,000 m^2 and its mean thickness 5.5 m. The surface of the lobe shows longitudinal ridges and grooves and narrow flow-like lobes, indicating that the debris mass evolved down glacier as a mixture of a slide and debris flow. The debris mass is coarse grained and boulder rich. Blocks over 5 to 8 m in diameter are common on the edges of the lobe up to 1.6 km from the source. No indication was seen of any deformation of the glacier surface under the debris mass.

The first glaciological measurements of Morsárjökull outlet glacier were carried out in the year 1896 and it is evident that since that time the glacier has retreated considerably. It is thought that undercutting of the mountain slope by glacial erosion and the retreat of the glacier are the main contributing factors leading to the rock avalanche. The glacial erosion has destabilized the slope, which is mainly composed of palagonite and dolerite rocks, affected by geothermal alteration. Hence a subsequent fracture formation has weakened the strength of the bedrock. However the exact triggering factor is not known. No seismic activity or meteorological signals such as heavy rainfall or intensive snowmelt were recorded prior to the rock avalanche which could be interpreted as triggering factors.

From the time of the rock avalanche considerable changes have been observed on the glacier. The ice-front has retreated considerably and the debris lobe of the rock avalanche has moved downward along with the glacier ice about 90-100 m per year. The rocky material, by insulating the ice, has reduced its melting, leading to a relative "thickening" of the ice beneath the rock avalanche debris up to 11-15 m per year. After four melting seasons the debris mass is about 40 m above the surrounding ice surface.

The ice mass and the rock debris covering the outlet glacier do not infect the movement rate of the glacier. The average moving rate of 90-100 m/year seems to be constant from the time of the rock avalanche in 2007. This moving rate also corresponds to the measurements of Jack Ives around 1950. Although the surface of the glacier has undergone considerable changes from the release of the rock avalanche, no indications of ice accumulation have been noticed above the ice/debris mass. The total amount of ice accumulating under the debris mass after four melt seasons from 2007 to 2010 is about 29.000.000 m^3 or 26.000.000 tons.

Metals in water and foams from NOM-rich sub-Alpine streams

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It is assumed that vegetation growth and leaching of NOM will be intensified in sub-Alpine environments with change towards a warmer and wetter climate. This may affect the quality of natural water and lead to increased costs of water treatment. Metal transport was investigated in a dozen small streams that feed Lake Jonsvatnet, the water supply for the city of Trondheim, Norway. All are brown-water streams with elevated concentrations of aqueous natural organic matter (NOM) which varies seasonally and with episodic rainfall events and annual snow melt.

The stream waters samples were analyzed for aqueous NOM, pH, electrical conductivity and major, minor, and trace metals/metalloids during August'07-April'09. Natural organic foams also characterize these waterways and these were sampled during the same period. The collapsed foams were analyzed in a manner similar to the water samples. Data analyses of over 350 water and 40 foam samples show strong correlations between dissolved organic carbon (DOC) content and the concentrations of several trace metals/metalloids, but the foam samples serve as a more reliable indicator of trace metal transport than the samples of the aqueous phase. The strongest correlations were in the foam samples between dissolved iron, which is in turn strongly correlated with DOC, and the concentrations of arsenic, selenium, chromium and molybdenum. Copper and mercury are strongly correlated with DOC in the foams, but less so in the aqueous samples.

The results of these analyses suggest that NOM foams are a reliable indicator of trace metal transport in NOM-rich streams and may provide a convenient proxy for estimating changes in metal loads in stream water.

Properties of initial soils developing on Fláajökull foreland

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Icelandic soils are mostly classified as Andosols. Parent material of all of them comprises volcanic ash, tephra or extrusive volcanic rocks, mainly basalts.

The aim of this paper is to present basic properties of young initial soils developing on the Fláajökull foreland.

Fláajökull is an outlet glacier of Vatnajökull ice cup localized in the south-eastern Iceland. Its front has retreated about 1700 metres since the end of 19th century left 7 well-developed moraine belts dated on 41 to 113 years. In glacier foreland soils have been forming on sediments made of original materials considerably mixed by glacier's activity.

Described soils have been forming under cold maritime climate with the mean annual temperature 4,4°C above 0 and precipitation about 1500 mm. The consequence of those conditions is lack of permafrost and intensive water percolation into the soil material. Frequent temperature fluctuations near 0°C causes intensive freeze-thaw processes which evidence are various forms of patterned grounds observed on the surface of the moraines. In the neighbourhood of the glacier catabatic winds are frequent.

Soil samples from the upper soil horizons from six moraine belts were taken to analyze to investigate the soil development in the initial stages of podzolization. Different micro-forms were taken into consideration as a factor of soil properties differentiation, like hollows, slopes and crests of the moraines as well as patterned grounds. One sample was taken from the youngest moraine without plant cover and visible pedogenesis processes.

Mineral composition, particle size distribution, organic matter content and pH analyzes were carry out. On all sites plant community composition was described.

XRD analysis indicates that in fine earth minerals characteristic for basalts occur. Plagioclase series, like bytownite and anorthite, and pyroxenes, like augite are abundant. Magnetite is also present. Among clay minerals smectite as and zeolite were identified. Characteristic feature of that material is lack of olivine and significant amount of quartz. There were no important differences of mineral composition between samples taken from different-aged moraines.

Particle size analysis shows that most samples of the soil material comprise loamy sand. On one site the soil material has features of loam. The material taken from the youngest moraine has loose sand texture weak of silt fraction compared with other soil samples, which can prove deflation and wind accumulation processes involved into pedogenesis. Patterned grounds give characteristic picture of texture displaying by increasing of fine silt with depth.

Young soils on the Fláajökull foreland have developed under plant cover relatively dense on the moraines dated on 54 years and older consist mostly of mosses and lichens with significant addition of vascular plants on the older moraines. There are 37 species of vascular plants has been identified on the moraines. The biggest variety of vascular plants is noted on the oldest moraines dated on 87 years and more, but hollows between the moraines were favorable environment for vascular species growth even on the youngest moraines.

Organic matter content is low and does not cross 0,2 % in all profiles. The biggest amounts of organic matter content was noted on the moraines dated on 87 years and older, within the youngest ones – in the hollows between the moraines which is correlated with places favorable for plants growth. The smallest amounts of organic matter content are noted on patterned grounds.

The time of pedogenesis on the Fláajökull foreland is too short to make signify differentiation in soil properties between particular moraines. More significant differences are connected with microenvironments like tops and hollows or patterned grounds which are related to specific conditions to plant growth and wind processes. Among other factors connected with microenvironments differentiation, exposition of the slope seems to be far less significant.

Overview of the Icelandic Environment & Short Field Trips Description

The bedrock, landscape and climatic characteristics in Iceland

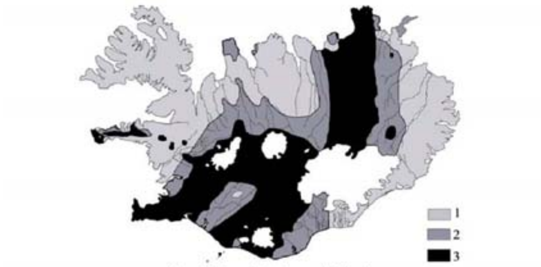
Bedrock

Iceland is a volcanic island located on the North Atlantic spreading ridge, which separates the North American and the Eurasian continental plates. The bedrock or the lava pile is composed of basaltic volcanic rocks and relatively thin sedimentary horizons. The lava pile of Iceland has been divided into three stratigraphical units, based on age and appearance; the Tertiary series, the early Quaternary series and the late Quaternary series, and the lava fields of the volcanic zones.

The oldest bedrock (3-16 m.yr), the Tertiary series, occur in the eastern, central northern and western part of the island. It is mostly composed of jointed basaltic lava flows, erupted subaerially, individual flows varying in thickness from 2-30 m and usually separated by lithified sedimentary horizons varying in thickness from few centimetres up to tens of meters. Acid rocks and intrusions are found locally in buried central volcanoes, which also have been centres of tectonic activity. The Tertiary lava pile is intersected by basaltic dykes, most of which confined to dyke-swarms and old fault zones. The lava beds of the Tertiary series dip generally towards the centre of island, towards the active volcanic zone in the centre of Iceland.

The Early Quaternary series form a zone intermediate between the Tertiary basaltic areas and the active volcanic zone. In this zone, more variation occurs in the general bedrock composition. The main reason for this is the periodically coverage with glaciers during that time interval (3-0.7 m.yr). The lava pile from this time consists predominantly of sub-glacial volcanic material erupted during glacial periods, made of pillow lavas, various types of breccias and hyaloclastites. This material is commonly interstratified with extensive sub-aerial lava flows erupted during interglacial periods. Sediment horizons from this time are also much ticker than in the Tertiary, due to much more erosion and landscape formation connected with the glacial activity.

The youngest bedrock, the Late Quaternary series (> 0.7 m.yr), consists of hyaloclastic volcanic ridges and table mountains erupted subglacially in glacial periods and interstadial glacially sculptured lava flows. It also consists of the postglacial lava fields of the active volcanic zone.



Simplified geological map of Iceland
1 - Basaltic Formations from Tertiary Period (Miocene-Pliocene) 2 - Plio-Pleistocene Formations
3 - Pleistocene and Holocene Formations (From Þ. Einarsson, 1994).

The landscape

The bedrock of Iceland has been sculptured by glacial, fluvial and marine erosion. The landscape characteristics are variable around the island and reflect the age of the bedrock and its composition.

The main topographical features in the Tertiary areas in the north-western, central northern and eastern parts of the island are glacially eroded, U-shaped fjords and valleys cut into the extensive highlands plateaux. The fjord and valley sides are often steep, with an average height of up to 600-800 m. The upper parts of the slopes are often nearly vertical cliffs whereas the lower parts are covered with various glaciogenic sediments and talus material.

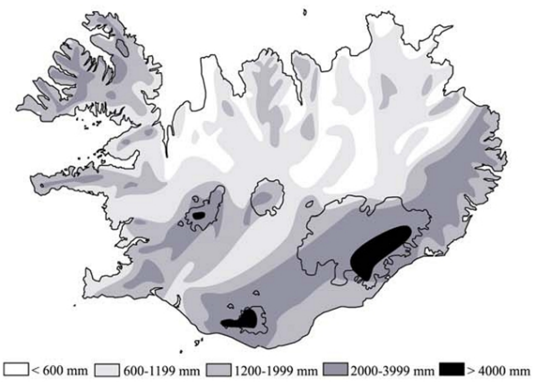
In Southern Iceland large glaciers and extensive sandur plains characterize the landscape in association with extensive mountains formed during the Quaternary period. Due to both glacial and marine erosion steep slopes and high cliffs up to 500 m have been cut into the mountains massive.

Hyaloclastics ridges and Table Mountains with steep slopes and extensive lava fields characterize the landscapes in the volcanic active zones in the central part of Iceland.

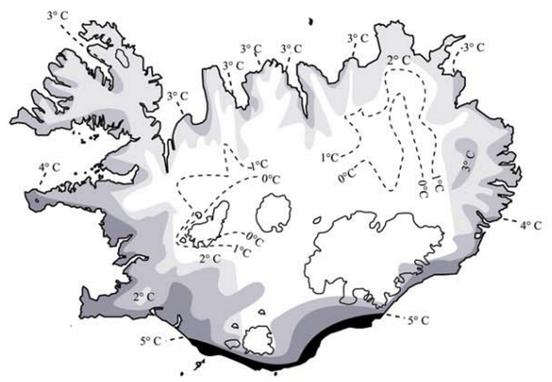
Climatic and soil characteristics in Iceland

Climate

According to the Köppen-Geiger system Iceland is located at the junction between the temperate and the arctic climatic regions. The climate is categorized as cool temperate and maritime, with cool summers and mild winters. The weather in Iceland is constantly changing with high variation in precipitation and temperature. This is mainly due to the fact that Iceland is located near the main low-pressure pathway over the North Atlantic Ocean, The Icelandic Low. The mean annual temperature is higher in the southern part of the island than in the northern part, due to higher winter temperatures in the south. The mean annual precipitation is highest in the southern and south-eastern parts of the island. This is mainly due to the fact that the prevailing winds producing precipitation are southerly and south-easterly lose their moisture over the southern highlands.



Mean annual precipitation in Iceland (From Þ. Einarsson, 1994)



Mean annual temperatures in Iceland (From Þ. Einarsson, 1994)

Soil

The slopes in the Tertiary basaltic areas in Iceland are usually covered by glacial till in the lower parts. The upper parts of these slopes are usually steep, terminating into cliffs. The areas are with till cover are often also covered by talus, colluviums and humus material with high permeability. Due to the high permeability these soils are strongly influenced by frost action. The valley bottoms are usually dominated by fluvial and glaciofluvial deposits.

Field trips

On-Conference Field Trip

Monday 20th of September

Departing from Sauðárkrókur at 8:00

During the trip we will travel inside the Skagafjörður and Siglufjörður fjords and end the trip swimming at the Hofsós swimming pool. Also, we will visit the Hólar campus, in the Hjaltadalur valley. Estimated return to Sauðárkrókur around 19:00.

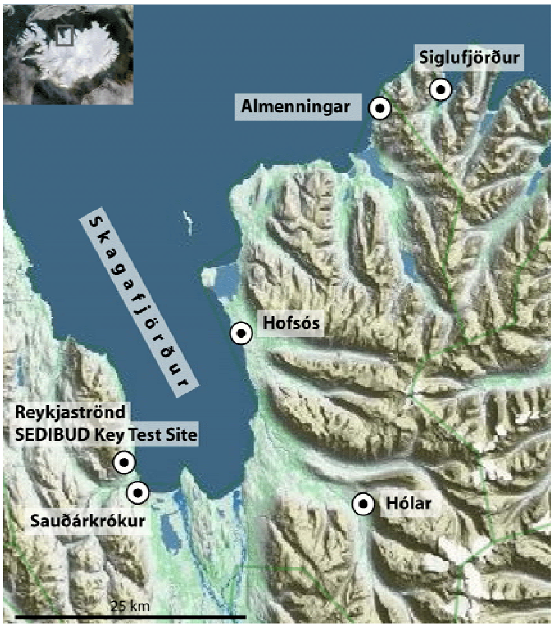
Stop 1. The Reykjaströnd SEDIBUD Key Test Site

Stop 2. The Almenningar landslide area

Stop 3. The Siglufjörður fjord, snow avalanche site

Stop 4. The Hofsós village

Stop 5. The Hólar area



Post-Conference Fields Trips

Thursday 23rd of September

Departure from Sauðárkrókur at 8:00

During this trip we will travel from the town of Sauðárkrókur to the town of Egilsstaðir. Estimated arrival in Egilsstaðir around 19:00.

Stop 1. The Kotárgil gully in the Norðurárdalur valley

Stop 2. The Hraun site in the Öxnardalur valley

Stop 3. The Akureyri town, free time

Stop 4. The Fnjóskadalur Key Test Site - snow avalanche site

Stop 5. The Goðafoss waterfall

Stop 6. The lake Mývatn area

Stop 7. The town of Egilsstaðir

Friday 24th of September

Departure from Egilsstaðir at 8:00

During this trip we will visit two SEDIBUD Key Test Sites in the fjords of Seyðisfjörður and Borgarfjörður Eystri. Estimated return time at Egilsstaðir around 19:00.

Stop 1. Seyðisfjörður, Austdalur SEDIBUD Key Test Site

Stop 2. Borgarfjörður Eystri, Hraundalur SEDIBUD Key Test Site

Stop 3. Egilsstaðir

Saturday 25th of September

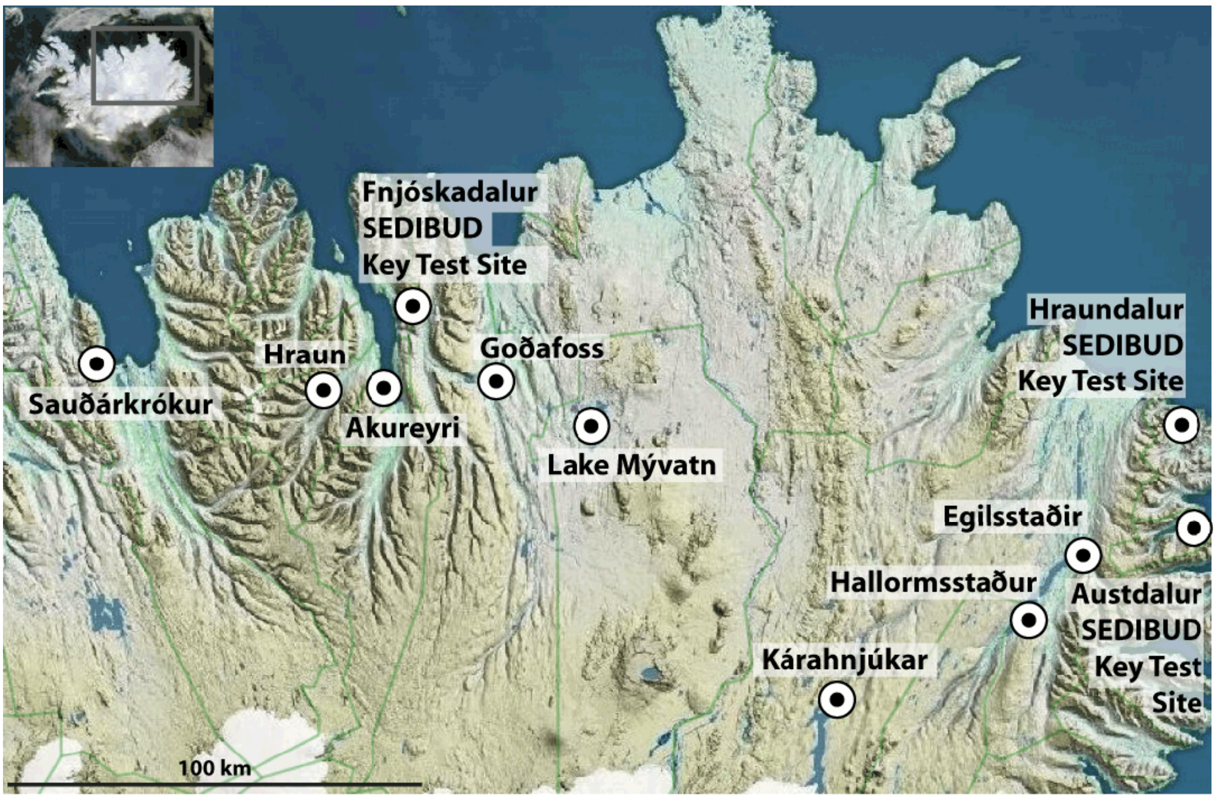
Departure from Egilsstaðir at 8:00

During this trip we will visit the Kárahnjúkar Hydropower dam, the Hálslón reservoir, the Dimmugljúfur canyon and the Fljótsdalur Hydropower Station. Estimated arrival at Egilsstaðir around 17:00. Flight from Egilsstaðir to Reykjavík at 18:10, landing in Reykjavík at 19:10.

Stop 1. The Kárahnjúkar Hydropower Dam / The Dimmugljúfur canyon

Stop 2. The Fljótsdalur Hydropower Station

Stop 3. The Hallormsstaður forest.



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