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8.1

Surface exposure dating of 1717 AD rock avalanche deposits in the upper Ferret Valley (Italy) with cosmogenic $^{10}$Be

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One of the largest rock avalanches of the Alps occurred on September 12th 1717 AD in Mont Blanc Massif. In the upper Ferret Valley (Italy), a rock volume larger than 10 million m³ and a huge volume of ice from the Triolet glacier were mobilized and moved more than 7.5 km downvalley and reached the lower part of the valley (Deline and Kirkbride, 2009). This mass composed of ice and sediment destroyed two small settlements with 7 casualties and loss of their cattle.

Accumulations of granitic boulders and irregular ridges over a distance of 2 km in the upper Ferret terminate downvalley with a 5 m-high arcuate front (Deline and Kirkbride, 2009). This extensive deposit was first attributed to glacial deposits (Deline, 2009). In their detailed study, Porter and Orombelli (1980) interpreted this deposit as the rock avalanche of 1717 AD. Aeschlimann (1983) debated this interpretation and claimed that the main part of this deposit is a Lateglacial moraine (Deline, 2009). Recently, Deline and Kirkbride (2009) concluded that this deposit is a complex of glacial, an earlier rock avalanche and 1717 AD rock avalanche deposits. Can cosmogenic $^{10}$Be tell us more on this dilemma?

With the aim of answering this question, 9 granitic boulders within the upper valley deposit and 3 from the boulders outside were sampled for surface exposure dating with $^{10}$Be and prepared for AMS analysis. $^{10}$Be exposure ages vary between 300 and 500 years within the limits of error. These exposure ages indicate that the extensive granitic boulder deposition with irregular ridges belongs to the 1717 AD rock avalanche. This relation confirms the main part of the Porter and Orombelli (1980) interpretations.

Figure 1. Deposits of upper Ferret Valley. Yellow line: extent of granitic boulder accumulations. Purple ribbon: limit of the recent morainic complex of Glacier de Triolet (Deline, 2009).
8.2

Origin of Bahamian laminar crusts: new geochronological and petrographic data

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Petrographic examination and radiometric dating of surficial laminar crusts collected from various Bahamian islands show that, contrary to previous thinking, these crusts mostly result from biologically controlled precipitation at the rock/atmosphere interface during the past 10 ka.

Laminar crusts are widely exposed on the Bahamas islands and have been interpreted as resulting mainly from physico-chemical precipitation during pedogenesis. Further, they have been identified as the lower horizon of a Wisconsinian paleosol, when occurring in association with clay-rich conglomerates between Pleistocene and Holocene carbonate units. To verify these hypotheses, we have examined microscopically and carbon dated several crusts collected from Mayaguana and San Salvador.

All studied profiles consist of one single, orange to brown, cm-thick crust, showing a smooth upper surface that rises and falls with the present topography. In all cases it rests on indurated Pleistocene limestone. At Green Cay (near San Salvador) and Betsy Bay (Mayaguana), the crust directly occurs at the rock/atmosphere interface, whereas at NW Point (Mayaguana) and Singer Bar Point (San Salvador) it is capped by a Holocene calcarenite, with intervening pockets of clay-rich breccia at the latter locality. The crust laminations correspond to mm-thin alternating zones of:

(a) dense, orange, homogeneous or clotted micrite containing sparse calcitic spherulites
(b) darker porous micrite containing rounded features with a cellular texture, and also peloids that have preserved their primary aragonitic mineralogy.

The boundary with the slightly altered underlying Pleistocene limestone is sharp, even at thin-section scale. Raw radiocarbon ages obtained from these crusts range from 9,210 to 3,270 years BP.

Our petrographic data show that biological factors, such as cyanobacterial, fungal, and pioneer-plant activity played a greater role than physico-chemical processes in the formation of these crusts. Their young age suggest that this biological activity could be related to the Holocene transgression, and that the overlying pockets of clay-rich breccia must be interpreted as a reworked soil sediment of Holocene age, rather than a Wisconsinian paleosol.
8.3

Organic and mineral sedimentary deposits in the evaporators’ environments of the Sahel of Tunisia (Mahdia): the Baghdadi swamp and the conjugated sebkha of Gotaia and Eliane.

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The mineral and organic sedimentary studies are realized on sedimentary columns of 1m of depth in evaporators systems in the sahel of Tunisia (Mahdia). These systems are the result of Tyrrenian tectonic accidents.

The analysis of the organic matter by pyrolysis Rock-Eval 6 revealed the presence of a heterogeneous organic matter stock dominated by the ligneous fraction. The originated organic fraction is limited in bacteria activity. The hypersaline environments or evaporatores systems are known for the low biological variety. It is identified well by the presence of some biomarkers: alkylbenzenes (C18, C19 and C20), hopanes (norlupane ans oleane,) and steranes (stigmastane, cholesate).

The silty fraction is the essential mineral fraction in the system of the Sahel from Tunisia. The quartz represents the main part of the mineral procession (90 %). Three clay minerals are presents: kaolinite, illite and smectite. Only the smectite is partially synthesized in these environments. The abundance of the kaolinite in peripheral sediments supports the significant terrigene contributions. The identified evaporates are halite, gypsum and calicite. In the center, the hailte constitutes the surface sediments.

Size distributions are influenced by the previous history of the sediment and climate condition. Clay particles are transported and deposit in the center of the system in low energy conditions. Sand located at the periphery is deposit by high energy. The presence of bimodal shape indicates the period of mudding in this evaporator system which is characterized by squat dynamic environment. However the levels of sand in the center specify the interruption by the cycle of important activity.

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8.4 How did fire, human impact and climate change affect Holocene treeline dynamics in the Alps? A case of study from Gouillé Rion (Valais, Switzerland)

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In the Alpine region, the treeline ecotone is highly sensitive to climatic and land-use changes. Rising temperatures induce upslope migration of individual species, allowing treeline expansion into unforested landscapes (Harsch et al. 2009). Additionally, ongoing agricultural abandonment favours afforestation in former high-elevation pastures (Rutherford et al. 2008). In contrast, forest fires affect the treeline ecotone, by reducing fuel loads and promoting dominance of fire-prone species. So far, few long-term paleoecological studies with high temporal-resolution investigated how fire variability affected treeline dynamics especially in the Alpine region, where people have altered fire regimes at least since the Neolithic (Gobet et al. 2003).

In this paper, we use a high-resolution record of macroscopic charcoal and plant macrofossil records from a lake in the Swiss Alps (Gouillé Rion, 2343 m a.s.l.) to: 1) investigate changes of biomass burning over the last 12,000 years; 2) to derive responses of tree-line vegetation to fire occurrence; 3) to disentangle the role of human vs. climatic factors for the observed variability in fire frequency. For our purposes, we used sediment charcoal to reconstruct the frequency of fire episodes around the lake (e.g. Gavin et al. 2007). Secondly, we used regression analyses between contiguous series of plant macrofossils, macroscopic charcoal and an available reconstruction of past summer temperature (Heiri et al. 2003), to derive species response to fire variability and to summer temperature. Finally, we used a dynamic landscape vegetation model (LANDCLIM), to explore potential forcing mechanisms of fire-regime change, specifically to disentangle the role of climate vs. humans on fire occurrence.

Our results show that fire was a natural disturbance agent at the treeline ecotone but since the Bronze Age (c. 4000 cal. years BP) human disturbance overrode the effect of climate in controlling fire variability. Also, anthropogenic fire and climate affected differently the composition of plant species at the treeline. For instance, when mean July temperatures were lower than modern mean July values, Juniperus nana and Larix decidua were at an advantage over P. cembra. With increasing anthropogenic fire, open lands with J. nana replaced L. decidua and P. cembra forest stands. Pinus cembra instead could expand during periods with temperature above the modern mean July temperature if fire disturbance was not too severe.

Figure 1. A) Location of the investigated site in the Valais. B) Occurrence of Pinus cembra near the site at the treeline (photo from Tinner 1996). C) Reconstructed local fire history over the last 12,000 years (modified from Colombaroli et al. in press).
Our study might be relevant for future development of Alpine ecosystems under global change scenarios, such as the response of the treeline ecotone to warming temperature and increasing anthropogenic fire (Tinner & Kaltenrieder 2005). Although climate change will alter vegetation composition, future dynamics of mountain forests will be co-determined by anthropogenic fire. For instance, high fire variability may delay or impede upslope establishment of forests in response to climatic warming as expected for this century, with serious implications for forest diversity.

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8.5

Erosion and filling of a glacially overdeepened trough in the northern Alpine Foreland as recorded in deep drill core NW09 from Niederweningen, Switzerland

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As the major weather divide in Europe, the Alps represent one of the most interesting areas for understanding past climate change and its impact on continental environments. However, our knowledge of the Quaternary environmental history of the region is still rather limited, especially for the time preceding the last glaciation of the Alps.

Geological and geophysical studies in the Wehntal, 20 km northwest of Zurich, in 2007 and 2008 have revealed the existence of a glacially overdeepened trough cut into Miocene molasse bedrock, which is today filled with ~90 to 180 m of Quaternary sediments.

In March 2009, a 93.6 m long sediment core NW09/1 has been drilled down to bedrock east of a famous mammoth-site in Niederweningen. This drill core represents one of the very few records in the northern Alpine Foreland that provides crucial insights into timing of erosion and infilling history of pre-Eemian glacially overdeepened structures and also helps to understand the climate and environmental history of multiple glacial-interglacial cycles.

On the basis of multi-proxy data and extended luminescence chronology, the recovered sediment succession is interpreted from bottom to top as: 4.1 m of in-situ molasse bedrock, overlain by 3.4 m of diamicitic till. The glacial sediment was deposited by a lobe of the combined Walensee branch of Rhine Glacier and the Linth Glacier during Marine Isotope Stage (MIS) 8. It is suggested that this extensive ice advance, which once covered the entire Wehntal valley, caused the final erosion of the bedrock. The till merges seamlessly into a 29.5 m thick sequence of laminated, carbonate-rich, fine-grained siliciclastic sediments that are interpreted as proglacial lake sediments, which accumulated also during MIS 8. This unit was likely deposited in a proximal setting to a calving glacier-front confirmed by the presence of numerous dropstones.

The damming of this Wehntal palaeolake was most likely caused by a terminal moraine located ~3 km to the northwest of the drill site. The overlying 37.9 m of fine-grained lake sediments are comparable to the former unit, but absence of dropstones indicates a more distal proglacial lake facies and thus, a retreat of the feeding glacier lobe.

Low organic carbon contents point to almost no biological activity within the lake and suggest cold environmental conditions. Feldspar luminescence dating showed that the formation of this unit occurred over the whole MIS 7. This unit is unconformably overlain by 9.5 m of fine-grained material. The hiatus covers almost the complete MIS 6, which is believed to represent a major glaciation of the northern Alpine Foreland.

Although, a striking drop in carbonate content (from ~45 to 20 wt%) and shear strength, as well as an increase in grain-size (from clayey silt to fine sand) can be noticed, no obvious erosional features can be seen in the sediment fabric. The change in carbonate content is interpreted as a decoupling of the Wehntal catchment from the Rhein/Linth Glacier systems that originate in a carbonate-rich hinterland.

The top of the unit documents a gradual infilling of the palaeolake and onset of biological productivity due to climate warming during early MIS 5. This is also documented by occurrence of post-sedimentary pyrite and siderite concretions.

The prominent environmental change culminates in the abrupt accumulation of peat (1.8 m) during late interglacial MIS 5e (Eemian). Afterwards, the Wehntal was reoccupied by a younger palaeolake flooding the peat. The resulting 4.9 m of bluish-gray silty sediments have carbonate contents of ~25 wt% and relative high organic carbon contents (~1 wt%). Luminescence dates put this sediment unit into early MIS 3.

The source of sediment is interpreted as derived from the molassic Zurich Highlands and the Jurassic limestone of the Lägern mountain chain, which borders the Wehntal valley to the south. The actual cause of rise in water level subsequent to deposition of the Eemian peat, however, has not yet been identified.

Thereafter, the younger palaeolake was filled, resulting in the accumulation of 0.7 m of fossil-rich Middle Würmian peat, the so called ‘Mammoth peat’, which was finally covered with 2.0 m of post-Würmian-to-recent alluvial silts and sands.
8.6

High-resolution sediment colour and geochemical analysis of Dansgaard-Oeschger events (Cariaco Basin, Northern Arabian Sea)

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The anoxic Cariaco Basin on the northern shelf of Venezuela preserves detailed records of past tropical climate variability. The sediment formation in this basin is controlled by the migration of the Atlantic Intertropical Convergence Zone (ITCZ) and the corresponding rain belt and trade winds. In the oxygen minimum zone off Pakistan in the northern Arabian Sea sediment archives of low-latitude monsoonal climate are preserved.

In this study sediments from the two settings that cover the last 80'000 to 110'000 years are compared with Greenland ice core records. Sediment colour analysis resulted in reflectance records with down to annual resolution. The reflectance records of the Cariaco Basin and the northern Arabian Sea faithfully mimic the Greenland ice core δ¹⁸O record. An age model was set up by correlation of these records to the δ¹⁸O record of NGRIP. The major element chemistry of the sediments was analysed with X-ray fluorescence scanning.

Colour variations in these marine sediments reflect changes in redox state and relative contributions of terrigenous and biogenic components. Changes in anoxia and productivity can be further explored using element proxies as molybdenum, manganese and bromine. Variability in the terrigenous input can be traced by elemental proxies as titanium.

The new high resolution proxy records indicate an unbroken association between warm climate conditions over Greenland, a northerly position of the Atlantic Intertropical Convergence Zone, and a strong Indian summer monsoon since the last glacial. The tight coupling is explained by a dominant role of the North Atlantic that is communicated largely through the atmosphere. New insights of dynamical mechanisms arise from comparison of individual Dansgaard-Oeschger events that suggests a threshold response of the tropics to North Atlantic cooling.

8.7

Rhone glacier deglaciation in western Lake Geneva : new sismo- and bio-chronostratigraphy results

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Seismic reflection and geotechnical drilling were performed in spring 2009 in the western part of Lake Geneva within a public project to build a large bridge over the lake. Scientific analyse of this seismic and sediment record reveals new insights in the history of the Rhone glacier deglaciation and Lake Geneva formation.

Seismic data, acquired with a 1 in³ airgun and a pinger source, images the bedrock lake basin as well as eight sismostratigraphic units of glacial, glacio-lacustrine and lacustrine facies. In the eastern part of studied area, gas reduces seismic data quality but nevertheless, the lateral asymmetry of the basin geometry and of the sediment infill appears. In the western part, the bedrock (i.e. Molasse) forms a 3° ramp bending toward east which is topped by only maximum 30 m of sediment. In the centre and eastern part of the lake basin, the bedrock lies deeper and is covered by 70 to 110 m of glacial to lacustrine units.

The deepest unit (U1), which was detected on seismic lines but not drilled, is interpreted as glacial sediments left during an older glacial cycle (Fiore 2007). It is topped by the thick U6b and U7 units, interpreted as melt-out till of the Rhone glacier. Four 35 to 75 m-deep drillings confirm this interpretation and show that unit U6b was certainly compacted by a
re-advance of the Rhone glacier. This data reveals a new glacial stage, older than stages of Coppet and Nyon, with a glacial front near ‘Le Reposoir’. The asymmetry of unit U7 also shows that the glacier melted first in the central and eastern part of the lake basin while it was still lying on the Molasse ‘ramp’ in the West.

The next sequence, represented by units U8-U12, is interpreted as glacio-lacustrine deposits. They have variable sedimentary facies ranging from massive silt to laminated clayed silt with rare sand layers. Gravels of alpine origin and ‘galets mous’ in the silty matrix, interpreted as dropstones’, point to the recurrent presence of icebergs in the lake.

The seismic infill ends with lacustrine units U13-U14. These units consist of lacustrine marls with shells and organic debris. In unit U14, a thickness asymmetry between east and west side of the lake, as well as onlapping geometry toward west, point to sediment erosion and transport by currents down to 35-m-depth.

This result agrees with previous work on deep currents action in western Lake Geneva (Girardclos et al. 2003). Ongoing palynological analyses and C¹⁴ dating will give an age to glaciolacustrine and lacustrine units. Preliminary palynological results reveal that non-reworked pollen is surprisingly present in glacier melt-out till (U7).

This project is partly financed by the Fondation Ernest Boninchi, the Fondation Ernest et Lucie Schmidheiny and the Swiss Civilian Service. Thanks to De Cerenville Geotechnique and the State of Geneva for access to drillings and geotechnical data.

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8.8
Climate in the southern Black Sea coast during the Holocene: Implications from the Sofular Cave record

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We present the updated Holocene section of the Sofular cave stalagmite stable isotope record from the southern Black Sea coast (northern Turkey). δ¹³C time series of this record and the growth rates prove to be more useful than δ¹⁸O in deciphering Holocene climate variations, as they apparently reflect the hydrological conditions above the cave.

Although the growth rates imply that precipitation amount was apparently higher in this region in the early to mid-Holocene and the rainfall patterns could well have been different than the present, there is no distinct difference in the effective moisture level; a finding which contrasts with the evidence from various Eastern Mediterranean sites. Moreover, some well-defined climatic anomalies such as the 4.2 and 8.2 kyr events are not clearly expressed in the Sofular cave record; at least they look unexceptional considering similar ‘anomalous’ periods.

We conclude that the peculiarities in our results reflect the influence of the Black Sea and the Anatolian topography in modifying the climate of this region, which should be important for the more subtle climatic changes during the Holocene. Nevertheless, the Sofular cave record does provide hints and pose new questions about the connection between regional and large scale climates, highlighting the need for a more extensive network of high quality paleoclimate records to better understand the Holocene climate.
8.9

Incision and deformation recorded by Quaternary fluvial terraces in Makran accretionary wedge, SE-Iran

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The well-preserved sequences of marine and fluvial terraces found along coastal and inner Makran are the geomorphic expression of surface uplift. The Makran accretionary wedge is an excellent example where the poorly described quaternary sequences and driving forces for their genesis can be studied for a better understanding of the contribution and feedback of surface processes to the growth of the wedge. We focused on fluvial terraces to extract possible tectonic and climatic driving forces. For this purpose, we aim to correlate river terraces between catchments and between different segments of the same river to document the distribution of deformation-uplift on the wedge in recent times. We investigated four main catchments in the Iranian Makran where the rivers preserve several terraces. Four terrace levels can be traced from field survey and detailed mapping in all the catchments. Out of these four levels, two are regionally preeminent. Deformed terraces are localized and associated with active faults and folds. Due to the lack of organic material and sandy deposits in inner Makran, our dating method was restricted to Terrestrial Cosmogenic Nuclides. The preliminary ages for the abandonment of two preeminent terraces are around 90ka (T1) and 21ka (T2). The fluvial incision rates based on the 10Be exposures ages of these two levels are 0.5 mm/yr in the late Pleistocene and 1mm/yr in latest Pleistocene, which suggests enhancement of surface uplift rate in the latest Pleistocene and Quaternary. These preliminary results differ from previous work on marine terraces, which documented 0 to 0.2 mm/yr uplift rate in Pleistocene times. To avoid any false interpretation, especially on regional scale, more terrace dating is in progress.

8.10

The Kestanbol Granite (Western Turkey) and its importance as a building stone: Application of cosmogenic 10Be to an archaeological problem

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Kestanbol Granite, outcropping in the Ezine village of Çanakkale (Fig. 1), have been operated for the production and export of building stones since ancient times. It is known that the Romans were trading the Kestanbol Granite (Marmor Troadense) all over the Mediterranean region (Lazzarini, 1987). Today, leftovers of building stones can still be found in relict quarries. The types of building stones vary from pavement stones to 11 meters long columns (Fig. 2). There is a lack of inscriptions and of absolute dating of these quarries (Ponti, 1995), so that the archaeologists can roughly estimate the time of the quarrying of the Kestanbol Granite from 500 BC to 500 AD (Feuser, 2009). Such vague limitation gives neither any possibility for understanding the development in time of the exploitation area of the quarries nor about the historical and political context of the quarrying (Ponti, 1995).

Keeping these in mind, the aim of our study is to determine the distribution and operation periods of antique quarries near the Ezine village of Çanakkale. In order to achieve this, the detailed archaeo-geological map of the extent of ancient
human impact has been produced and surface exposure dating with in-situ produced cosmogenic $^{10}$Be applied. For exposure dating, 27 samples from the quarries, building stones and natural (without any human impact) bedrock were collected. According to our first results from the bedrock samples, the landscape in the study area is older than 120 ka. The samples from building stones and quarries are still in progress. During our mapping, fundaments of several building of unknown purposes (not yet described in the literature) were determined. Furthermore, ore and slag pieces in the study area were found.

Our results give both insights to the importance of the quarries in the social structure in ancient cities in the region such as Neandreia and Alexandria Troas and the chronological development of the areal quarry exploitation. In brief, the results of our study can contribute in short-term to the declaration of these quarries as a geoarchaeological heritage site, and in long-term to their rehabilitation as an open-air museum.

![Map of the approximate areal distribution of the quarries in the Kestanbol Granite (Ponti, 1995).](image1)

Figure 1. Map of the approximate areal distribution of the quarries in the Kestanbol Granite (Ponti, 1995).

![Ancient roman quarry “Yedi Taşlar” near Koçali.](image2)

Figure 2. Ancient roman quarry “Yedi Taşlar” near Koçali.

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8.11

European climate change at the end of the last glaciation: chironomid-based temperature reconstruction on a continental scale

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In Europe the warming trend at the end of the last ice age was characterized by a number of abrupt temperatures shifts, including the rapid transitions to warmer climate at the beginning of the Lateglacial Interstadial and the Holocene, and the cooling at the start of the Younger Dryas cold period. The amplitude and spatial pattern of Lateglacial changes in temperature can provide information about the forcing factors causing these climate shifts and about processes affecting the European climate system during a transition to a warmer climate state. However, spatially resolved datasets describing temperature change across the European continent during the Lateglacial period at centennial or higher time resolution and based on the same standardized approach are presently not available. We aim to develop such a standardized dataset based on records of past summer temperature reconstructed from fossil chironomid assemblages preserved in lake sediments. A combination of regional calibration datasets provided the basis for a chironomid-based inference model for July air temperature which covers the range of expected temperatures and chironomid assemblage states expected for Europe during the Lateglacial period. This model, which is based on modern chironomid assemblages from 274 lakes in Norway and Switzerland and associated observed values of mean July air temperature, was then used to produce first chironomid-based temperature records from Estonia, Denmark, the Netherlands, southeastern France, southern Switzerland, and southern Romania. The preliminary results indicate distinct variations in the amplitude of reconstructed temperature changes across Europe with stronger shifts in inferred July air temperatures recorded in northern parts than at localities more to the south of the continent. Future work will expand this dataset to include additional sites on the British Isles, the Iberian Peninsula, Italy, Bulgaria and Scandinavia in order to confirm the observed spatial pattern of Lateglacial temperature changes.

8.12

Reconstructing the deglaciation history of the Gotthard Pass area, Central Swiss Alps, using cosmogenic 10Be and in-situ 14C

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During the Last Glacial Maximum (LGM) up to 500 m of ice covered the Gotthard Pass area (2106 m a.s.l.) at peak conditions (Florineth & Schlüchter 1998). This ice originated from the Rhone ice dome, one of the two big ice domes that existed in the Central Swiss Alps during the LGM. Ice from the Rhone glacier flowed over the Furka Pass down towards the Urseren area, where massive ice accumulated and flowed further south using the Gotthard Pass as a central pathway for mass transport. Ice flow over the Gotthard Pass ceased with the collapse of the LGM ice domes and the decrease of ice elevation in the Urseren area.
To determine the timing of ice retreat we have sampled glacially polished bedrock along an altitude transect at the western Gotthard Pass area. Surface exposure dating by cosmogenic $^{10}$Be yield preliminary ages of ~9.5-12.8 ky (corrected for snow and erosion). The oldest age was obtained from the lowest elevation right in the pass area, while higher sampling points give younger exposure ages. This supports the concept that the pass area records the ice extent of the LGM whereas slightly higher elevations were affected by local ice, probably during the Lateglacial.

Our data are in agreement with $^{10}$Be exposure ages from the nearby Grimsel Pass, giving a minimum age of ~14.0 ky for the final breakdown of ice domes in the Central Alps (Kelly et al. 2006). Within the errors, our ages also agree with radiocarbon data from the Gotthard region indicating a final retreat of small local glaciers at the beginning of the Holocene (Renner 1982).

Compared to radiocarbon ages from the Rhone valley (Welten 1982) and Simplon Pass (Müller 1984), which show completely ice-free main valleys, the Gotthard ages are slightly younger. Thus, to detect possible periods of post-LGM local ice coverage, especially in areas apparently only affected by LGM ice, cosmogenic in-situ $^{14}$C is currently analyzed. The short-lived $^{14}$C ($t_1/2 = 5730$ y) decays during periods of burial and can provide information on complex exposure histories and the duration of burial episodes. Results will be presented at the meeting.

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8.13
Do magnetic properties reflect climate history in Swiss lakes?
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The question of this study is whether magnetic parameters of lacustrine sediments from Swiss lakes can be used as high-resolution proxy for environmental change. We examine variations in the magnetic mineralogy from two lakes, Soppensee and Baldeegsee, covering the late Pleistocene and Holocene to investigate how the sediments are affected by changes in vegetation, erosional input, sedimentation, redox changes, and geochemistry. Magnetic mineralogy is determined by a combination of low-temperature measurements, coercivity distributions and extraction. The multi proxy climate records are currently being established. Magnetic properties are used to indicate the type and concentration of ferromagnetic minerals in the lake. We utilize a combination of: 1) concentration dependent parameters (magnetic susceptibility $\chi$, anhysteretic remanent magnetization IRM), 2) composition indicative parameters (saturation isothermal remanent magnetization IRM/SIRM), and 3) grain size dependent parameters (ARM/IRM, hysteresis parameters).

Significant changes are seen in the sedimentology, geochemistry and magnetic mineralogy in the Soppensee that are related to the Wuerm deglaciation, Bøling/Allerød (B/A), Younger Dryas (YD), and to the Holocene with the climatic optimum (Lotter,2001, Lotter et al., 1997a, Lotter et al.,1997). The Wuerm deglaciation is characterized by higher detrital input with a mixture of pseudo-single domain/multi domain (PSD/MD) magnetite and low concentration of superparamagnetic/single domain (SPSD) hematite. Climatic transition from the colder Wuerm period to the warmer B/A is characterized by an increase of low coercive magnetite/maghemite, as a consequence of decreasing detrital input. The beginning YD reflects more oxidizing conditions at the sediment-water interface, and is interpreted to be trigger for the appearance of magnetotactic bacteria (MTB), resulting in SD magnetite of uniform grain size, as shown in Figure 1.
The formation of siderite varves is initiated in the colder and anoxic YD with a subsequent transition to calcitic varves between 10 to 6 cal kyr BP (Lotter et al., 1997, Hajdas et al., 1993). Rising temperature during the climate optimum in Lake Soppen around 6 cal kyr BP increased primary production, leading to increased organic content. Varves disappear around 5.5 cal kyr BP as a consequence of geochemical changes at the sediment-water interface. The higher primary production at the surface leads to an uptake of oxygen at the bottom of the lake due to decomposition of organic matter. Hence this stage is marked by rapid increase of ferromagnetic minerals as displayed in Figure 1 a) and b). In conclusion, we can approve the initial question. The good agreement between the changes in magnetic properties and the climatic evolution demonstrate that the magnetic properties are a useful and fast tool to provide additional information for high resolution climate studies.

**Figure 1:** Magnetic properties from Lake Soppen a) low-field magnetic susceptibility, ARM intensity (120 mT AF with a bias field of 100 μT), b) S-ratio (IRM with a back field of 300 mT normalized by IRM at 1200 mT), c) ARM/IRM, e) Ca content, and sum parameter reflecting detrital input (Al,K,Ti;Rb;Zr) measured with XRF core scanning.

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8.14

Giant sub-lacustrine mass movement in Lake Geneva sediment record

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Lake Geneva with an area of 582 km$^2$ and a maximal depth of 310 m, was formed during the Pleistocene by glacial erosion and is the first large sink for sediment transported by the Rhone river.

As part of a Swiss National Fund project on clastic sediment in lacustrine records (nr. 200021-121666/1), more than 100 km of high-resolution seismic reflection profiles were acquired with a 3.5 kHz pinger source in the deepest part of lake Geneva.

Preliminary results show that the upper 5 m of this sequence consist of alternating seismic facies, interpreted as turbiditic and hemipelagic layers. These facies occur again from a 10-m depth downwards. Between these two sequences a 5-m-thick unit with chaotic/transparent facies, interpreted as a mass movement deposit, covers an area of 50 km$^2$. This unit, with an estimated minimum volume of 0.3 km$^3$, represents the largest sub-lacustrine mass-movement deposit in Switzerland. The thickness map of this unit shows an increase towards east, thus attributing its origin to the Rhone delta area. Possible trigger of this mass movement is earthquake, rockfall, slope slide or a combination of these causes.

Ongoing 10-m-deep sediment coring will characterize the deposit as well as the age of the mass movement in order to link it to known historical and prehistorical events.

8.15

Contribution of geoelectrical measurements and shallow drillings for detection of Holocene palaeochannels in the Saillon region (Valais)

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Upstream of Lake Geneva, the Rhône River underwent several morphological changes during the Holocene. Several geoelectrical measurements have been carried out between Sion and Martigny (Valais), particularly in the Saillon region, in order to identify former buried channels. Comparisons of several historical maps show that the Rhône River underwent fluvial metamorphoses during the 19th century (Reynard et al., 2009 ; Laigre et al., in press). The association of historical maps and DEM-LIDAR analyses helped us to identify some palaeochannels anterior to those indicated by maps.

Because of the different electrical responses given by gravels, sand, clay and silts, geoelectrical measurements can give precious information about the geometry of sediments. Furthermore, it helped us to localise former channels and to retrace fluvial dynamics (channel migration, change of fluvial pattern). Two sets of measurements were applied on a 500-m wide site: (i) a 5 m-depth profile, with a fine resolution, in order to observe recent architecture of sediments; (ii) a 40 m-depth profile, with a lower resolution that provided a deeper view of the sediment stratigraphy. In parallel, some hand hauger drillings (up to 3 m-depth) were done regularly along the geoelectrical profiles in order to compare the nature of the extracted sediments with returned electrical signals. These two resolution records show the existence of braided channels now buried at a depth of almost 20 m that disappear at a depth of 6 m. Some channel migrations are also visible in the first 5 meters, and bring fundamental information that helps us to reconstruct the fluvial dynamics of the Rhône River, that is little documented upstream of Lake Geneva.
8.16

Chironomids as indicators of the past 1000 years of mean July air temperatures: the Sivaplana and Seebergsee records

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Chironomid (non-biting midges) larvae preserved in lake sediments can be used to quantitatively and successfully reconstruct mean July air temperature, as shown by a comparison between chironomid-inferred temperatures and instrumental data (Larocque et al., 2009). Although they are one of the most promising biological proxy to reconstruct climate, they were, up-to-date, rarely used to reconstruct high-resolution climatic changes of the past 1000 years. The first near-annual temperature reconstruction was recently published (Fig. 1; Larocque-Tabler et al., 2010) and showed ±1°C temperature variations (compared to the climate normal (1961-1990) during the end of the “Medieval Climate Anomaly”, the “Little Ice Age” and during the “Anthropocene” in Lake Silvaplana, Engadine. Lake Silvaplana (46°26’56’’N, 9°47’33’’E) is at an altitude of 1791m a.s.l., it has a maximum depth of 77 m and a volume of 127 X 106 m³. Attempting a temperature reconstruction is such a deep, varved lake was, for chironomids, unprecedented at near-annual resolution.

Based on this success, a second attempt at reconstructing mean July temperature for the past 1000 years at high temporal resolution using chironomids preserved in the sediment of the meromictic Seebergsee was made. Seebergsee (46°37’N, 7°28’E) is located at 1830 m a.s.l. in the northern Swiss Alps. The surface area of the lake is 0.06 km², its volume is 0.38 km³ and it has two basins with maximum depths of 15.5 and 9 m. Anoxia is one of the influential factors, other than climate, affecting chironomid assemblages and anoxic lakes are usually dismissed for climate reconstruction. However, biogenic varves are often created when anoxia is present. If anoxic lakes are disregarded for temperature reconstruction using chironomids, it hampers the possibility of high-resolution records. Here, we reconstructed climate using chironomids in the sediment of Seebergsee to determine if a) chironomids in anoxic lake can be used to quantitatively and successfully reconstruct mean July air temperature and b) if the pattern of temperature changes for the past 1000 years in both cantons (Engadine and Bern) is similar.

Today, the analysis in Seebergsee has been made for the Anthropocene period (Fig. 1). The pattern of temperature changes for the past 100 years is similar to the instrumental data (Larocque-Tabler et al. submitted) and similar to the Silvaplana record. 68 more samples are being currently analyzed and will be presented during the meeting, to complete the past 1000-year reconstruction of mean July temperature at Seebergsee and compare with the Silvaplana record.

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8.17

Pre-Columbian human adaptation to seasonal inundations in the Llanos de Moxos, Bolivian Amazonia.

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The Llanos de Moxos (LM), in Bolivia, is one of the largest seasonally flooded savannah in the world and covers most of the southeastern Amazon basin. In the last decade, the LM, has captured the interest of geographers and archaeologists because of the impressive amount of pre-Columbian earthworks it holds.

Different kinds of earthworks are found in different areas of the LM, but it is still unclear whether this is due to the different cultures that inhabited the LM or to differences in the geographical settings between the eastern and western sides of the region. The western Llanos holds an impressive amount of pre-Columbian agricultural fields (raised fields), (Lombardo et al. submitted) while the eastern Llanos is characterized by a dense distribution of monumental earth mounds, canals and causeways (figure 1) (Lombardo & Prümers, 2010). Earth mounds are huge buildings that can cover up to 20 hectares and can be up to 20 meters high. Archaeological excavations have shown that they are man made and date back to pre-Columbian times.

Current models suggest that raised field agriculture provided high yields without the need of fallow periods, representing a kind of pre-Columbian green revolution. However, evidence suggests that the highest level of social complexity was reached in the eastern Llanos, where raised fields are not present. Our research has focused on trying to explain this apparent contradiction.

An important difference between the eastern Llanos and the western Llanos which has often been overlooked is their hydrology. Flooding in the western Llanos is more severe than in the eastern Llanos because it is the result of local precipitations and river overflows, while further east it only responds to local precipitations. Therefore, in the western Llanos, in order to produce food, more far-reaching drainage infrastructures were needed than in the east, where conditions were more favorable for cultivation and canals were sufficient to drain the soil.

We believe that raised field agriculture was not a prehistoric green revolution, as suggested by some, but rather a flood risk mitigation strategy. Raised fields allowed pre-Columbian peoples in the western LM lessen the risk of more intense and frequent flooding than was experienced in the eastern LM. It would appear that pre-Columbian peoples adapted to

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Figure 1. Temperature reconstructions using chironomids preserved in the sediment of Silvaplana (left graph; from Larocque-Tobler et al. 2010) and Seebergsee (right graph).
the harsh environmental conditions of the LM following different strategies in different areas: In the eastern LM a better natural drainage seems to have favored the flourishing of pre-Columbian societies with high levels of social complexity, while further west severe flooding obliged pre-Columbian peoples to build raised fields and constrained their growth and development.

This study highlights the importance of environmental constraints in conditioning population growth and cultural development in the Tropics.

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Figure 1. Map of the earth works in the eastern Llanos. The small triangles represent mounds of less than 8 hectares, the medium triangles represent mounds between 8 and 16 hectares and the large triangles represent mounds larger than 16 hectares. The dots represent forest islands and the black lines causeways and canals. The forest area is shaded in light grey and the lakes are a darker grey (Lombardo & Prümers, 2010).
8.18

Holocene Climatic Variability In Central Asia; A Geo-Archaeological Case Study In Samarkand, Uzbekistan

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The late Holocene (around 0-500 a. AD) climatic regime of Central Asia is characterised by cold winters, relatively cool summers and arid conditions (Oberhänslsi et al., 2007). To the West, the Aral Sea experienced an important regression of over 20 m during the 4th c. AD (Boomer et al., 2000). The precipitation pattern in the Aral basin is linked by the Westerlies to the atmospheric changes in the Eastern Mediterranean, which is the main moisture source for the region (Sorrel et al., 2007). Paleoclimatic data for this region have been mostly gained by the study of sediment cores from the Aral Sea (Boomer et al., 2000). Furthermore Historical paleoclimatic data for the last two millenniums in Eastern Asia indicate a cooling trend in the order of ca. 1.2°C between 250 and 350 a AD (Zheng et al., 2001).

The dense human History of the central Asian Mesopotamia – the land between the two tributaries of the Aral Sea, the Syr Darya and the Amu Darya – provides a potential supplementary record of paleoclimate evolution. Settlements, which were influenced by local climate variability, strongly modified in return the hydrologic regime of the catchment draining to the Aral Sea through extensive irrigation works (Kes, 1995; Oberhänslsi et al., 2007).

This is particularly true in the Zeravshan Valley, an important tributary of the Amu Darya. From the 4th c. BC onwards, it was one of the Silk Road main paths. Large irrigation works were engineered to sustain the agriculture around the historical city of Afrosiab, now Samarkand (Mantellini, 2001; Stride et al., 2009).

The irrigation system upstream from the historical city of Afrosiab consists of two main canals, the Dargom and the Jangi Aryk (Stride et al., 2009). A particularly well studied dwelling next to the Dargom documents destructive floods. By applying sedimentological and surface processes methods to this archaeological site we bring original constraints to the framework and nature of precipitations at this time.

We dated the main flooding event at 160±80 a. AD. X-Ray Diffraction analysis of the flood-related sediments suggests a source for the sands further upstream in the valley, i.e. transported in the canal and not coming from the natural surrounding hillslopes. We estimate that an intense precipitation event of at least 65 mm/h for at least 2 hours allows for a 0.5 m deep flooding of the archaeological site based on a numerical model surface overland flow (Simpson and Castelltort, 2006). The usual construction type in the valley at this time, elevated dwellings, and the recurrence of flood horizons in the stratigraphy attest a repetition of floods of similar magnitude during the first centuries AD in western Central Asia.

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8.19

Holocene glacier oscillations at Damma

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In the recently free forefield of the Damma glacier in the Göscheneralp, canton Uri, scientists of the BIGLINK project of the ETH Zurich are studying mineral weathering, soil formation and initial ecosystem development. In order to constrain in detail when the BIGLINK sampling sites became ice-free, a geomorphologic map was drawn, together with a short history of the glacier retreats and advances since 1956. For more information about the age of the moraines and associated landforms, some rock samples will be taken and measured.

For the mapping of the Damma glacier forefield, the focus was set on geomorphologic features. Characteristic for the area are the two big Holocene lateral moraines reaching about 100 m over the valley bottom. In between, a few much smaller distinct moraines are clearly visible.

The front position of the Dammanfirn has been measured every year since 1921. Detailed documentation including reference points and sketch maps exists back to 1956. The measurements show a retreat phase before 1972 when the glacier re-advanced until 1991, followed by retreat still lasting until today. Observed front variations do not exactly match with existing moraines in the forefield. The data base allows us to geo-locate former observations and combine with maps and resolve inconsistency.

8.20

Holocene landscape evolution of the Llanos de Moxos, NE Bolivia

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The Llanos de Moxos, which are located in the lowlands of north eastern Bolivia (Beni), are one of the largest seasonally inundated savannahs in the world. The region is characterized by a complex fluvial drainage pattern belonging to the Amazon system. In 2009, the University of Bern started to investigate the Holocene hydrogeomorphology and pre-Columbian water management in the Llanos de Moxos (funded by the Swiss National Science Foundation). As so far little data exist about human-environmental interactions in the Beni region, palaeoenvironmental and geoarchaeological studies are being conducted. First results with respect to landscape evolution are being presented here.

We examined sedimentary sequences along river banks across a 300-km-long N-S transect and found largely a systematic pedostratigraphic pattern. Sandy silts at the bottom are superimposed by yellow-ochre to red clayey silts. Above these sediments a palaeosol was found in all sections. Its maximum thickness is about 1.5 m and it is superimposed by silty-clayey deposits again. In some profiles we identified a second buried soil in these silty-clayey layers. AMS ¹⁴C dates indicate that soil formation occurred between 9.3 to 3.4 cal ka BP and around 2.9 to 2.0 cal ka BP.

Based on the evaluation of the sedimentary sequences we developed a preliminary chronology of landscape evolution. The deposition of silty clays prior to 9.3 cal ka BP is interpreted as a low energetic sedimentary environment. It is assumed that relatively humid conditions prevailed, with seasonal inundation of the savannah. Between approximately 9.3 and 2.0 cal ka BP soil formation was the dominant process, suggesting a dryer early to mid-Holocene. Inundations during that period were absent or less severe. This long soil formation period was probably interrupted by several short more humid phases. The subsequent deposition of silty clays indicate a shift to modern wet conditions around 2 cal ka BP.

This interpretation is in accordance with pollen records from Noel Kempff Mercado National Park (Burbridge et al., 2004), lake level fluctuations of Lake Titicaca (Baker et al., 2001) and geomorphologocal and sedimentary analysis in the Bolivian Chaco (May et al., 2008 a,b). A dry early to mid Holocene could be the consequence of minimum summer insolation at 15-20°S during that time and a corresponding weakening of the South American Summer Monsoon (SASM).
8.21

Quaternary glaciation history of northern Switzerland

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A revised glaciation history of the northern foreland of the Swiss Alps is presented by summarising field evidence and chronological data for different key sites and regions. The oldest Quaternary sediments of Switzerland are multiphase gravels intercalated by till and overbank deposits (‘Deckenschotter’). Mammal remains place the oldest of these deposits into Mammalia Neogene Zone 17 (2.5-1.8 Ma). The presence of till within the sedimentary sequences implies glaciations of the Swiss alpine foreland during the Early Pleistocene. Important differences in the base level of the gravel deposits allow distinguishing two sub-units (‘Höhere Deckenschotter’, ‘Tiefere Deckenschotter’), separated by a period of substantial incision. Each of the sub-units contains evidence for at least two but probably even four individual glaciations. The Early Pleistocene is separated from Middle Pleistocene deposition by a time of important erosion, probably related to tectonic movements and/or re-direction of the Alpine Rhine. The Middle-Late Pleistocene comprises four or five glaciations, named Möhlin, Habsburg, Hagenholz (uncertain, inadequately documented), Beringen, and Birrfeld after their key regions. Möhlin represents the most extensive glaciation of the Swiss alpine foreland and Beringen was only of just smaller extent. The last glacial cycle (Birrfeld glaciation) probably comprises two or even three independent glacial advances dated to about 105 ka, 65 ka, and 25 ka. For the last glacial advance, a detailed radiocarbon chronology for ice build-up and melt-down is presented.
8.22
Quaternary glacial chronology in Anatolia

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Surface exposure dating is a method used to place glacier fluctuations and moraine sequences into a chronological frame. Anatolia is one of the most sensitive places to the changes in atmospheric circulation patterns that influence the climate of the Eastern Mediterranean Region. Consequently it is important to construct the Quaternary glacial chronology to understand the climate changes in the past.

From cosmogenic $^{10}$Be, $^{26}$Al and $^{36}$Cl surface exposure ages it is known that the last local maximum glaciation occurred no later than around 20 ka in Uludağ (Zahno et al., 2010), 21 ka in Mount Erciyes (Sarıkaya et al., 2009), 20 ka Mount Sandıras (Sarıkaya et al., 2008); and between around 24 and 18 ka in the Dedegöl Mts. (Zahno et al., 2009), 22 – 18 ka in the Eastern Black Sea Mountains (Akçar et al., 2008 and references therein). This appear to be synchronous with the last maximum glaciation occurred in the European Alps, Central Apennines (Italy) and the Greek Mountains during the global Last Glacial Maximum (21± 2 ka) within Marine Isotope Stage-2.

At the Lateglacial subsequent glacier oscillations were dated: at around 16 ka in Mount Sandıras (Sarıkaya et al., 2008), 15 ka in Mount Erciyes (Sarıkaya et al., 2009); between around 16 and 15 ka in Uludağ (Zahno et al., 2010). Probably the Late Glacial advance in the Eastern Black Sea Mts. was restricted to the tributary valleys, but the timing of this advance is still unknown, however this advance continued until around 16 ka (Akçar et al., 2008 and references therein). So an oscillating glacier recession in Anatolia during Termination-1 is suggested by this evidence. In good agreement with this Anatolia data are published surface exposure ages related to the Lateglacial Gschnitz and Egesen moraines in the European Alps. This implies the parallel occurrence of major climatic shifts on millennial time-scale in the European Alps and Anatolia during MIS-2.

Already ice-free were the glacial valleys in SW Anatolia (Mt. Sandıras, Dedegöl Mountains) and in central Anatolia (Mt. Erciyes) during Younger Dryas (Sarıkaya et al., 2008, 2009; Zahno et al., 2009), whereas in the southern Black Sea coast, Younger Dryas occurred between around 13 ka and 11 ka (Akçar et al., 2008 and references therein; Zahno et al., 2010). During the Holocene after the deglaciation of the valleys in the Eastern Black Sea Mountains, rock glaciers and snow-avalanche ridges have been active processes. Then $^{10}$Be exposure ages from these ridges show that these events occurred during the Holocene and are therefore not linked to glacier fluctuations (Akçar et al., 2008 and references therein). In Anatolia Little Ice Age (LIA) moraines appear to be absent. Terrestrial geological records in Anatolia with regard to the Younger Dryas and the LIA cooling still remain to be studied in detail. Huge and active rock glaciers in the cirque areas may be related to the LIA cooling; absolute dates, however, are still absent. Dry and cold climatic conditions during the LIA could explain the absence of glacier advance, as the conditions were not conducive for the build-up of ice.

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8.23

Late Glacial and early Holocene climatic changes in the Southern Swiss Alps, reconstructed using subfossil chironomid assemblages.

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Lakes are archives of past environmental conditions. Biological, chemical, and physical components accumulate in the sediments, from within and without the lake (Douglas 2006). Larvae of the Chironomidae are found in most freshwater situations from the tropics to the arctic; some species are terrestrial or semi-terrestrial; some are even marine (Brooks et al. 2007). Due to their short generation times and the dispersal capacity of the winged adults, the Chironomidae rapidly respond to environmental changes. The strongly sclerotized head capsules of the Chironomidae larvae preserve well in lake sediments for thousands of years. Different taxa have specific ecological preferences and tolerances with respect to environmental variables, including temperature, pH, water depth, substrate morphology etc. (Brooks et al. 2007), making them useful as proxy indicators. Knowledge of chironomid ecology, together with the development of transfer functions, has allowed for the reconstruction of palaeotemperatures (Walker et al. 1991; Lotter et al. 1997). With these transfer functions summer air temperatures with a prediction error of 1-1.5°C can be reconstructed. Today, midges are widely used, especially as indicators of climatic change, and have been considered to be “the most promising biological method for reconstructing past temperature” (Battarbee 2000).

Available climatic reconstructions of Late Glacial and Holocene climate from the Northern, Western, and Central Alps and the Jura mountains are mainly based on pollen and chironomid assemblages (Lotter et al. 2000; Hofmann 2001; Heiri et al. 2003a, b, 2005; Ilyashuk et al. 2009). In the Southern Alps only few quantitative palaeoclimatic reconstructions are available so far (Frisia et al. 2005; Heiri et al. 2007, Larocque and Finsinger 2008). The absence of quantitative temperature reconstructions limits our comprehension of climatic patterns and of the biotic response of vegetation to temperature changes on both sides of the Alps. In this study we present a Late Glacial and early Holocene chironomid-based summer temperature reconstruction from Foppe (1470m a.s.l.) in the Southern Swiss Alps. Chironomid assemblages were studied in 58 samples along a 6.4m long sediment core covering the past 17200 years. Two training set (Swiss, Norwegian/Swiss) were used to infer summer temperatures (Heiri 2003a, Heiri unpublished).

On the basis of a preliminary chronology, our analyses suggest that midge assemblages have responded to major and minor climatic fluctuations during the last 17200 years, such as the Younger Dryas event in the Late Glacial and the Preboreal Oscillation at the beginning of the Holocene. The models reconstructed similar July air temperatures of around 9.2°C during the Oldest Dryas, an abrupt rise in temperature of about 3.6°C between 17000 and 15500 cal. BP (Pre-Bölling warming) up to 12.8°C. At this time afforestation in the Southern Alps started ca. 2000 years earlier than North of the Alps (i.e. before the Bolling onset at ca. 14700 cal. BP (Vescovi et al. 2007). This warming is in good agreement with high-resolution faunal, isotopic, and sedimentologic data from the European North Atlantic. These records indicate a strong temperature increase from 17500-17300 cal. BP (Lagerklint & Wright 1999). A climatic warming prior to the large-scale climate change at 15900 cal. BP was also recorded in the GRIP ice-core at ca. 17500-17000 cal. BP (Björck et al. 1998). A distinct cooling of about 1°C at around 14300 cal. BP (11.8°C, may be synchronous with the Older Dryas) is apparent. Temperatures increase gradually from 14500 cal. BP until 12800 cal. BP. Temperatures of about 12.8°C are reached at the end of the Allerød before temperatures decline again at the Allerød/Younger Dryas transition. Low temperatures of around 10.4°C are inferred during the Younger Dryas with several minor fluctuations. The Holocene starts with an abrupt warming of around 4.4°C and reaches values of about 14.8°C. At 11600 cal. BP the Foppe core shows a cooling of about 1.4°C which can probably be referred to as the Preboreal Oscillation. At Foppe the following amplitudes of change at climate transitions were recorded: Oldest Dryas/Bolling: 3.6°C, Allerød/Younger Dryas: 2.4°C, and Younger Dryas/Preboreal: 4.4°C. In a second step temperature reconstructions from the Southern, Northern and Central Alps will be compared with other records from the North Atlantic realm to infer spatial variability of summer temperature changes.

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8.24

Switzerland at the Last Glacial Maximum (LGM):
A new map (2009) by swisstopo 1 : 500 000

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Map-sheet No. 9 of the Atlas of Switzerland (1970) showing the area of the country at the Last Glacial Maximum by Eduard Imhof und Heinrich Jäckli has been sold out for many years. This simple fact and new data on the geometry of the inner-alpine LGM glaciers, mainly by Florineth (2000) and Kelly (2004), initiated the idea to produce a new map of the LGM in Switzerland. This idea was the beginning of a hard job which has kept us busy for almost 10 years. The new map 1 : 500 000 is available now through book- and map-stores and can be downloaded at www.swisstopo.ch.

What information is new on this map? This are the following reconstructions:

(1) The ice cover on the highest and central parts of the Jura Mountains is more extensive and more important than previously thought. The main data in support of this reconstruction is excellent mapping evidence to the northwest of the High Jura in France;

(2) The Highlands of the Napf in the central Swiss Midlands with a max. elevation of 1408 m has been covered with small, however well defined valley glaciers. This has not been recognised on the previous map. The local LGM valley glaciation of the Napf is supported by the existence of nivation areas and small glaciers in the adjoining hills;

(3) Detailed mapping of trimlines in the High Alps between the Engadine Valley to the east and the Mont Blanc area to the west shows the existence during LGM time of well defined ice dome areas in the Upper Engadine, in the Surselva and in the Upper Rhone Valley (including the ice plateau in the Zermatt area). All four such ice accumulations are situated to the south of the main orographic divide of the Alps with interesting implications on atmospheric paleocirculation patterns. As a result of this configuration ice flow was from south to north along certain transfluences across the the High Alps. – The huge outlet glacier from the Mättartal (draining the ice plateau in the upper valley of Zermatt) to the main valley of the Wallis was so important that the ice from the upper Rhone valley was blocked-off at Brig-Visp and diverted directly to the south accross Simplon pass (causing a complex divergent transflu ent ice flow regime in the Brig-Visp area). With such a reconstruction of the paleo iceflow in the Rhone valley it is possible now fort he first time to explain the distribution of erratic indicator lithologies in the western Swiss Midlands;

(4) The glaciers in southern Switzerland display a narrow valley glacier morphology, quite different from earlier reconstructions. This morphology may reflect glaciers with very high mass turnover (compared to the glaciers in South Westland of New Zealand’s South Island) as a result of the main track of precipitation to the Alps from the south. The positions of the LGM ice domes coincide with the centers of foehn controlled precipitation today.

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How to derive weathering rates from ice core measurements of atmospheric tetrafluoromethane?

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Fluorite, which is an accessory mineral found in rocks like granite and gneiss, contains trace amounts of tetrafluoromethane (Harnisch et al., 1996). Recent sources are dominated by anthropogenic emissions from aluminum smelters and the production for the semiconductor industry, whereas weathering of fluorite bearing rocks is the only natural source of this atmospheric trace gas.

As tetrafluoromethane (CF$_4$) is inert to destruction processes in the troposphere and stratosphere the only sink lies in the high mesosphere due to destruction by short wave UV radiation. As a consequence, CF$_4$ has a very long life time in the order of 50-100 ka or even longer.

As CF$_4$ is mainly released from weathering of granitic rocks we assume that its atmospheric concentration might show fluctuations on longer time scales as weathering intensity should change on glacial-interglacial timescales or longer. Also glacial erosion of the large continental ice sheets in Canada and Scandinavia could be important as these areas have widespread granitic or gneiss basement rocks and glacial erosion is more intense than ordinary fluvial erosion.

From firn air measurements we know that its preindustrial concentration was about 35 pptv (Worton et al., 2007). The only information from older times comes from a few measurements around the LGM and the last deglaciation on outcropping ice from Greenland, with almost constant values around 35 pptv (Muhle et al., 2010). So, there exists no indication of variations on time scales of 10000 years.

Our first low resolution measurements covering the last 750 ka show relatively constant CF$_4$ concentrations, ranging between 31 and 37 pptv. Additionally, we don’t see marked concentration changes during glacial-interglacial transitions. However, a lot of questions have to be answered before past atmospheric CF$_4$ concentrations can be used to estimate weathering rates, e.g. only few rock samples per continent have been analysed on their CF$_4$ content (Harnisch et al., 1998, Harnisch et al., 2000). As the CF$_4$ concentration of these granite samples showed a large variability (one order of magnitude), it is clear that weathering in one region emits more CF$_4$ than other regions thus biasing any global estimate. With a better data basis on CF$_4$ rock concentration one could possibly identify key regions, which dominate the global CF$_4$ budged.

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Detection of volcanic ash layers by high-resolution XRF core scanning

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Volcanic ash layers (tephras) in lake sediments are very important marker beds for establishing robust age models and to synchronize records from different archive. So far, detecting tephras in the sedimentary records of lacustrine lakes has been laborious as they are often very thin. X-ray fluorescence (XRF) core scanning, a rapid, non-destructive method to scan split sediment cores for their relative chemical composition, was now successfully used for the detection of tephras in the sedimentary records of four Swiss lakes (Soppensee, Gerzensee, Baldeggersee and Burgäischisee).

Having tested four different analytical settings for XRF core scanning on the Laacher See Tephra (12'880 varve years BP; Brauer et al., 1999) in the sediment core of Soppensee (So08-02 C2), it can be concluded that it is most likely to detect volcanic ashes with a maximum tube voltage of 2000µA, a high count time of 50s and a down core resolution of 0.2mm. The element peaks in the LST are higher in using setting 4 than in the other tested settings.

The Laacher See Tephra (LST), very prominent in the observed lakes and therefore easily detectable with this method, could be characterized by high element peaks of mainly K, Ca, Rb, Zr and Nb. The chemical composition of the surrounding sediment and the thickness of the ash influence the XRF expressions of the LST. Two invisible volcanic ash layers (cryptotephras) could be located by XRF core scanning. The Vasset Kilian Tephra (VKT) from the Massif Central (9407 ± 44 cal years BP; Hajdas et al., 1993) was found in Soppensee and the Icelandic Vedde Ash, erupted 12'225 –11’832 cal years BP (Blockley et al., 2007) could successfully be located in Baldeggersee and Burgäischisee, where it has not been found before. Both of these ashes have positive element peaks of K, Rb and Zr in XRF core scanning data. The XRF data of the VKT in the Soppensee core is shown in detail in Figure 1.

The evidence for having indeed detected a volcanic ash layer by XRF core scanning was given for all the named tephras by smear slides analysis, where the presence of volcanic glass shards could be confirmed (Fig. 2).

Detecting the Vedde Ash and the Vasset Kilian Tephra by XRF core scanning is a promising result, which shows the high potential of this application for nicely laminated and well-preserved sediment cores with homogeneous grain sizes. The possibility to apply this non-destructive, fast and easy technique to detect cryptotephras in sediment cores is a step to a more efficient use of tephrochronology in lake sediment studies.

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Fig. 1: XRF core scanning data (in total counts of peak surface) around the VKT (shaded area) in the Soppensee core (So08-01 B3)
8.27

A review on tunnel valleys in northern Europe

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The existence of buried Quaternary valleys indicates that glacial erosion is an important process in shaping the landscape of the Swiss alpine foreland. Considering the time of concern of 1 Ma for high-level nuclear waste repositories glacial erosion needs to be addressed for assessing their long-term safety. As one approach to better understand the formation processes of Quaternary valleys, a literature review with focus ‘tunnel valleys’ outside the alpine realm was carried out.

Deep glacial valleys have been documented in Europe, North America, Africa, Australia and Antarctica. However, the focus of the literature review is on tunnel valleys in northern Europe (North Sea, Denmark, northern Germany, the Netherlands and northern Poland) which have been investigated in detail. Here we give an overview of observed valley morphologies, their geographical distributions, bedrock morphologies and formation process theories.

Tunnel valleys are defined as large, elongated, overdeepened depressions cut into sediments or bedrock (Ó Cofaigh 1996). They occur as individual segments or as an anastomosing network, are often several kilometres long, maximum a few hundred metres deep and hundreds of metres up to a couple of kilometres wide (Jørgensen & Sandersen 2006). Usually they are steep-sided with flat undulating bottoms, begin and terminate abruptly and are open or filled with sediments (Kristensen et al. 2007; Fig. 1). Occasionally, eskers and lakes occupy the valleys. Tunnel valleys are formed below past ice sheet margins, and are generally oriented parallel to the subglacial hydraulic potential gradient. In some cases, the tunnel valleys terminate at major moraines where they may grade into large outwash fans.

The most important formation processes of tunnel valleys discussed in the literature include meltwater drainage, catastrophic outbursts (jökulhlaups) and sediment deformation, and are occasionally combined with direct glacial erosion (e.g. Boulton & Hindmarsh 1987; Jørgensen & Sandersen 2006). However, there is still controversy about the origin of tunnel valleys (Ó Cofaigh 1996).

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Fig. 2: Microscope picture of volcanic glass shards (smear slide) from the Laacher See Tephra layer in the Gerzensee core (left) and the Burgäschisee core (right)
Figure 1. Example of buried tunnel valleys in the eastern North Sea in (A) plan and (B) perspective view (TWT: two-way-travel time). The seafloor is about 60 m b.s.l. (80 ms TWT) and the upper limit of the tunnel valleys, and the coloured plane is the Near Base Quaternary (NBQ) horizon. The tunnel valleys seem to deflect around two salt diapirs (SD) that possibly controlled the local subglacial drainage system (Kristensen et al. 2007).

REFERENCES

Calibration of $^{36}$Cl Production Rate on $^{39}$K in Saturated Antarctica Samples

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The surface exposure dating of K-rich minerals like K-feldspar and biotite with the cosmogenic $^{36}$Cl is presently limited by poorly known rate of $^{36}$Cl production from $^{39}$K. $^{36}$Cl produced in situ on $^{39}$K by secondary particles of cosmic rays in following nuclear reactions: high energy spallation, negative muon capture and thermal neutron capture. At the surface major contribution to $^{36}$Cl production is made by spallation reactions, while the negative muon capture dominates below 2 meters of rock. Previously published $^{36}$Cl production rates on $^{39}$K by spallation reactions lies in wide band of numbers between 106±8 and 228±18 at·g(K)⁻¹·yr⁻¹ (Evans 1997, Phillips 1996, Swanson 2001, Zreda 1991). More accurate evaluation of $^{36}$Cl production rate from $^{39}$K from is essential because the inaccuracy of the production rate translates into significant errors in derived ages.

Proper production rate calibration requires many conditions on samples to be met. K-rich minerals in the samples for calibration should contain low level of $^{40}$Ca and $^{35}$Cl to reduce the other $^{36}$Cl production pathways. Exposure history (shielding, erosion) of the samples since their exposure should be clear. Exposure time must be well-determined by other independent methods or the steady state assumption must be justified.

In an ideal case, the obtained production rate can be uniquely scaled to any other latitude and altitude, and applied in any possible time span. However, due to present day knowledge of scaling procedures and past magnetic field variations, the scaling and application of production rates can have a certain bias due to scaling scheme and estimations of the magnetic field during time span of the calibrated site. These uncertainties can influence the application of the production rate at the level of up to 10%, therefore our estimated local production rates will be given together with all relevant local parameters.

Long term exposed samples of granites from Table Mountain, Antarctica were chosen (Ivy-Ochs 1995). Steady state of $^{36}$Cl build up and independent dating by $^{10}$Be make these samples perfect for calibration. However previous calibration based on similar samples gave a value, which is higher than all other available estimates. Verification and explanation of this outlier will be important for $^{36}$Cl dating of long term exposed K-feldspars.

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How does the elemental composition of Swiss lake sediments reflect past climate conditions?

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As part of an interdisciplinary multi-proxy study, we conducted a high-resolution XRF-core scan analysis on lacustrine sediments from Soppensee (Central Switzerland) covering the late Pleistocene and Holocene to answer the question of how the elemental composition of lake sediments reflects past climate conditions.

Climate has a strong influence on sedimentation rates, redox conditions, primary production, and the amount of erosive input of a lake, and this in turn affects the composition of the lake sediment. Since specific elements and element ratios often characterize specific lithological properties, XRF analysis helps to define the sediment’s source and gives hints to reconstruct the paleo-environment and -climate.

At Soppensee, the sediment deposited at the end of the Würm glaciation mainly consist of detrital material, detected in high rates of K, Al, Rb, Ti, and Zr. We observe a strong decrease in these elements just at the onset of the Bölling/Alleröd (B/A) warm period. With the beginning of the B/A the Ca values start to increase indicating first authigenic calcite precipitation due to higher temperatures and developing primary production. Siderite is detected by XRD analyses (Fischer 1996) in sediments deposited during the B/A and Younger Dryas (YD). The presence of Siderite can also be seen in high Fe and at the same time low K, Al, Rb, Ti and Zr values in the XRF core scan results. These depositions coincide with a period of summer anoxia most probably caused by additional organic matter input from the catchment, as well as longer phases of stratification due to reduced wind exposure caused by the increased vegetation cover (Lotter 2001). At the same time first magnetotactic bacteria appear, resulting in single domain magnetite of uniform grain size.

At the end of the YD, first formation of calcitic varves starts. These annually laminated sediments, mainly reflected in high Ca values, indicate rising primary production at the lake surface due to warmer temperatures in the upper water column, and anoxic conditions at the sediment surface due to decomposition of organic material and poor mixing of the hypolimnion. Varves become darker, discontinuous and eventually faint at around 5500 cal y BP. For the same time period, previous studies report increasing air temperatures and a change in tree cover in the environment from mainly mixed oak forest to shadow-tolerant fir-beech forest (Lotter 2001). These changes in the environment lead to more organic matter produced within the epilimnion and also transported into the lake, which then decays at the lake bottom. This rotting process uses up oxygen and produces carbonic acid and hence leads to pH changes in the hypolimnion, which supposedly circumvents the build-up of calcite varves. In addition, these more acidic and reducing conditions result in an rapid increase of ferromagnetic minerals as well as increased mobility of metal ions, resulting in higher values of mainly Fe, but also Mn, Zn and Pb.

First human activity in the catchment and first local settlements may be seen in the sediment recorded by decreasing Ca and increasing Fe and Mn values at about 5500 and 3500 y cal BP due to anthropogenic changes of the environment. An abrupt increase in Fe and Mn during the Middle Ages (about 1500-500 y cal BP) coincides with massive deforestation in the catchment and around the lake. The lack of forest presumably enabled mixing of the lake water due to winds and increased soil erosion supplied additional nutrients to the lake. The topmost part of the lake sediment is strongly influenced by anthropogenic eutrophication of the lake due to intense agriculture in the catchment.

Our results not only confirm previously published climate reconstructions of Switzerland and Europe, but together with the interpretation of paleomagnetic properties of the exact same sediment core material, we are able to add new insights about the development and effects of past environmental and climate change.

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Past glaciation in the Central Andes record alteration in the tropical circulation and the Southern Westerlies

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The mass balance of glaciers is most sensitive to changes in precipitation and temperature. Thus the reconstruction of past glacial advances can provide important information about past climate changes. In the arid Central Andes, where glaciers are particularly sensitive to precipitation changes (Kull et al. 2008), the timing of glaciation documents how and when the three main atmospheric circulation systems - the South American Summer Monsoon (SASM), the El Niño Southern Oscillation and the Southern Westerlies - changed their intensity and position over time.

We dated several well preserved glacial stages in the Sierra de Quilmes (~26°S) applying 10Be surface exposure dating. Our results show that glaciers advanced in phase with the global last glacial maximum (LGM) at 25.8 ± 0.8 ka and during the Lateglacial at 13.5 ± 0.5 ka and 12.8 ± 0.5 ka. The Lateglacial advances are coincide with the Tauca (16-14 ka) and Coipasa (13-11 ka) lake transgression phases on the Altiplano and reflect the precipitation sensitivity of glaciers in the arid Central Andes. A glacier climate modeling study corroborates that the Lateglacial advances occurred as a result of moderate to massive precipitation increases; reconstructed temperature depressions are -1.4 to -5.4°C (Schmidhauser 2007). Sufficient moisture for the Lateglacial glacial advance can be explained by enhanced upper tropospheric easterlies as response to an intensified tropical circulation and sustained La Niña-like conditions in the eastern Pacific. These results agree closely with previously reported Lateglacial advances farther north in NW Argentina (~22°S) (Zech et al. 2009) and Bolivia (~17°S) (Zech et al. 2010).

Our new glacial chronology from the Sierra de Quilmes, however, is unique, insofar as the oldest dated moraine documents an earlier glacial advance at ~34.6 ± 1.1 ka. This is roughly contemporaneous with the local LGM further south, dated to ~38 ka in northern Chile (~30°S) and Central Argentina (~39°S) (Zech et al. 2008). These pre-LGM advances document increased precipitation related to a northward shift and intensification of the Southern Westerlies, which affected the hydrological conditions in regions further north (north of 30°S) than previously assumed.

The new results from the Sierra de Quilmes thus raise questions regarding the southernmost migration of the tropical circulation system and the role of the Southern Westerlies for glacial advances even north of 30°S.

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