Cosmogenic nuclide dating of Swiss Deckenschotter

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Duration of the Project	3 years

ABSTRACT

The goal of our project is to date selected sites of the Swiss Deckenschotter using depth-profile and isochron-burial dating with the cosmogenic nuclides ^{10}Be, ^{26}Al and ^{36}Cl in order to reconstruct the timing of Early and Middle Pleistocene glaciations in the Alps. Obtaining ages for these glaciofluvial units will provide fundamental information about the onset of glaciation in the Alps and the northern Hemisphere as a whole. Furthermore it will become possible to quantify the magnitude of incision in the foreland. In the first year of the project, 54 samples were collected from three different sites for depth-profile and isochron-burial dating. First results from the depth-profile for the Lower Deckenschotter at Pratteln yields a model age of around 270 ka. Similarly, the Higher Deckenschotter at Stadlerberg indicates a depth-profile age of around 1.7 Ma. Samples from the Higher Deckenschotter at Irchel are still in progress. Meanwhile, we are currently working on several fronts to improve and optimize the isochron-burial dating methodology, especially in measuring very low cosmogenic nuclide concentrations with low uncertainties.

Project goals

For a long time, the glaciation history of Switzerland was correlated to that of southern Germany where Penck and Brückner [1] differentiated four Quaternary stratigraphic units based on their distinct topographical position. According to this, Lower Terrace deposits (NT) were attributed with the Würm glaciation, Higher Terrace (HT) with the Riss glaciation, Lower Deckenschotter (TDS) with the Mindel glaciation and Higher Deckenschotter (HDS) with the Günz glaciation. In 1986 however, Schlüchter [2] provided an alternative stratigraphy for the northern Swiss Alpine Foreland showing that glaciers advanced at least 15 times into the foreland during the Quaternary. These are the 4 to 8 Deckenschotter glaciations in the Early Pleistocene and the Möhlin-, Habsburg-, Hagenholz-, Beringen- and Birrfeld glaciations in the Middle-Late Pleistocence [3]. Our study focusses on the Swiss Deckenschotter, which are proximal glaciofluvial gravels showing locally an interbedding of till and overbank deposits. These Quaternary sediments cover Tertiary Molasse or Mesozoic bedrock and are located beyond the limit of the Last Glacial Maximum. These deposits, which can be differentiated by their distinct topographical position, are divided into two main geomorphic units: Higher and Lower Deckenschotter. Even though the Higher Deckenschotter occupies a topographically higher position, they are older than the Lower Deckenschotter as the two are separated from each other by a phase of incision (Figure 1). Both Higher and Lower Deckenschotter bear evidence of at least four glacial advances that reached the

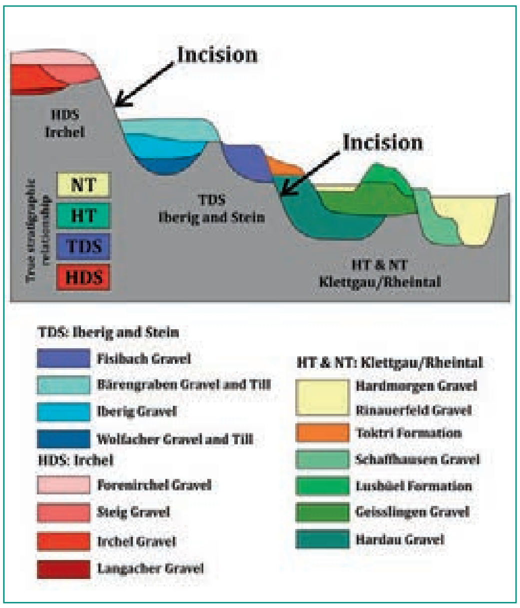


Figure 1: *Schematic stratigraphy of the Quaternary deposits of the northern Swiss Alpine foreland [after 5].*

Alpine foreland and are, therefore, complex lithostratigraphic sequences. The age of the Swiss Deckenschotter complexes is poorly constrained. In the Higher Deckenschotter at the Irchel site, mammalian faunal assemblages (MN17) were found which place the Deckenschotter between 2.5 and 1.8 Ma [4]. This is the only available quantitative age until this study and they are therefore the oldest Quaternary units in the northern Swiss Alpine Foreland known so far. The reconstruction of the chronology of these glaciofluvial units will therefore provide fundamental information about the onset of Quaternary glaciation in the northern hemisphere, especially in the Alps. Moreover the age determination will then make it possible to quantify the timing and magnitude of incision in the foreland.

In our project we select key sites for Swiss Deckenschotter outcrops and apply depth-profile dating and isochron-burial dating with cosmogenic ^{10}Be, ^{26}Al and ^{36}Cl to reconstruct the timing of deposition. Application of ^{10}Be and ^{26}Al requires quartz, whereas any rock type can be used for ^{36}Cl applications. The method of depth-profile dating is based on the build-up of nuclides und uses the fact that the production of cosmogenic nuclides decreased exponentially with depth [6]. At least four samples (sediment or amalgamated clasts) are taken every 10–20 centimetres in a vertical profile. For ^{10}Be and ^{26}Al, a depth-profile age can then be modelled in Matlab using a code by Hidy et al. [7], based on exposure age, erosion rate and inheritance. For ^{36}Cl, the age is modelled with MathCad codes developed by our group [8]. The method of isochron-burial dating however is based on the decay of the cosmogenic nuclides and uses the difference in half-lives of ^{10}Be and ^{26}Al. In this method, samples are taken from the same timeline and therefore have the same post-burial histories but different pre-burial histories [9, 10]. The surface production ratio of ^{26}Al/^{10}Be is 6.75. When plotting the measured ^{26}Al concentrations vs. ^{10}Be concentrations, they should theoretically plot on a line. Thus a line can be plotted through the data points and the slope of the regression line indicates the measured ratio. With this ratio, an initial age estimate can be calculated, which in turn can be used to model the post-burial component. Once the post-burial component is known, the ^{26}Al/^{10}Be ratio at the time of burial (initial ratio) can be calculated and the burial age determined. This method requires sampling at least three fist-sized quartz pebbles along a chronostratigraphic horizon.

Work carried out and results obtained

The Deckenschotter project started with a pilot study at the sites in Mandach and Irchel (gravel pit Steig). After that, before October 2012, a further testing site at Pratteln was chosen in collaboration with IPNA (Institut für Prähistorische und Naturwissenschaftliche Archäologie). This Lower Deckenschotter site was sampled for depth-profile dating with cosmogenic ^{10}Be and ^{36}Cl (Figure 2). This site is important for the early Human history in the Alpine Foreland, since a hand axe was found associated with this Deckenschotter deposit at this location. A new 1.3 m long outcrop was opened by the archaeologists. At this location, the Lower Deckenschotter overlies limestone bedrock. From this profile, we collected 8 sediment samples and one from the bedrock. Samples were then processed in the Surface Exposure Dating Laboratory at the Institute of Geological Sciences in Bern and measured at the AMS facility (LIP group) in Zurich. ^{10}Be concentrations from this profile show a decrease with depth and hence we modelled an age of around 270 ka using the Matlab code by Hidy et al. [6]. We consider this a preliminary age we are waiting for the ^{36}Cl analysis, which can then also be used to model an age using the MathCad codes [8]. After modelling the ^{36}Cl age, we will finalize the chronology of the Lower Deckenschotter site at Pratteln.

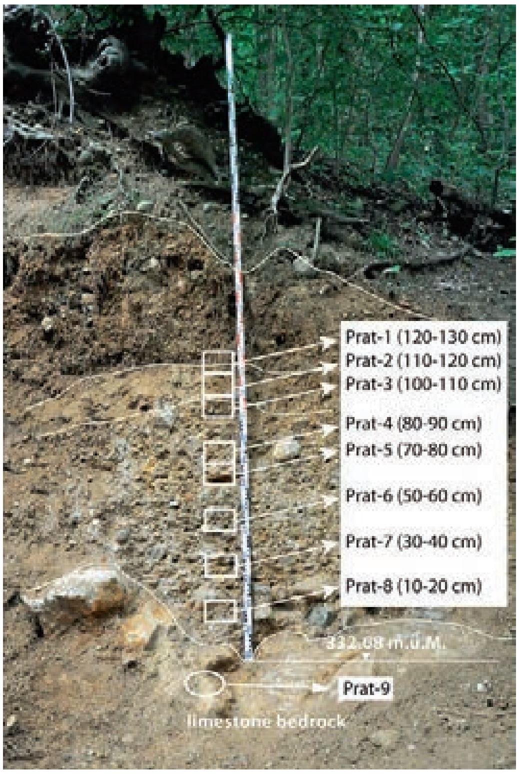


Figure 2:
Sampling a 1.30 m long depth-profile at Pratteln.

In 2013, we focused on the Higher Deckenschotter. Therefore, we first selected candidate sites and then we organized 3 reconnaissance fieldwork campaigns to these sites. Among them, we sampled the Summerhalden gravel pit (abandoned) at Stadlerberg, the contact of the Deckenschotter to the Molasse (Hütz) and the Steig gravel pit (abandoned) both at Irchel. At Stadlerberg there was recent collapse of part of the outcrop, which gave us access to fresh material. Seven sediment samples for depth-profile dating and 9 quartz clasts for

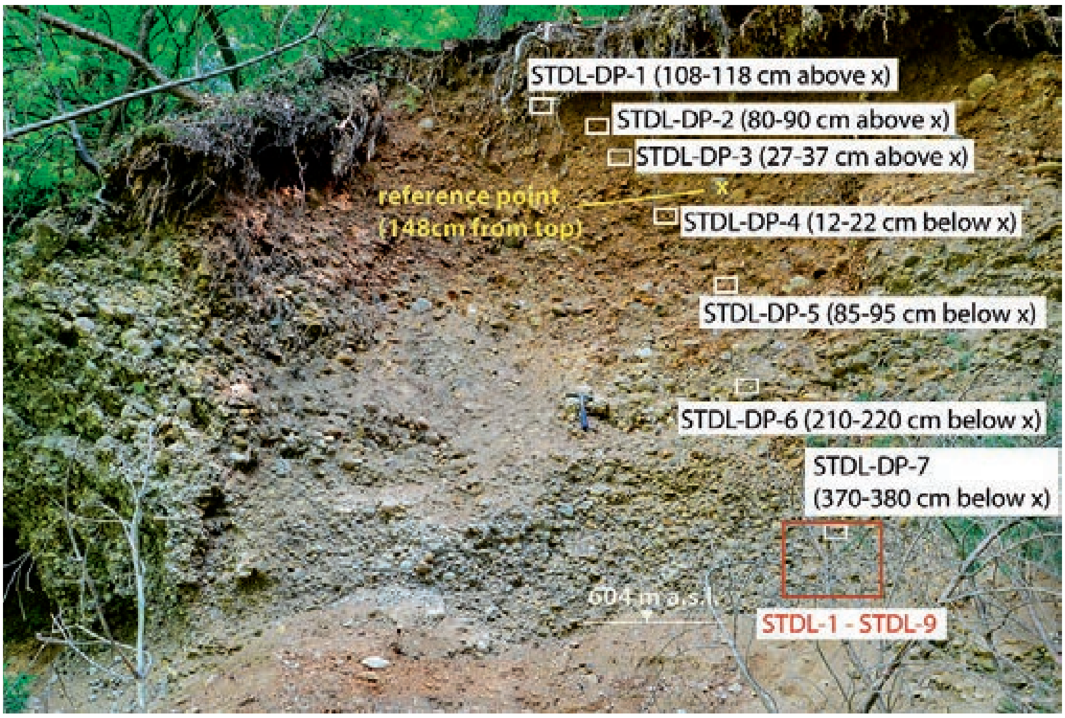
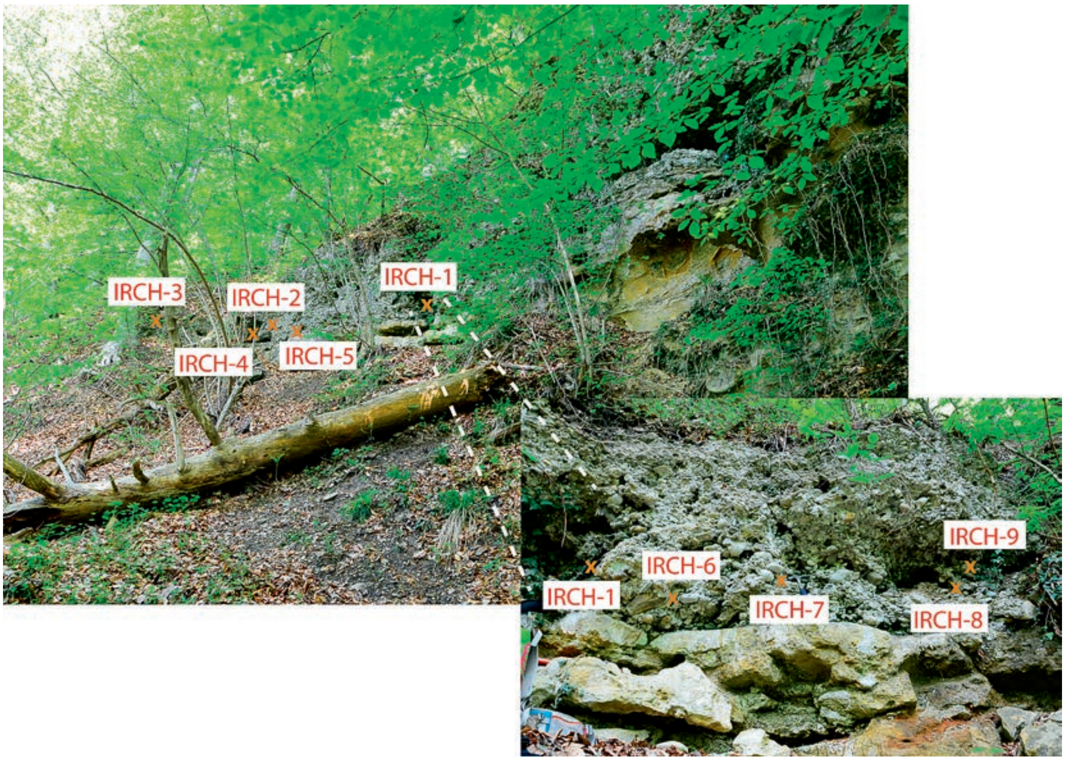


Figure 3:
Sampling a 5 m long depth-profile at Stadlerberg. The red square shows the location of the samples (STDL-1 to STDL-9) for isochron dating.

Figure 4:
Isochron sampling locations at the contact to the bedrock.



isochron-burial dating were sampled (Figure 3). At Hütz at Irchel, we sampled 9 quartz clasts at the contact between the Molasse and the overlying Deckenschotter for isochron-burial dating (Figure 4). The Steig gravel pit was sampled for both depth-profile dating (7 samples) and isochron dating (13 samples). From this sampling campaign, we have the first results for the depth-profile at Stadlerberg. These indicate an exponential decrease of the ^{10}Be concentrations with depth, which yields a model age of deposition of around 1.7 Ma.

Deckenschotter are topographically distinct and discontinuous terrestrial archives. They have a reverse stratigraphic relationship, i.e. older deposits are located at higher altitudes and vice versa. In addition, they are remnants of an old landscape, which was certainly not flat. Therefore we don't expect the same age for each site. While reconstructing the chronology at our sites, we will reveal the evolution of landscape change during the Deckenschotter glaciations. Our highest sampling site is Irchel (ca. 700 m) and should thus be the oldest. The outcrop at Stadlerberg is located at an elevation of approximately 600 m and the minimum age of 1.7 Ma fits to the geological context. The study site at Pratteln lies at an elevation of only 330 m that is why we should expect here a much younger age. The results yielded a minimum age of approximately 300 ka. In brief, our results from 2013 are the first quantitative dataset, which is extremely encouraging for 2014.

National Cooperation

The scientific collaboration on cosmogenic nuclide methodology and applications between the Institute of Geological Sciences at the University of Bern and the Laboratory of Ion Beam Physics (LIP) at ETH Zürich, established in the early 90's, yielded several research projects, international publications, PhD and MSc. theses. This consortium has a long tradition and a wealth of experience in applying cosmogenic nuclides (^{10}Be, ^{26}Al and ^{36}Cl) to determining the timing of events and rates of landscape change in four different settings: Quaternary glaciations, local and large-scale surface erosion, landslides, and neotectonics. In addition, the specificity of the LIP group is its 30 years of innovations and experience in AMS, while being the largest European tandem accelerator facility with a broad AMS program in the European scientific landscape.

International Cooperation

Our group has several projects in collaboration with international institutions. We are collaborating with the Norwegian Geological Survey (NGU), Norway, and the Istanbul Technical, the Tunceli, the Ankara and the Hacettepe Universities in Turkey. These projects focus on the dating of several Quaternary deposits in different geological settings (e.g. alluvial fans) with different approaches of cosmogenic nuclide dating (burial, isochron-burial, depth-profile dating). Here we underline our project with the Ankara and the Hacettepe Universities. Within this collaboration, we recently dated three fluvial terraces in Central Turkey with isochron-burial dating to ca. 160 ka, ca. 1 Ma and ca. 1.7 Ma. Using this chronology, we calculated a long-term incision rate of around 50 m/Ma for Central Anatolia [11].

Assessment 2013 and Perspectives for 2014

The first results from Stadlerberg showed that the depth-profile dating method is appropriate when geological setting and methodological requirements match. This method requires sampling of geological layers in artificial outcrops, preferably with a flat topped landform in order to guarantee that the uppermost surface of the deposit remains as unmodified as possible.

As a result of repeated glaciations in mountains like the Alps [12] derived sediment, thus the Deckenschotter have rather low cosmogenic nuclide concentrations. Furthermore the nuclide concentrations in sediments in glaciated areas are considerably low compared to non-glaciated terrains [12]. In such a setting, the total amount of aluminium, i.e. the amount of cosmogenic ^{26}Al and non-cosmogenic ^{27}Al, in the sample is of utmost importance for successful isochron-burial dating. Our objective is to have samples with an amount of ^{27}Al of approximately 20 ppm in order to be able to obtain higher ^{26}Al/^{27}Al ratios with low uncertainties (<10%). During summer 2013, we refined the leaching process of the samples by adding a treatment with phosphoric acid after the third HF step. This yielded very successful results. We were able to reduce the amount of total aluminium to the desired concentrations. The next step is to optimize the ^{26}Al measurements. Together with the LIP group in Zurich we are working on several fronts. First, the purity of the quartz needs to be checked and the cation columns, which separate Al from Be, need to be optimized. Second, the purity of the final sample precipitate that is delivered to the AMS facility has to be tested by ICP-MS. Third, at the LIP, tests are being performed on the 6MV Tandem accelerator in order to obtain higher currents and to improve detection; and moreover to improve and optimize the ^{26}Al measurements on the smaller 0.6MV Tandy accelerator.

As soon as we have first results from isochron-burial dating, an evaluation on the next sampling sites will be made. A second field campaign will focus on the Lower Deckenschotter and likely take place in spring 2014. In the second half of 2014, we will prepare the first manuscripts of Pratteln and Stadlerberg.

Publications

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Claude A., Akçar N., Ivy-Ochs S., Graf H.R., Kubik P.W., Vockenhuber C., Dehnert A., Rahn M., Schlüchter C., Rentzel P., Pümpin C. The challenge of dating Swiss Deckenschotter with cosmogenic nuclides. 11th Swiss Geoscience Meeting, abstract for talk.

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