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Thesis abstract

Landscape evolution of the northern Alpine Foreland: constructing a temporal framework for early to middle Pleistocene glaciations

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The Deckenschotter deposits are believed to represent the oldest Quaternary sediments in the Alpine Foreland and are thus a geoarchive, documenting paleoenvironmental changes during the Quaternary. Lithostratigraphic positions of the Deckenschotter deposits in Switzerland have been extensively studied. However, compared to late Quaternary glaciations, the timing of these accumulations is poorly understood. The investigations related to the dissertation shed light on this timing and hence on the landscape evolution of the northern Alpine Foreland.

The study area is located in the northern Alpine Foreland of Switzerland where seven sites of the Höhere ("higher"; HDS) Deckenschotter, Tiefere ("lower"; TDS) Deckenschotter and Hochterrasse ("higher terrace") were investigated; from east to west, these sites are Irchel (three sites: Wilemer, Steig and Hütz), Stadlerberg, Siglistorf, Rechberg, Ängi, Mandach and Pratteln (Hohle Gasse) (Fig. 1). From each site either sediment samples were collected for dating with cosmogenic ^{10}Be and/or ^{36}Cl depth-profile dating or clasts with quartz-rich lithologies were sampled for isochron burial dating with ^{10}Be and ^{26}Al. At Irchel Steig, the same outcrop was dated using both methods. In addition, detailed investigations of clast fabrics, petrographic compositions and clast morphometries enable the identification of sediment source areas and the interpretation of their transport mechanisms and depositional environments. Finally, coupling the reconstructed chronologies with interpolated vertical height differences between the bedrock underlying the Deckenschotter deposits and the bedrock beneath the modern Rhine River allows for the estimation of post-depositional bedrock incision rates.

Analyses show that the HDS at Wilemer Irchel (Claude et al., 2017c), Stadlerberg (Claude et al., 2017a) and Siglistorf (Akçar et al., 2017) accumulated approximately around 2 Ma ago. Clasts were eroded from the northern Central Alps and brought to the foreland by paleoglaciers (Fig. 2a). In the foreland, glaciers also eroded conglomerates of the Miocene Molasse and transport was furthermore provided by glacial outwash. The influence of mainly the Linth paleoglacier is recognized in the provenance of the sediments. Clasts at the sites Wilemer Irchel, Stadlerberg and Siglistorf were deposited in a glacier-proximal environment. At that time, the Alpine Rhine, originating in the central Eastern Alps, was draining through Lake Constance into the Danube River and finally eastwards into the Black Sea (Fig. 2a). Estimated long-term bedrock incision rates are on the order of 130 ± 60–150 ± 40 m Ma^{-1} for the time interval from 2 Ma until the

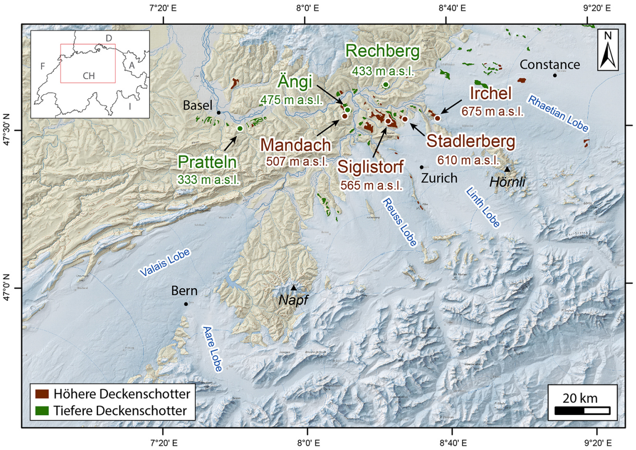

Figure 1. Extension of the Valais, Aare, Reuss, Linth and Rhaetian loves during the last Glacial Maximum (from Bini et al., 2009); location of the study sites Irchel, Stadlerberg, Siglistorf, Rechberg, Ängi, Mandach and Pratteln and distribution of the Deckenschotter deposits in the northern Alpine Foreland (© Federal Office of Topography, swisstopo). Figure modified from Claude et al. (2017a).

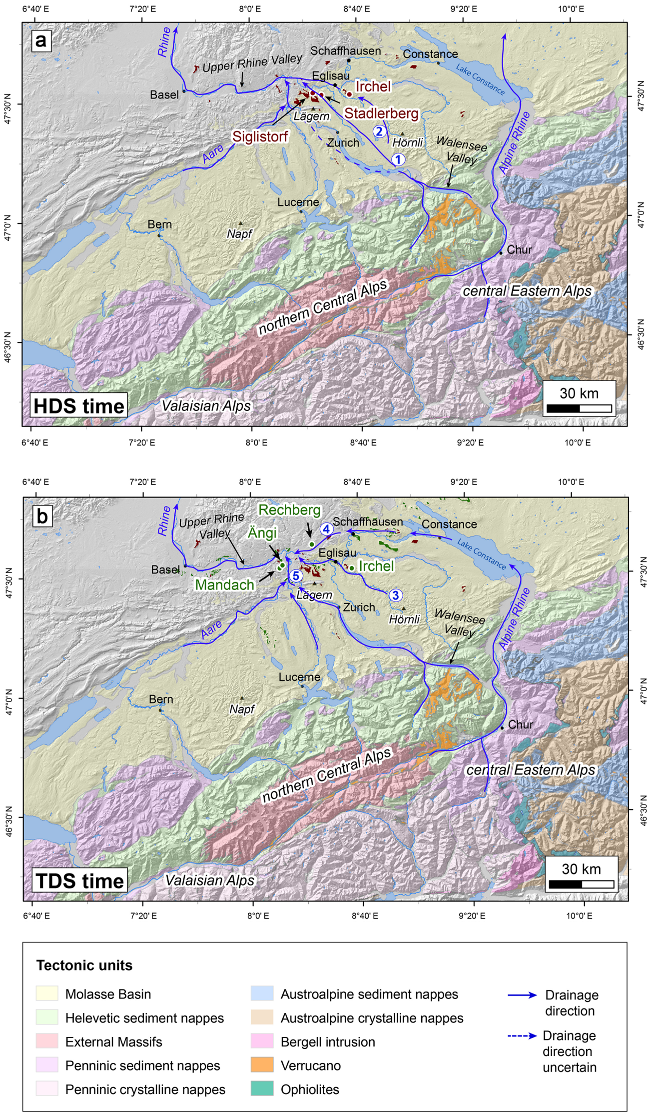

Figure 2. Map showing the tectonic units (© Federal Office of Topography, swisstopo) with possible source areas of the clasts at the study sites. The blue lines mark the evolution of the drainage network in the northern Alpine Foreland during the Pleistocene (Claude et al., 2017c). **(a)** Drainage network during the time of HDS accumulation. **(b)** Drainage network during the time of TDS accumulation.

present. The landscape prior to 2 Ma was a low-relief landscape with smoother hillslopes than at present.

A second phase of gravel accumulation, the TDS at Irchel Steig and Hütz, Rechberg, Ängi and Mandach occurred at around 1 Ma, coinciding with the Mid-Pleistocene Revolution (MPR; Akçar et al., 2014; Claude et al., 2017c). At this time, sediments were eroded from both the northern Central and central Eastern Alps and brought to the Alpine Foreland by the Rheatian, Linth and Reuss paleoglaciers (Fig. 2b). Additionally, to the material derived directly from the Alps, all these deposits contain erosional products that were reworked from the Miocene Molasse. Similar to the older HDS deposits, the younger 1 Ma deposits were also transported as bedload in rivers in a proximal glaciofluvial system. After the Mid-Pleistocene Revolution, accelerated bedrock incision rates between 170 ± 80 and $340 \pm 110\,\mathrm{m\,Ma^{-1}}$ were estimated. Higher rates suggest that a landscape with a more pronounced topographic relief developed compared to the early Pleistocene. These high rates might be the result of the Alpine Rhine draining westwards into the Upper Rhine Valley. As a consequence, the Danube River lost its Alpine catchment, and the discharge, the sediment flux and the erosional capacity increased within the Rhine River. Accordingly, we conclude that the principal driver of the accelerated incision rates in the Alpine Foreland was the climatic signal around the MPR along with a reorganization of the Alpine Rhine and that tectonics likely had only a minor influence.

In the area between Basel and Rheinfelden, the boundaries between the different terrace levels are not always clear. Here, both HDS and TDS deposits occur between elevations of 360 and 390 m a.s.l. At the site Pratteln (Hohle Gasse) a multi-isotope approach using cosmogenic ^{10}Be and ^{36}Cl yielded an age of ca. 270 ka for this site (Claude et al., 2017b). Our findings revealed that this site should be assigned to the morphostratigraphic unit Hochterrasse rather than TDS. The location of this site ca. 40 km downstream of the confluence of the Aare with the Rhine River (Fig. 1) makes it impossible to distinguish whether the western and/or Central Alps contributed more material to the study site. Compared to the older Deckenschotter deposits, the gravels in Pratteln were deposited in a distal glaciofluvial environment in a high-concentration braided river system.

This work shows that great progress was made in cosmogenic nuclide dating using both depth-profile and isochron burial dating methods and that both methods are suitable to date such old sediments. In addition, this study helps to understand the past landscape evolution of the northern Swiss Alpine Foreland, which is of utmost importance for the planning of deep geological repositories that will be located in the Alpine Foreland. As many radionuclides in the waste have long half-life times, the on-site fluvial and glacial erosion of the future 1 Ma is a key issue with respect to long-term safety of the waste repository. Hence, this study is not only a direct input for research on Quaternary geology but also an input for the environmental safety of deep geological repositories for radioactive waste.

Competing interests. The author declares that she has no conflict of interest.

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