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Luminescence dating of the Rissian type section in southern Germany as a base for correlation

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The exact timing of the Rissian has been under discussion since being established by Penck and Brückner (1909) at the beginning of the 20th century. Difficulties in correlating and especially dating the sediments associated with the Rissian have led to different nomenclatures in the different regions of the Northern Alpine Foreland (NAF). Various dating approaches have led so far to often unsatisfying results. In this study we successfully dated the “High Terrace Gravels” of the Rissian type section. Using single grain feldspar luminescence we were able to evade the problems of incomplete bleaching in fluvioglacial sediments. Using the post Infrared IRSL protocol (at 225 °C) we were able to show that the feldspar in the research area only shows low rates of anomalous fading. We were able to show that these low fading rates have an influence on the age determination. This is remarkable because many of the signals were close to saturation. The conclusive age range of 149 ± 15–179 ± 17 ka corresponds to Marine Isotope Stage 6. Defining an age for the Rissian is a first step to consolidate the heterogeneous nomenclature and to reconstruct the chronology of past major Alpine glaciations.

1. Introduction

The Northern Alpine Foreland (NAF) has been a key region for Quaternary research since Penck and Brückner (1909) established their concept of the “glacial series” which consists of four alpine glaciations in the area corresponding to a set of four terraces primarily defined as “Older Cover Gravels” (German: “Ältere Deckenschotter”, associated with the Günzian), “Younger Cover Gravels” (German: “Jüngere Deckenschotter”, associated with the Mindelian), “High Terrace Gravels” (German: “Hochterrassenschotter”, associated with the Rissian) and “Lower Terrace Gravels” (German: “Niederterasseschotter”, associated with the Würmian), which were each deposited during the respective glacial cycle. The basic concept of the glaciations and the resulting terrace formation has since been extended by three more glacials (Biber, Donau, Haslach) by Eberl (1930), Schäfer (1952) and Schreiner and Haag (1982), but not fundamentally challenged. However, the timing of the sedimentation and subsequent erosion is in ongoing debate (Ellwanger et al., 2011). Assignment of the terrace sediments to a specific glacial was mostly achieved by morphostratigraphic correlation and relative dating which is often not trivial, because especially the older terraces show only poor preservation. Numerical dating of the sedimentation of these landforms would be a tremendous help to clarify the status of key sites in the NAF, providing a chronological framework for the system of glacials and interglacials in this region.

Studies presenting numerical ages from the central NAF are scarce (Doppler et al., 2011; Ellwanger et al., 2011). Different methods were used to assess the age of the sediments including U/Th-dating, radiocarbon dating, cosmogenic nuclide burial dating and ESR dating (Jerz and Mangelsdorf, 1989; Häuselmann et al., 2007), but mostly luminescence dating (Rögner et al., 1988; Fiebig and Preusser, 2003; Klasen et al., 2006, 2007, in press; Klasen 2008; Rentzel et al., 2009; Fiebig et al., 2014; Lowick et al., 2015; Salcher et al., 2015; Schielein et al., 2015; Bickel et al., 2015a, 2015b). The ages presented in these studies do not all yield consistent results, which may be caused by the limitations of the individual methodological approaches. However, Fiebig and Preusser (2003) dated fluvial terrace sediments from the Ingolstadt area and showed that correlating terrace deposits in the central NAF may not be straight forward. One of the most comprehensive studies yet, is that of Klasen et al. (in press) who tried to characterize the quartz and feldspar signals from various

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sites of the Northern Alpine Foreland and concluded that quartz and feldspar luminescence is highly challenging and the dating results from the area remain questionable. For the main site re-investigated in this study, Klasen et al. (in press) determined two ages: a quartz OSL age of 72.1 ± 8.2 ka and an IRSL age of 173 ± 15 ka (not corrected for fading). However, the authors point out that the reliability of both ages may be questionable because of methodological reasons, possibly resulting in age underestimation of quartz based ages caused by the occurrence of unstable signal components, and a possible age overestimation of feldspar based ages because of incomplete bleaching.

However, Klasen et al. (in press) conclude that future studies in the research area should rather focus on feldspar as a dosimeter and should consider single grain techniques as a viable tool for dating. This is exactly the issue we want to address in this study, aiming at providing a more reliable numerical dating framework for the central NAF. For this purpose we selected sediments from the gravelpit Scholterhaus, a type section of the Rissian (Penck and Brückner, 1909), which was also one of the sites sampled by Klasen et al. (in press). The sediments of this section can conclusively be tied to the penultimate glaciation, owing to the fact that they are located between two terminal moraines of the Rissian. In this study single grain feldspar luminescence dating is applied for the first time to the "High Terrace Gravels" of the NAF to clarify the timing of the Rissian.

Table 1
Location of the samples, external and internal dose rate.

Field-ID	VLL-ID	Latitude	Longitude	Elevation of sample	Depth below surface	Grain size fraction	Radionuclide concentration			Cosmic dose rate	Total dose rate	K content
		WGS 84					U	Th	K			
		(°N)	(°E)	(m)	(m)	(μm)	(Bq/kg)	(Bq/kg)	(Bq/kg)	(mGy/ka)	(Gy/ka)[a]	(W%)
Gravelpit Scholterhaus												
SHSn-1	VLL-0173-L	9.7897	48.1108	554	27	200–250	12.76 ± 0.34	9.16 ± 0.31	239.5 ± 5.3	13.0 ± 1.3	1.9	13.37 ± 0.42
SHSn-2	VLL-0174-L	9.7905	48.1122	559	27	200–250	14.11 ± 0.37	10.41 ± 0.35	229.0 ± 5.1	13.0 ± 1.3	1.9	13.49 ± 0.36
SHSn-3	VLL-0175-L	9.7905	48.1122	559	25	200–250	16.00 ± 0.12	11.84 ± 0.39	227.1 ± 5.0	15.0 ± 1.5	1.9	13.56 ± 0.20
SHSn-4	VLL-0176-L	9.7879	48.1105	574	14.5	200–250	17.79 ± 0.39	12.61 ± 0.39	257.1 ± 5.6	34.0 ± 3.4	2.0	13.42 ± 0.37
Gravelpit Gärtner												
GÄRn-1	VLL-0172-L	10.3900	48.4418	475	6.5	150–250	27.29 ± 0.65	26.88 ± 0.76	349.4 ± 7.6	81.0 ± 8.1	2.7	–

[a] For all samples, a water content of 15 ± 10% was assumed following Bickel et al. (2015a,b) were measured. The calculation of the dose rate was carried out using the software ADELE (Kulig, 2005) which does not provide individual errors for the dose rates, but they are included in the error of the final age calculation.

2. Geological setting and sampling

2.1. Lake Constance Area and the gravelpit Scholterhaus

During past glaciations large ice masses built up in the European Alps extending wide into the alpine foreland. Based on glacial landforms and glacial sediments the extent of these glaciations was reconstructed (Fig. 1). One of the biggest foreland glaciers was the Rhineglacier extending north of the alpine front into the NAF (Fig. 1). It had a great impact on the Lake Constance Area. Each glacial advance incised deeper, lowering the hydraulic base level and shaping an amphitheatre like structure in the glaciated area. In the proglacial area the rivers incised to deeper levels with each glaciation which lead to the development of a terrace staircase. These distinct terraces can be correlated over long distances and have widely been used to build relative chronologies in the NAF.

The gravelpit Scholterhaus (Biberach am Riß) is located in the northeastern margin of the area once covered by the Rhineglacier and therefore in direct proximity to the glacier forefront (Fig. 1). The gravelpit is located between two terminal moraines associated with the penultimate glaciation, i.e. the "Rissian" (Fig. 2). The sediments exposed in the gravelpit Scholterhaus are the "High Terrace Gravels". These sediments as well as both terminal moraines are associated with the maximum extent of the Rissian ("Doppelwall-riss"). Exposed in a nearly 40 m high profile they mostly consist of matrix supported gravels and therefore are not suitable for luminescence dating (Figs. 3 and 4). In an elevation between 561 and 563 asl. a diamicton layer of glacial origin is present (Figs. 3 and 4). Sand lenses can be found at few locations in the profile with thicknesses between 0.1 and 0.6 m. The sand proved to consist of grain size fractions which are suitable for luminescence dating. Samples were taken from four different sand lenses between 550 and 570 m asl. (Fig. 4; Table 1) using steel tubes. Samples SHSn 1–3 are located below the diamicton, while sample SHSn-4 is located above it. Material directly surrounding the sampled material was taken for gamma spectrometry analyses to determine the radiation by naturally occurring radionuclides. Fig. 4 also shows the relative position of the sample analysed by Klasen (2008).

The sedimentological characteristics of the sand lenses sampled in the Scholterhaus section (cross bedding, coarse grain size: mainly medium to coarse sand) point towards a depositional environment with high sedimentation rates and rapid deposition. Such characteristics may strongly enhance the chance of incomplete resetting of the luminescence signal prior to deposition. For that reason we chose to include an additional sample for methodological comparison from another section. Sample GÄRn-1 was taken from a sand lens from the gravelpit Gärtner (Fig. 3). The gravelpit Gärtner is located near Burgau in the NAF which is located ~60 km NE of Scholterhaus. The gravelpit is not located in the Riss but in the Mindel valley. The reason why we chose this sample as a comparison is that although the general depositional environment is most probably similar to the Scholterhaus site, the sediment from this sand lens is finer and much better sorted than the sediments of the Scholterhaus samples. The finer grain size composition and the bedding structure suggest that a local aeolian re-deposition may have taken place in the drying braided river system. Aeolian transport, even over short distances, increases the chances of bleaching tremendously because the light can reach individual grains much easier. The drawback of the Gärtner sample from a stratigraphical point of view is, that the deposit where the sample was taken from is generally associated with the "Lower Cover Gravels" and correlated with the Mindelian glaciation (Habbe and Rögner, 1989). We are aware that sample GÄRn-1 as a single sample only has restricted possibilities to reliably date the sediments from gravelpit Gärtner, therefore we stress the point that this sample is intended to function as a control sample from a methodological point of view. A more suitable sample from the Riss valley could unfortunately not be obtained.