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Postglacial evolution and recent siltation of the protected lake Taferlklaussee (Salzkammergut, Upper Austria)

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Abstract

The study focuses on the nature reserve 'Taferlklaussee' in Upper Austria. This small freshwater body fills a glacially overdeepened basin carved by the Aurach valley glacier isolated from the alpine ice flow network during the Last Glacial Maximum. Nature conservation versus human interaction causes multifaceted areas of conflict and views on future management are diverging. We provide first-hand data on short and long-term lake siltation using a bundle of methods and focussing on the postglacial infill history as well as decadal-scale trends of lake development.

Keywords

Postglacial Lake; Infill History; Overdeepened Basin

Introduction

Sediment production, (intermediate) deposition, remobilization, and (final) storage are strongly controlled by topography, climatic parameters, and particularly by glaciation and deglaciation. Overdeepened alpine basins and lakes are characteristic results of glacial erosion. They represent sedimentologically (semi-)closed archives most suitable to reconstruct postglacial landscape evolution and establish sediment budgets (Hinderer 2012).
Nature reserves are intended to preserve ecosystems but also the physical environment and landscape. Consequently, areas under nature conservation are widely unaffected by humans and represent undisturbed landscape archives. As nature conservation and human interaction with the environment often causes various areas of conflict, our research is intended to provide first data on the evolution of the protected alpine lake 'Taferlklaussee' (TKS) to underpin the current debate and inform best-practise management.

Major aims of our research include i) understanding decadal scale trends of siltation, ii) reconstructing the postglacial evolution of the lake basin, iii) quantifying the amount of postglacial sediment storage in the basin and iv) understanding the dynamics of erosion and sedimentation since deglaciation (Lateglacial, Holocene, Anthropocene). We use a bundle of direct and indirect methods, consisting of field surveying (mapping, DC-resistivity, core drilling), lab analyses (e.g. grain size and 14C dating), GIS modelling (sediment storage volume), and the interpretation of a set of historic aerial images.

Study Area

The TKS, a small lake (12170 m2, 763 m) in the Aurach catchment (3.02 km2, 763-1708 m; Salzkammergut region, Upper Austria), is located at the border of the Northern Limestone Alps in the south (Höllengebirge) and the Flysch Zone in the north. The east-west oriented Höllengebirge with its highest peaks of ca. 1700 m (eg. Brunnkogel, Hochlecken) is dominated by Wetterstein limestone and dolomite underneath (Hauptdolomit; below ca. 1200 m). The Flysch Zone (composed of marls, clays and sandstones) in the north of the study site is less rugged with highest elevations of 1090 m (Krahberg) (Fig. 1).

Several small streams drain the north facing cirques of the Höllengebirge and feed the TKS, where the Aurach river originates. The area is characterised by a mean annual precipitation of 1900 l/m2 and mean annual temperatures of 3.6 °C (Höllengebirge, Feuerkogel, 1618 m; 1971-2000; ZAMG).

The formation of the TKS basin is considered to result from glacial overdeepening (Van Husen 1977). During the Würm glaciation the Aurach glacier was independent and not connected to the larger neighbouring glaciers (Traun outlet glaciers forming the Attersee and Traunsee basins). At the recent lake and further downstream, several recessional stages of the Aurach glacier are clearly marked by terminal moraines and attributed to glacier extends of the Last Glacial Maximum (LGM, MIS 2) and Late Glacial stadials (probably between 14 and 20 ka, Van Husen 1977; Fig. 1). So far, no chronometric constrains exist for these depositional landforms and the age of the lake.

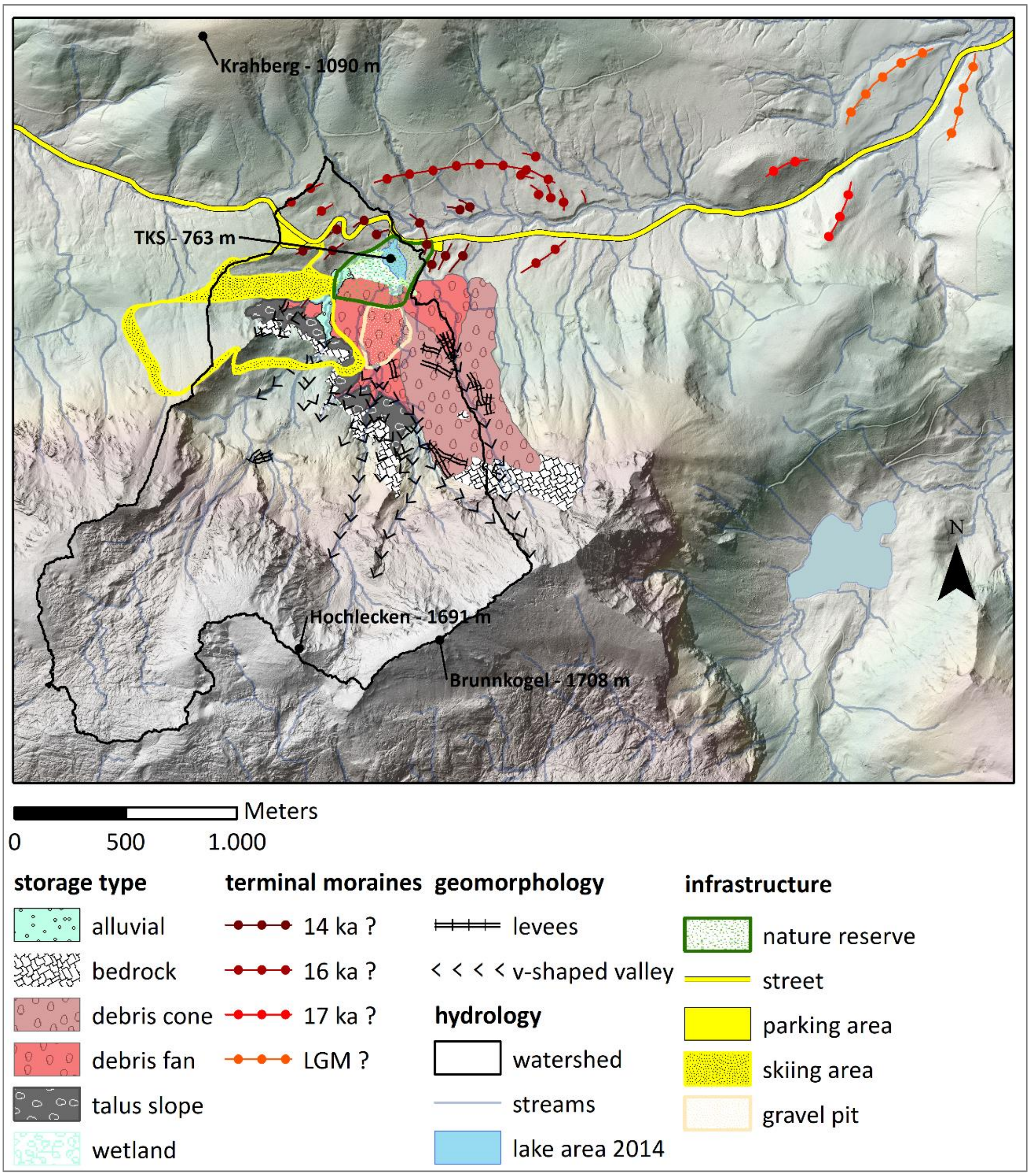

Figure 1: Overview map of the study area providing information on landforms, hydrology and infrastructure. Lateglacial stadials (ca. 17 ka = 'Ischler Stand'; ca. 16 ka = 'Jochwand Stand', ca. 14 ka = 'Goiserer Stand') refer to VAN HUSEN (1977). Location within Austria is marked with a red dot. Symbols refer to OTTO & DIKAU (2004).

In historical times, the area was deforested and the lake level artificially raised in AD 1716 to allow log rafting on the river Aurach. Today, the TKS is under nature conservation but highly frequented as recreational area for summer and winter sports.

Methods

We mapped depositional landforms, bed rock, hydrological features and infrastructure based on both, field surveying (GPS) and the interpretation of ALS data and derivatives (e.g. slope, curvature, hillshade; spatial resolution 0.5 m).

For the investigation of the thickness and internal structure of the postglacial basin fill, we acquired several DC-resistivity surveys (Wenner arrays) (Fig. 2). Three of them were taken as roll-along surveys (overlap 75 %) with total lengths of 596 and 496 m. Two shorter surveys (196 m) were acquired in the distal part of the basin.

Stratigraphic information of the basin fill is based on several drill cores (Fig. 2) and is also used to validate geophysical models. Two samples of organic material (from B2) were taken for 14C dating.
Historic aerial photographs and orthophotos available since 1953 (Fig. 3) were used to quantify the lake area on a decadal scale.

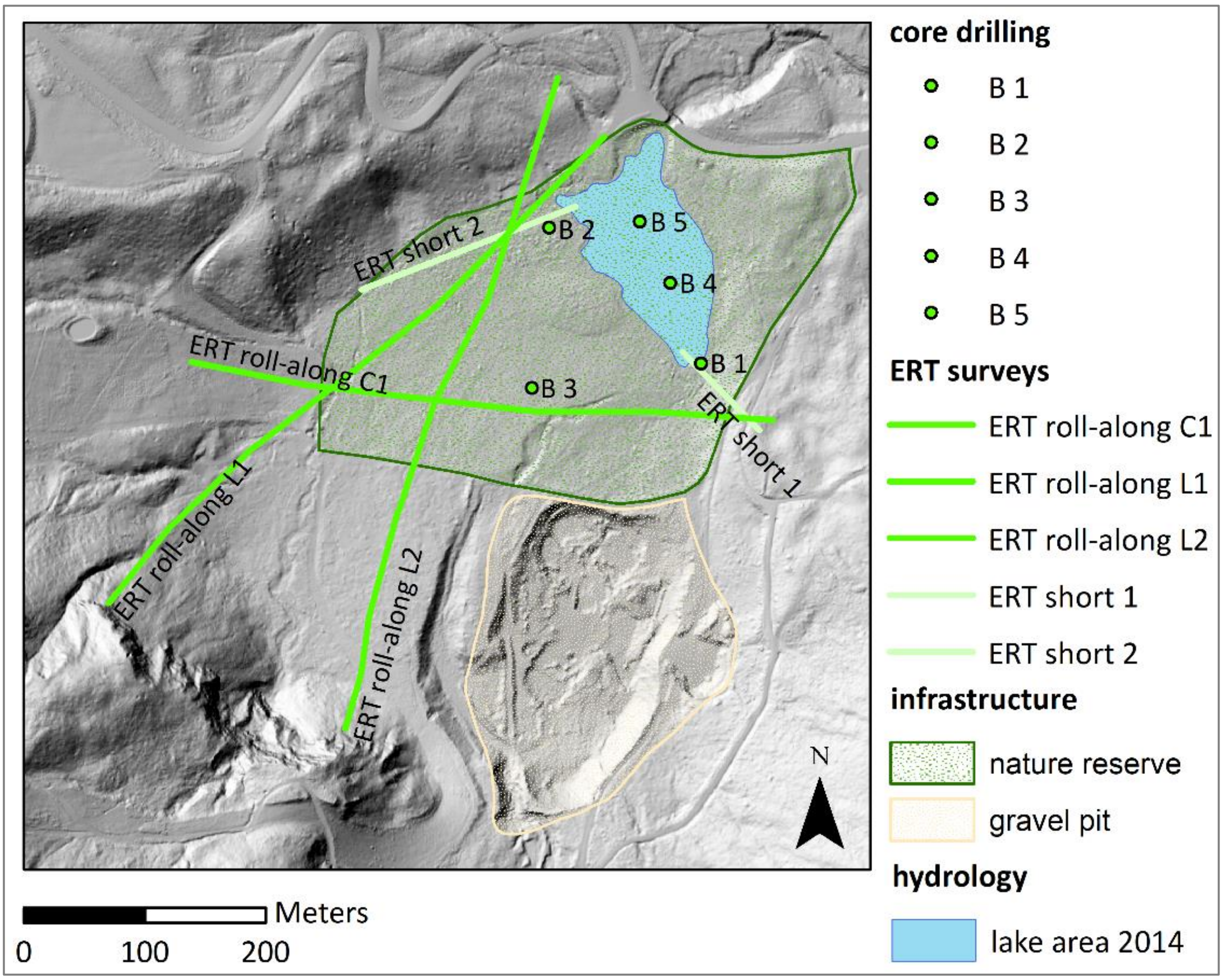

Figure 2: Locations of core drillings and DC resistivity (ERT) surveys in the TKS basin and the lake extend of 2014. Boundaries of the preserved area and the gravel pit are based on hillshaded ALS data (spatial resolution: 0.5m).

Results

The mapped landforms were categorised into alluvial plains, bedrock, debris cones/fans, talus slopes and terminal moraines (Fig. 1). Several debris flow channels drain the steep cirques in the southern part of the catchment and enter the basin in the proximal part. Large amounts of debris flow and rockfall material were supplied through these channels forming major fans and cones that cover the entire proximal basin. Since the 1960s a gravel pit is located within these fans for mining the dolomitic sediment.

ERT surveys show rather low apparent resistivities mainly below 500 Ωm, with highest measured values of up to ca. 2200 Ωm. The 2D tomographies of the roll-along surveys (Fig. 4) allowed capturing the entire basin length- (L1 and L2) and crosswise (C1). The basin boundaries (lateral moraines and talus slopes) show higher resistivities (ca. 400-2200 Ωm) and sharp borders to the material in the centre of the basin with significantly lower values (ca. 20-70 Ωm). This highly conductive material shows quite homogenous values, except for a high resistive near-surface layer (ca. 400-700 Ωm) in the basin centre. All three roll-along profiles show a parabolic-shaped structure running through the basin in depth between 5 and 35 m, with relatively higher resistivities (ca. 100-250 Ωm) compared to the material above and below.

The drillings in the siltation zones (B1 and B2) and within the recent lake (B4 and B5) reached depth between 4.6 and 6.5 m. With the drilling B3, located on a major debris fan and close to the ERT survey C1, we reached a depth of 10 m. First radiocarbon ages of two samples (core B2; sample depths: 2.2-2.3 m and 3.7-3.8 m) yielded ages of ca. 4600-4500 cal BC using Intcal13 (REIMER et al. 2013).
With respect to the (sub-) recent lake history the lake area diminished by 4540 m2 between 1953 and 2014 as shown below (Fig. 3).

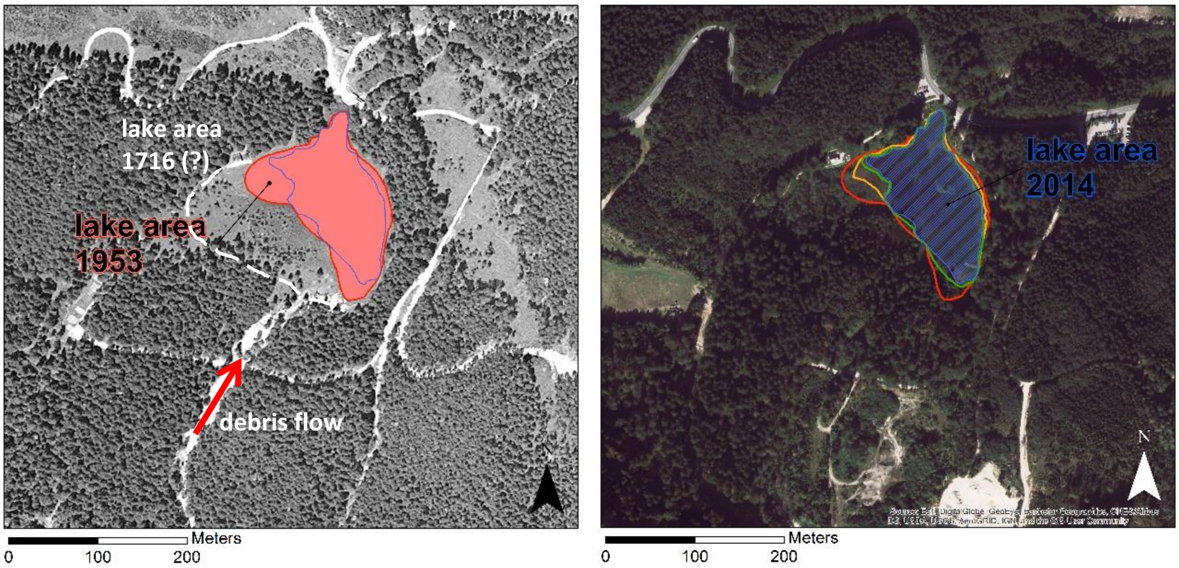

Figure 3: Orthophotos from 1953 and 2014 based on aerial photographs showing changes in lake area.

Discussion

Preliminary results of analysed surface, subsurface and temporal data indicate a glacially overdeepened basin, which is rather shallow in the distal part (ca. 5-7 m), whereas in the proximal part, sediment thickness increases strongly (up to ca. 35 m).

The basin infill can be summarised in a simplified model composed of four main units (Fig. 4): The first 2-5 m underneath the present surface show high resistivities. This major fan mainly consists of dolomite debris showing a loose, sandy to silty matrix. The fan sediments are underlain by well conductive lake sediments (from 5-35 m) mainly consisting of clay and silt. Underneath, a parabolic shaped structure with slightly higher resistivities indicates a layer of basal till which is interpreted as the lowest depositional material in the basin. Relatively low resistivities underneath suggest that the basin-base is composed of highly conductive material.

From first interpretations the stratigraphy of the drill cores in the distal part of the basin (B1, B2, B4 and B5) consists of three main sections (from bottom to surface): basal till, lake sediments (partially interrupted by dolomite debris) and peat. The stratigraphy of B3 fits well with the results of the DC-resistivity surveys and is composed of lake sediments (10-5.5 m) and dolomite debris (from 5.5-0 m). However, lower units and the base of the basin could not be reached.

Radiocarbon ages taken from B2 verify the hypothesis that a postglacial lake already existed in the basin before the recent TKS was dammed up in AD 1716. However, since samples from the basin-base have not been dated yet, the period of lake formation remains unknown but the similar ages of the two samples, though being ca. 1.5 m apart, suggest former periods of high sediment delivery.

The most recent lake development, as reconstructed from multi-temporal aerial photographs, shows that two zones of siltation have strongly expanded since 1953 and that lake area decreased by 4540 m2 (Fig. 3). Recent sediment input seems to be controlled by organic material and rare debris flow events. Several levees and lobes were recently deposited through active debris flows in the most proximal part of the basin, demonstrating that sediment delivery from the steep cirques above is still ongoing. Multiple debris flow generations are clearly recognizable in the field and give an idea of the high frequency and magnitude of past events.

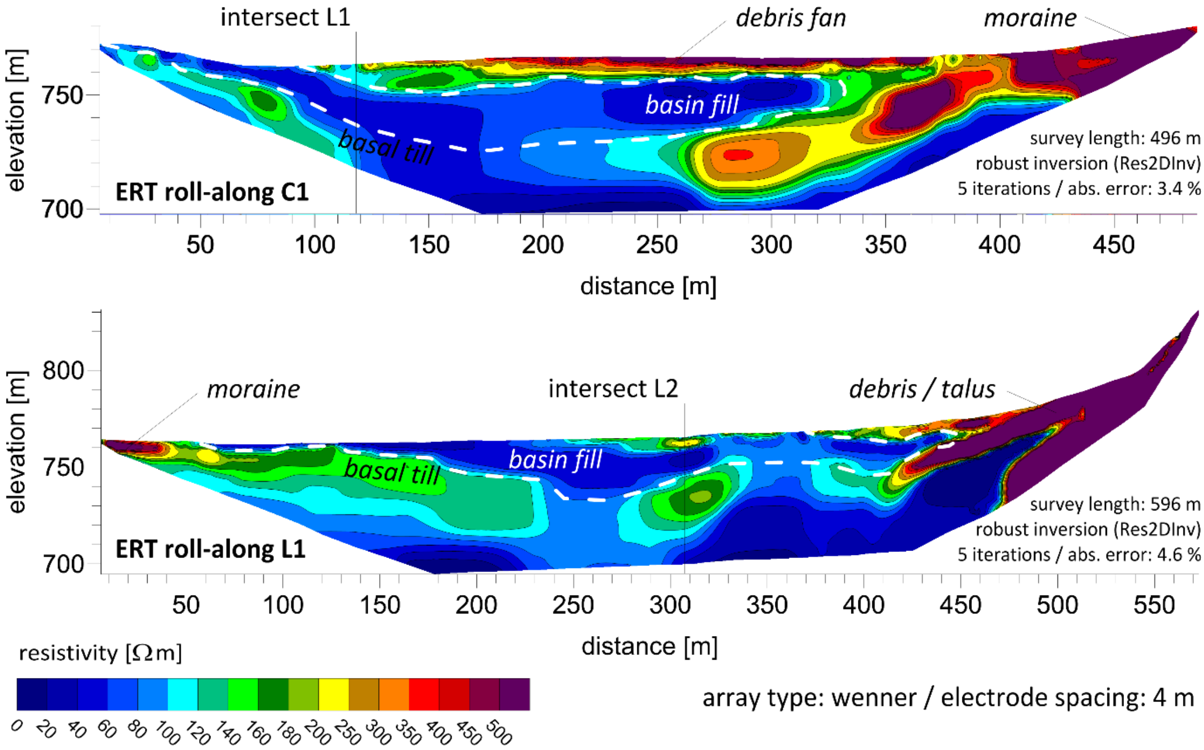

Figure 4: Electrical resistivity tomographies (ERT roll-along C1 and L1) with interpretation. For locations see Fig. 2.

Conclusion and Perspectives

To capture the extent/geometry of the TKS basin (recent lake area: 12170 m²) and the surrounding depositional landforms, a combination of different methods has been applied (analyses of ALS-data and orthophotos, DC-resistivity, core drilling, radiocarbon dating). Most important preliminary results of our ongoing study show that

- an overdeepened basin framed by terminal/lateral moraines and talus slopes was verified by DC-resistivity surveys, core drilling and geomorphological mapping (cf. VAN HUSEN 1977),
- the depth of the recent lake basin is only ca. 5-7 m whereas the total depth of the sedimentary fill increases up to 35 m in the proximal part,
- the basin fill can be structured in four main units: the base of the basin potentially reflecting Flysch material, basal till, lake sediments, and alluvial/debris flow material on top,
- 14C ages of two samples from B2 suggest the existence of a lake in the basin after glacier retreat and before the lake level was risen AD 1716, and
- the lake area decreased since 1953 by 27% (4540 m2).

In the next steps, we aim to calculate sediment storage volumes and reconstruct the postglacial evolution of the basin. Finally, postglacial erosion rates and their Holocene variation will be investigated combining stratigraphic analyses, further radiocarbon ages, and GIS-modelling.

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