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# <sup>14</sup>C EVIDENCE FOR AN EARLY TO PRE-WÜRMIAN AGE FOR PARTS OF THE SALZBURGER SEETON, URSTEIN, SALZACH VALLEY, AUSTRIA

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## KEYWORDS

Glacial sedimentation  
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Radiocarbon age  
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## ABSTRACT

A peat layer, which was found above lacustrine Salzburger Seeton sediments during drilling operations near Urstein, in the Salzach Valley, has been C<sup>14</sup> dated. The peat-layer, which was proven from three boreholes at the same altitude to have a N-S longitudinal extent of > 300 m and a thickness of 1.5 m, is overlain by sands and gravels. Two <sup>14</sup>C ages (> 38,600 YBP and > 43,400 YBP) indicate that the peat was deposited before the climax of the Last Glacial Maximum (LGM - Würmian) and that at least this part of the Salzburger Seeton is of early to pre-Würmian age rather than the previously inferred late Würmian age. Such age data are rare for the Salzach valley/glacier in an inner-Alpine position and provide a new insight into the history of the last glacial-interglacial cycle and the filling of this overdeepened Alpine valley.

Bei Bohrarbeiten im Salzachtal wurde an der Oberkante von lakustrinen Sedimenten, welchen bis jetzt ein spät-würmzeitliches Alter zugewiesen wurde, eine Torflage mit einer Ausdehnung von mehr als 300 m aufgefunden und in drei Bohrungen auf gleicher absoluter Höhe nachgewiesen. Datierungen zweier Torfproben zeigen Alter von > 38.600 aBP und > 43.400 aBP und manifestieren somit eine Torfbildung vor dem Höhepunkt der letzten Eiszeit. Diese Daten sind sehr selten für die inneralpinen Bereiche des Salzachgletschers und geben neue Einblicke in die Ablagerungsgeschichte während des letzten Interglazials und Glazials und die Verfüllung des übertieften Tales.

## 1. INTRODUCTION AND GENERAL GEOLOGY OF THE SALZACH VALLEY

Together with the smaller Traun glacier to the east, the Salzach glacier was the easternmost outlet-glacier in the Alps during the Quaternary. The accumulation area for the Salzach glacier was situated between the Inn and Enns rivers (Fig. 1a) and bordered to the south by the main ridge of the Alps. During the Last Glacial Maximum (LGM), the accumulation area reached approximately as far north as the Northern Calcareous Alps (Fig. 1b). In the inner-Alpine region, the main glacier had a south-north orientation, feeding the Inn glacier/Chiemsee glacier (via Pass Thurn, Reitner 2005), the Saalach Valley (via Zell am See) and the Salzach Valley, with ice from the south-north-striking valleys east of Bad Gastein (Fig. 1a).

East of Schwarzach, the Salzach Valley changes its direction from west-east to south-north, breaking through the Northern Calcareous Alps to the wide valley between Golling and Salzburg in the north (Fig. 1b). This was filled by the Salzach Glacier, which spread out into the Alpine foothills consisting of flysch, with altitudes up to 1114 m a.s.l., and molasse, forming a major basin north of Salzburg, where the Würmian (and all older) outlet-glacier(s) formed up to nine lobes which reached far out into the lowlands (Molasse in Fig. 1b). To the west, the Salzach Glacier touched the Inn Glacier (Chiemsee Glacier) whilst, to the east, it was in contact with the Traun glacier (Ebers et al., 1966, Van Husen, 1977; Fig. 1b).

The Salzach Valley is an overdeepened Alpine valley between Golling in the south and its northern aperture to the foreland north of Salzburg (Fig. 1b). This was filled by fine-grained lacustrine sediments, with delta-complexes along its lateral margins. The

age of deposition is unclear but was inferred to be of late-Würmian and Holocene age by Van Husen (1979). The melting outlet-glacier from the recorded four last ice-ages left huge terminal moraines (see Fig. 1b for the Würmian moraine, all others lying farther north) in the foreland of the Alps which were partly used as dams for large lakes.

Stummer (1936, 1947) and Ebers et al. (1966) described lakes for the Eemian (Riss-Würm-Interglacial), the Gollinger See, with a level of ca. 440 m a.s.l., which filled only the inner-Alpine regions of the Salzach Valley, and the Salzburger See for the Mindel-Riss-Interglacial, with a level of 530 m a.s.l.

The generalised stratigraphy of the glacial, glacio-fluvial, lacustrine and fluvial sediments in the Salzach valley basin is summarized in Fig. 2. Discontinuous relics of lodgement till of varying thickness have been preserved on top of the pre-Quaternary basement (Mesozoic carbonates of the Northern Calcareous Alps). Hell (1963) described the markedly rough morphology of the basement surface, with slope-angles (of up to 16°) changing within relatively short horizontal distances.

Above the basement and lodgement till, the Salzburger Seeton, a poorly consolidated, typically grey and blue coloured series of silts, sands and clays with a coarsening upwards trend (Prey, 1959), has been traced throughout the basin. The age of this succession is unclear, although most authors have suggested a late Würmian age (e.g. Stummer, 1936).

In deep boreholes in Salzburg, Prey (1959) found some coarse, sandy layers within the Salzburger Seeton, suggesting an interruption in the lacustrine sedimentary facies. Similarly,

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Stummer (1947) described a borehole in Salzburg which ended in gravels and sands at 70 m, underlying 50 m of Salzburger Seeton whilst four layers of till were recorded within the Quaternary lacustrine sediments in a borehole near Vigaun (Kramer & Kröll 1979; Fig. 1b). These layers were re-interpreted by Van Husen (1979) as subaquatic slides and alluvial cones from a nearby torrent, respectively.

The highest member of the sediment package comprises fluvial gravels which, especially north of Salzburg, vary in thickness, reflecting a braided river network in the Salzach river, occupying the whole valley width.

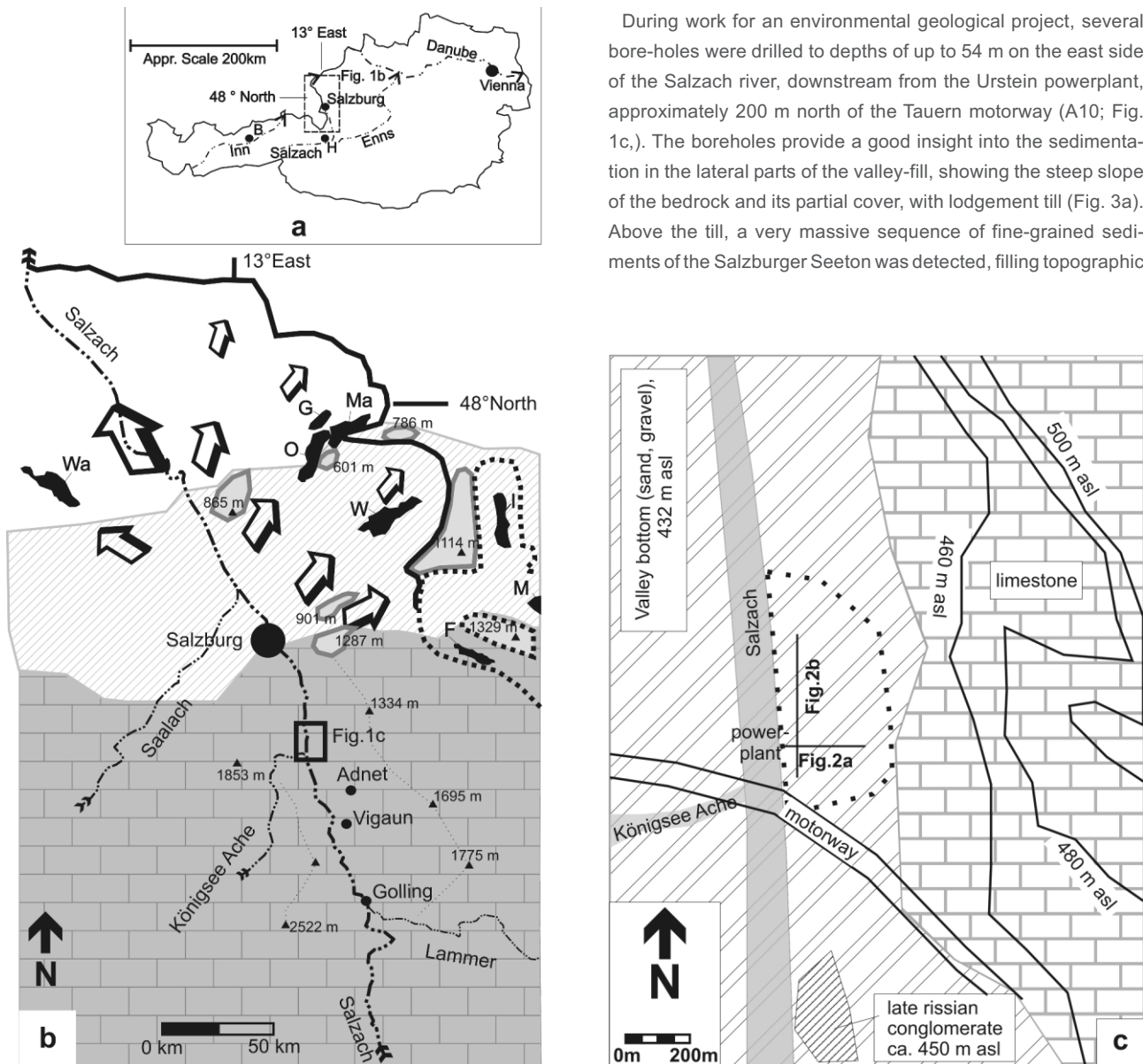
The maximum thickness of 340 m of Quaternary sediments

recorded in the Salzach valley was found in a deep borehole in Vigaun (Fig. 1b; Kramer and Kröll, 1979, Van Husen, 2000a) whilst two boreholes in Salzburg gave thicknesses of 198 m and 262 m (Prey, 1959).

Within the valley and along the lower regions of the slopes, two types of conglomerates have been recorded: (1) conglomerates of the Mindel-Riss-Interglacial and, in a lower topographic position, (2) conglomerates of late Rissian age (Van Husen, 1990). These conglomerates represent remnants of the coarse-grained fill of the lakes (deltas) in the vicinity of rivers and torrents draining from the steep valley-sides. One such body lies only a few hundred metres south of the peat documented here (Fig. 1c).

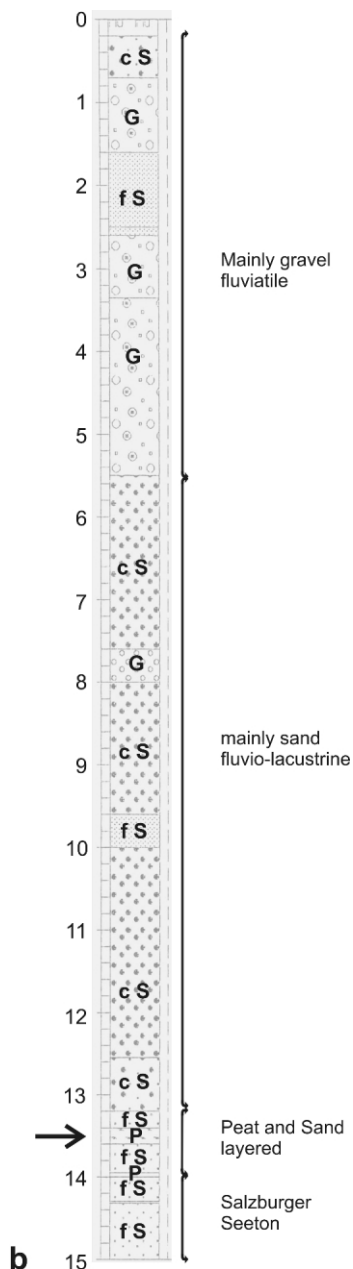
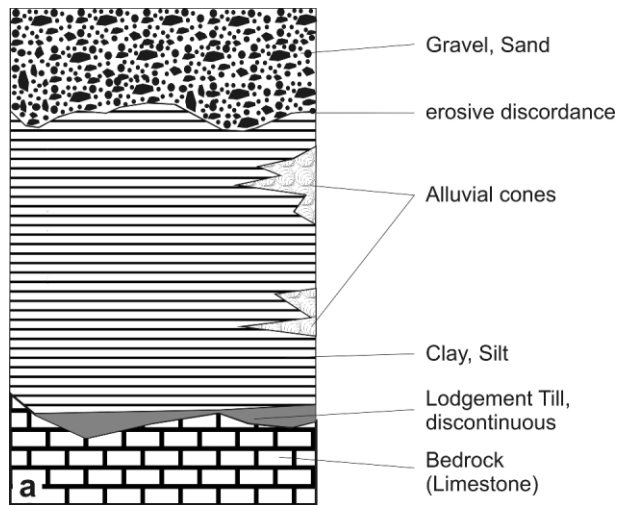
## 2. SAMPLE MATERIAL AND RESULTS

During work for an environmental geological project, several bore-holes were drilled to depths of up to 54 m on the east side of the Salzach river, downstream from the Urstein powerplant, approximately 200 m north of the Tauern motorway (A10; Fig. 1c.). The boreholes provide a good insight into the sedimentation in the lateral parts of the valley-fill, showing the steep slope of the bedrock and its partial cover, with lodgement till (Fig. 3a). Above the till, a very massive sequence of fine-grained sediments of the Salzburger Seeton was detected, filling topographic



**FIGURE 1:** (a) Map of the research area. B – Baumkirchen, H – Halldorf/ Schwarzach. (b) sketch of the northern area covered by the Würmian Salzach glacier, with a simplified geological map. Hatch (bricks) – Northern Calcareous Alps (NCA): angular hatch – flysch: white – foreland molasse: light grey – prominent nunataks within the flysch mountains and the NCA and the inner-alpine location of the research area (Box 1c); position of the terminal moraines of the LGM is marked by bold black line; bold dotted line: terminal moraines of the Traun glacier; Salzach, Saalach, Lammer, Königsee Ache: main rivers in the area; arrows indicate flow-direction of ice during LGM. Main recent lakes in the area: Wa – Waginger See, G – Grabensee, O – Obertrumer See, M – Mattsee, W – Wallersee, I – Irrsee, F – Fuschlsee (c) area of research (dotted line) with location of the cross-profiles and the general geology of the surface including the position of late Rissian conglomerates.

**FIGURE 2:** (a) Generalised stratigraphy of the area; (b) log profiles of one borehole (U6) with location of the dated sample (arrow). G: gravel; c S: coarse Sand; f S: fine Sand; P: Peat



irregularities in the tillite. On the N-S profile, this is overlain by an up to 1.5 m thick peat-layer. The youngest sediments comprise sands and gravels, filling the erosional topography above the peat and the Salzburger Seeton.

The peat layer was traced continuously over a distance of more than 300 m in a N-S-direction (Fig. 3b), although the lateral extent (E-W) of the peat could not be determined; it did not, however, appear in any of the borings to the east, on the E-W profile (Fig. 3a). The peat consisted of a very fine-grained black matrix with large amounts of consolidated plant fragments and is inferred to reflect a swampy environment. The extent and the thickness of the peat-layer strongly suggest that it is an autochthonous deposit. Due to logistic reasons, a pollen analysis could not be performed.

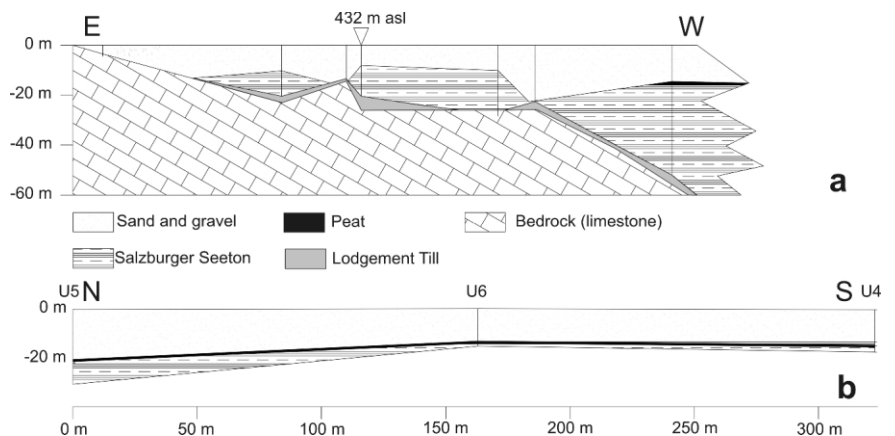
Two samples from two different boreholes (U4 and U6 in Fig. 3b) were dated at the University of Vienna (Institut für Isotopenforschung und Kernphysik), using the "conventional" radiocarbon-method (proportional gas counting, cf. Felber & Vychytil, 1962). These yielded ages of > 38.600 YBP (lab. nr. VRI-1955; U4) and > 43.400 YBP (lab. nr. VRI-1956; U6), respectively, with a 2-σ standard deviation resulting in a probability of 97.7 %.

### 3. DISCUSSION

The research-area (Fig. 1c) lies approx. 50 km south of the position of the LGM terminal moraines and thus within the inner-Alpine, over-deepened sector of the Würmian Salzach glacier. The existence of an early (or pre-) Würmian peat at a depth of 15 to 20 m below the recent topography, lying on top of the Salzburger Seeton is the first evidence of such early/pre-Würmian sediments in deeper sections of the sediment column in the over-deepened part of the Salzach glacier. Van Husen (1979), however, had noted the possibility of such sediments occurring in lateral positions of the valley.

Proven Eemian sediments within the extension of the glacier have only been found in the Alpine foreland. Ebers (in Ebers et al. 1966) described the Interglazial von Zeifen (Zeifen interglacial) at the SE-margin of Waginger See (Bavaria, Fig. 1b), where fine-grained sediments in the hanging-wall of deltaic gravels yielded a fauna of molluscs and ostracods similar to species found at other locations in Bavaria. Pollen showed a cooling trend towards the hanging-wall, indicating a early Würmian age for the highest parts of the outcrop.

South of Salzburg, Del Negro (in Ebers et al. 1966) described a small outcrop with coals and



**FIGURE 3:** (a) Cross-section (W-E) with bore-holes and the described sequence of sediments. For the location of the profiles, see Fig. 1c. The morphology of the Salzburger Seeton represents erosional effects by the Salzach river. (b) S-N section showing the longitudinal extent of the peat-layer. Samples for radiocarbon-dating were taken from boreholes U4 and U6.

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mud near Adnet (Fig. 1b) containing pollen indicating an interglacial sediment age, but which interglacial was meant is not clear. However, since this outcrop lies at 530 m a.s.l., a Mindel-Riss-Interglacial age could be inferred, based on the level of the interglacial lake of that time (530 m a.s.l.). At the east-neighbouring Traun glacier, a complete section from Eemian up to the Würmian (MIS6 to MIS3; Fig. 4) has been found in a deltaic complex at the northern margin of Mondsee (van Husen, 2000b; Fig. 1b).

Slupetzky (1976) reported the first evidence for pre-LGM sediments within the Salzach valley, at Halldorf (Fig. 1a), at the end of the west-east-striking part of the Salzach Valley. In this outcrop, a number of peat and wood fragments were found in a 1 m thick layer of sand within gravels. All the organic material showed signs of fluvial transport. One piece of peat and one of wood were <sup>14</sup>C dated; the latter gave an age of 35,470 (+2,580/-1,950) YBP (Lab. Nr. VRI-452), and the former an age of > 36,500 YBP (VRI-444). These data demonstrated the existence of pre-LGM fluvial sediments in the Salzach Valley (Fig. 4).

All the settings described, except for Slupetzky (1976), are situated along the margins of the glacier-valleys or within the foreland, in the region of the outlet-part of the glacier. None shows features similar to those described here (i.e. fine-grained sediment of the Salzburger Seeton in lower parts).

In the Inn Valley, Fliri et al. (1970) presented <sup>14</sup>C data from Baumkirchen (Fig. 1a), which has a similar position, in relation to the extent of the Inn glacier, to the one documented here (inner-Alpine, over-deepened section). Three samples within a 60 m layer of banded silts and clays gave ages of 26,800 – 31,000 years YBP (Fig. 4), representing interstadial ages within the Würmian. Spötl & Mangini (2006) presented new data for the Inn Valley showing the absence of ice during Marine Isotope Stages (MIS) 5c to 5a and also during the MIS 5/4 transition. These data were collected from calcitic flowstones within a Pleistocene breccia and showed a discontinuous flowstone growth. The growth phases gave evidence for an ice-free, soil-covered and vegetated environment.

The new data presented here confirm the existence of rem-

nants of older ice-ages and possibly of interglacials within the sediment body filling the Salzach valley. The interglacial/interstadial lacustrine Salzburger Seeton sediments below the peat-layer must be of pre- or early Würmian age, and thus the fragments of lodgement till lying on the basement must be of pre-Würmian age. The local situation, lying in the pressure shadow of a rigid conglomerate-hill up-glacier (Fig. 1c) of presumably late Rissian age (van Husen, 1990), sheltering the region against the oncoming ice might be the reason for the preservation of these sediments from erosion during the LGM. This implies an Eemian/early Würmian age for the peat and therefore a late Rissian/Eemian age for the underlying fine-grained sediments in parts of the valley, presuming the conglomerate lies directly on the basement (limestone). Late- and post-Würmian sedimentation covered and compacted the peat.

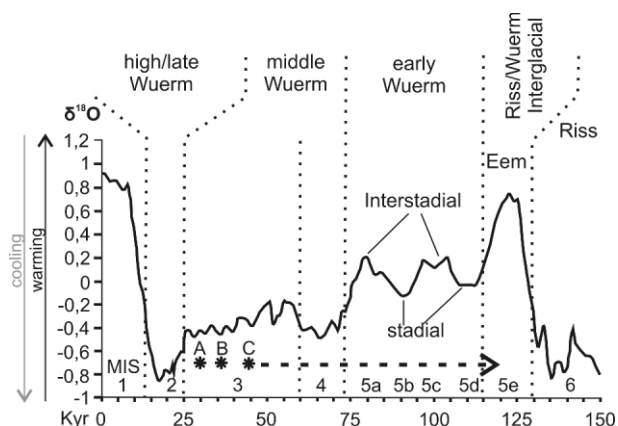
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**FIGURE 4:** Spectral Mapping Project (SPECMAP) with time-scale modified from Reitner (2005) and inserted radiocarbon ages (stars) of samples 1 - Inn-Valley (Fliri et al., 1970), 2 - Salzach-Valley (Slupetzky, 1976), 3 - this study.



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