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Bericht 2009 über geologische Aufnahmen der quartären Sedimente im Zemmgrund, Schlegeisgrund und im Bereich Dristner und Tuxer Joch auf Blatt 149 Lanersbach, 150 Mayrhofen und 176 Mühlbach

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The two largest tributary valleys of the Zemmtal valley system – the Zemmgrund and Schlegeisgrund valleys – were mapped during 2009. Additional investigations were carried out into the western flank of the Dristner mountain and in the vicinity of Tuxer Joch pass. Special attention was paid to sediments and erosional forms of former glacier extent during the Last Glacial Maximum (LGM, „Würm-Hochglazial"), the Lateglacial period, and the Holocene.

Evidence of the maximal ice extent (LGM)

The vertical extent of glacial erosion landforms provides evidence of former ice-surface geometry during maximal glaciation, which in the Alps can generally be considered to have occurred during the LGM.

At the mouth of the Zemmgrund valley the glacial trimline can be observed at a level of 2400–2425 m on the western slope of the Kleiner Ingent mountain, where the uppermost limit of polished bedrock is visible. The glacial trimline occurs at a similar level on the opposite side of the Zemmtal valley, on a spur descending from the Kleiner Riffler and Schönlahnerkopf peaks. Further up the Zemmgrund valley the upper limit of glacial erosion features can best be seen on arêtes and spurs between valley-side cirques. The limit of glacial erosion can be inferred from the gross morphology of the spurs, which have gentle, ice polished shapes on their lower slopes and sharp crests above. However, the best evidence of ice extent is provided by perfectly developed truncated spurs in the upper Zemmgrund valley: at the lower end of the spur (2588 m), which runs down from Schönbichler Horn peak; at Steinmandl (2634 m), at the end of the Roßrugg spur; at Am Horn (2647 m); and the spur that runs down from the Ochsner peak towards Schwarzensteinalm (2632 m). These indicate that the ice-surface in the area where several glacial basins coalesce in the upper Zemmgrund valley did not exceed a level of 2600 m.

Glacial trimlines are especially well developed in the Schlegeisgrund valley. At the valley mouth glacially moulded bedrock occurs up to 2400–2480 m on the right-hand side slope running down from the spur (2511 m), which runs from the Greinermauer peak, towards the Schlegeisspeicher reservoir. This is at the same level as on the nearby Zamser Egg spur and the lower end of Schrammerkopf truncated spur. Further up the Schlegeisgrund valley two prominent trimlines cut the eastern flanks of the Kleiner Hochsteller and Hochsteller range: the upper limit of the ice-surface can here be taken to have been at the level of the top of the steepest rock walls, which stand approximately 100–150 m above narrow and gently inclined surface of trough shoulder. On the eastern flank of the Hochsteller mountain the trimline indicates an ice level at about 2600 m. Evidence of the ice-surface level is also present on the opposite side of the valley on the ridge of the Totenkopf truncated spur (2603 m), which has a glacially moulded bedrock surface up to 2620 m. At this level a sharp boundary occurs between the lower part of the ridge with glacially moulded bedrock surfaces, and the upper part of the ridge with intensely frost-cracked Grainer Shear Zone rocks. Poorly preserved striae indicate a S to N direction of ice flow, cutting across the spur.

The Dristner mountain (2767 m) rises above the village of Ginzling, on the right side of the Zemmtal valley and close to its mouth. Basal till and glacial boulders occur to the SW of the Dristner summit, in the Wandalm and Jagdhütte Wandegg areas (ca. 1400–2000 m). At higher levels up to 2120 m, glacially moulded bedrock and individual glacially transported boulders also occur on a gently inclined surface. Above this level and up to 2300 m, only weathered, glacially moulded bedrock can be seen. Glacial overprint is clearly visible on the spur descending from the Dristner peak towards Jaunalm. The lower and steeper part of this spur exhibits glacially polished bedrock, extending up to 2250 m. A steeply inclined spur descending from Dristner (2767 m) towards the Hochstegen village (ca. 700 m) is till-covered up to 1400 m. Glacially transported boulders and till patches occur at higher levels, up to 2000 m, while glacially moulded bedrock can be traced up to 2230–2270 m, where it ends below a steep, 30 m high rock wall that cuts across the spur ridge. This rock wall marks the maximal ice truncation on the spur. Erosional landforms on the spur are very well developed and have a relatively fresh appearance. The 45° azimuths of roches moutonnées indicate a SW to NE, cross-spur ice flow direction, from the Zemmtal valley to the Stillupgrund valley. The ice flow direction was also oblique to the Ahorn gneiss metamorphic foliation (60-80/65/NW). Above 2270 m the ridge is sharp and frost-cracked, with no traces of glacial overprint. On the opposite side of the Zemmtal valley, above Gamshütte, glacially moulded bedrock can be seen as high as 2230 m on the spur that descends from Mittlere Grinbergspitze peak.

The Tuxer Joch pass (2338 m) was considered in earlier maps and papers to be a transfluence pass. On the watershed divide, between the Frauenwand summit (2541 m) and the level of 2460 m on the ridge descending towards the Tuxer Joch pass from the Hornspitze peak (2650 m), glacially moulded bedrock is evident. However, to the south of the Frauenwand summit along the watershed ridge that descends towards Kaserer Schartl (2450 m), the bedrock has no glacial overprint until at Kaserer Schartl glacial landforms again appear along the watershed. The metasedimentary rocks that form the area of the Tuxer Joch pass are prone to weathering and do not show any glacial streamline features such as striae or roches moutonnées, which could have provided evidence of ice flow direction through the pass. Investigations also failed to reveal any Zentralgneis erratic boulders at this location, which would have provided evidence of long-distance glacial transport from the Tuxer Ferner area. The Lateglacial moraines around the pass, however, suggest the presence of a small ice field that covered the broad and gently sloping area of the pass and the northern slopes of Frauenwand. This glacier was linked to cirques around the Tuxer Joch by small outlet glaciers. During this stage of glaciation – probably the Egesen Stadial – the line of ice divide is likely to have followed that of the watershed. However, a similar type of glaciation in the pass but involving diffluence rather than transfluence can not be excluded, even during the LGM.

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The Zemmgrund valley

Zemmgrund is the largest tributary valley in the Zemmtal valley system. The valley represents a typical, perfectly developed, glacial trough. It is oriented towards the NW and consists of distinctive lower and upper sections separated by a prominent, 300 m high rock threshold (or "Riegel"). This threshold is controlled by the geological structure of the Greiner Shear Zone. The lower part of the trough is 3.7 km long and 600–800 m wide, with the relief between valley floor and ridgelines reaching 2000 m. The Zemmgrund trough hangs several tens of meters above the Zemmtal trough at Gasthof Breitlahner. However, the upper part of the Zemmtal is even higher, hanging 100 to 150 m above Gasthof Breitlahner, which indicates that during Quaternary glaciations ice discharge and erosion rates were higher in the Zemmgrund valley than in the upper part of Zemmtal valley system (the Zamsergrund and Schlegeisgrund valleys).

The lower part of Zemmgrund valley is composed of Tuxer Gneiss (the "Zentralgneis"). Almost the whole of the valley floor is covered with alluvial, debris flow, and avalanche deposits, mainly as depositional cones. These cones are located below deeply incised ravines descending from adjacent cirques and trough walls. Pure talus accumulations predominate in those valley sections where smooth-faced rock walls occur and where debris transport is less channeled into ravines. There are also valley sections where large overlapping avalanche and debris flow cones create a natural valley blockade, raising the erosional base and resulting in alluvial infilling of the valley floor, as can be seen at Schwemmalm. On the valley floor, glacial sediments can only be traced at the valley mouth, immediately south of Breitlahner, where some till cover is still preserved on glacially moulded bedrock and glacial striae are preserved on polished bedrock surfaces. The right-hand side of the Zemmgrund valley between Klausenalm and Breitlahner is, in addition, covered with large angular blocks several meters across from postglacial rockfalls. Bouldery rockfall deposits also cover the right-hand slope further up the valley, near Grawandhütte (ca. 1600 m).

Glacial cirques in the lower Zemmgrund valley

The cirques in the lower Zemmgrund valley are in most cases barely accessible, as they hang 600-900 m above the valley floor. On the right-hand side of the valley, the Äußeres and Inneres Bratenbergkar cirques are dominated by talus accumulations, covering the remnants of glacial sediments. In the Steinkar cirque, however, Lateglacial lateral-frontal moraine is preserved on the proximal side of talus slopes. The moraine is bilobate in shape, has a 20 to 40 m high rock glacier-like distal slope, and consists of large angular blocks. Two or three systems of parallel moraines can be distinguished, probably from the Egesen Stadial. Below the headwall, NW of Hennsteigenspitze (3002 m) and in front of the ice-firn field, there is a small, intact rock glacier (at ca. 2700 m) of Holocene age.

On the left-hand side of the lower Zemmgrund valley the Holocene glacial land system is better developed in the cirques at NE of Greinermauer and Greinerkar, whereas only fragments of the Lateglacial moraines are preserved. These are probably remnants of glaciers that had hung up on cirque thresholds or flowed down-valley to the Zemmgrund trough. At Breites Kar, remnants of Lateglacial latero-frontal moraine occur between 2050 and 2150 m and the maximal Holocene extent of a small glacier is marked by a moraine that extends between 2500 and 2600 m. At Greinerkar there is a right-lateral moraine from the Lateglacial period (Egesen stadial?) on a gentle surface of the Prediger trough shoulder (2080–2180 m). In the Greinerkar glacier forefield a massive, latero-frontal, Holocene moraine occurs between 2300 and 2500 m. The distal slope of the moraine grades into glacigenic debris flow deposits, which cover a vast area of the cirque floor below. The moraine is tens of meters high and it is divided into two independent lobes. The western lobe is 600 m long and 120 m wide, and its terminal part has a rock glacier appearance. It consists of angular blocks 1–2 m in diameter, which were passively transported by glacier and subsequently remobilized periglacially, as indicated by the convex surface of the debris tongue with ridge and furrow morphology. The rock glacier front can be considered inactive at the present time. There are also two recessional moraines in the glacier forefield, which can be related to the 1920 and 1980 advances. Both moraine systems are composed of passively transported angular blocks. In the eastern lobe, recessional moraines are stacked on top of the Holocene maximal moraine. A considerable part of Greinerkar glacier is now covered in debris.

The upper Zemmgrund valley ("Obere Zemmgrund")

There is a long tradition of geological, geomorphological, glaciological and geoecological investigations in the upper Zemmgrund valley (summarized by HEUBERGER, Alpenvereinsjahrbuch, 102, 1977). The glacier front positions for three major glaciers (the Waxeggkees, Hornkees, and Schwarzensteinkees glaciers) have been recorded since 1890, which is the one of the longest series of glacier measurements in the Alps. Several systems of Holocene moraines occur in the merged forefields of the Waxeggkees and Hornkees glaciers. Near the Alpenrose Hütte at Waxeggalm (1870 m) there are two moraine systems older than the 1850 advance. The oldest (maximal) of the two consists of larger blocks than the internal one. A small fragment only one or two meters high of the most extensive Holocene moraine is also preserved outside the left lateral moraine in the upper part of the Waxeggkees forefield, between 2420 and 2480 m. Older moraines also occur to the north of the Steinmandl peak, where the lateral moraines of the Waxeggkees and Hornkees glaciers coalesce. A similar moraine sequence can be found close to the Berliner Hütte, to the south of the Zemmbach gorge (1980–2040 m), where three or four moraines older than the internal one (from the 1850 advance) can be distinguished. In both forefields two recessional moraines occur 400–500 m up-valley from the maximal moraines. They are 1 to 3 m high and are made up of bouldery, clast-dominated diamicton. In the Waxeggkees forefield these recessional moraines are closely spaced and partially stacked on top of each other, but in the Hornkees forefield they are 40 to 50 m apart. These moraines are known from direct glaciological observations to have been formed during the 1902 and 1923 advances. Some remnants of younger ice-marginal moraine walls can also be traced up-valley in both glacier forefields; these are related to the 1970/80 advance.

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The terminal part of the Schwarzensteinkees forefield is located on a bedrock overdeepening. The valley floor is gently inclined and filled with fluvioglacial sediments, which consist of rounded and very rounded gravel and coarse sand. A sequence of closely-spaced, parallel recessional moraines emerges from the fluvioglacial plain, which can be traced for 700 or 800 m up-valley from the terminal moraine. Interestingly, the walls of these moraines are mainly composed of fluvial material: angular, glacially transported blocks are also present but they are, in places, made up entirely of sand and gravels, which suggests that these landforms were a result of glacier pushing. Proglacial fluvial sediments were incorporated and stacked during winter advances of the glacier (annual moraines). Subdued fluted moraines can also be distinguished in this forefield; they appear as longitudinal strips of moraine material, oriented parallel to glacier flow and crosswise to recessional moraines.

In the upper Zemmgrund valley fresh Holocene moraines also occur in the Schönbichler Kar cirque, the cirque („Kar") to the west of the Ochsner peak, the Mörchnerkees glacier forefields, and in four small glacier forefields in the Roßkar cirque. Interesting landforms that are transitional between moraines and rock glaciers can be found in two of the forefields in the Roßkar cirque. One of these is situated to the west of the Mörchnerscharte notch and the second to the SW of the Roßkopfe peak (3031 m). In both forefields, glaciers have melted out completely, leaving depressions that are surrounded by passively transported debris material in massive latero-frontal arcs. This debris is ice-cored (ice-cored moraine), as indicated by the low temperatures measured in spring water (0.5°C) and relief that is suggestive of active creep. The distal slopes of these landforms are also steep (35–45° slope), high (between 10 and 40 m), and have the appearance of a typical active rock glacier front.

In the lower section of the upper Zemmgrund valley between Waxeggalm and Grawandalm, a Lateglacial lateral moraine on the left-hand slope is spread discontinuously over a distance of 1 km, descending from 2200 to 2040 m. Three separated moraine walls can be seen on a gentle part of the slope, 400 m east of the Schönbichl peak (2263 m). They consist of till with subrounded and angular blocks of Zillertal gneiss up to 2 m across. A latero-frontal moraine from the same stadial (Egesen) can also be seen in the Schönbichler Kar cirque (2100–2320 m). It is composed of the slatey material from the Grainer Zone. Striation trends measured at this location mimic very well the moraine pattern. They also indicate an ice flow direction parallel to the talweg in the main trough, where the glacier was about 270–300 m thick, and divergent flow of the Schönbichler Kar glacier around the Schönbichl peak. Up-valley, the same moraine system can be traced in the Schwarzensteinalm between 2240 and 2340 m. Although the moraine wall there is barely visible, the ice-marginal position can be easily inferred from the line of large erratic boulders, which are mainly composed of serpentinite derived from the Ochsner mountain. In the area between the Schwarzensteinkees forefield and Waxeggalm, the direction of striae and friction cracks (mainly crescentic gouges) indicate that during the Lateglacial stadial (Egesen) the three largest glaciers of the upper Zemmgrund valley and the Schönbichler Kar glacier coalesced and flowed towards the rock threshold at Grawandalm. In the vicinity of the Berlinner Hütte and Waxeggalm, streamline erosional features have not been completely erased by glacial erosion during the Holocene advances (cf. HEUBERGER op. cit. and Wintges, Salzburger Geographische Arbeiten, 11, 1984). Here, cross-cutting striae and friction cracks can be found on one bedrock surface. The older erosional stage is mainly represented by crescentic gouges, while the Holocene erosion is, in places, represented by more than one generation of striations.

The Schlegeisgrund valley

Schlegeisgrund is a 6 km long glacial trough, the lower section of which is occupied by the Schlegeis reservoir („Schlegeisspeicher"). The steep trough walls above the valley floor do not generally carry any sediments, except on the left-hand side slope at the valley mouth where till cover is preserved. The valley floor is filled with alluvial and talus sediments. Holocene moraines only occur in the upper section of the valley. The lower station of the cable-railway used to supply the Furtschaglhaus stands on the 1850 moraine. There are also two more extensive moraines. The older of these is located 180 m down-valley from the 1850 moraine and extends to a level of 1850 m. Most of the maximal terminal moraines are covered with debris flow and talus deposits or have been destroyed by fluvioglacial streams. Two advance moraines younger than 1850 occur up-valley, at a level of 2000 m (possibly from the 1900 and 1920 advances). A well-developed Holocene moraine can also be seen in Furtschaglbach valley, which hangs above the Schlegeis trough. Near the Furtschaglhaus several maximal moraines can be distinguished over an altitude ranging from 2240 to 2340 m. Two recessional latero-frontal moraines occur up-valley, into the forefield. They are composed of large, angular blocks and are 2 to 4 m high. They are probably equivalents of the Zemmgrund moraines related to the ~1900 and 1920 advances. Smaller Holocene moraine complexes in the Schlegeisgrund valley can also be seen in the forefield of the Rötkees glacier, in two forefields at the Furtschaglkar cirque, in the Reischbergkar cirque, and in the forefield of a debris-covered glacier located to the north of the Hochsteller peak. Only small, active rock glaciers occur in the Schlegeisgrund valley. One of these is located at 2780 m in the Reischbergkar cirque to the NW of the Talggenköpfe peak, while a second occurs at a level of 2640 m, to the SE of the Hochsteller peak, and is composed of slatey material derived from the Grainer Zone. A third rock glacier can be distinguished as a rock-glacierized part of the right-lateral moraine of the Schlegeiskees glacier. The creeping part of this moraine occurs above 2600 m.

The Lateglacial land system in the Schlegeisgrund valley is poorly developed. The till cover and dispersed glacially transported material can, however, be traced in the lower section of Furtschaglbach valley, where some poorly developed moraines can also be seen. Remnants of Lateglacial moraines occur in the Reischbergkar cirque, where the moraines and identifiable till cover indicate a glacier extent down to a level of 2100 m. Bouldery latero-frontal moraines occur on the northern side of this cirque. Lateglacial moraines and relict rock glacier deposits can also be found in the Schrofenkar cirque.

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