Bericht 2010 über geologische Aufnahmen der quartären Sedimente im Bereich Mölstal, Wattener Lizum, Klammalm, Tarntäler, Navisbach, Junsbach und Madseitbach auf Blatt 2223 Innsbruck und auf Blatt 2229 Fulpmes

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During 2010 Quaternary sediments and landforms were mapped over an area of about 60 km^2 around the Lizumer-Reckner peak in the Tux Alps. Investigations were conducted in the Mölsbach (Mölstal) and Lizumbach (Wattener Lizum) valleys (i.e. the upper part of the Wattental valley), the Klammalm area and the Oberes and Unteres Tarntal valleys in the upper part of the Navisbach valley, and the upper parts of the Junsbach and Madseitbach valleys (tributaries to the Tuxerbach stream). Lateglacial moraines, mass movement landforms, and postglacial sediments within these valleys are described in detail below. Glacial land systems relating to the maximum glacier extent during the Last Glacial Maximum (LGM, Würm-Hochglazial) and the Holocene rock glaciers are described separately.

Evidence of maximum ice extent (LGM)

Tracing evidence of the maximum ice extent has been rendered difficult by the mass movements that have affected a considerable proportion of the mapped area, altering the original glacial landforms. Moreover, the phyllites, schists and metasedimentary rocks that make up the main rock-types within the area are prone to frost weathering and hence provide only relatively poorly-developed glacial landforms. Landforms on the slopes around the Mölser Berg peak and on the eastern side of the Lizumbach valley, in particular, have been affected by mass movements to the extent that, even if glacially moulded rocks occur, their original location and elevation are no longer clear. The highest ice-moulded bedrock located within the area is on a plateau in the Lizumer-Reckner massif. For example polished bedrock surface occurs at 2850 m close to the Geier peak. Lizumer-Reckner massif is a local topographic culmination from which ice flowed down to surrounding valleys in every direction during periods of glaciation. Flat-topped summits are common within the mapped area, surrounded by gentle slopes and indistinct spurs, for example the summits at Mölser Berg, Hippoldspitze and Torspitze. These summits are likely to have been ice-capped or covered with slope glaciers during the LGM and the Lateglacial period, and hence ice-moulded rocks located at high levels around these peaks should be treated with caution when attempting to reconstruct ice thicknesses in the main valleys.

However, steep rock walls on the eastern flank of the Malgrübler peak (at Grünegg, above the Lager Walchen) show clear evidence of ice polishing at a level of 2100-2170 m, caused by the Mölsbach valley (Mölstal) ice stream. In the upper section of the Mölsbach valley, close to the end of the glacial trough (in the Mölsalm area) and north-east of the Eisenkar cirque, distinctive ice polishing occurs at a level of about 2320 m. Another piece of evidence of glacial erosion during the maximum ice extent lies on the watershed ridge at the head of the valley, in the vicinity of the Mölsjoch pass (2330 m), where glacially moulded phyllites are evident. 120 m to the east of this pass, a frost-weathered bedrock crest is preserved at a level of 2360 m, and 250 m north of the Mölsjoch pass there is evidence of a palaeonunatak of carbonate rocks, with a frost-weathered summit (ca. 2330 m) surrounded by polished bedrock surfaces with glacial karst features. An occurrence of ice-moulded marble can be seen here, some 10 m below the summit. These pieces of evidence suggest that during the maximum ice extent, Mölsjoch pass and ridges adjacent to it were capped with a relatively thin layer of ice that flowed away from the ridge towards the north and the south. No evidence for ice transfluence can be seen in this area. The Klammjoch (2359 m) and Mölser Scharte (2379 m) passes can, in contrast, be considered to have been transfluence passes with glacial polishing indicating a relatively high level for the ice-surface in relation to these passes. The ice flowed from south to north, i.e. from the relatively high area at the northern flank of the Tarntaler Köpfe peak (2757 m), through the Klammjoch and Mölser Sharte passes to the Mölsbach and Wattener Lizum valleys. On the ridge 180 m south-west of Mölser Scharte pass, rock drumlins and whalebacks indicate ice erosion on quartz phyllites at a level of 2415 m, and an ice-flow direction towards 350°.

In the Klammalm area at the head of the Navisbach valley, evidence of maximum ice extent is generally poorly preserved due to the schists of the Bündner Schiefer Formation having little resistance to weathering and erosion. It can however be inferred from the sharp crests to the south and south-west of Klammalm that, in this area, the watersheds above 2180 to 2200 m were never eroded by ice.

No traces of ice transfluence have been preserved at the Junsjoch pass (2484 m), whereas moraines occur on the Torjoch pass (2386 m) indicating that this pass was glaciated during the Lateglacial. Around the Torjoch pass sharp, frost-cracked ridges and spurs occur above 2460 or 2470 m on the southern and eastern flanks of the Graue Wand peak, and above 2430 m on the prominent Reisennock spur that runs down from the Torwand ridge. The maximum ice surface during the LGM can therefore be reconstructed to have been slightly below these altitudes. Ice masses that originated in a glacial cirque on the northern side of the Torwand peak probably split into two directions at the Torjoch pass, flowing east towards Nasse Tuxalm and west towards Wattener Lizum valley.

The head of the Junsbach and Madseitbach valleys is delimited by sharp, frost-shattered ridges that run from Sägenhorst in the west to Wandspitze in the south. These ridges must have protruded above the maximum ice-surface. The highest ice-moulded bedrock along the ridge that descends from Wandspitze to Kellenspitze occurs at a level of 2400 m. The upper section of the ridge that separates the Madseitbach and Junsbach valleys, between Kristallner and Hochwartspitze (2491 m), has been largely destroyed by glacial erosion. There are three culminations in the ridgeline, with clearly visible frost-weathered tops at Dunkle Spitze (2479 m) and Hochwartspitze (2491 m). During the LGM these peaks will have protruded above the ice-surface, but the smooth shape of the lower part of the same ridge, descending towards the Madseitberg peak (2292 m) indicates erosion by the Tuxertal ice stream up to a level of at least 2292 m.

The Mölsbach valley (Mölstal)

The lowest section of the Mölsbach valley has a thick layer of till covering the valley floor, which outcrops along the left-hand side of the valley. The till is matrix-supported with quartz phyllite boulders, commonly 20 to 70 cm across. It forms a distinct terrace at around the 1800 m level, and represents a remnant of a lateral moraine from a large glacier that occupied the upper part of the Wattental valley, probably during the Gschnitz stadial. On the opposite side of the Mölsbach valley, in the Möls-Niederleger, the lower part of slope is also made up of till material. However, as can be inferred from the surface morphology, the till has been incorporated into mass movement deposits resulting from creeping or sliding in the upper part of the slope. Higher up the slope, above the Möls-Niederleger, there is a line of frontal bulges of landslide colluvium composed of large, angular blocks within a mixture of debris and finer material. Still higher up the slope, above 1800 m, the deposits are increasingly dominated by boulders and cracked bedrock also occur. Landslide bulges also descend from the right-hand slope in the upper part of the valley, between Möls-Niederleger and Mölsalm, where they reach to the valley floor. Till material can also be discerned within this landslide colluvium.

The slopes on the left-hand side of the Mölsbach valley are, in general, less affected by mass movements although several smaller but clearly distinguishable landslide tongues can be seen running down to the valley floor. Moreover, landslide niches, gravitational faults, and cracks in the bedrock can be seen higher up the slope and on rock walls. To the north of Mölsalm the Mölsbach valley floor is filled with alluvial sediments containing interlayers of peat and wood fragments.

Blocky latero-frontal moraines from small Lateglacial cirque glaciers and a relict rock glacier can be seen in hanging cirques on the left-hand side of the Mölsbach valley. Their high elevation and fresh morphology, together with the abundance of passively transported debris with features commonly association with rock glaciers, suggest an Egesen stadial age for these features. The head of the Mölsbach valley above the trough end riegel is, in general, less affected by mass movements and carries some glacial sediments. At Rossboden the valley floor is covered by till up to 5 m thick showing barely visible longitudinal surface landforms indicative of glacial fluting. Karst sinkholes in the till or alluvial infill also occur. A barely visible Lateglacial latero-frontal moraine (Egesen stadial?), only 0.5 m high, occurs in the Mölsjoch pass, close to the ridgeline. It is composed of quartz phyllites which makes it distinguishable from the Rauhwacke bedrock. A sequence of three moraines can be recognized in a cirque-like depression to the north of an unnamed peak 2448 m high, immediately north of the Klammer Schober peak. A small drainage running down from the Mölser Scharte pass has been blocked by another moraine to form the Mölssee lake. The distinctive frontal slope of a relict rock glacier that reached the Mölssee lake from the east, is discordant with this moraine. In addition, there are fragments of subdued moraines at Möls Hochleger (between 2030 and 2080 m) that represent an older stadial than that of the above-mentioned moraines. The area between the Mölssee lake and Rossboden is, in general, free of sediments and consists of quartz phyllite bedrock with relatively well-developed ice moulding and local glacial striations.

The Klammalm and Oberes and Unteres Tarntal areas

In the Klammalm area of the upper Navisbach valley, near Bettlerstiegl, a relatively large landslide (covering ~0.5 km2) can be seen; it encompasses the lower part of a spur that runs down from the Kreuzjöchl peak (2536 m) and extends down to the valley floor. Scarps and ridge-top trenches with small ponds occur back up the ridge towards (Naviser) Kreuzjöchl, at around at 2300 m. The landslide is composed of debris and fine material with local bedrock lithologies (Bündner Schiefer Formation), and a rare admixture of serpentinite blocks that indicate the presence of dispersed glacial material within the colluvium. Small landslide and sackung structures also occur closer to (Naviser) Kreuzjöchl peak. In addition, in Tarntaler Köpfe peak a system of cross-cutting cracks are visible in bedrocks. The northern slope of this peak is covered with talus-like debris and very large blocks that are a product of mass movements.

At Obere Knappenkuchl and Untere Knappenkuchl (east and south-east of Klammalm) there are two Lateglacial lateral moraines between 2000 and 2220 m that mark the former position of a large glacier (Egesen stadial). This glacier had its accumulation area in a high plateau on the Lizumer-Reckner massif and flowed down the valley towards the west. It probably reached as far as Klammalm but there is no frontal moraine preserved. An admixture of serpentinite blocks can be found in the left-hand lateral moraine, whereas the right-hand moraine contains only Tarntaler Berge metasedimentary rocks and quartz phyllite debris. The Obere and Untere Knappenkuchl alms lie between these two lateral moraines. Fresh, glacially abraded bedrock with large, well-developed whalebacks, roches moutonnées, and glacial striations are evident here. A large bedrock depression (ca. 2.8 ha) between roches moutonnées (at Obere Knappenkuchl, altitude 2120 m) is filled with peat deposits.

In Obere Knappenkuchl (about 1,200 m north-west of Navise-Reckner) there are two younger relict rock glaciers (protalus lobes), which are largely covered with debris flow and talus deposits. The largest relict rock glacier (0.5 km2) within the mapped area occurs at Kuchlböden. It occupies a discordant position in relation to the right lateral moraine at Obere Knappenkuchl described above and spans an interval from 2160 from 2400 m. Its frontal slope is distinct and up to 20 m high. Despite being a relict landform subordinate bulges of debris material, as well as ridges and furrows transverse to the flow direction, can be easily seen on its surface. These characteristics are typical of active rock glaciers. On the surface of this landform some small depressions occur between ridges, often filled with pond water. The nearby Klammsee lake also owes its origin to a rock glacier deposit, which blocked its outflow from the south. At the foot of the frontal slope of this rock glacier there are springs with water temperatures exceeding 2.7 °C, which confirms the lack of permafrost (or interstitial ice) in the debris material.

Smaller relict rock glaciers also occur around the Klammer Schober peak and to the south of the Mölsjoch pass. Dispersed moraine material (serpentinite blocks) and remnants of moraine walls – probably from the end of the Lateglacial period – can also be traced on the threshold (2640 m) at the mouth of the Oberes Tarntal valley (2640 m) and on the threshold between lakes in the Unteres Tarntal

valley (2530 m). These two valleys are in fact complex glacial cirques.

The Wattener Lizum (Lizumbach) valley

The Lizumbach valley falls into two distinct sections. The lower section is a 3.5 km long glacial trough that is terminated where the stream crosses the 1760 m contour by the 200 m high rock threshold (riegel) located 350 m north of the Wattener Lizum military camp (1975 m). The large sloping areas on both sides of the valley have been affected by mass movements, with features on the western side of the valley having been destroyed by a large landslide shedding from the Mölser Berg mountain. The entire slope up to the top of Mölser Berg is made up of typical landslide sediments, i.e. diamicton composed of large angular blocks with finer crushed quartz phyllite material. On the eastern side of the valley some till patches and till admixture within the landslide colluvium can be found. A rounded glacial boulders can be seen in colluvium south of Zirmachalm. Almost the entire upper part of slope above 2000 or 2100 m between Graue Wand and Außerlann-Hochleger (Außermelan-Hochleger), has been affected by sackung processes, as shown by the abundance of ridge-top trenches, gravitational faults and cracks in bedrock. This part of slope is, in general, covered by a thin layer of till mixed with slope weathering deposits. In places these deposits are cemented with calcium carbonate, for example at Außerlann Niederleger (Außermelan-Niederleger) close to the road at an altitude of 1770 m. An interesting relation between mass movement faults and relict rock glacier deposits can be seen to the north of the Graue Wand, where a relict rock glacier is cross-cut by parallel scarps that continued into the bedrock alongside the rock glacier, indicating a Holocene age for the mass movements. There is also a section of slope preserved that was not destroyed by mass movements about 1 km to the east of the Lager Walchen, between 1700 and 2000 m, where a large area of till cover and two parallel lateral moraines remain well preserved. The position of these moraines indicates the former presence of a relatively large glacier in a small tributary valley. Moraines also occur at low altitudes (below 1880 m), which indicates that they are an equivalent of the Gchnitz stadial.

Several basins have been formed on the valley floor as a result of landslides blocking the valley. These are filled with alluvial sediments: mainly gravels and coarse sand. In some places, peat layers and wood fragments can be found within the sediments, e.g., south of the Kleibenbach tributary.

In the upper section of the valley (Wattener Lizum) only a few areas have had their slopes modified by mass movements; till cover and talus deposits generally predominate. The main valley floor between the riegel (1960 m) and the valley step (2200 m) above Lizumer Böden, is covered with glacial till, as well as large blocks of Tarntaler Berge metasedimentary rocks and serpentinite that were passively transported by a Lateglacial glacier. There is also a very well developed sequence of latero-frontal moraines, which can be grouped into three main sets, probably associated with the Egesen I-III stadials. During the formation of the oldest set, the glacier reached the valley threshold and hence the terminal moraines have not been preserved. At this stage the glacier left two main, closely-spaced, lateral moraine walls, and several minor ones formed during the recessional stage. This set of moraines can best be seen on the left side of the valley close to the military firing range (2000 m) at an altitude between 1960 and 2080 m. The right-lateral moraine of the maximal stage can also be traced on the opposite side of the valley over a distance of 1300 m at an altitude between 2060 and 2200 m. The second moraine set is composed of two morainic walls, which are associated with a large quantity of passively transported blocks. These blocks are particularly dominant in the right lateral moraine to the south-east of the military camp. During the formation of these moraines the glacier snout reached as far as the military camp (1975 m). The youngest set of moraines is composed of at least seven moraine walls. Lizumer Hutte (2020 m) is located on the maximal ones. A relatively large amount of serpentinite material occurs in the right-hand lateral moraine, 350 m south-east of the Lizumer Hutte, which can only have derived from the Lizumer Reckner massif. This clearly indicates a rock avalanche contribution to debris transport across the valley; glacial transport alone cannot explain the position of these blocks.

Well-developed and morphologically fresh latero-frontal moraines also occur at Melkboden. They are partially covered with debris flow deposits from the Torwand ridge. In the Torjoch pass the exact extent of Lateglacial glaciers is not easy to determine from the moraine geometry. As well as the moraines located directly on the pass, a barely visible latero-frontal moraine also occurs 90 m to the east of Rosskopf (2170 m). This moraine was deposited by the same glacier that flowed from the Torjoch area. The common occurrence of relict protalus lobes and rock glaciers on the south-eastern flank of the Graue Wand mountain, in the vicinity of Klammspitzen and the Klammjoch pass, and on the south-eastern flank of the Mölser Berg mountain, indicates the dominance of rock glacier types of glaciation during the final stage of the Lateglacial (the Egesen stadial).

The largest landslide in the Wattener Lizum area occurs on the western side of the Graue Wand mountain. It is composed of large blocks (up to 10 m across) of Tarntaler breccia and has a distinct lobate form. Initial slope-failure features such as ridge-top trenches and cracks in the bedrock can also be traced in the Junsjoch pass, on the Mölser Berg mountain, and on the northern flank of Klammspitzen to the east of the Klammjoch pass. Close to this last location, near Schotteben, a circular depression 25 m deep and 70 m across occurs in the right lateral moraine. This depression probably originated from extensional cracks in the bedrock that formed a sinkhole into which the till sank. A pseudokarstic explanation for the origin of this landform can be supported by the spatial relationships between other similar depressions and mass movement features that can be seen across the entire (relatively) flat area between Mölser Berg and Klammspitzen. However, a contribution from real karst processes cannot be excluded. The sinkholes in till cover are associated with fresh-looking scarps, trenches and bedrock cracks. The best developed cracks occur north of the relict rock glacier at a level of 2150 m, where the bedrock is exposed. These bedrock cracks

are several metres wide, and in some places they are so deep that the bottom can not be seen. It is worth noting that two larger sinkholes are located on the rim of the relict rock glacier 390 m north-east of location point marked on the map as 2203 m. Another large depression also occurs on the margin of a relict rock glacier on the south-eastern flank of Mölser Berg, where the original rock glacier shape (i.e. the frontal slope) has clearly been considerably modified by the loss of a large amount of sediment into the sinkhole. The described relationships between mass movement features and relict rock glaciers again suggest a Holocene age for these mass movements.

The Junsbach and Madseitbach valleys

A vast area in the Junsbach and Madseitbach valleys is covered with slope deposits of various kinds: colluvium, solifluction cover, and talus debris. Glacial tills in this area are poorly developed due to the presence of Bündner Schiefer Formation, which is not very resistant and is consequently prone to weathering. The till on the slopes is usually mixed with products from bedrock frost weathering, which makes distinguishing these sediments difficult. In areas at high elevations that are free of vegetation (above 2400–2500 m), well developed patterned ground and clast segregation due to frost action can often be seen, for example at Tote Böden. Calcium cemented debris (slope tufa) about 0.5–1 m thick occurs to the north of the Dunkle Spitze peak close to the foot path.

To the east of the Junsjoch pass, till covers the left-hand side of the Junsbach valley. Many good outcrops of these sediments have recently been provided by the construction of a road to Junsgrube. To the south of Kalkgrube and above Junsbergalm Hochleger glacial till is covered with large blocks up to 20–30 m in diameter from a large rock avalanche that originated from the Kalkwand peak. Some small Lateglacial moraines can be distinguished in the Kalkgrube hollow and below the talus slope on the south-eastern flank of Kalkwand. Lateglacial moraines from small cirque glaciers or relict rock glaciers also occur in the northern slopes of Hochwartspitze at Hochwartböden and Moosgrube, as well as near Kellenspitze in the Madseitbach valley. Larger patches of till cover occur close to the Junbach stream at An der Needer, and on the elevated plateau of Tote Böden at the head of the Madseitbach valley.

Intact Holocene rock glaciers

Neither modern glaciers nor Holocene moraines occur within the mapped area, but a small firn or ice field is suspected to have existed during colder periods of the Holocene (such as the Little Ice Age) on the eastern side of the Lizumer-Reckner summit, in the root zone of a rock glacier (2760–2800 m). Evidence for this comes from a well defined spoon-shaped depression surrounded by small ice-marginal debris ridges in the upper part of a rock glacier and fresh glacial polishing below the headwall. In the rest of the mapping area the formation of glaciers during the Holocene is only represented by intact (active and inactive) rock glaciers. Rock glaciers are considered to represent alpine permafrost, i.e. debris mixed with ice that creeps down the slope under gravity. Within the investigated area there are about 17 rock glaciers at altitudes ranging between 2430 and 2750 m, with variable sizes and morphologies. Differences result primarily from the lithology of the debris material within the rock glaciers. The largest rock glaciers occur in the Oberes Tarntal valley and on the highly elevated plateau around the Naviser-Reckner and Lizumer-Reckner ridge. They reach up to 16 hectares in size (a glacier in the southern side of the Oberes Tarntal valley) and have high frontal slopes (up to 40 m). They are generally active, which can be inferred from their fresh appearance and steep frontal slopes. The largest rock glaciers (i.e., four rock glaciers around the Luzimer-Reckner peak and one to the east of the Geier peak) are composed of serpentinite blocks. The rock glaciers occurring to the north-east of Lizumer Sonnenspitze and Tarntaler Köpfe are probably inactive. They are composed of Tarntaler Berge metasedimentary rocks. Similar debris material makes up two relatively large and possibly active rock glaciers on the northern side of the Kalkwand and Torwand ridge. In the area close to the Torseen lakes, at Pluderling, and on the northern side of Gamskarspitze and Gschützspitze in the Junsbach and Madseitbach valleys, there are rock glaciers that are morphologically different from those mentioned above. These are made up of schist fragments from the Bündner Schiefer Formation ranging from 0.1 to 0.5 m in size. These types of rock glaciers usually tend to have a lower and more subdued frontal slope and less distinct clast segregation than the normal bouldery rock glaciers. The frontal slope height of these rock glaciers is usually above 2 m but does not exceed 10 m, and in some cases they resemble large solifluction lobes. However, well developed flow structures on their surfaces, the lack of vegetation cover, and associated snowfields all indicate the existence of permafrost within their bodies.