moraine of the Egesen III advance occurs exactly in the Bodenalm alp location at a level of 1,680 m. Further up the valley talus and debris flow cone deposits entirely cover the valley floor. Some rest of the left-hand lateral moraines (Egesen I and III) and several meters thick till cover, however, occur on the slope running down to the valley floor form the Lahnkar cirque. In the bottom of the Lahnkar cirque distinct sequence of 5–6 fresh in shape and boulder-rich moraine ridges occurs which probably represent full Egesen sequence (I–III). These latero-frontal moraines are arranged into two independent moraine lobes. Frontal moraines of these lobes occur at elevation 2,050–2,160 m, are up to 5 m high and are composed of till with large, angular boulders up to 2–3 m in diameter. Less distinct, a third morainic lobe, composed of schistose material (Schönach zone lithology) occurs in the northern part of this cirque (2,200–2,300 m). In the Rachkaralm cirque distinct terminal moraines occur at 2,100–2,140 m (Egesen I?). They surround cirque overdeepening. Further up the cirque bottom (up to 2,400–2,460 m), these moraines are continued in lateral moraines which bend to form secondary latero-frontal lobe with distinct, high proximal slope (at 2,260 m). In the remaining area of the Sundergrund valley, Lateglacial moraines are poorly developed and are confined to the lower parts of cirques bottoms and areas of the Sundergrund trough shoulders. Steeply descending lateral moraines of glaciers which flowed from Kainzenkar and Hasenkar cirques can be traced close to the Rinderschneid spur (ca. 2,100–2,340 m). A lateral moraine occurs also north of the Mannlschneid spur (2,080–2,280 m) and a blocky till cover and poorly developed moraine walls can be observed in Grasleite site, 1,600 m east of the Vordere Stangenspitze mountain.

In valley floor of the Zillergrund and Sundergrund valley trough lacks of glacial deposits. They are entirely covered with talus, rock avalanche and debris flow deposits. The most of large debris cones are built of angular boulders very often up to 10 m in diameter with finer material matrix.

Holocene

The Holocene glacial landsystem and present-day glaciers occur in the head part of the Bodenbach stream valley and in the Sundergrund valley tributary cirques with exception of the Rachkar cirque. In the Bodenbach stream valley well-developed, high morainic ramps of small cirque/niche glaciers occur in the northern face of Grundschartner mountain (Roβkar cirque). In inner side of the most prominent latero-frontal moraine ramp which surrounds the easternmost glacial niche (north of Kainzenkarscharte cool), close-spaced recessional moraines and debris covers on glacier surface can be observed. A remnant of the most extensive Holocene terminal moraine (older than 1850 advance) is preserved on the high, distal slope of this ramp. Indistinct Holocene moraine systems occur also near small niche glaciers located north of Wilhelmer mountain and west of Pobergscharte cool. A complicated configuration of multilobate latero-frontal moraines of the Holocene system occur in left-hand Sundergrund tributary cirques, mostly above 2,200–2,300 m and below 2,500–2,600 m. The lowermost position of frontal moraine occurs in the trough end, in the Grieslaub site at 2,000 m. This is also an older than 1850 advance moraine, which is considerable rewashed and partially buried by debris flows. A fresh and prominent latero-frontal moraine occurs 80 m higher up slope (1850 advance). In most of the glacier forefields two recessional moraines which were formed during 1920 and 1970/1980 advances, can be distinguished. The best developed sequence of this moraine set occurs in the Schafkarkees glacier forefield. Recessional moraines in glacier forefields are commonly composed with passively transported angular blocks. In areas inside a glacier forefield where thicker till cover occurs, fluted moraines are also developed. They are clear visible, especially in the Schafkarkees glacier forefield, in the northern part of Kainzenkarkees glacier forefield and inside the northern morainic lobes in Hassenkarkees glacier and Grasleitenkees glacier forefields. Some small active rock glacier feature is also developed with association with right-hand lateral moraine of the 1850 advance in the Schafkarkees glacier forefield in Schafleite location (2,340 m). It has fresh looking, 40 m high frontal slope. An active rock glacier also occurs in the head of the Sundergrund valley, 500 m NW of the Hollenzkofel mountain. The front of this rock glacier descends to 2,370 m. There are no other intact (Holocene) rock glaciers in the mapped area.

Bericht 2013 über geologische Aufnahmen von quartären Sedimenten im Zillergrund, Sundergrund und Bodenbach auf Blatt 2230 Mayrhofen

Jerzy Zasadni

(Auswärtiger Mitarbeiter)

During 2013 Quaternary sediments and landforms were mapped over an area of ca. 40 km^2 in the lower section of Zillergrund valley, east from Mayrhofen. The major part of mapping area covers north facing slope of Ahornspitze (2,973 m) massif dissected with Arbesseitbach, Fellenbergbach, Ahornachbach and Stadelbach valleys. Remaining part of mapping area is located in vicinity of Brandberg village, on the 1,400–1,700 m high, south facing slope of Zillergrund valley descending from crest which runs between Hollenzberg, Hochfeld, Torhelm and Brandberger Kolm summits. In this area only one small valley occur. It stretches between location of Kolmhaus inn (1,845 m) and Brandberger Joch pass (2,307 m).

Evidence of the maximum ice extent (Last Glacial Maximum, LGM)

One of the best evidence of the highest position of ice erosion – glacial trimline – in the study area occurs in the spur descending westward from Ahornspitze summit toward Hauser Berg slope above Mayrhofen town. Glacially flattened topography of this spur can be observed up to ca. 2,200 m, close to Filzenkogel summit (2,227 m). Higher part of this spur has sharp, periglacially modeled form (arête). The highest location of roche moutonnées occurs at the level of 2,100 m on the flat ridge, 300 m west from Filzenkogel summit. Flat surface around Filzenalm alp is dominated with ice-moulded bedrock knobs surrounded with thin and patchy cover of till. Continues till cover composed of local Ahorn gneiss boulders occurs on the slope of Hauser Berg, below 1,600 m. Around Filzenalm alp (ca.

1,900 m) an orientation of streamlined bedrock and rarely preserved striation, indicates that ice coming from Stillupgrund valley and overpassing the ridge flowed parallel to Stillupgrund valley axe direction (toward NW). In the lower and steeper part of the spur, above Hauser Berg site (1,500–1,800 m), orientation of striation and streamlined bedrock turn to the NE direction, indicating dominance of ice masses which flowed from Zemmtal valley over the spur descending northward from Dristner summit. Glacial trimline is also well distinguishable around Hochfeld summit (2,350 m). Ice-moulded bedrock occurs there up to 2,170 m in the spur, which goes westward from this summit. In lower part of this spur, in Laberg alp (1,850 m), several angular boulders of Ahorn gneiss are dispersed on the slope. The largest boulders are 3 m in size. Provenance of boulder's lithology clearly indicates their glacial transport (erratic boulders). Very probably they were transported with glacier from the middle section of Zillergrund valley. An evidence of ice transfluence can be seen in the middle section of the ridge which runs between Hochfeld and Torhelm summits. Ice-moulded bedrock occurs there in discernible depression of the ridgeline (below 2,240 m). This section of the ridgeline stretches from point located 100 m east from the Geiskopf summits toward the east over distance of 700 m. Ice overpassed this ridge from the south (Zillergrund valley) to the north (Schönbergbach valley a tributary of Gerlosbach valley), what is evidenced with south faced ice-abraded bedrock surfaces on ridgeline.

Holocene moraines and intact rock glaciers

In the mapped area Holocene moraines occur only on the forefield of small Schneekarl glacier which is located in the highest part of Stadelbachalm valley, in the eastern flank of Ahornspitze summit. Beside high left-hand lateral moraine of 1850 advance, two recessional moraines can be distinguished on this forefield. These moraines are probably related to 1920 and 1980 advances. Two small intact (active or inactive) rock glaciers occur also in upper part of Fellenbergbach valley in Fellenbergkar cirque, north of Popbergschneid ridge. Theirs fronts reach an elevation of 2,470 and 2,650 m.

Lateglacial moraines and relict rock glaciers

In the mapping area two groups of Lateglacial moraines are distinguished basing on morphostratigraphic relations. Gschnitz equivalent moraines represent a sequence of the most distant moraines in glaciated valleys and tributary cirques. In the mapping area lateral moraines of this advance do not occur higher than 1,800–1,900 m. The second group of moraines is related to Egesen advance. It is presented as multi-moraine sequence with clearly fresher appearance than Gschnitz moraines. Egesen moraines are commonly associated with relict rock glaciers. In the Zillertal Alps upper reaches of lateral moraines of this advance commonly occur between 2,200 and 2,500 m of elevation.

Egesen equivalent moraines are restricted to tributary valleys and cirques. In Fellenbergbach valley distinct terminal moraine, represented with three moraine lobes, occurs on the valley threshold close to Hochleger site, at elevation range 1,850–2,020 m. East from Hochleger site, prominent mass of large angular blocks covers the valley floor inside the extent of terminal moraine. This 700 m long tongue of block mass reaches similar position to younger, recessional moraines (? Egesen II). The upper part of this blocky landform reveals distinct, 30–40 m high lateral walls. This landform is interpreted as a deposit of rock avalanche traveled and deposited on glacier surface during or after the second stage of Egesen advance (rock avalanche moraine). In the rooting zone of this landform small relict rock glacier developed probably during the last stage of Egesen. Well-developed relict rock glacier, characterized with distinct ridges and furrows relief on surface, occurs also in small cirque west from Am Glatzer summit. In Ahornachbach valley Egesen moraines display two distinct systems. Two terminal lobes of the first stage are located on the valley threshold in elevation range 1,900–2,100 m. The second system is represented with two rock glacier tongues located closer to cirque side rock walls and terminal moraine in the central part of the cirque (Steinkarl cirque). One of the best developed sequence of Egesen moraines in the Zillertal Alps occurs in Stadelbach valley. In the valley bottom, in Stadelbachalm alp (ca 1,700 m), up to seven moraine systems can be distinguished. Well-developed and sharp in appearance lateral moraines reach there the highest position close to 2,200 m in Stadelbacher Kar cirque. Egesen advance landforms occur also in the valley between Kolmhaus inn and Brandberger Joch pass. Sharp and blocky moraine goes there westward from Brandberger Joch over a distance of 500 m. There are also two relict rock glacier landforms, built of Hochstegen marble boulders, which occupied hanging cirque between Kleiner Kolm and Brandberger Kolm summits.

Remnants of Gschnitz equivalent glacier advance can be mapped in the lower part of tributary valleys and cirques as well in the main valleys. On the slope of Hauser Berg, close to the mouth of Stillupgrund valley, a 1,000 m long moraine wall goes from elevation 1,090 m to 920 m. It is up to 5 m high. The lower section of this moraine is destroyed with large landslide (described below). The end of moraine crest truncated by landslide is located 450 m west from Wh. Wiesenhof inn. The moraine is mostly composed of Zillertal gneiss boulders, what indicate longer transport from middle section of Stillupgrund valley. Larger boulders resting on moraine crest are up to 2 m high. In contrast, all of thick till covers, which stretch on the lower section of the southern slope of Zillergrund valley, revile only local Ahorn gneiss lithology, with no admixture of Zillertal gneiss boulders. The upper part of the moraine goes steeper and parallel to Stillupgrund valley axe, toward the north. In the lower section, the slope of this moraine crest decreases and its direction turn to the east. Course of this moraine in a given topographic context, strongly indicates low sloping, minimum 290 m thick, glacier body which occupied the depression of Mayrhofen during the Gschnitz advance. However, exact extent of terminus of this glacier cannot be determined because of lack of terminal moraine in Zillertal valley (probably filled up by alluvial deposits). Different situation is in Zillergrund valley, where terminal moraine of large Gschnitz dendritic glacier which putted together all of the ice from Zillergrund catchment (glacier ca 22 km long and ca. 130 km^2 in size) is well-preserved in Pignellen village, close to the Zillergrund valley mouth (800 m). Lateral moraines and ice-marginal moraine terraces of this advance are also preserved on both sides of the valley over a distance of 7 km up valley from terminus. On the northern side of the valley remnants of lateral moraine can be observed on slope located 800 m west from cen-

ter of Brandberg village, at elevation of 1,070–1,100 m. It is mostly composed of angular to subangular Zillertal gneiss blocks (up to 4 m in size), partially occurred as open-work deposits. The westward continuation of this moraine was destroyed by landslide which occurs below Emberg site. Redeposited boulders of this moraine are well-visible on the landslide surface. Going toward the east, a moraine terrace associated with this advance can be traced on the slope above Brandberg village and Ritzl hamlet. It ascends in elevation from 1,135 m close to Brandberg village to 1,300 m in location 700 m east from Ritzl hamlet. This terrace is built of matrix supported till with subangular to subrounded boulders, what can be observed in artificial outcrop in Schrofen hamlet, by the route which goes from Brandberg to Ritzl. On the southern side of Zillergrund valley well-developed moraine wall occurs on the slope 750 m west from Burgalm alp. It stretches over a distance of 350 m from elevation 1,205 to 1,280 m. It is composed with large, up to 3 m in size blocks. The moraine is located on the Ahorn gneiss bedrock, however, the Zillertal gneiss lithology predominates in composition of moraine boulders, what also indicates far distance glacial transport from the middle part of Zillergrund valley system. Remarkably, the eastern, upper section of this moraine is built of open-work bouldery deposit. Gschnitz equivalent moraines occur also in the tributary valleys. Remnants of latero-frontal moraines occur close to Alpenrose inn (1,350 m) in Fellenbergbach valley and in Ahornachalm alp (1,510–1,560 m) in Ahornachbach valley. In Stadelbachalm valley, similar to Egesen advance moraines, Gschnitz advance is well-recorded in moraines morphology and it also displays several moraine systems. The left-hand moraine in this valley is composed of six individual moraine walls. This moraine sequence is best discernible in transect located west from Kühböden alp, along the 1,600 m contour line. Partially, these moraines display bouldery surface. Moraine boulders in this valley have local, Ahorn gneiss lithology.

Landslides

On the both slopes of Zillergrund valley, large deep-seated landslides occur. Four such landslides can be distinguished there. The Hauser Wiesen landslide (ca. 1 km^2) is located on the slope located south from Mayrhofen. Its well-developed, 80 m high, main scarp occurs at 1,580 m, below Hauser Berg site. There is also secondary scarp above the main, which is 20–30 m high and begins at 1,750 m. The front of this landslide descends to flat alluvial fan surface at elevation 700 m. The upper part of landslide masses, just below the main scarp, is mainly composed of large blocks of Ahorn gneiss with debris admixture. The middle and lower part of landslide masses is entirely composed of till deposit. Lateral and terminal boundary of the lower part of landslide is well-defined by oversteepened marginal bulges of landsliding masses and ravine conducts along landslide sheer zones. Age of this landslide is younger than the Gschnitz advance, as the landslide destroyed the lower section of Gschnitz equivalent moraine of Stillupklamm described above. It is also younger than Mayrhofen alluvial fan (described below) as it front protrudes on this fan.

Large landslide (1.7 km^2) occurs on Ziller valley side south from Alpachaste location (810 m). Main scarp of this landside is located at 1,810 m, 1.2 km NW from Schafkarspitze. A landslide masse includes crushed bedrock packets and local bedrock blocks as well as thick till cover, which predominates in lower part of the landslide.

The next landslide (0.8 km^2) occurs on the slope between Ritzlaste (967 m) site and Kühböden alp. Mostly it is composed of large Ahorn gneiss blocks and debris/loamy matrix. It begins with prominent rock-wall scarp at elevation 1,510–1,570, below flat, till covered, surface of Kühböden alp.

In the northern side of Zillergrund valley the largest well-mappable landslide occur below Emberg site and above the location Wh. Zillergrund in the valley bottom. It has an area of 0.46 km^2 and a relief of 430 m. In the middle section of the landslide, subangular and subrounded Zillertal gneiss blocks up to 2–3 m in size can be traced on landslide surface. They are related to ice-marginal deposits of Gschnitz advance glacier which were incorporated in landslide.

Mayrhofen alluvial fan

Mayrhofen town is located on large 2.2 km wide and 1.6 km long alluvial fan, covering almost entire valley floor at the head of Zillertal valley. The discharge point of this fan is rooted in the mouth of Zillergrund valley. Interestingly, Zillergrund valley is the one of four large valleys which joins to Mayrhofen depression, but there are no comparable alluvial fans related to remaining valleys. The fan is located in urban area; therefore insight to its original surface relief and sediments is possible only in urban park in the south-eastern part of Mayrhofen. In this park abandoned distribution channels on the fan surface can be observed. They are up to 2 m deep and have steep margins, where sediments also outcrop. The fan is composed of gravels and boulders up to 1.5 m in diameter with sandy matrix. Boulders are subangular and subrounded, rarely rounded. An increase of largest boulder size going upward the fan slope is there clearly visible. Boulders are composed of Ahorn gneiss lithology, with no other lithological components, which commonly occur in the catchment of Zillergrund valley. The fan apex is located in Pignellen hamlet, at the mouth of the latest Zillergrund tributary – Arbesseitbach valley – which is entirely dissected in Ahorn gneiss bedrock. It can be inferred, that the fan deposition was related to an event of high rate of erosion in this small valley. It is worth noting, that in Arbesseitbach valley catchment do not occur any glacial sediments (till). Thus, this valley has to be dissected after full glacial condition of the last glaciation. If taking into account, that the valley dissection is related to Mayrhofen fan deposition its age of formation is also younger than Gschnitz advance.