AUSTRIAN JOURNAL OF EARTH SCIENCES
[MITTEILUNGEN DER ÖSTERREICHISCHEN GEOLOGISCHEN GESELLSCHAFT]

AN INTERNATIONAL JOURNAL OF THE AUSTRIAN GEOLOGICAL SOCIETY

VOLUME 100 2007

100 JAHRE ÖGG

Dirk van HUSEN & Michael MAYR:
The hole of Bad Aussee. An unexpected overdeepened area in NW Steiermark, Austria. 128 - 136

www.univie.ac.at/ajes

EDITORS: Grasemann Bernhard, Hugh Rice, Wagreich Michael

PUBLISHER: Österreichische Geologische Gesellschaft
Neulinggasse 38, 1030 Vienna, Austria

TYPESETTER: Copy-Shop Urban,
Lichtensteinstraße 13, 2130 Mistelbach, Austria

PRINTER: Holzhausen Druck & Medien GmbH
Holzhausenplatz 1, 1140 Vienna, Austria

ISSN 0251-7493

Gedruckt mit Unterstützung des Bundesministeriums für Wissenschaft und Forschung

The hole of Bad Aussee. An unexpected overdeepened area in NW Steiermark, Austria.

Dirk van HUSEN[1)*)] & Michael MAYR[2)]

[1)] Simetstrasse 18, 4813 Altmünster, Austria.

[2)] Salinen Austria A.G., 139, 8992 Altaussee, Austria.

[*)] Corresponding author, dirk.van-husen@telering.at

KEYWORDS

Bad Aussee, Styria
Evaporititic rocks
overdeepening
Haselgebirge

Abstract

Gravimetrical investigations show a distinct negative gravity anomaly west of Bad Aussee, in NW Steiermark, Austria. This so-called Bad Aussee Anomaly was evaluated by different geophysical methods and was believed to have been caused by a large salt body within Haselgebirge type rocks, at a depth of about 200 - 1100 m below the surface. However, an exploratory drilling revealed only lake beds down to 880 m. The generally coarsening upward sequence showed ca.300 m of very fine-grained bottom set beds influenced by calving glaciers and instabilities at the lake margins and the steep slopes with in it, covered by about 500 m of sandy to gravelly foreset beds which may be divided into ca. 300 m of distal and ca. 200 m of proximal sediments. Due to subglacial solution during an older glaciation, the inferred salt body was apparently eroded and a narrow overdeepened area was created and refilled with lake sediments during the following termination of the glaciation. The whole structure is now completely hidden by a thick till blanket from younger glaciations.

Gravimetrische Untersuchungen entdeckten eine deutliche negative Schwereanomalie westlich von Bad Aussee, in NW Steiermark, Österreich. Diese so genannte "Bad Ausseer Anomalie" wurde mit verschiedenen geophysikalischen Methoden überprüft. Es wurde als gesichert angenommen, dass sie durch einen großen Salzstock zwischen ca. 200 und 1100m innerhalb des Haselgebirges be-

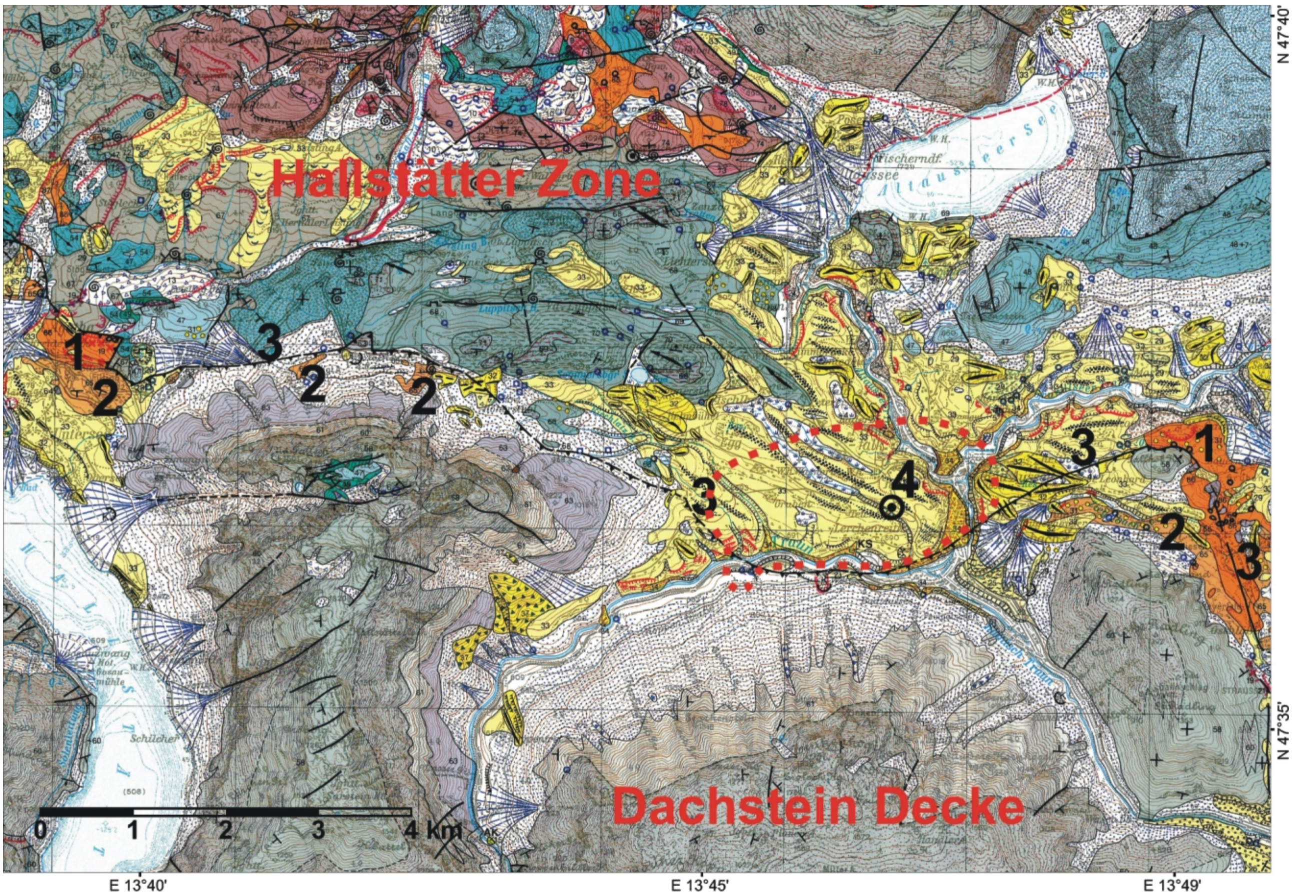

Figure 1: Geological map of the basin of Bad Aussee and the surroundings.1 "Haselgebirge" 2 "Werfener Schichten" 3 overthrust 4 drilling site Red dots mark the gravity anomaly. For more details see:Schäffer et.al. 1982.

gründet sei. Eine Aufschlussbohrung erschloss bis zu einer Teufe von 880 m nur Seesedimente. Die Abfolge zeigt ca. 300 m sehr feinkörnige bottom set Sedimente, die stark durch kalbende Gletscher und Instabilitäten der Seeböschungen beeinflusst sind. Das bottom set wird von ca. 500 m mächtigen fore set Ablagerungen überlagert, von denen wieder ca. 300 m als distale und ca. 200 m als proximale Teile der Deltaschüttung angesehen werden können. Offensichtlich ist der Salzstock während einer älteren Eiszeit erodiert worden wodurch eine kleinräumige Übertiefung entstand, die in der folgenden Termination verfüllt wurde. Die gesamte Struktur ist unter einer mächtigen Grundmoränendecke jüngerer Eiszeiten verborgen.

1. Introduction

As a result of surface and aeromagnetic investigations by the former Institute of Meteorology and Geophysics, Vienna University, the Bad Aussee gravity anomaly, was recognised. In 1980, a more detailed study, along with refraction and reflection seismic work, was carried out to get a more detailed view of its structure and extent (Steinhauser et al. 1985). This study was intended to confirm the existence and volume of the salt body, which from the beginning was assumed to be the reason for this strong gravity anomaly; the existence of a salt body at 200 - 1100 m depth was indeed confirmed geophysically (Steinhauser et al. 1985, p.19).

The geophysical data indicate that the Bad Aussee Anomaly continues for about 6 km to the east of Sarstein village and for 3 km to the north of the river Traun (Fig. 1). The central and deepest part was recognised to lie around 1 km east of the Hotel Wasnerin. On the basis of these results and misinterpretations, an exploratory drilling (13° 46' 30'' East, 47° 36' 25'' North) was carried out in 1998 by Salinen Austria Ges.m.b.H. No salt was found. The results are summarized here.

2. Geological setting

The Bad Aussee Anomaly lies directly north of the thrust emplacing the Dachstein Decke over the Hallstätter Zone in the Calcareous Alps (Fig. 1). South of it, the Triassic sedimentary sequence of Dachsteinkalk-facies forms the steep slopes along the northern edge of Sarstein, Zinken and Radling. In the north, the Hallstätter-facies forms the hilly lower surface around Pötschen Pass and the Bad Aussee basin (Schäffer et al. 1982). In many places along the thrust plane, Werfener Schichten (shale, sandstone) crop out on the lowest parts of the slopes (Radling, Sarstein). On the north slope of Zinken, these deposits are most probably covered by a thick talus. In the west (St. Agatha), as well as in the east (north of Radling), the Werfener Schichten are underlain by extensive deposits of ‘Haselgebirge’ rock types, comprising variegated claystones, gypsum, anhydrite, halite and accessory evaporitic minerals with the character of a breccia (Mandl 1999). This area of Haselgebirge rock types probably also extended to the north and west, eventually causing the entire morphological basin of Bad Aussee (Fig. 1). The Haselgebirge rock types apparently bore a huge body of salt rock that may have been located in the middle of the anomaly structure.

The Augensteinsediment, which is a distinct lithology in the Calcareous Alps, has also been found around Bad Aussee (Frisch et. al. 2001, 2002). This is predominantly composed of fragments of crystalline rocks that were deposited during Eocene and Oligocene times on top of the Mesozoic sediments of the Calcareous Alps by rivers coming from the Central Alps. Only occasional remnants of the former thick blanket of Augensteinsediment have been found on plateaus or in caves. Fragments of micaschists, phyllites, greenschists, gneisses, quartzites, and coarse quartz sand are the main sedimentary components. In the Bad Aussee basin, these crystalline rocks are frequent components of a conglomerate above the Traun riverbank (Fig.1 KS).

During the Quaternary glaciations, the Bad Aussee area was filled by a thick glacier mainly fed from the huge accumulation areas on the Toten Gebirge plateau and the eastern part of Dachstein plateau, forming the eastern branch of the Traun

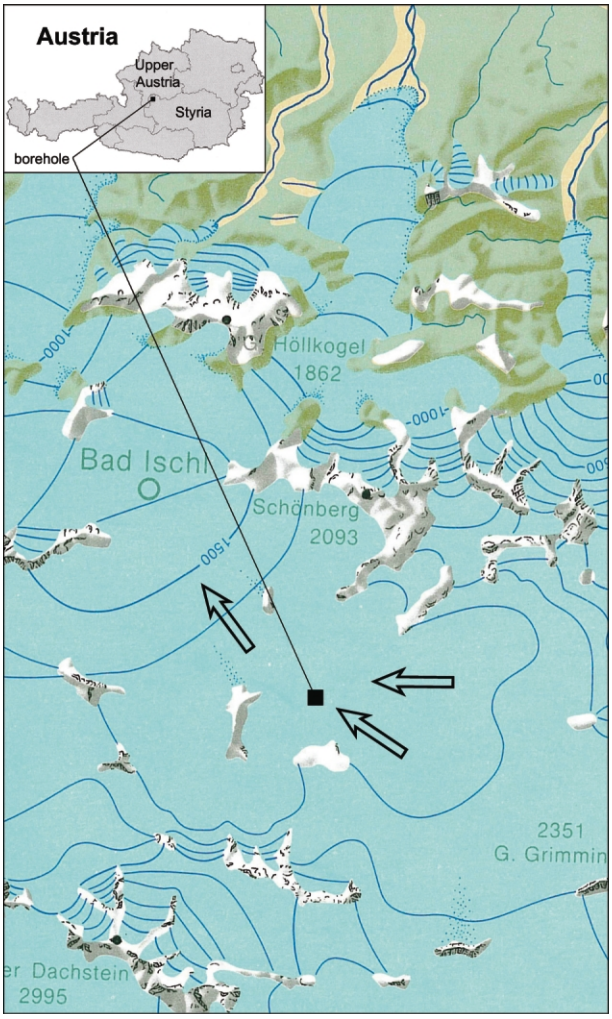

Figure 2: Sketch map of the Traun glacier system (van Husen 1987). White: nunatak, blue lines: glacier surface a.s.l. during LGM, yellow: autwash terrace, green: unglaciated area, arrows: ice flow direction in the basin of Bad Aussee.

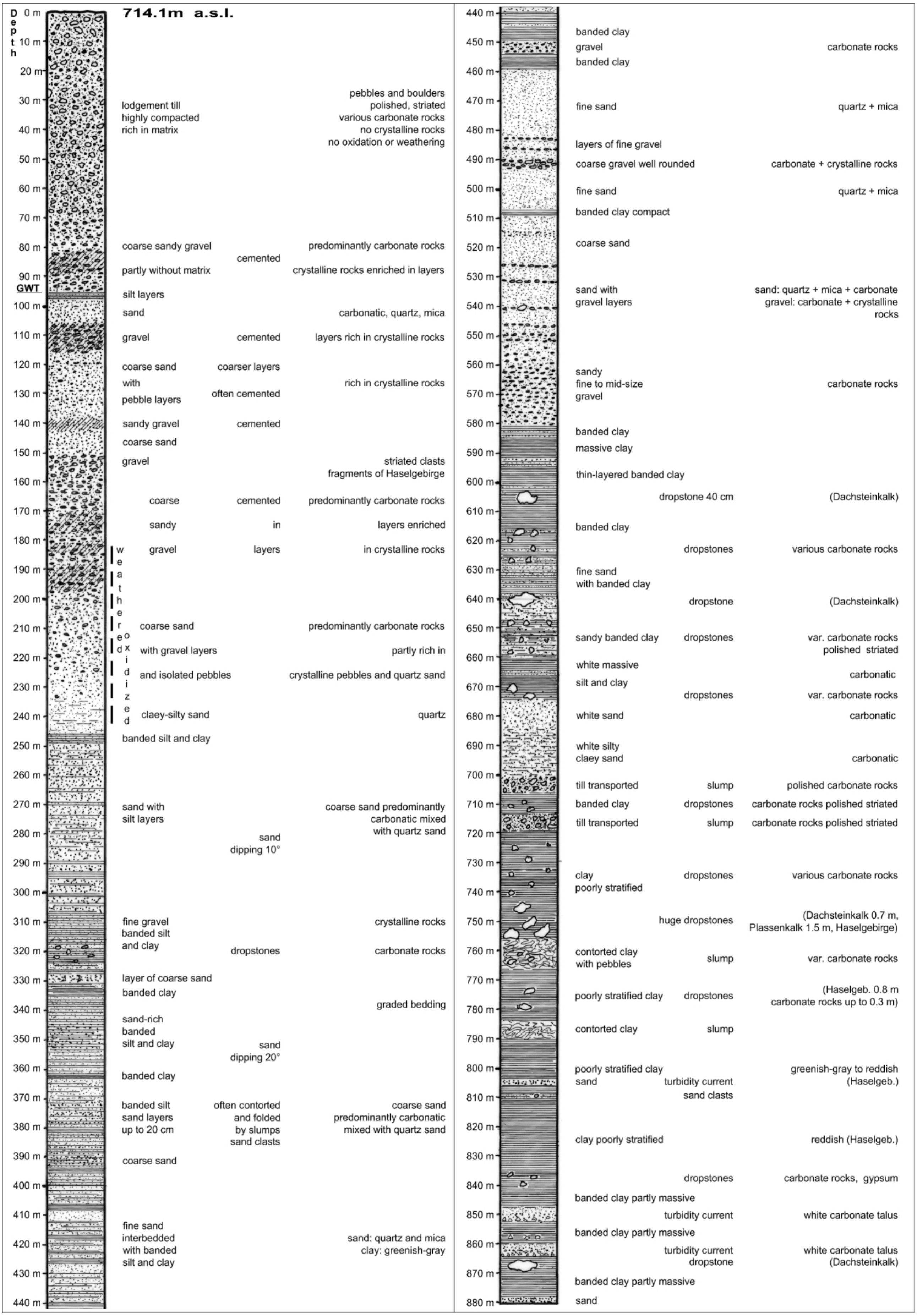

FIGURE 3: Condensed description of the sediment sequence of the exploratory drilling (Reitern 1).

glacier system (Fig. 2). This flowed from the east and southeast, following the Hallstätter Zone (Fig.1), to the northwest. The development of the last glaciation (van Husen 1977, 2000) indicates that the area was rapidly freed of ice during glacial terminations and, furthermore, was not affected by glaciers during Late Glacial periods (e.g. the Gschnitz stadial).

3. Sediment sequence of the core.

The sediments exposed by the drilling may be divided into 5 different parts classified by their grain-size distribution and the sediment type (Fig. 3). Thicknesses are given from the top downwards.

3.1 0 - ca. 68 m

At the top of the core, a highly compacted matrix-rich diamicton, generally with boulders up to 10 cm size was exposed. Boulders and clasts are often polished and striated Triassic and Jurassic limestones or dolomites, derived from the surrounding area, mixed with some Werfener Schichten sandstones. There is absolutely no evidence in the core for an unconformity or a hiatus within the diamicton. Lithology, grain-size composition and compactness of this diamicton are identical with the till of the last glaciation (Würm) outcropping along the existing river Traun, documenting an ice flow to the northwest by a well developed till fabric. Here the till is overlying on a sedimentary contact coarse gravels at ca. 670 m a.s.l. These accumulated directly in front of an advancing glacier (Vorstoßschotter, van Husen 1977) in the Traun valley at that time.

These observations suggest probably that at least the lowest 20 m of the till in the core (between 45-68m) accumulated during an older (pre-Würm) glaciation. Otherwise the Vorstoßschotter must have been deposited on this level (ca. 670 m) instead of the existing older till. Hence, the Würm-till was obviously deposited on a non-weathered erosional surface of the older till.

3.2 ca. 68 - ca. 230 m

This part is characterised by coarse gravelly sediments. The dominant grain-sizes are sand and gravel, containing boulders up to 20 - 25 cm in diameter. Although the gravels are usually sand-rich, sand-free layers also occur frequently. Changes in the sand content and gravel grain-size are never sharp. Only the 10 cm thick silt layers at 97/98 m has sharp contacts with the underlying sand and the overlying gravel. However, the drilling process influenced these contacts such that no clear bedding was recognizable. Apart from this, no sharp boundaries between layers of different grain-sizes were preserved in the core. As a result, no clinoforms could be observed.

Thick layers of coarse sand at 120 - 150 and 200 - 230 m have a marked content of mid-size rounded and well-rounded gravel clasts, in contrast to the other subrounded or subangular pebbles. Between 156 and 158m, pieces of Haselgebirgston and some striated boulders occurred within the sandy gravels.

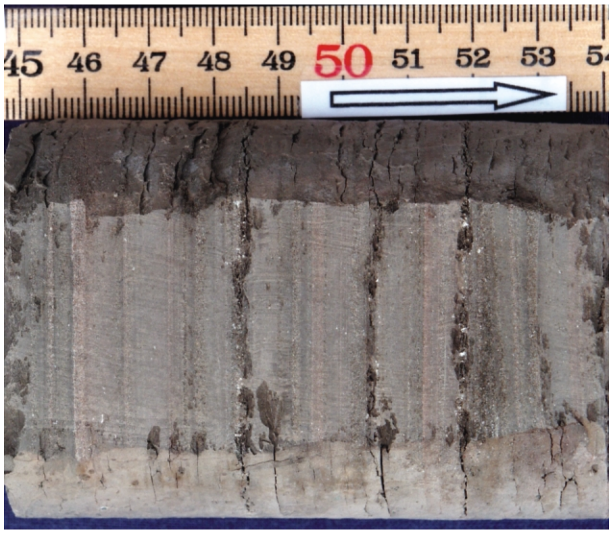

Figure 4: Depth 840m. Thin layered banded clay mainly reworked "Haselgebirgston" (grey, greenish, reddish).The variety of colours and grain-size of the thin layers are due to different sources ("Haselgebirge" and "Werfener Schichten"). Some of the layers show graded bedding (e. g. 46 cm on the scale). Arrows on the scale point to the top.

In the whole sequence of these coarse sediments, the parts with lower sand contents show cementation. The cementation varies from sticking together of some gravels to a complete massive conglomerate and is obviously related to on the grain-size distribution of the layers.

Between 180 and 240 m, both the conglomerates and the gravels show weathering and oxidation similar to outcrops of the identical material (KS in Fig. 1) above the Traun riverbank (van Husen 1977). Surprisingly, the gravel in the core above 180 m shows no oxidation and, apart from in some larger single clasts, no weathering.

The gravels are predominantly composed of limestone and dolostone grains derived from the surrounding areas. In addition, there are boulders and larger clasts of gneiss, amphibo-

Figure 5: Depth 820m. Grey and reddish reworked "Haselgebirgston". Fissures on the surface of the core paralleling the bedding are perhaps caused by different clay content due to desiccation Arrows on the scale point to the top.

Figure 6: Depth 664m. Massive unstratified white carbonatic clay.

lite, and quartz. In some layers, fragments of metamorphic rocks (phyllite, quartzite, greenstone, and quartz) occur, in particular with grain-sizes around 2 cm forming a high percentage (30 - 60 %).

The source of this material was most likely the Augensteinsediment deposited on the plateaus around the Bad Aussee basin or in caves, such as the Koppenbrüller Höhle in the Trauntal southwest of Bad Aussee.

Where water circulation was possible, cementation and weathering probably took place over a very long time, above the more clayey sediments below 246m. As a result, layers of coarser gravels with a lower sand content seem to be relatively well cemented. The astonishing lack of signs of weathering between 100 - 180 m may probably be due to the drilling process, during which weathered clasts were more or less completely mechanically destroyed.

3.3 ca. 245 - ca. 460 m

This part of the sequence is characterised by sand interbedded with layers of silt and clay. Down to 300 m, unstratified sand layers up to 20 - 40 cm thick intercalated with thin layers of silt and clay dominate the deposits. With increasing depth, the fine-grained layers become continuously thicker and more numerous. Eventually, they start to have only thin layers of very fine sand. This banded clay, for example, forms thick layers between 440 - 460 m. Only the gravel layer at ca. 450 m indicates a short interruption of the fine-grained sedimentation and was obviously due to a single and very short event.

The sand layers between 270 - 280 m and 370 - 390 m show graded and cross-bedding. There is also evidence of slumping and sliding processes like folded banded clay and clay clasts. There are also sand clasts that were deposited as frozen bodies.

The coarser material (sand, fine gravel) comprises limestone and dolostone fragments. Only at 310 - 312 m do thin layers containing metamorphic rocks occur. This is the first occurrence of material from the Augensteinsediment in the core. At this level, the influence of the coarser quartz sand from the Augensteinsediment decreases whilst the fine uniform quartz sand, detritus of the Werfener Schichten, becomes dominant within the banded clay. Mica as an associated component to the fine quartz appears around 400 m.

The greenish-grey colour of the clay beds (Grüntongebirge, Mandl 1999) indicates that the Haselgebirge rock types were the main source rock of the clay.

3.4 ca. 460 - ca. 580 m

This part is again heavily dominated by sand and gravel and lacking in clay and silt. The uppermost 50 m are composed of mica-bearing fine sand (quartz) mixed with slightly coarser sand (limestone, dolostone fragments) in varying percentages. Well-rounded pebbles of limestone, dolostone and some metamorphic rocks are embedded within these deposits. Apart from one compact layer of banded clay, the sediments are very poor in silt and clay.

3.5 ca. 580 - ca. 880 m

The lowermost part of the drilled sequence is dominated by banded clay with a decreasing sand content downwards. The mostly poorly stratified massive clay has only very thin layers of silt or fine sand (Fig 4) and its colours (Fig. 5; grey, greenish-grey or reddish) indicate it is mainly reworked Haselgebirgston (Rotsalz-, Grünton-, Buntsalz-, Grausalzgebirge, Schauberger 1986; Mandl 1999). In addition, small pieces of gypsum embedded in the clay also identify these as source material. The silt and fine sand are typical detritus of the Werfener Schichten.

Within the clay, dropstones of various carbonate rocks are often found. The undisturbed surfaces of these show striations and polishing. These rocks were carried by icebergs floating on the basin.

Massive white clay is a notable sediment (Fig. 6) as are sand layers at 660 - 700 m without any content derived from either the Haselgebirge rock types or the Werfener Schichten. In contrast, both layers of highly compacted diamicton (700 - 706 and 713 - 720 m) contain polished and striated boulders of limestone very similar to the material in the uppermost part of the core (0 -

Figure 7: Depth 705m. Till with polished carbonatic clasts.

FIGURE 8: Depth 802m. Deposits (0.5m) of a small turbidity current. Arrows on the scale point to the top.

68 m). The materials in both layers are likely resedimented till clasts transported by slumping (Fig. 7).

The uniform massive banded clay below 720 m is often interrupted by layers of contorted clay resulting from frequent slumps or sliding processes on steep slopes within the basin. The very thick contorted layers at 760 m and 790 m indicate that these slumps were transporting huge masses of clay to the bottom of the basin.

4. Interpretation

Generally, the whole sedimentary sequence below the till cover (0 - 68 m) is a coarsening-upward sequence of a delta complex (Fig. 3). The frequent evidence of sub-aquatic slumps and slides, and turbidity currents suggests it can be characterized as a 'gravitationally modified Gilbert-type deepwater delta' (Postma 1990), typical of lake deposits in considerably overdeepened basins.

Assuming that the basin morphology around Bad Aussee (Fig.1) has not changed significantly since the lake existed it had a size of around 15 km^2 and was at least ca. 900 m deep. Since the conglomerate above the Traun riverbank with metamorphic clasts (Fig. 1 KS) has the same composition as the coarse gravels in the drill core below 68 m, they can be seen as the top of the refill. The horizontal bedding indicates that these are very likely topset deposits of the whole sequence, such that the water table was probably at around 670 m a.s.l. or slightly higher.

The drainage pattern at this time was not necessarily the same as it is today. Thus, for example, during the last deglaciation the river Traun flowed to the east, into the Bad Mitterndorf basin, as a result of the different extension of the valley glaciers (van Husen 1977). For short periods, huge masses of inactive ice may also have caused local changes of the drainage pattern. Good evidence for such a change may be, for example, the deposits between 660 and 700 m (Fig. 3+6+7). Here, the resedimented tills and the conspicuous white calcareous sand and clay in contrast to the grey to greenish banded clays (Haselgebirge rock types and Werfener Schichten source areas) below and above, may indicate another source and in addition a stronger current for a short time at this place, during the deposition of the sand.

The sediment sequence from 880 - 580 m shows typical bottomset deposits of a glacier lake with calving glaciers and high sedimentation rates. Dropstones, graded bedding by turbidity currents (Fig. 8+9) and slumps with contorted clay beds are typical features (Fig. 10+11+12) of such an environment (van Husen 1977, see especially the clay pit of St. Agatha). For the fine-grained sediments, source areas in the immediate surroundings of the lake and to the east (Radling, Wienern) have been assumed. Here, large areas with Haselgebirge rock types and Werfener Schiefer were probably eroded by glaciers and rivers, and transported to the lake. Differences in the till matrix from the last two glaciations demonstrate that greater areas of these rocks were probably available for erosion in former times. Thus, the till of the Riß glaciation holds 2-3 times more of such materials than that of the Würm glaciation in the Bad Aussee basin (van Husen 1977). On the other hand, the source area of this material was also the slopes within the lake and the immediate shores around it. The different character and lithology of the sediments between 720 and 660 m are due to a short change in the drainage pattern, probably caused by active glaciers or inactive ice bodies in the vicinity of the lake (see 5).

These typical bottomset deposits of the glacial lake were followed by distal foreset sediments of a prograding delta. The transition probably starts around 590 m (Fig. 3). The abrupt appearance of gravel and sand between 580 and 515m seems to be again only a short interruption of the calm sedimentation and may have been caused by heavy flooding. The following layers of fine sand may be due to changed current conditions in this part of the lake (possibly a temporally changed drainage system at the delta plain after the flood). As a result, only fine sand was accumulated (510 - 460 m). The composition and

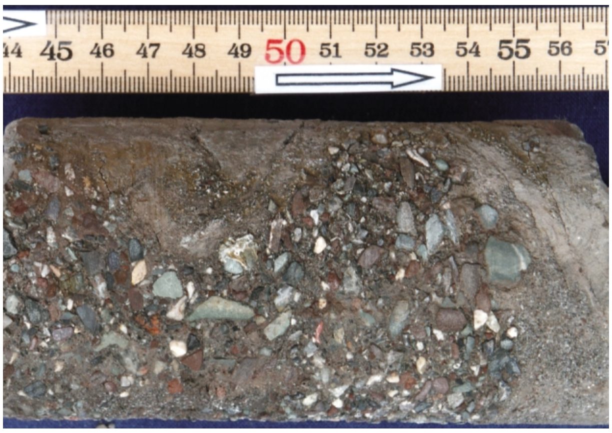

FIGURE 9: Depth 803m. Coarse part of one of the turbidity currents (different limestones, and a variety of Werfener schists). Arrows on the scale point to the top.

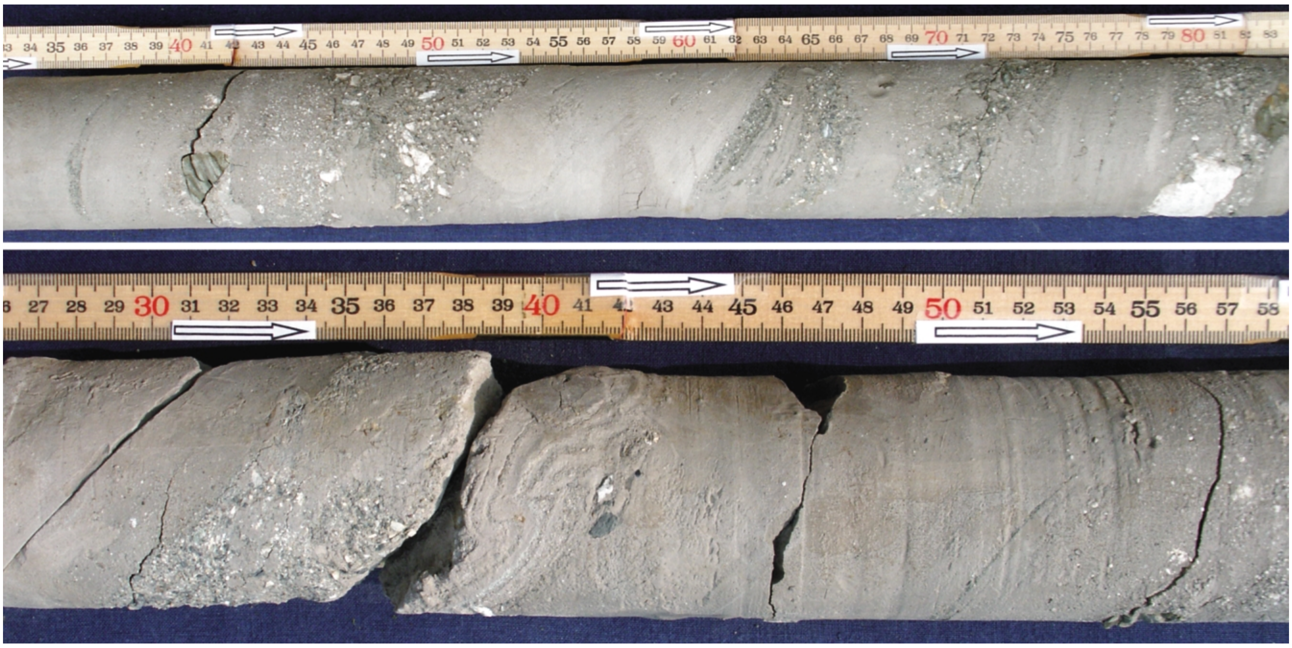

Figure 10 + 11: Depth 784/785m. Parts of a slump deposit: Intensive mixing of silty clay with talus (white limestone) and folding (note dipping in Fig. 11). Arrows on the scale point to the top.

grain-size of the sands are identical to the sand layers above 460 m; only the lack of banded silt and clay layers marks the difference to the deposits up to around 300 m. Thus they are probably also a part of the distal foreset sedimentation. This part of the sedimentary sequence, with cross-bedding, some dropstones, as well as folded and contorted banded clays can be interpreted as distal foreset deposits although they were still strongly influenced by slumps and turbidity currents. The decreasing number of these features may be due to a lower sedimentation rate at the delta and a declining slope angle and water depth compared to the bottom set deposits. A transition to proximal foresets and also perhaps to the topsets is documented by a grain coarsening (starting at around 300m) and a change in the lithological composition of the deposits.

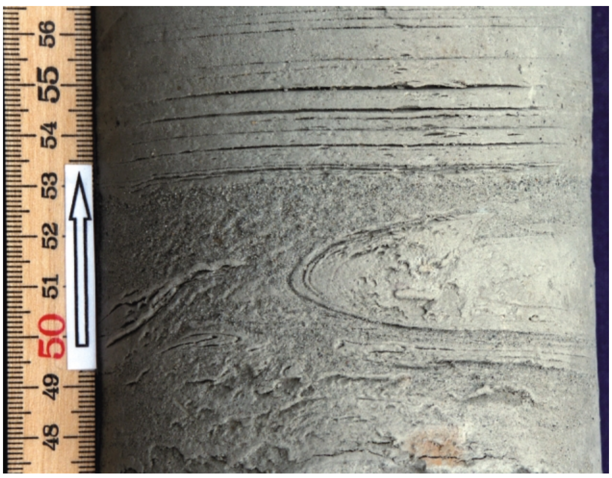

Figure 12: Depth 730m. Upper part of a ~10cm thick layer of slump deposit (fine sand and clay) with folded clay beds followed by banded clay with very thin fine sand layers. Arrows on the scale point to the top.

Thus the sandy gravels progressively became similar to the recent sediment load of the river Traun, with all the Triassic and Jurassic limestones and dolostones. The only differences are the layers with a high content of especially fine-grained gravel from metamorphic rocks and coarser quartz sand. The lithological composition of these metamorphic gravels is very similar to the Augensteinsediment (Frisch 2001, 2002) or the recent sediment load of the river Enns and its southern tributaries. It is unlikely that transport from the Enns valley was able to reach the basin of Aussee after the down melting of the valley glaciers. Hence, the source of these materials would more likely have been the Augensteinsediment from the limestone plateau or from caves.

The large volume of this material may be pointing to the formation and refilling of this overdeepened site during an early glaciation. At that time, more of the Augensteinsediment may still have been available.

5. Discussion

The drill core only documents the narrow deep hole that it was taken from. As the whole basin is hidden below a thick blanket of till, the morphology of the basin geometry can only be defined by geophysical data and the surrounding geological situation.

The formation of the overdeepened basin was very likely caused by an extensive area of Haselgebirge rock types containing one or more large salt bodies, along with the thrusting of the Dachstein Decke over the Hallstätter Zone (Fig. 1). This area was also probably one of the reasons for the morphological formation of the whole Bad Aussee basin as far as Grundlsee. During one of the glaciations, when the basin was totally covered by a thick glacier, the glacial erosion, especially in combination with the meltwater at the base of the glacier, cut through the clayey cover of the leached Haselgebirge rock types and started to dissolve the salt bodies. This likely happened below a thick, long-lasting glacier because it takes a long time to dissolve salt bodies of such dimensions. According to the gravitational prospecting, the dissolution induced the formation of a hole like an east - west stretching oval funnel (Fig. 1) with a depth of around 1100 m. This was primarily filled by glacier ice flowing into the forming hole due to its plasticity. Further glacial erosion may have occurred only in a restricted extent because the structure seems to be developed only within the former extent of the Haselgebirge rock types that may be expected by the geological situation (Fig. 1).

In contrast to the overdeepened area around the lakes in the Traun glacier system, this area was not an area of overdeepening through all the glaciations (van Husen 1979). Thus this cut probably happened accidentally. There are many other areas with similar geological situations (e.g. south and west of Bad Ischl) where the salt-bearing Haselgebirge rock types were only slightly eroded throughout all the glaciations, and were later covered by till and gravel (Neuhold et al. 1985; Mayr 1996, 1997). On the other hand the vulnerability may have been caused by salt mobility and diapirism. Simi lar features of narrow and deep dissolution and overdeepening in association with evaporitic rocks are unknown in the literature.

Whether this happened during the termination of an early glaciation or of a later one cannot be said with certainty. However, an early formation seems to be more likely because of the greater availability of the Augensteinsediment around the Bad Aussee basin at that time.

6. Conclusion

Overdeepened sections in glacial valleys have been known since the beginning of research on ancient glaciers and their palaeographic distributions. In more recent times, investigations, mostly on groundwater resources carried out by geophysical methods and drillings in such structures, have provided more and more knowledge on the shape and sedimentary fills of these basins.

In the Alps, values of some hundreds of metres of overdeepening have been documented (van Husen 2000). Only in the largest valleys has overdeepening of around 1000m been observed (Pfiffner et. al. 1997, Weber et. al. 1990). However, all of these basins are more or less elongate troughs, extending along the valley axis. As far as is known, a narrow, hole-like feature such as the Bad Aussee basin has not been reported elsewhere within either the Alps or other former glaciated areas. Even the common salt diapirs in Northern Germany had no influence on the configuration of the subglacially formed channel system (Kuster and Meyer 1979, Hinsch 1979).

This amazingly deep and narrow hole within the basin of Bad Aussee resulting from glacier activities may be a unique feature and never could have been revealed below the thick blanket of till without the drilling based on data-misinterpretations.

Acknowledgements

The authors wish to thank the "Salinen Austria A. G." for permission to publishing data from the exploratory drilling Reitern 1. Mr. R. Nußbaumer ZT-Büro Moser / Jaritz Gmunden for doing the drawings, and an anonymous reviewer for the suggestions to improve the paper.

References

Arbeitstagung der GBA Blatt 96 Bad Ischl. 1976. Geologische Bundesanstalt, Wien 48 pp.

Arndt, R. and Mayr, M. 2003. Prospection and Exploration of Alpine Salt Deposits. A Challenge for Geologists and Geophysicists. Erzmetall 56, 257-264.

Frisch, W., Kuhlemann, J., Dunkl, I., and Székely B. 2001. The Dachstein paleosurface and the Augenstein formation in the Northern Calcereous Alps - a mosaic stone in the geomorphological evolution of the Eastern Alps. Intnational Journal of Earth Sciences, 90, 500-518.

Frisch, W., Kuhlemann, J., Dunkl, I., Székely B., Vennemann, T., and Rettenbacher, A. 2002. Dachsteinaltfläche , Augenstein - Formation und Höhlenentwicklung - die Geschichte der letzten 35 Millionen Jahre in den zentralen Nördlichen Kalkalpen. Die Höhle, 53, 1-37.

Hinsch, W. 1979. Rinnen an der Basis des glaziären Pleistozäns in Schleswig-Holsteins. Eiszeitalter u. Gegenwart 29, 173-178.

Husen van, D. 1977. Zur Fazies und Stratigraphie der Jungpleistozänen Ablagerungen im Trauntal. Jahrbuch Geologische Bundesanstalt, 120, 1-130.

Husen van, D. 1979. Verbreitung, Ursachen und Füllung glazial übertiefter Talabschnitte an Beispielen in den Ostalpen. Eiszeitalter u. Gegenwart 29, 9-22.

Husen van, D. 1987. Die Ostalpen in den Eiszeiten. Geologische Bundesanstalt, Wien, pp24.

Husen van, D. 2000. Geological Processes during the Quaternary. Mitteilungen Österreichischen Geologischen Geselschaft 92, 135-156.

Kuster, H. and Meyer, K.D. 1979. Glaziäre Rinnen im mittleren und nordöstlichen Niedersachsen. Eiszeitalter u. Gegenwart 29, 135-156.

Mandl, G. W. 1999. Short notes on the Hallstatt salt rock - the "Haselgebirge". Berichte d. Geologischen Bundesanstalt, 49, 91-95.

Mayr, M. 1996. Die Aufschlussbohrung "Rabennest 3. Salz aktuell, Nachrichten des Unternehmensverbandes der Österreichischen Salinen, 6-8. Bad Ischl.

Mayr, M. 1997. Die Aufschluss-Bohrung Kaltenbach 11. Salz aktuell, Nachrichten des Unternehmensverbandes der Österreichischen Salinen, 9-11.Bad Ischl.

Neuhold, R.; Schauberger, O. and Thomanek, K. 1985. Die Entwicklung der Bohrlochsolegewinnung aus dem Trauntaler Salzlager bei Bad Ischl, Berg- u. Hüttenmännische Monatshefte 130, 104-110.

Pfiffner, O. A.,Heitzmann, P., Lehner, P., Frei, W., Pugin, A. and Felber, M., 1997. Dynamic Alps. Incision and backfilling of Alpine valleys: Pliocene, Pleistocene and Holocene processes. In: O.A. Pfiffner, P. Heitzmann and P. Lehner (eds.), Deep structure of the Swiss Alps., Birkhäuser, Basel pp 265-288.

Postma, G. 1990. Depositional architecture and facies of river and fan deltas: a synthesis. Special Publications international Association. Sedimentology. 10, 13-27.

Schauberger, O. 1986. Bau und Bildung der Salzlagerstätten des ostalpinen Slinars. Arch. f. Lagerstättenforschung Geologische Bundesanstalt, 7, 217-254.

Schäffer, G., van Husen, D., Janoschek, W., Pistotnik, U., and Schöllnberger, W..1982. Geoleogische Karte der Republik Österreich 1:50.000. Geologische Bundesanstalt.

Steinhauser, P., Meurers, B. and Aric K.1985. Geophysikalische Detailuntersuchung der Schwereanomalie von Bad Aussee. Geophysikal. Forschungsbericht Nr. 18. Institut f. Meteorologie und Geophysik Univ. Wien,31pp.

Weber, F., Schmid, Ch. and Figala, G., 1990. Vorläufige Ergebnisse reflxionsseismischer Messungen im Quartär des Inntals/Tirol. Zeitschrift für Gletscherkunde und Glazialgeologie, 26, 121-144.

Received: 03. July 2007
Accepted: 28. August 2007

Dirk van HUSEN[1)*)] & Michael MAYR[2)]

[1)] Simetstrasse 18, 4813 Altmünster, Austria.

[2)] Salinen Austria A.G., 139, 8992 Altaussee, Austria.

[*)] Corresponding author, dirk.van-husen@telering.at