T. Pippan

THE LATE GLACIAL TERRACES AND REMNANTS OF INTERGLACIAL SEDIMENTATION IN THE SALZBURG BASIN

Reprinted from :

REPORT OF THE VIth INTERNATIONAL CONGRESS ON QUATERNARY
WARSAW 1961
VOL. III: GEOMORPHOLOGICAL SECTION

Łódź 1963

Therese Pippan
Salzburg

THE LATE GLACIAL TERRACES AND REMNANTS OF INTERGLACIAL SEDIMENTATION IN THE SALZBURG BASIN

In the Salzach valley between Salzburg and Golling, the Salzburg Basin *sensu lato*, there are terraces of late glacial age which I was able to distinguish during the course of mapping for the Geological Survey of Vienna. The most important criterion for dating is the morphology of the terraces, i.e. their height, surface form, the sharpness of their edges and the angle of slope of the bluffs. Another distinguishing feature is the thickness of the soil, which however has been modified by agricultural activity. The situation is farther complicated by artificial terracing associated with road and railway cuts and the banks of water courses.

On the concave side of the meanders the terraces are usually much reduced in area, while on the slipoff slope they are broadly developed. In the true Salzburg Basin between the city and Grödig the terraces are particularly extensive. On the concave bends of the Salzach and near the apices of the tributary fans, the terrace bluffs are abnormally high; where the river has retreated to a greater distance from the bluffs they become lower and the edges are more rounded. The terraces bordering tributary entries are extremely difficult to trace because of the mutual interference of erosion and deposition by the tributaries and by the Salzach. Between this river and the Saalach the bluffs are very distinct but their relationship is obscured by the occurrence of secondary bluffs.

The angle of slope of escarpments cut purely in gravel deposits is 25—30°, but in nagelfluh or solid rock it is steeper. Even if the solid rock is only intermittent the whole course of the bluff remains steep, and may attain an angle of 45—50°.

The Salzach valley was covered by a lake during the retreat phase of the Würm glaciation and consequently the sediments were not much affected by periglacial influences. Instances of cryoturbation are rare, but "Delle" frequently cut back into the terrace edges. The terraces can be classified as flood plain, Gschnitz- and Schlern terraces, and a similar division marks the dissection phases of the tributary fans.

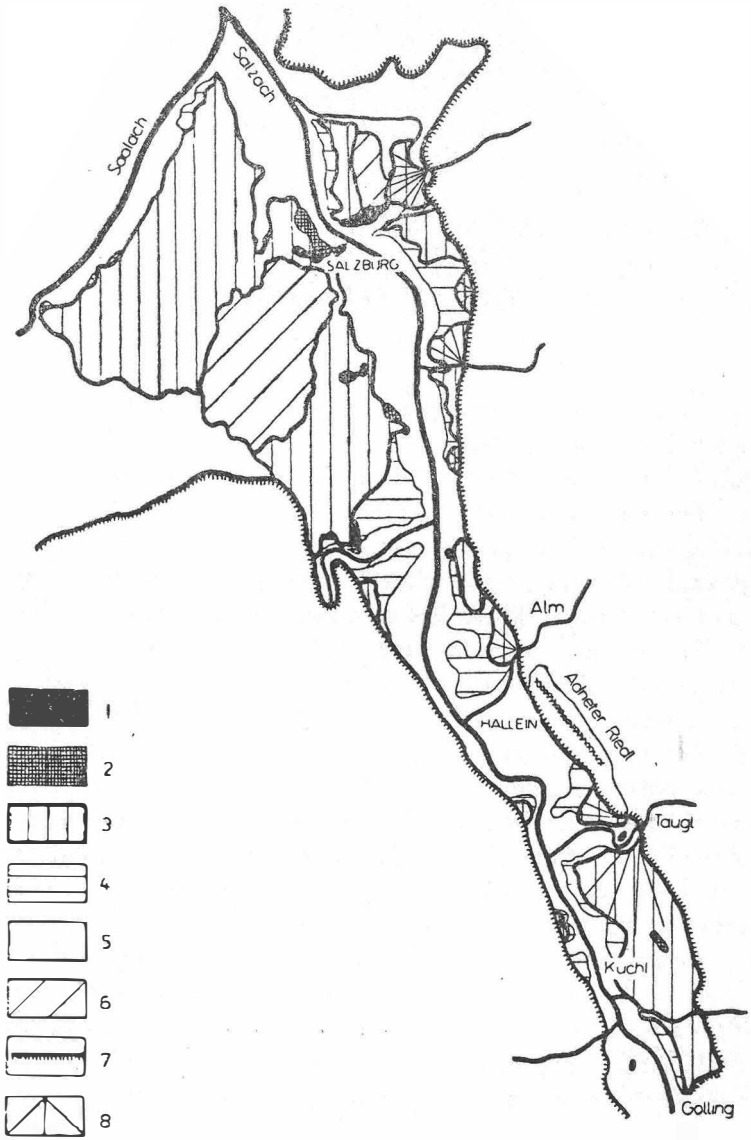

Fig. 1. The late glacial terraces and interglacial sediments in the Salzburg Bassin
1. solid rock; 2. Interglacial — Nagelfluh; 3. Schlern terrace; 4. Gschnitz terrace; 5. flood plain; 6. bog, peat; 7. foot of the valley sides; 8. fan

For a better understanding, the flood-plain terraces may be briefly discussed. These are particularly extensive in the true Salzburg Basin. They are composed in part of horizontal- and cross bedded coarse-grained gravels, with much sand. The coarse constituents are a strong mixture of local Salzach gravel and well rounded pebbles from more distant sources including abundant crystalline material from the High Tauern. However, where tributary fans are incorporated in the gravel train there are concentrations of local limestone fragments which are coarser, less well rounded and more poorly bedded, while near Salzburg flysch material is predominant too. The flood plain is often covered with waterlaid loam. The soil thickness ist most commonly 1,5 dm. The surface of the terrace retains features of the former river bed: in this it contrasts with the Gschnitz- and Schlern terraces. The most typical features are shallow dry channels which run for several decameters roughly parallel to the river. They are from half a meter to two meters deep and up to 15 meters wide, with gentle sides. They originated as the branches of a braided river during periods of flood, and have been abandoned as the result of changes in the flow axis. They often occur on the back of the flood-plain terrace at the foot of the Gschnitz- or Schlern terraces.

In addition to these channels, the surface also shows an irregular alternation of very gentle rises, which are gravel banks, with intervening broad flat troughs. This topography of channels, rises and troughs is best observed in the flood-plain woodland, in contrast to the more softly rolling surface where cultivation has probably levelled the relief artificially.

The bluff of the flood-plain terrace drops two to three meters towards the Salzach or its tributaries. It is sometimes composite in form with two or three steps.

THE GSCHNITZ TERRACES

The Gschnitz terrace is also known as the Hammerau terrace, so-called by E. Seefeldner from the type locality of Hammerau near Salzburg. It is attributed to the Gschnitz stage because it is intermediate in level between the flood-plain and the Schlern stage. As there are occasional cryoturbation features in the gravel mass the terrace is believed to have originated during a cold phase. It is found in discontinuous fragments on both sides of the Salzach from the northern edge of the Salzburg Basin to Golling. The terrace varies in freshness and in level, and is often cut into tributary fans. It is difficult to trace it in the built-up area of the city,

because of human interference with the relief. The sediments are similar in character to those of the flood plain. The gravels are unvariably uncemented. At the top there is often clay or sandy loam. The soil averages 2 dm in thickness and is often thicker in the flysch area. The bluffs are usually one and a half to two meters high where the river has retreated from them, 2 and a half to five meters where undercut by the river, and up to 3 and a half meters near the apices of fans. Sometimes the bluffs of the flood plain and the Gschnitz terrace are united into a single slope. The surface of the latter has no channels, and the rises and troughs are much gentler than those of the flood-plain terrace. The levelling of the surface has again been influenced by human activity. The angle of slope of the bluffs ranges from 25 do 50°. The higher values are found at escarpments near the river or at concave slopes.

In the confluence angle between the Salzach and its tributaries the bluff of the Gschnitz terrace is low, ill-formed and difficult to trace because the picture has been obliterated by gravel shoal deposition.

THE SCHLERN TERRACE

The Schlern terrace of the Salzach valley was designated by E. Seefeldner as the Friedhof terrace. He correlated it with the Schlern stage through its relationship with the Schlern moraine at Melleck in the Saalach valley. It is particularly well developed in the true Salzburg Basin, especially at the city cemetary or Friedhof which is the type locality. From here it extends, with interruptions, both downstream to the northern edge of the city on either side of the Salzach, and upstream to Golling. Its level is variable, and so is also its degree of freshness.

In composition, bedding and lack of cementation the gravels of the Schlern terrace are similar to those of the Gschnitz- and flood-plain terraces. Both the far-travelled, sandy, crystalline gravels of the Salzach and the local calcareous gravels of the tributaries are quite uncemented. The steeply falling tributaries often have very coarse boulders. In addition to its gravels, the terrace surface is formed locally of rock waste, solid rock and interglacial nagelfluh, which is a puddingstone conglomerate. The nagelfluh occasionally projects through the terrace surface to form knob-like hills, both in the true Salzburg Basin and at Kuchl and Golling.

The average soil thickness on the Schlern terrace is two and a half to three dms on mixed gravels, two dms on calcareous gravels, and up to a meter on the flysch.

The surface is generally more levelled out than that of the Gschnitz terrace and most of it is extremely flat. At the confluence angle of the

Salzach and the Saalach the frontal bluff is often somewhat composite, probably because the weaker Saalach has been depositing while the more vigorous Salzach has been eroding. The secondary steps with the bluffs could also be caused by the existence of solid rock- or nagelfluh cores.

The bluff of the Schlern terrace commonly rises two and a half meters above the Gschnitz terrace but attains 5 to 8 m where it is undercut or at the axis of tributary fans. Where the bluff is higher its average gradient is greater. 40 to 50° is attained where the river has cut beneath fan apices, and 45 to 50° on the concave banks of meanders, while where the river has retreated from the bluff it averages only 20 to 30°. Where solid rock is incorporated in the bluff the slope gradient may be as much as 45°. In this case, that part of the bluff which is gravel, is also steeper. When the insertion is of nagelfluh, the gravel slope is 35°.

Both in built-up areas and at the confluence angle between the main river and its tributaries, the bluffs are vague and therefore it is difficult to delimit the Schlern terrace from the Gschnitz or flood-plain terraces.

In the true Salzburg Basin bogs have become inserted in the Schlern terrace. These have developed in the hollows between fan and terrace deposits.

THE INTERGLACIAL NAGELFLUH REMNANTS

In the Salzburg Basin, *sensu lato*, there are numerous outcrops of nagelfluh, the distribution of which is similar to that of the late glacial sediments. The position of these remnants is in the main related to the Salzach meanders. They are generally located in sheltered sites, often in the lee of a projecting valley spur. Their occurrence in widely separated parts of the valley shows that the whole valley must have been infilled with interglacial sediments which have subsequently been eroded by river action and surrounded by late glacial and recent deposits.

The nagelfluh of the northern Salzburg Basin is represented notably by the Mönchsberg and the Rainberg. It is very well bedded, but the beds change rapidly in thickness and grain-size in both the horizontal and the vertical direction. The irregular sequence of coarse and fine beds is not due to seasonal alternations of sedimentation, but comes from the wandering of the flow axis, and variations of discharge in the catchment areas of the various streams which delivered the gravels into the interglacial lake. The nagelfluh is generally well cemented. The beds dip at angles from 10 to 30°, in a west to northwesterly direction. There is a predominance of local material from the Calcareous Alps as compared with far travelled crystalline pebbles. The components are well rounded

and in the main very coarse. The nagelfluh has been preserved in the lee of the Castle Hill at Salzburg, and also in the angle between the Salzach- and the Saalach glacier, where glacial erosion was rendered less effective by the mutual damming of the two confluent ice bodies. The rock faces display horizontal notches which are due to incision by the river, and inclined notches following the dip which result from the outcropping of less cemented sandy beds. The latter kind are termed „Gufeln", and are caused by the combined action of weathering and rainwash. The nagelfluh south of the true Salzburg Basin consists mainly of local limestones from the Calcareous Alps. The fragments are well cemented in horizontal, or sometimes dipping beds. They often display strong honeycomb weathering of the medium- to fine-grained, rather angular material.

There is an unconformity between topset- and foreset beds at 490 m which has hitherto been thought to indicate a Riss—Würm interglacial lake level and that at 540 m a Mindel—Riss lake level. These lakes submerged the Salzach valley after the ice retreats until the overflow channel had cut down through the enclosing terminal moraines in the Foreland.

Contrary to these accepted views I could find that the level of the nagelfluh and of the unconformity between topset- and foreset beds are not necessarily a reliable criteria for dating. This problem is most marked at the tributary mouths, where deposits may have been laid down in ice--dammed lakes during the ice retreat. The interglacial nagelfluh was deposited over a strongly dissected relief cut in solid rock and possibly remnants of older nagelfluh. A. Penck pointed out the uneven base of these sediments. According to him the level of the unconformity between topset- and foreset beds of Riss—Würm age falls from 490 to 440 m down the valley, and thus it is often difficult or impossible to date the particular exposures. The possibility of late tectonic displacement must be considered: interglacial sediments on the valley sides may have been uplifted, while those in the valley bottom which follows a dislocation, rejuvenated by isostatic adjustement to the weight of the subsequent glacier may have been depressed. The great thickness of the nagelfluh in the Salzach valley is consistant with this idea of tectonic depression. The only stratigraphical proof of dating which could be considered valid would be the direct superposition of two nagelfluh sequences at several places, seperated by moraines and each with its own topset- and foreset beds. But such unequivocal cases have not yet been found.

The degree of cementation too is no firm evidence in dating. In fact it changes very quickly according to the availability of calcareous material and lime-rich water. The nagelfluh of the Riss—Würm interglacial can be as strongly cemented as that of the Mindel—Riss. On the other hand the earlier sediments may contain quite loose sandy insertions.

Honeycomb weathering is equally inadequate as a criterion of age. It occurs in both early and late nagelfluh and is dependant upon local variations in the material. The pebbles weather very quickly and intensely in the permanently damp and shady gorges.

A. Penck's view, that Mindel—Riss nagelfluh consists mainly of Salzach sediments and Riss—Würm — mostly of tributary deposits, is not correct. In both interglacials conditions of sedimentation produced a composition of materials similar to the present, and it is near the tributary mouths that local pebbles are most concentrated. It was not possible in any case to date the nagelfluh from its constituents.

The large erosion remnants of nagelfluh preserved at the Adneter Riedl near Hallein are particularly illuminating upon this problem of dating. The sediment occurs from 560 m at the top of the hill down to 460 m near the bottom of the Salzach valley. A. Penck interpreted this as an upper Mindel—Riss nagelfluh of Adnet extending down to 530 m and a Riss—Würm nagelfluh of St. Margarethen reaching up to 500 m. The upper edge of the latter is supposed never to touch the lower edge of the Adneter nagelfluh. But the latest investigations show two sections where the sediment can be traced through a vertical distance of 45 to 80 m respectively almost without interruption down nearly to the Salzach valley floor. It is not possible to find any clear break between the upper and more ancient deposits and the lower later ones. The Adneter nagelfluh has been deposited by the Wiestal Alm where it opens into the Salzach valley and therefore consists of coarse, well cemented gravels from the local Calcareous Alps. Further west, on a lower part of the slope the Salzach has a stronger influence and progressively contributes more far-travelled gravels of finer grain size and more crystalline components. The petrographic differences in the deposits do not necessarily mean a difference in age, as they can be explained by differences in the respective catchment areas. The bedrock, which is Oberalmer limestone occurs at various levels beneath the nagelfluh. A. Penck's statement concerning the basal level of the upper nagelfluh and the upper edge of the lower nagelfluh does not agree with the latest findings, probably because of the inaccuracy of the base-map in his time. As he assumed that the Riss—Würm interglacial sediments were of local character, he should have dated the Adneter nagelfluh as Riss—Würm, but in fact he dated it as Mindel—Riss. The horizontal beds of the northwestern part of the Adneter nagelfluh come down to 510 m without any deltaic beds beneath them. If, after A. Penck, we were to interpret them as Mindel—Riss topset beds, they should not come down below 540 m if they are to correspond in level to the Mindel—Riss interglacial lake assumed by E. Stummer. Thus discrepancies arise if we consider the Adneter Riedl nagelfluh not

to be of the same age throughout[1]. If according to A. Penck, we correlate the horizontal beds of the Adneter Riedl as topset beds related to the Mindel—Riss deltaic sediments of the Mönchsberg, this would involve a total thickness of 130 m, and if we assume that the Adneter and St. Margarethen nagelfluh is all of one age this would mean a thickness of 86 to 100 m, which is a very likely value.

Similar conditions are true of the Georgenberg near Kuchl. In this case A. Penck has assumed correctly that the whole deposit is unitary as to age. However E. Stummer distinguished a Mindel—Riss northern part and a Riss—Würm southern part, but the present investigation has not confirmed this view, because there is no break separating the sediments of assumed different ages and no difference of level and bedding.

---

[1] According to latest pollen analytical investigations of W. Klaus (*Verhandl. Geol. Bundesanstalt, Wien*, 1962) the Adneter Nagelfluh of Mayerhof on the Adneter Riedl contains pollen from the R-W interglacial. This result supports my view that the nagelfluh of the whole Adneter Riedl is of one age.