Preserved strata of synsedimentary rotated loose sediments formed in a dead ice environment

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In Drau valley (Carinthia, Austria) cohesionless unconsolidated sediment sequence with an inclination between ca. 90°–40° were found. The arrangement of the strata indicate a synsedimentary rotation. Formation of these strata probably occurred in contact with dead ice.

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Introduction

In 1977, during the opening of the construction pit of the water power station Annabrücke (Carinthia, Austria) by »Österreichische Draukraftwerke AG« a sedimentary sequence was exposed on the valley floor with a texture and dimension which at the time of writing are unique in the Eastern Alps. The layers consists of cohesionless gravels and sands with steep (30–40°) to vertical inclination and are visible over the whole area of the construction pit (ca. 100 × 300 m). Boreholes revealed that the areal extent of these strata could be increased som 100 m or more along the valley (Fig. 1).

For general description of the geological situation in the water power area see Ucik (1982). The technical difficulties resulting from these extraordinary sediment structures and their solution are explained by Breth, Demmer and Ludwig (1982).

This paper will give only a short description of the sedimentological features and their genesis.

Sediments

The surfacial cover in the construction pit area is formed by several meters of recent sandy gravels from the river Drau. This fluvially formed layer was deposited on an erosive surface.

The underlaying sediments consisted sporadically of till, but generally of gravels, and and silt forming the steeply dipping cohesionless strata. Within these strata mixtures of gravels and sand, common to river sediments, occurred rarely. A very limited grain size distribution within most layers was found. Some layers contained only coarse gravels and no fine material, whereas others contained silty and or silt-free sand but no gravel (fig. 2).

These layers of thicknesses up to 5 meters and more formed an aperiodic sequence. Between these fluviatile layers a concordantly deposited 0,5 m thick till was found (with only limited distribution). The till was interpreted as a flow till even though exact differentiation was not possible, which would indicate deposition of this sedimentary sequence close to an ice margin.

However, the gravels of the coarser layers showed the same degree of roundness as the modern gravels of the Drau river. This, as well as the lack of faceted or striated pebbles, suggests transport of the material over longer distances, probably along or within the down wasting ice masses of the Drau glacier.

The contact of such differently composed layers was in all places concordant. Thus, the younger layer filled up the given relief of the underlying one (fig. 3). Further more, in no case could faults or folding of the layers or their contact plains be seen.

Despite the concordant nature of the strata an no apparent indication of tectonic activity the inclination of the strata varied systematically throughout the pit. The layers in the northern

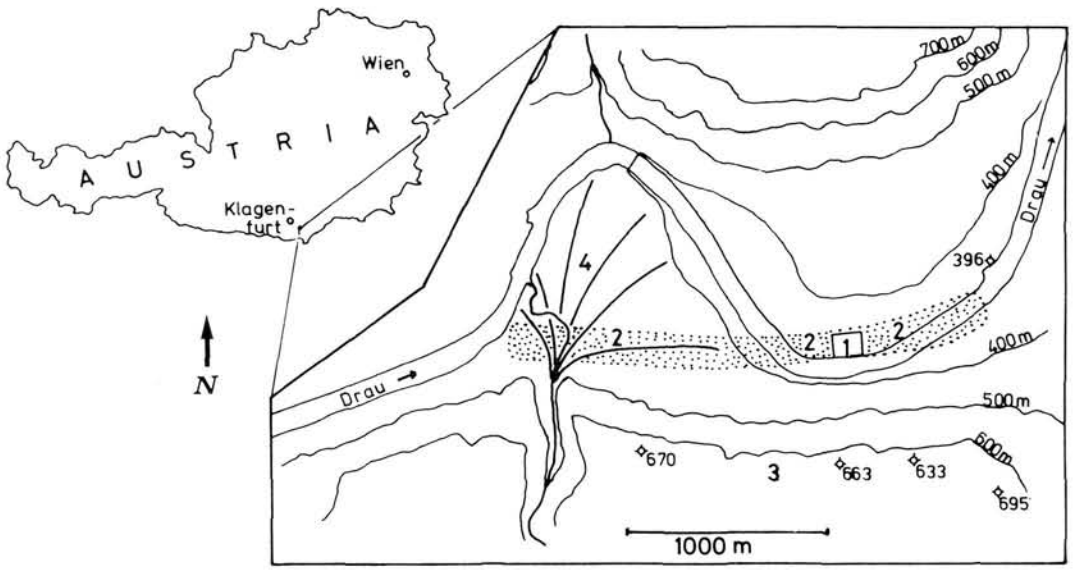

Fig. 1. Position of the water power station Annabrücke and general topographic situation.
1: water power station.
2: known distribution of described and similar sediments.
3: south rim of Drau valley.
4: alluvial cone of Freiback river.

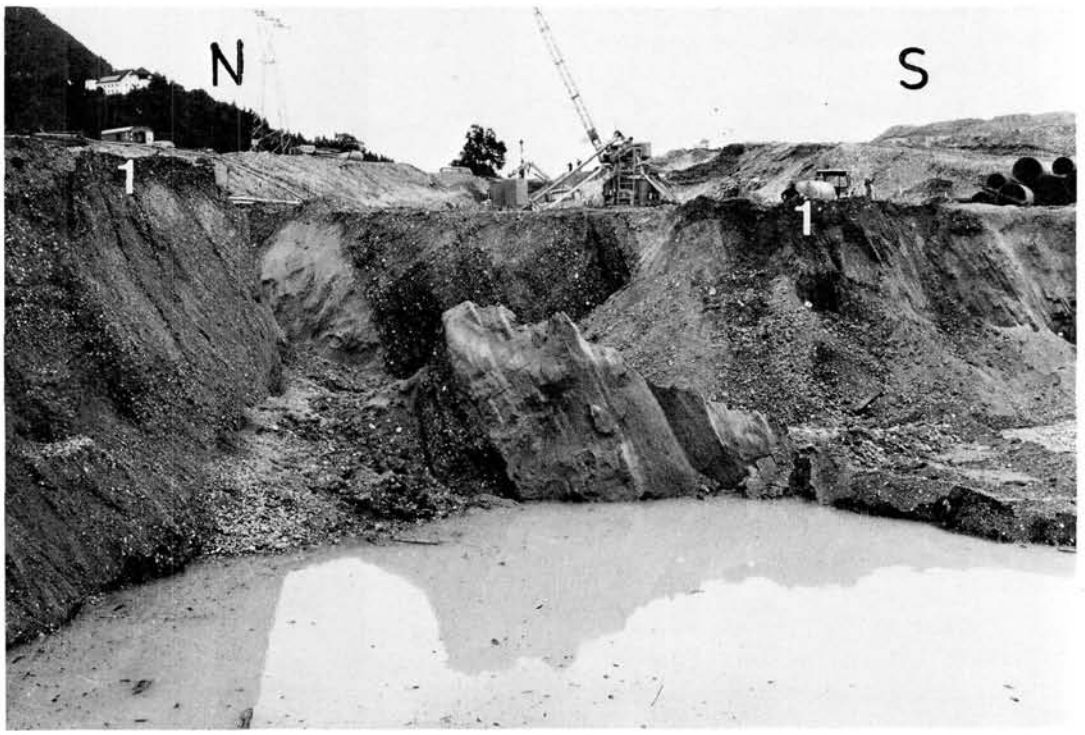

Fig. 2. Steeply inclined sand and coarse gravel layers covered with till (1)

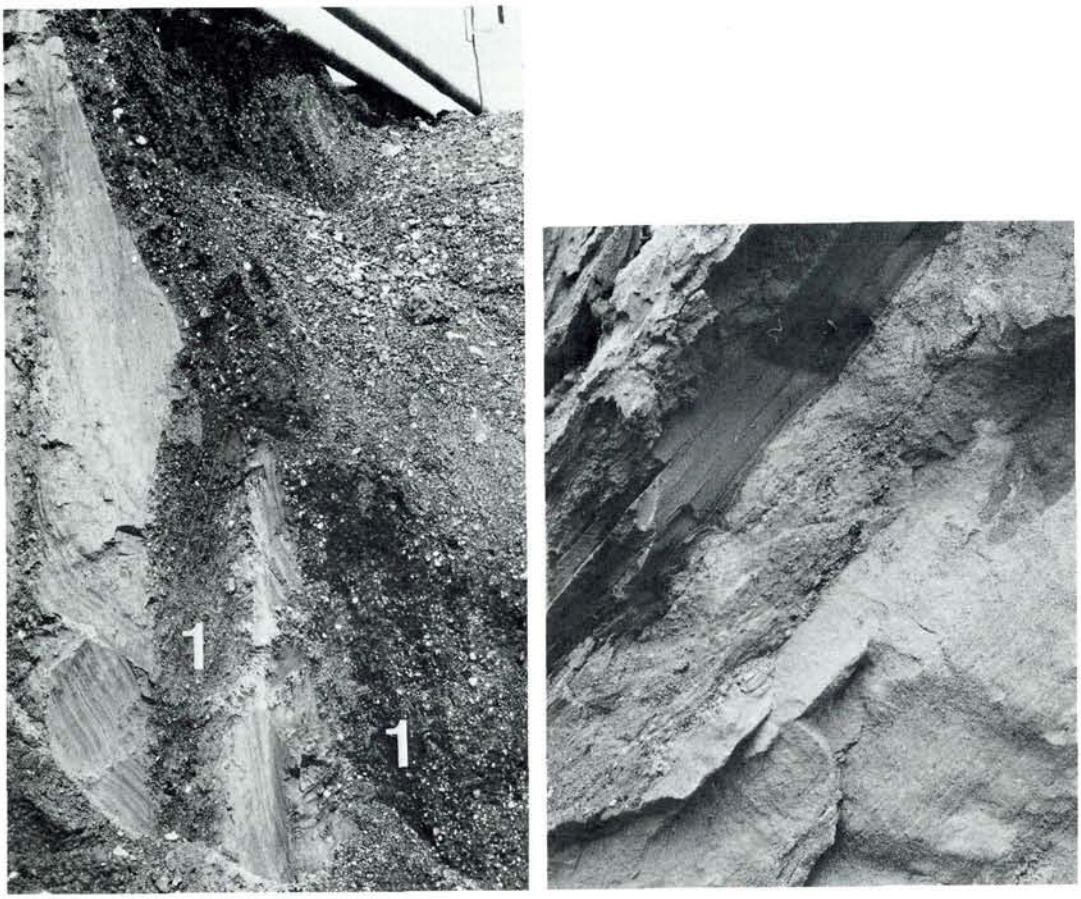

Fig. 3. Two examples of sedimentary contacts of different layers.
1: delta structures of coarse sediments in a relief of the sand layer.

part of the construction pit were steeply inclined (ca. 80°) in some parts even 90°. Southward the inclination decreased over a distance of approximately 50 meters to ca. 40° (fig. 4).

The inclination of the strata was consistently towards the south, in the direction of the steep high slope on the southern rim (see fig. 1) of the valley. The fanning of the layers without distinct discordance indicates a synsedimentary subsidence of the southern part of the sediment sequence over which a new horizontal sedimentation occurred again and again (fig. 5, A–C).

The relief built after the deposition of this sequence was filled up by till of varying thickness (see fig. 2). This till showed in some places lamination and flow structures (cf. waterlain till; Dreimanis 1979) and, in places contained no clay or fine-silt components. The existance of this till indicates that also after the deposition of the rotated sequence at least inactive ice masses were present.

Genesis

The formation of the steeply inclined sedimentary strata is most easily related to the downmelting of the last ice masses in the Drau valley at the end of the last glaciation (Würm). The rate of melting of these ice masses was probably greatly influenced by the local topography. The steep slope on the southern rim probably provided enough shade so that the ice masses here

Fig. 4. General view of the fanned sediments.

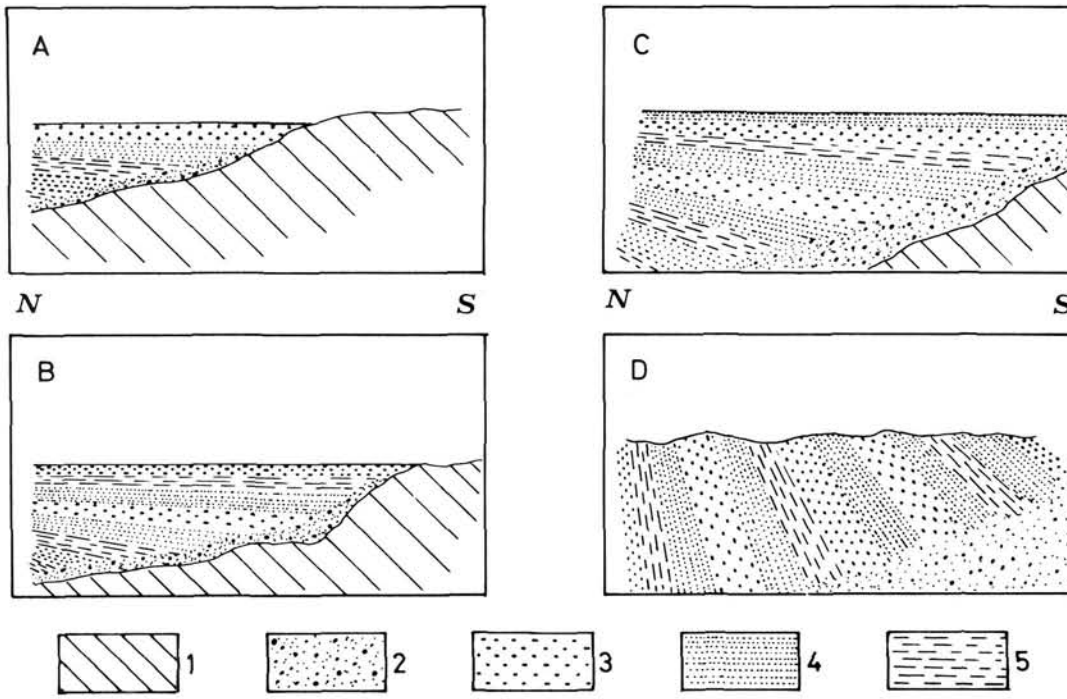

Fig. 5. Sketch of 4 phases during the development of sedimentary structures.
A: shortly after rotation started.
B–C: during development.
D: after final rotation and erosin but before being covered with till material.
1: ice.
2: disturbed sediments and till.
3: coarse gravel.
4: sand.
5: silty sand and silt.

melted more slowly than else where on the valley floor.

The sedimentation of the steeply inclinated sand and gravel beds probably occurred on the northern margin of this ice body and above the ice. The quickly changing conditions along the margins of melting ice bodies can lead to a sedimentary sequence with abrupt changes in grain size composition similar to those described here.

During sedimentation, probably also in its breaks, a slow rotation of the whole deposit occured by subsidence in the southern part. Thereby every following strata was deposited on a sediment sequence, which had been rotated for some degrees. This explains the fan-shape of the undisturbed sequence when viewed in section (fig. 5). The downmelting of an ice body in the southern part of the valley bottom is the probable reason for this slow rotation.

During its development the whole sequence was neither disturbed nor did there occur any movement along its bedding plains, which is due to the fact that the sediment body was frozen in its core.

After the deposition of this sediment sequence immediately after the complete melting of the ice – the topmost strata were rotated to an inclination of about 40°, whereas the lowest layers reached almost 90° (see fig. 5 D).

At a much later date these sediments and the covering till were eroded by the Drau river and covered with its gravels.

Summary

In the water power construction pit Annabrücke (Carinthia, Austria) steeply inclined cohesionless sedimentary strata were exposed. The inclination of the single layers went from about 80–90° to 40° without any discernible tectonic activity or unconformity.

The explanation of this extraordinary sedimentary feature is best given by a synsedimentary subsidence and rotation of a frozen sedimentary sequence on the margin of a dead ice mass.

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Dansk sammendrag

Ved udgravningen til et vandkraftværk ved Annabrücke i Østrig observeredes stejltstillede usammenkittede kvartære lag. Hældningen af lagene varierer mellem 40° og 80–90°, men den stejle hældning til trods er der ikke observeret tegn på glacialtektoniske forstyrrelser. Forfatteren anser det derfor sandsynligt, at den stejle lagstilling er fremkommet ved en synsedimentær nedglidning og rotation af frosne sedimenter fra kanten af dødis.

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