ICE-RICH, REDEPOSITED DIAMICTON BLOCKS AND ASSOCIATED STRUCTURES IN QUATERNARY OUTWASH SEDIMENTS OF THE INN VALLEY NEAR INNSBRUCK, AUSTRIA

BY
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ABSTRACT. In Quaternary sandy glacial outwash sediments situated in the Inn Valley NE of Innsbruck (Austria) occur redeposited diamicton blocks containing flatiron-shaped and ice-striated pebbles. Associated with these blocks are small, graben-like structures offset by small high-angle faults ("ice-melt graben structures") interpreted to have been caused by the melting of underlying ice-rich blocks. The diamicton blocks most likely originated from frozen glacial sediments, probably tills from the advancing Inn Glacier by fluvial erosion and are believed to be a prominent indicator for periglacial environments.

Introduction

Ice-cemented glacial debris blocks redeposited in glacial outwash sediments and associated structures, especially faults, have only infrequently been reported in the literature. Ice-cemented sand-blocks have been described by Dillon and Conover (1965) from Charlestown Beach, Rhode Island, where they formed during winter storms, and by Illich, Hall and Alt (1972) from the Pilcher Quartzite, Western Montana.

Faults in glaciofluvial sediments formed in ice-marginal or intramarginal environments, particularly in esker sediments are well known (McDonald and Shilts 1975), but have seldom been described from proglacial outwash plain sediments.

The glacial outwash sediments exposed in a large gravel pit (pit A) in an outwash terrace NE of Innsbruck (Fig. 1), which were deposited during the last glacial period (Würm), contain sediment blocks which appear to be redeposited glacial deb-

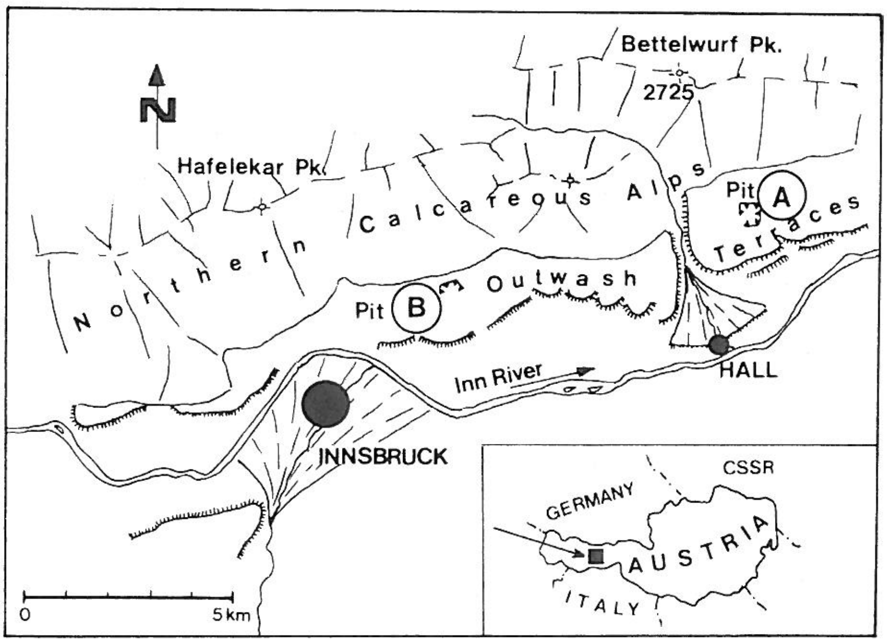

Fig. 1. Location map of the investigated gravel pits (A, B) in an outwash terrace NE of Innsbruck.

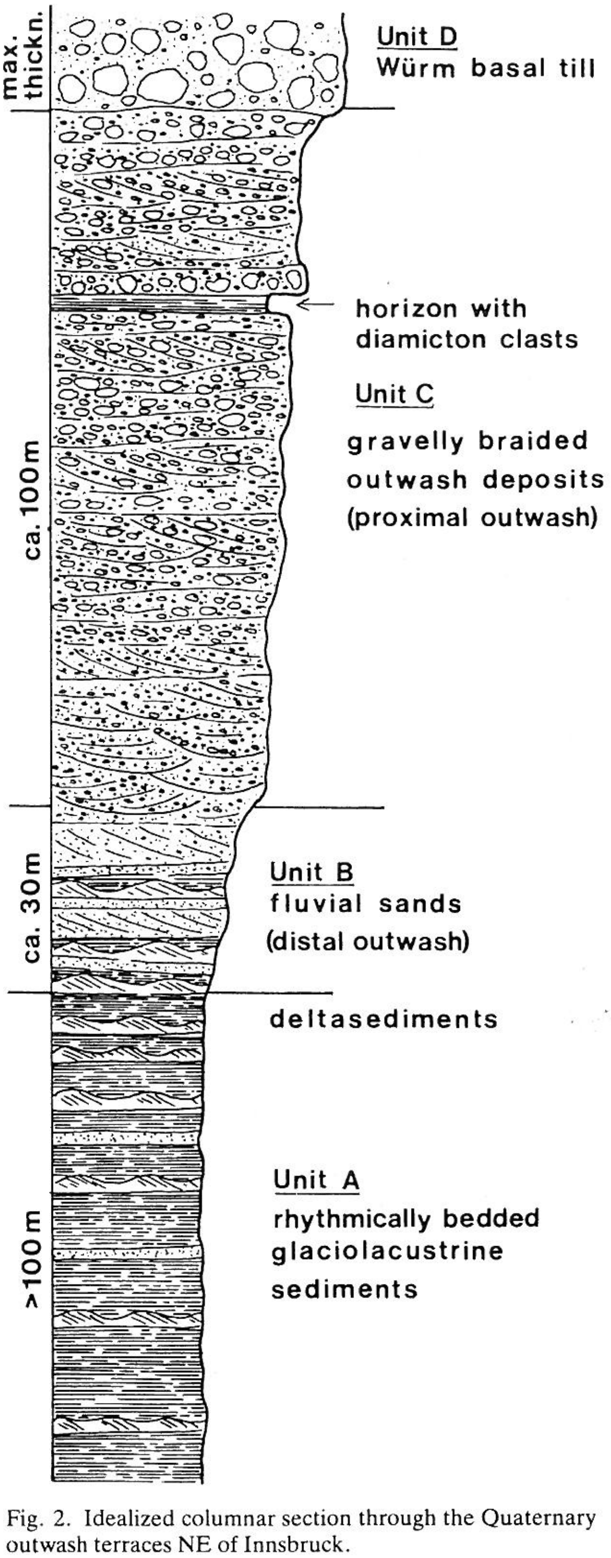

Fig. 2. Idealized columnar section through the Quaternary outwash terraces NE of Innsbruck.

ris. This paper is an attempt to describe the composition, textures and structures of these redeposited glacial debris blocks (diamicton blocks) and the surrounding sediments, and to discuss their origin and climatic significance.

Quaternary stratigraphy

At many places in the Inn Valley, particularly around Innsbruck, there are well developed, thick outwash terraces built up of tills, glaciolacustrine and glaciofluvial sediments from the Würm glacial period.

East of Innsbruck these outwash terraces are built up of rhythmically bedded varve-like glaciolacustrine sediments at the base ("Bändertone"). The radiocarbon dates of 31.000-27.000 y BP are determined from plant fossils embedded in the middle part of this lacustrine sequence (Fliri 1964, 1973, Patzelt and Resch 1986). The glaciolacustrine sediments grade upward into sandy deltaic and fluvial deposits which are overlain by a thick coarsening-upward sequence of gravels with features similar to modern braided outwash plains (Boothroyd and Ashley 1975, McDonald and Banerjee 1971, Church 1972). At many places the outwash sediments are overlain by basal till of the last glacial period (Würm) (Fig. 2).

Within the upper part of this gravelly braided outwash deposits there is a few meter thick sequence of glaciofluvial and glaciolacustrine, sometimes pebbly sands, which contain redeposited diamicton blocks (location see Fig. 1).

Description of the redeposited diamicton blocks and surrounding sediments

This intercalated sandy glaciofluvial and glaciolacustrine sequence which contains the diamicton blocks forms a distinct horizon within the braided outwash gravels at an elevation of about 800 m above sea-level.

There is a sharp contact between the sand and the gravelly braided outwash deposits. The beds dip slightly toward the east (about 1°) marking the paleogradient of the Inn Valley.

In the southern wall of the gravel pit A (Fig. 1), where these sediments have been studied, the lower part of the sandy sequence is built up of horizontally laminated sands containing a few clasts with diameters up to about 20 cm and seldome dm-large glacial debris-blocks, both interpreted to have been transported and deposited by ice-raft-

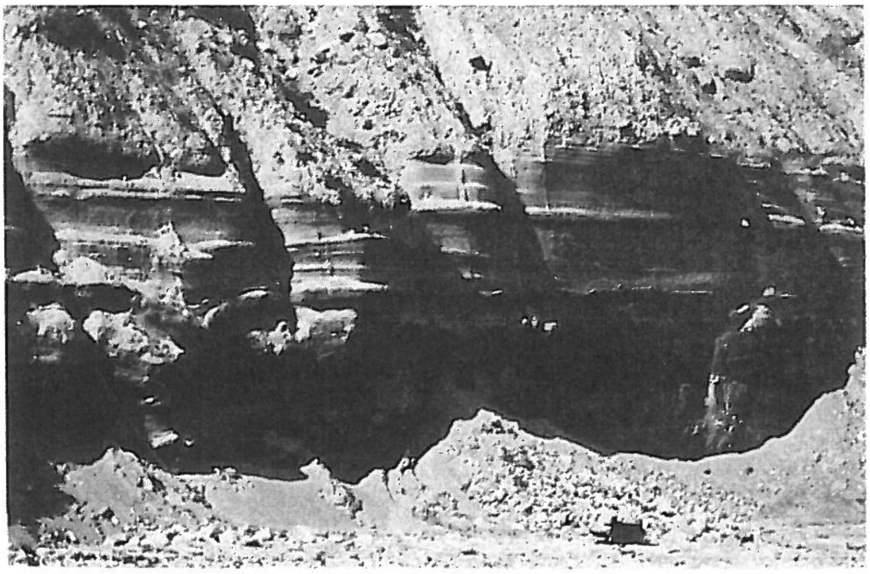

Fig. 3. Sandy horizon with redeposited diamicton blocks and associated graben-like structures in the northern wall of the gravel pit A (Fig. 1), details see Figs. 5 and 6. Camera-bag for scale.

ing. The horizontally laminated sands probably represent upper flow plane beds, but they may also have been formed in a small and shallow glacial lake with high sediment influx. Shaw (1972) described horizontally-stratified sands intercalated in glaciofluvial sediments and he interpreted them to have accumulated on wide shoals below shallow sheet-flooding streams (upper flow-regime).

In gravel pit B (Fig. 1) fine-grained lacustrine sediments, probably the same horizon as in pit A, are closely connected with mudflows from the adjacent steep mountain slopes. This suggests that intense mudflow activity from the steep valley slopes could have blocked the fluvial drainage and caused local backflows leading to the formation of wide shoals and small and shallow lakes which were rapidly filled with sandy sediments.

The laminated sands are erosively overlain with a pebbly lag deposit at the base of sandy, small scale fluvial channels. These fluvial sands are sharply overlain by braided outwash gravels. Along the northern wall of gravel pit A the facies of this sandy horizon slightly differs from the southern wall (Fig. 3).

The sands are slightly coarser, sometimes pebbly. Horizontal bedding is again the most prominent sedimentary structure observed, but trough-crossbedding with erosive contacts (small isolated scours) and ripple-crossbedding (current ripples) as well as graded bedding also occur throughout the sandy sequence.

This sediments are interpreted to be formed on the marginal parts of a small and shallow lake by lacustrine and fluvial processes. There are slight discordances in strike and dip between individual sets of horizontal stratification probably indicating changes in the paleoslope.

The sandy sediments are interpreted to be formed in small and shallow lakes by sheet-flooding streams (upper flow-regime). Within this sandy sequence there are several up to about 1 m large, poorly sorted, redeposited diamicton blocks which contain diamicton clasts with diameters up to about 20 cm. (Figs. 3, 4, 5)

Immediately above the redeposited diamicton blocks occur significant, graben-like structures offset by mini-faults (Fig. 4). The amount of metamorphic clasts (incl. quartz) within the redeposited diamicton blocks is about 20% higher than of the surrounding outwash sediments. The carbonate clasts (>4 mm, mostly limestone clasts) are more rounded (subrounded in most cases) than the metamorphic clasts (angular - subrounded). Many of the carbonate clasts are polished and show prominent ice-striations.

Some of the metamorphic clasts in the redeposited diamicton blocks are of typical flatiron-shape.

The sorting of the diamicton blocks is very poor, sedimentary structures are missing. Although the amount of fines (<0.063 mm) ranges from 12-14% and is lower than that of most tills, the flatiron-shaped and esp. striated clasts unequivocally indicate that these diamicton blocks are redeposited glacial sediment. In a study on particle morphogenesis Sneed and Folk (1958) pointed out that

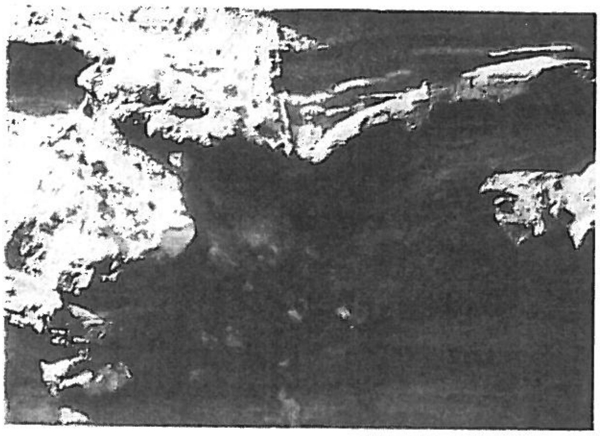

Fig. 4. Redeposited diamicton block and graben-like structures bounded by small, high-angle normal faults caused by melting of ice within the diamicton block after deposition. Lense-cap (5 cm) for scale.

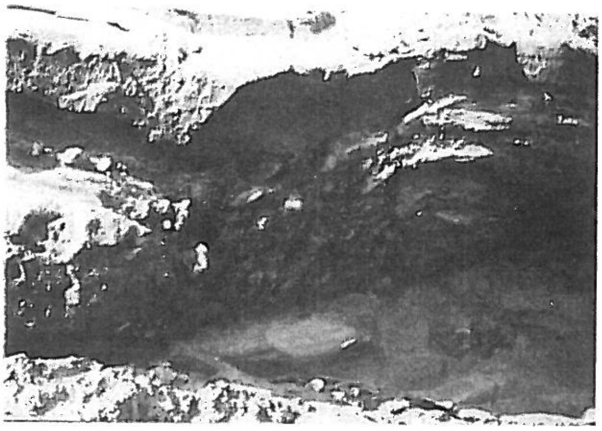

Fig. 5. Redeposited diamicton block within horizontally stratified sands showing slight discordances between the sets. Graben-like structures above the block are not well developed, however the overlying sediments have sunk downwards above the diamicton block. This indicates that the ice within the block melted after deposition of the overlying sediments.

limestone pebbles are so soft that they reach their limiting roundness after a few miles of transport. From this observation it is concluded that ice-striations on carbonate clasts, esp. limestone clasts are destroyed by abrasion during fluvial transport after distances of less than 1 km. Wentworth (1922), for example, determined that about 0.35 miles (560 m) of travel would remove glacial striations from limestone pebbles without significant modification of their shape.

The surrounding sandy sediments as well as the braided outwash gravels are significantly better sorted and both, metamorphic and carbonate clasts are more rounded compared to the clasts within the redeposited diamicton blocks.

Sandy and gravelly fluvial sediments are moderately sorted, containing very small amounts of fines (<3%) and show bimodal or polymodal grain-size distributions. The horizontally laminated lacustrine sands are characterized by high contents of fines (up to 25%).

Origin and significance of redeposited diamicton blocks

From the features mentioned above, esp. flatiron-shaped and striated clasts it is concluded that the redeposited diamicton blocks are glacial debris-blocks. These blocks probably originated from erosion of frozen glacial sediments along river banks. Fluvial undercutting of riverbanks formed by glacial sediments during runnoff-peaks in late spring - early summer would result in undercutting of frozen sediments which may collapse into the meltwater stream, transported away and redeposited downstreams. Church (1972) reported that during a jokulhlaup in the Lewis River (Baffin Island) the meltwater carried high amounts of slush and ice.

A subglacial source of the diamicton blocks is also possible. These processes are common in many present-day periglacial regions and have been described by Péwé (1948), Walker and Arnborg (1966), Czudek and Demek (1970).

Another possibility would be that the diamicton blocks represent eroded and redeposited landslide material or mudflows rich in snow and ice from the adjacent valley sides, composed of glacial till cover. However, we do not favour this interpretation, because it is very likely that the glacial till cover of the steep valley sides was eroded very rapidly, long before redeposition of the diamicton blocks.

Ice-rich diamicton blocks are very susceptible to abrasion during fluvial transport and transport distances of such redeposited blocks are not expected to be greater than a few (tens of?) kilometres.

After deposition the ice-rich diamicton blocks were rapidly covered by the sandy sediment due to high sedimentation rates during glacial advance on the outwash plain. Melting of the ice-cemented blocks after deposition caused decrease in volume, causing the overlying sediments to sink down and graben-like structures bounded by small faults

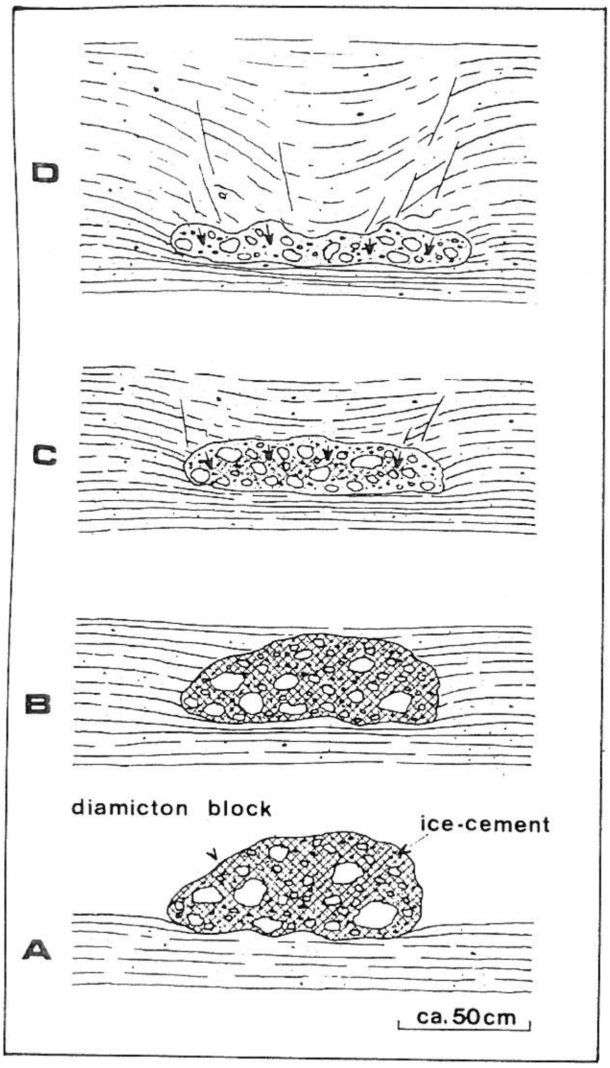

Fig. 6. Evolution of graben-like structures above a redeposited ice-rich diamicton block. A sedimentation of ice-cemented diamicton block, B block buried by sandy sediments, C,D melting of ice within the diamicton block causes decrease in volume and sinking downwards of the overlying sediments and formation of graben-like structures bounded by small high-angle normal faults.

("ice-melt graben structures") to form (Fig. 6 A-D).

The composition of the redeposited diamicton blocks, containing carbonate clasts derived from the Northern Calcareous Alps, and their position within fluvial sediments of a glacial outwash-plain indicates that sedimentation of the redeposited diamicton blocks took place under periglacial conditions in front of the advancing Inn Glacier. The redeposited diamicton blocks most likely originated from erosion of ice-proximal glacial sediments or from debris rich glacial ice from a subglacial environment.

Therefore redeposited diamicton blocks should be good indication that the surrounding sediments formed in a periglacial depositional environment.

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