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Late Pleistocene periglacial conditions in Blaksmark near Varde (Denmark)

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Abstract

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During pipe line construction in Blaksmark north of Varde in Denmark a shallow depression with a tilted block of sand and gravel, and an infill of layered sand and silt was found. It is suggested that fluvio-thermal erosion has taken place here. Ice wedge casts present in the adjacent sand indicate that permafrost existed during a former cold period. It is suggested that the thermal erosion and the filling, as well as the formation of the frost wedges date from the last permafrost period of the Weichselian.

Introduction

During the summer of 1983, a gas pipe line system was constructed between the North Sea and Egtved in middle Jutland. The continuous, almost two metres deep trench that was dug for the pipe, cut east-west through the so-called Varde hill-island (Varde bakkeø: Nielsen 1967, p. 272), approximately 5 kilometres north of Varde in western Jutland (Fig. 1). In Blaksmark a deposit of layered sand is present in which ice wedge casts and a valley-infill deposit were recorded. This paper describes these phenomena and attempts to reconstruct and date the palaeoenvironment.

Frost wedge pseudomorphs

Frost wedge pseudomorphs were observed at localities 1, 2, 4, and 5 (Fig. 1).

The sediment in the trench between these localities is stratified, fluvial sand with single layers of gravel. The structureless top layer is normally about 0.5 thick but above frost wedge pseudomorphs it may be between 0.7 and 1.0 m thick.

In locallity 1, four frost wedge pseudomorphs were identified. Each extends downwards in the trench from the lower part of the 0.7 m thick top layer. They extend beyond the bottom of the trench and accordingly are more than 1.3 m deep. The true width at the top of the wedges is about 25 cm. From there the structures gradually narrow to less than 10 cm at the trench bottom. The infilling is sand, dominated by the 250 μm size fraction, with gravel. The sand exhibits discontinuous, vertical foliation and the gravels are oriented vertically. The infilling appears derived mainly from the top layer. The surrounding sediments turn down toward the wedges and locally small faults are present.

The diameter of the mesh of the polygonal system is estimated to be 25 m or more.

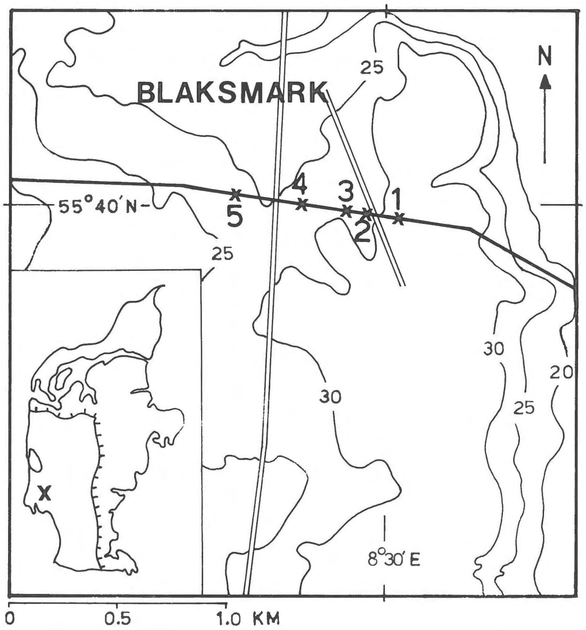

Fig. 1. Map of the Blaksmark area with localities 1 to 5 along the gas pipe line. The elevations of the contour lines of 20, 25, and 30 m are reproduced from map 1113 IV SØ VARDE, 1:25.000 with permission of Geodætisk Institut (A 83). The road running south-north in the middle of the figure goes from Varde (south) to Skjern (old highway, A 11). A part of the new road has been added to the map. The Main Stationary Line is indicated in the insert map.

In locality 2 two similar frost wedge casts occur. One of these is shown in figure 2. In locality 4 only one frost wedge cast was seen and in locality 5 there are five frost wedge pseudomorphs over almost 400 m of profile.

The presence of the large wedge casts together with small faults in the host material, and the spacing of the wedges, suggests that the Blaksmark area has once had a large scale network of ice wedges in a permafrost environment similar to that found in the Arctic today (e.g. Black 1976; Washburn 1979).

Valley-infill deposits

Locality 3 is situated in a shallow depression, approximately 2 m deep. The east-northeast facing slope has an angle of between 10° and 20°. The eastern slope around the locality is less clearly defined with an angle of slope toward the west of between 1 and 5°.

The depression slopes gently towards the north and can be followed over about 150 m. Over this stretch it forms a rather diffuse outline of what might once have formed a half length of a meander. The cross profile shown in figure 3 is situated in the deepest (i.e., western) part of the depression.

At this site there is a filling of two fining-upward sequences next to each other with a few metres overlap, and a deposit of sand and gravel on top of these. In the western part there is a tilted block of sand and gravel.

The ice wedge casts in the adjacent parts of the ditch suggest the previous occurrence of permafrost. Therefore the sequence of sediments and structures observed at locality 3 can be reasonably interpreted within a similar context. For example it might be argued that the sediments represent either a thermokarst lake basin that has been

Fig. 2. Ice wedge cast from locality 2 in figure 1. The ruler is 2 m long.

infilled, or are the remnant of a collapsed pingo. To begin with these two possibilities shall be discussed.

There is a striking resemblance between figure 4-4 in the present paper and the lower left half in figure 78 in Jahn (1975, p. 110) where a fossil thermokarst depression or alas is illustrated (cf. also Soloviev 1973). It might be suggested, therefore, that the feature presented in figure 4-4 is an infilled thermokarst depression or alas (cf. e.g. Washburn 1979, p. 274).

If the filling in locality 3 had been the filling of a thermokarst depression formed in an ice rich sediment (i.e., a permafrost environment with more or less massive, segregated ice) it might be expected that the sediments accumulated in the locality would have formed a relatively high area after the ground ice in the surrounding sediments had melted. But this is not the case. Besides, the only post-sedimentary distortions in the surrounding sediments are the frost wedge casts. There are no indications for melting of ice lenses or massive segregated ice; so it seems that during the time of perennially frozen ground the sediments around locality 3 have only contained pore ice (Péwé et al. 1969) (i.e., that the frozen ground has not been super-saturated). Consequently the environment was not suitable for the forming of alases.

If there had been massive ice or an ice lense in the ground at the site but not in the surrounding area it would have created some kind of frost mound (i.e., pingo) in the periglacial environment. This is not very likely either, because upon melting of the mound, the original sediments would either fall back, distorted, into the original place, or, there would be pressure structures in the adjacent sediment and (remains of) a rampart at the sides (see Pissart & French 1976; French et al. 1982).

The most likely explanation for locality 3 is that thermal erosion by water took place in an area with permafrost, and that the sediments are periglacial valley infill deposits.

The development may have been as follows:

In the fluvial sand deposit more than 2 m of sediment was eroded laterally over approximately 25 m. Since the layering of the sediments of the filling (Fig. 3) is almost horizontal in the eastern part and only slightly westward dipping in the western part, the bottom of the former depression may have been rather flat with its deeper part to the west. This type of relatively wide, flat-bottomed depressions with steep sides can be found in permafrost areas where lateral erosion by water can take place more easily than bottom erosion (for further discussion, see e.g., French 1976, p. 141 ff. on slopewash and p. 167-176 on fluvial processes).

In the depression a fining-upward sequence of sand with a little gravel overlain by clayey, fine sandy silt was deposited in the eastern part (Fig. 4-1). Later, some of the sediment of this eastern half lost its western 'support' and slumped downward. At the western bank lateral erosion (thermo-erosion) created a more than two metres deep niche, leaving an at least one metres thick frozen bluff that must have fallen down in one piece leaving the fining-upward sequence tilted but almost intact (Fig. 4-1 and 4-2) (for recent examples compare e.g., figures 4 and 5 in Walker 1983; Walker & Morgan 1964).

Next, fluvial sand with gravel overlain by clayey, sandy silt became deposited in the western part of the locality (Fig. 4-2). It seems that the silty layer constituted the surface of this deposit for a while. Fine cracks extend downwards from the silt layer and the contact between sand and silt is undulating.

On top of the two fining-upward sequences a layer of sand and gravel was laid down over the whole width of the locality (fig. 4-3).

The fining-upward sequences in the locality might suggest that discharge came in pulses.

At a later stage the remaining (bottom?) ice melted in the western part and the sediments were slightly tilted. In the top layer of sand and gravel there is indication for slumping toward the west, and in the bottom part there are indications of movement of material westward (Fig. 4-4 and 3).

In the eastern part of the locality there are intrusions upwards through the sand and silt layers. Where the sand and gravel broke through the silt this layer is bent upward and sometimes also outward and a dilution in the content of gravel is

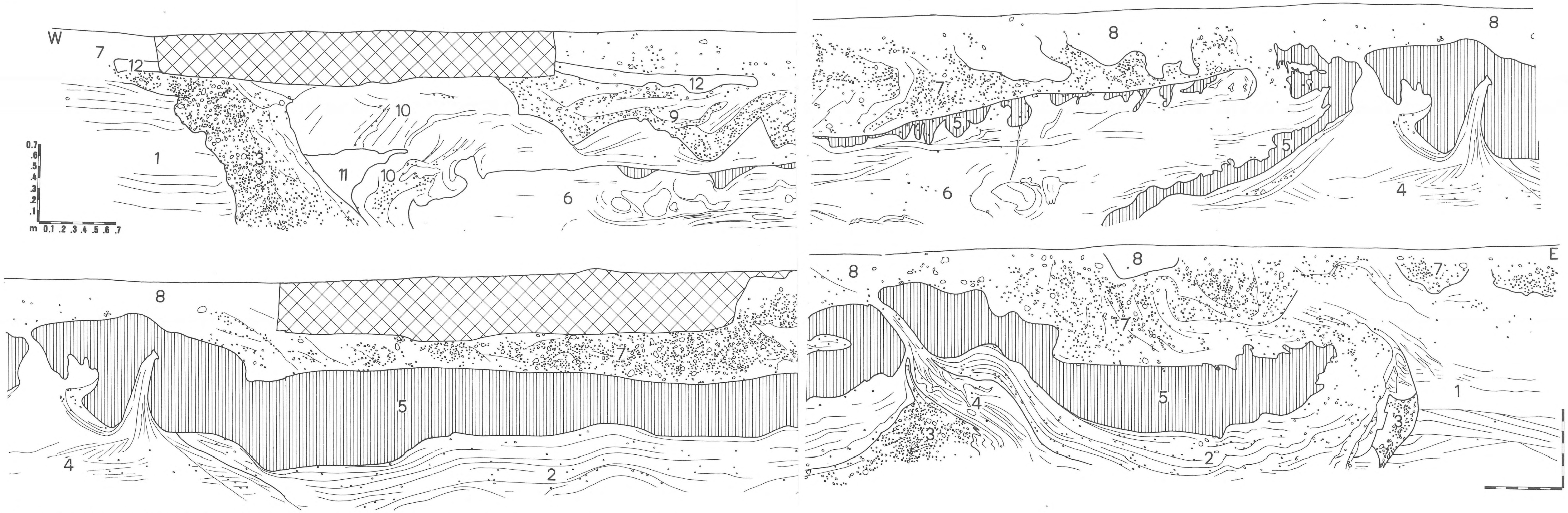

Fig. 3. Drawing of locality 3 made from a field drawing combined with colour slides. The two areas with hatching in the upper part represent filling material. The sediments are:

1) Well-medium sorted, 250-375 µm size sand with parallel lamination and cross-bedding and single layers of gravel.
2) Alternating layers dominated by 250 µm size sand and 150 µm size sand particles respectively.
3) Gravel and small stones with a little sand.
4) 250 µm size sand with primary structures more or less vertically arranged. In the eastern part there is small-scale faulting.
5) (vertical hatching). Clayey silt with a little fine sand.
6) Silty fine sand with scattered small gravels. There is undulating, parallel lamination, single small-scale faulting, and a couple of 150-250 µm size clods of well-sorted sand.
7) Sand and gravel. The 250-375 µm size is dominant in the sand fraction. The content of gravel and stones varies between ca. 15 and 60%. The largest stone has a diameter of 12 cm.
8) Like (7) with fewer gravels and stones.
9) Is (7) alternating with well-sorted, 150-250 µm size sand.
10) Like (1) with gently folded and undulating layers.
11) Well-sorted, 105 µm size sand.
12) Sand-loess with scattered fine gravels.

found in the top layer where the sand from below has been added (Fig. 3).

These intrusions might be a result of saturated conditions in combination with loading following deposition. A possible relation to frost cracking cannot be excluded (see Jahn 1975, p. 64).

Time of formation

The ice wedge casts and the sediments at locality 3 are found in the upper sediments of a so-called 'hill-island' which is generally regarded as having been situated west of the area that was glaciated during the Weichselian (Jessen 1922; Milthers 1948). This means that the phenomena must have formed between the time of melting of the Saalian ice that covered the area, and the end of the Weichselian. Since no soils and no organic deposits are found that can be radio-carbon dated in the sediments along this part of the pipe line trench, dating remains uncertain. The possibility exists that a polygonal network, formed during one period of permafrost, was 'reactivated' during a subsequent cold spell. However, indirect evidence suggests that the sediments in locality 3 date from the upper part of the Weichselian.

First, small polygons immediately east of locality 3 do not occur in the locality itself (see figure 3, upper eastern part). This might mean that the infill in the site is either contemporaneous with, or younger than, the polygons.

Second, in almost every locality in the pipe line trenches in Jutland, where sediments deposited before or during the period of maximum cold of the Weichselian have been observed, alternating layers of silt and sand have been deformed (cryoturbated). This could mean that the events suggested for locality 3 took place during the last cold period of the Weichselian, a period during which permafrost existed in Denmark (Nielsen 1967, p. 285; Kolstrup 1980). After the sediments were deposited, the climate had become too warm for cryoturbations to occur.

The duration of the sequence of events outlined in figure 4 is uncertain. It could probably all have happened within a short period of time, maybe even within one season (compare e.g. Pissart 1967). Therefore, it is not clear whether it took place during a season with high rainfall and/or excessive snowfall and melt, or whether it might represent a relatively warm period during which permafrost degraded temporarily causing excessive run-off, or whether it represents the complete disappearance of permafrost from the area.

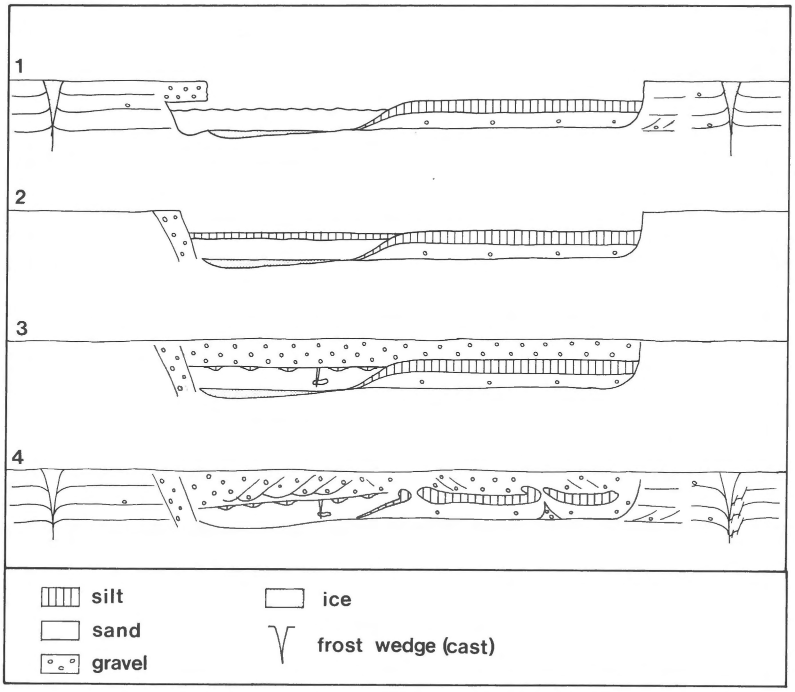

Fig. 4. Suggested outline of the development in locality 3. The shape of the bottom is suggested. For further explanation see text.

Conclusion

In Blaksmark the presence of ice wedge casts points to the previous existence of permafrost. In this environment a thermoerosional valley was eroded and filled with fining-upward sequences of gravel, sand, and silt.

Dylik (1969) described a cross section of an infilled valley at Walewice in Poland. In that locality blocks of stratified sediment were incorporated in slopewash deposits, and buried thermoerosional niches were preserved.

Remodeling of the periglacial European landscape by thermal erosion may have been more widespread than the literature on this subject suggests, but confirmation of this assumption is difficult to obtain except from diggings for construction purposes.

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