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Noncryogenic deformations in Loch Lomond Stadial to Early Flandrian coversands in North Lincolnshire, England

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Abstract

In contrast to the Late Dryas Stadial aeolian coversands in the Netherlands, there are no frost structures in their approximately coeval counterparts in north Lincolnshire, England. Faunal evidence for cold conditions in the latter category can be reconciled with the absence of cryogenic deformations by assuming that the annual snow cover was thick enough to insulate the sands from frost action.

This paper discusses two types of postdepositional deformations in the north Lincolnshire coversands to which, at first glance, a cryogenic origin might be attributed. It is shown, however, that nonperiglacial processes account more adequately for their presence in these deposits.

Involutions associated with a hydromorphic paleosol are due to unequal loading and slow upward percolation of ground water when the sands that underlie the contorted layer were waterlogged during some period in the past.

Fissures reminiscent of frost cracks, are interpreted as tension gashes produced by a slight updoming of the clayey or shaley substrate of the coversands in the proximity of cuesta scarp-faces.

Introduction

The coversands of north Lincolnshire are aeolian deposits with, mostly, gently undulating relief and thicknesses of up to 6 m. From the work of Straw (1963), Buckland (1982), and Schwan (1988) their characteristics may be summarised as follows:

1. predominance of (sub)horizontal parallel bedding and concordantly-infilled wind scours in well-sorted sand (see Fig. 1);
2. presence of beds formed by shallow current flow and intercalations of slightly organic sand, often with moss remains;
3. occurrence of Mesolithic artifacts and pebble-sized gelifluction layers where the blown sand is banked against steep cuesta scarps;
4. a substratum of frost-shattered limestone or shale intersected by sand-filled ice-wedge casts. In many places this level is overlain by a basal peat;
5. indications for deposition in a cold climate at the close of the Loch Lomond Stadial based on insect evidence and radiocarbon data.

With respect to the last feature it must be added that, in all likelihood, deposition continued for a time into the Early Flandrian until a sufficient vegetation cover had developed. Renewed sand drifting occurred in historical times as a result of forest clearance by man. The corresponding deposits differ from the coversands since they form dunes that do not occur in most of the older blown sands. To distinguish the Loch Lomond Stadial to Early

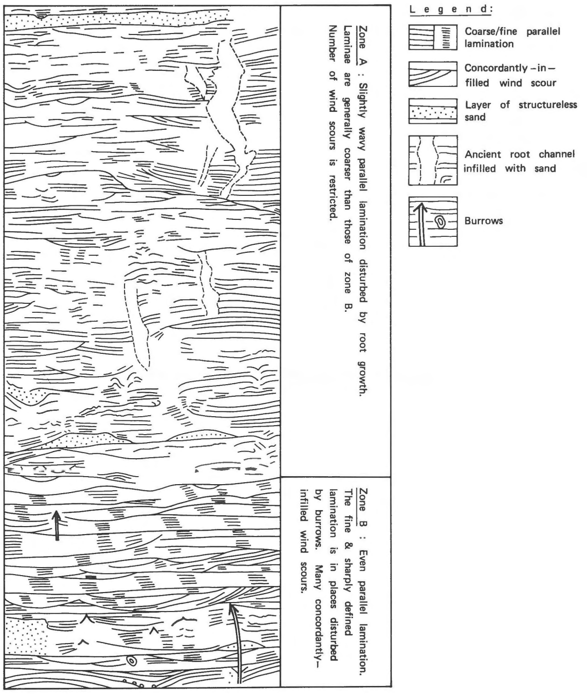

Fig. 1. Coversand profile from north Lincolnshire. Drawing traced from photograph of a lacquer peel. Height of profile = 125 cm. Location: Sandhowes Farm (see Fig. 2).

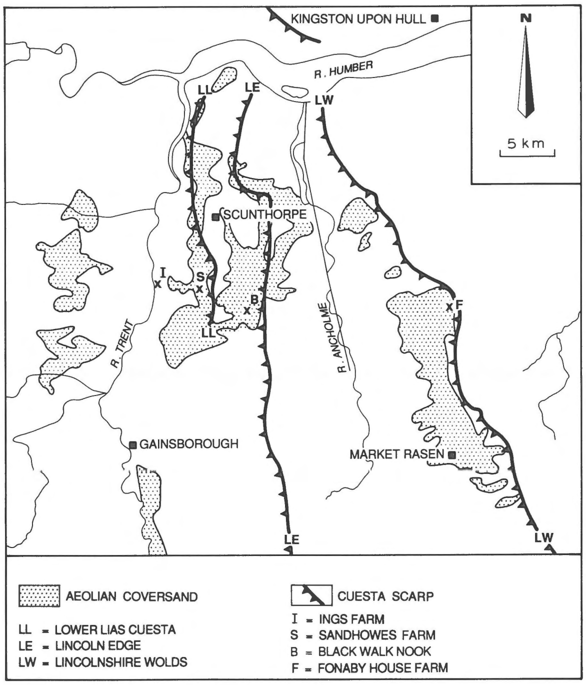

Fig. 2. Distribution of coversand in north Lincolnshire. Exposures are marked with X. Based on Institute of Geological Sciences (1977).

Flandrian aeolian sand sheets in north Lincolnshire from the younger Flandrian dunes which in places overlie them, Buckland (1982) proposed the formation name 'Messingham Sands' for the former class. The areal distribution of this unit, its investigated exposures and its stratigraphy are given in Figs 2 and 3.

Buckland (1982) emphasised that cryogenic deformations are absent from the coversands of north Lincolnshire. This is of interest, in the first place since frost structures are found in nearly coeval aeolian sand sheets in the Netherlands and secondly because deformation features do occur in the Messingham Sands.

In this paper, two kinds of postdepositional deformations in the north Lincolnshire sand sheets are discussed which, at first glance, appear to be of cryogenic origin. Here, however, it will be demonstrated that nonperiglacial processes account more adequately for their presence in the aeolian sands.

Frost structures

Cryogenic deformations (frost cracks, ice-wedge casts, sand wedges, cryoturbatic involutions, frost thrusting features, joints) in Weichselian aeolian sand sheets in the Netherlands and its adjacent parts of Belgium and Germany are discussed by e.g. Maarleveld (1976), Kolstrup (1980), Ruegg (1983), Vandenberghe (1983, 1985) and Schwan (1986, 1987, 1988). In several of these papers, however, the chronostatitigraphic position of the affected units could not be unambigously established. Moreover, at least a part of the cyrogenic features, in particular the ice-wedge casts and involutions, may be epigenetic. This latter type, therefore, is not directly related to the environmental conditions under which the aeolian host-sediment itself was laid down. Frost cracks and frost fissures have been reported from windborne sands of Late Dryas Stadial age in the northern and central part of the Netherlands (Van der Tak-Schneider 1968). Whereas seasonally frozen ground is a sufficient

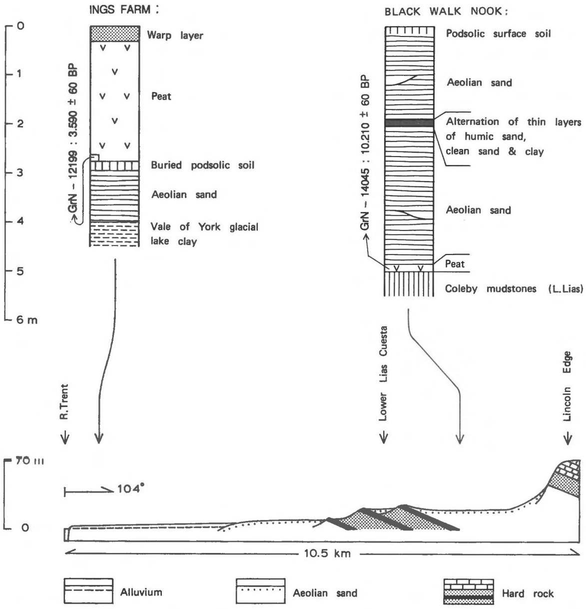

Fig. 3. Stratigraphy and geochronology (radiocarbon dates) of coversand in two exposures in north Lincolnshire.

condition for the formation of frost cracks, frost fissures, on the other hand, require a state of (dis) continuous permafrost to come into being (Maarleveld 1976, Vandenberghe 1983). The work of Van der Tak-Schneider (1968) is relevant in the present context since it refers to coversands that are virtually coeval with those of north Lincolnshire.

Deformation structures in the Messingham sands

Two types of deformation structures were found in the coversand exposures in north Lincolnshire. These are: (i) involuted beds and (ii) tension gashes.

Involuted beds

Figure 4 shows the topography of a hydromorphic paleosol which is intercalated in a body of aeolian sand. The lowest part of the paleosol is covered by a thin gyttja-bed and distorted by involutions which are marked by streaks and pockets of blackish gyttja (see Fig. 5). In the whole exposure, the occur-

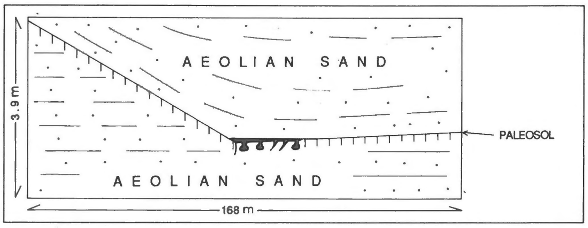

Fig. 4. Paleosol in aeolian sand. Lowest part of the paleosol is covered by a thin gyttja-bed and is distorted by involutions. For details of the involution layer see Fig. 5. Location: Fonaby House.

rence of these involutions is restricted to the paleodepression depicted in Fig. 4. Both thc hydromorphic character of the paleosol and the presence of an organic bed in the lowest part of the now buried surface suggest that the basal aeolian unit was saturated with water during a certain length of time in the past. It is presumed that subsequent deposition of the upper unit caused unequal loading of the waterlogged subsoil. Apart from the action of differential vertical pressure, the rise and fall of the water table through the sediment may have added to bring about a partial liquefaction of the affected beds (Collinson & Thompson 1982). Thus, the resulting distortions would have formed independent of permafrost conditions and as such they differ from periglacial involutions in the sense of Washburn (1979) and Vanderberghe (1983).

Fossil phreatic surfaces recognisable by organic intercalations or hydromorphic paleosols are present at several places in the sand sheets of north Lincolnshire. In that area, the aeolian units overlie Mesozoic strata which gently dip to the east. It is imaginable that, during the close of the Loch Lomond Stadial, reversed gradients in the ancient substratum locally and temporally impeded the drainage of meltwater from the snow-clad coversands. Upon loading by an overburden of new sediment the soaked sands became prone to distortion and noncryogenic involutions could form.

Closely similar phenomena have been found in aeolian sands in the Netherlands (see Fig. 6). For these involutions a periglacial origin could be ruled out with certainty since the host-sediment is of young Holocene age. In this case an underlying impervious clay was responsible for the temporary

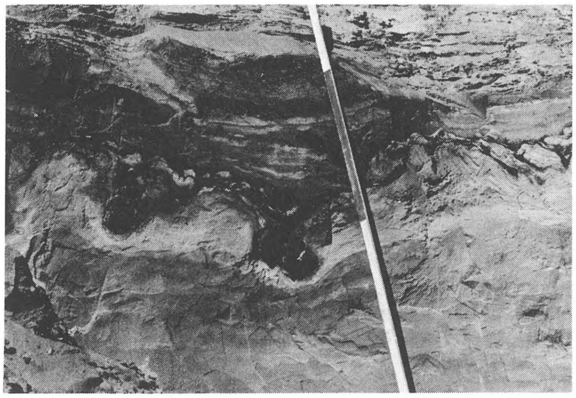

Fig. 5. Involuted gyttja-bed in coversand. Length of rod = 1.2 m. Location: Fonagy House.

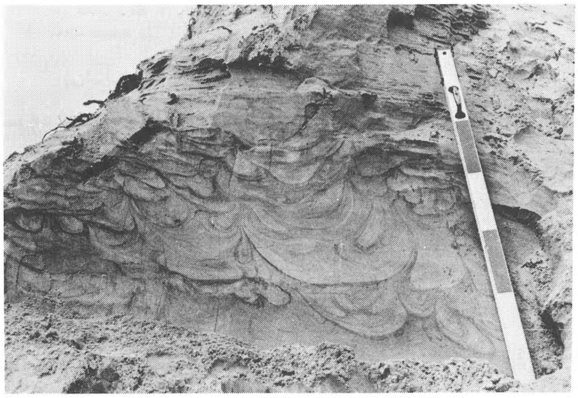

Fig. 6. Load casts in aeolian sand of Subatlantic age (Kootwijk Formation). Length of staff = 1.5 m. Location: Ossendrecht, the Netherlands.

existence of a perched ground water table. Deformation of aeolian sands due to slow upward percolation of ground water is also discussed by Horowitz (1982) and Marzolf (1983).

Tension gashes

In two exposures in north Lincolnshire sets of gashes are present which cut across the horizontally-bedded aeolian sand (see Fig. 7). The gashes depart either from the ground surface or from levels below it. Their width, which may be up to 10 cm at the top, gradually decreases downward and they are filled with sand that has a massive or vertically-laminated structure. Horizontally, the gashes can be traced over distances of 10 m or more. In these respects, the fissures under discussion are reminiscent of frost cracks though their spatial attitude speaks against this interpretation. At two different sites it was found that the gashes, rather than forming a polygonal pattern, mostly paralleled each other (see Fig. 8). Besides, their mean strike-direction differs by less than 15° from that of nearby cuesta scarp-faces.

Here it is tentatively suggested that the occurrence of fissures in the coversand is due to the presence, in many places, of relatively ductile materials such as clay or shale, which underlie the sand sheets. Near the cuesta scarps these lithologies are probably subject to slow plastic deformation. Inasmuch as this involves a slight updoming of the clayey beds, the superjacent aeolian sand layers would suffer extension and, consequently, form gashes. In this way, ductile behaviour of the substratum rather than climate-induced thermal contraction might account for the structures under discussion.

Mobility of ductile strata on a large scale is known from valleys cut into alternations of hard and soft beds as in cuesta landscapes. In British literature, the processes associated with it are referred to as 'valley bulging', 'scarp-foot bulging' and 'cambering' (Straw & Clayton 1979, Eyles & Paul 1983).

Discussion

From his observations Buckland (1982) deduced an annual cycle of sedimentation. He suggested that aeolian deposition by westerly storms in autumn was followed by deep snowfall in early winter and partial reworking of the sand by spring thaws. Faunal evidence for cold conditions can be reconciled with the absence of cryogenic deformations by assuming that the snow cover was thick enough to insulate the sands from frost action. It would appear that this hypothesis satisfactorily explains the absence of frost structures. A further implication is that neither permafrost nor even seasonal ground-

Fig. 7. Tension gashes in aeolian sand. Length of staff = 2 m. Location: Black Walk Nook.

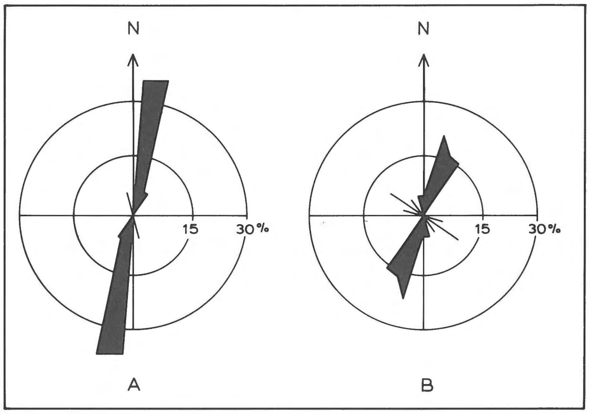

Fig. 8. Strike directions of tension gashes in coversand. A: Exposure Black Walk Nook; N = 15. B: Exposure Fonaby House; N = 18.

freezing occurred when the coversands were laid down.

The periglacial blown sands in north Lincolnshire not only differ from those on the continent by the absence of frost structures but also by that of adhesion structures, i.e. structures resulting from aeolian tractional deposition on a wet or damp surface. From the model of Buckland (1982) it can be inferred that the main phase of aeolian deposition and that of general wetness were separated in time by approximately six months. Thus, in the study area the former event occurred under essentially dry conditions and hence, adhesion structures would not form.

The absence of snow-induced deformations in the coversands, despite their sedimentation in an assumedly humid cold climate, is discussed by Schwan (1986 & 1988). He has suggested that in permeable sand beds with horizontal topography snowy intercalations may melt away without any structural disturbance of the host sediment. The conditions under which these features do form (and survive) are summarised by Koster & Dijkmans (1988).

Thin beds formed by shallow current flow occur here and there in the Messingham Sands. In fact they are the only sedimentologic evidence for the former presence of snowcovers but they are different from the structures discussed above.

Conclusions

1. The involutions and fissures observable in the Messingham Sands have a noncryogenic origin. The involutions are believed to be due to unequal loading and slow upward percolation of ground water when the sands that underlie the contorted bed were in a water-saturated state during some period in the past. The fissures are, in fact, tension gashes resulting from a slight updoming of the clayey or shaley substrate in the proximity of cuesta scarp-faces.
2. The rarity of adhesion structures in the Messingham Sands is tentatively attributed to a time lag between the main phase of aeolian deposition and that of general wetness. As a result, accumulation of sand took place under dry conditions most years.
3. The absence of snow-induced deformations is thought to be due to the general horizontality and permeability of the sand beds which permit-

ted nondeformational melting of snowy intercalations.

4. The cyclic depositional model of the Messingham Sands, originally proposed by Buckland (1982), adequately accounts for the lack of cryogenic deformations, adhesion structures and snow-induced deformations in the subject sediment.

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