The Periglacial form group of Southwestern Denmark

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By means of air-photo interpretation, traces of fossil periglacial forms are identified in transections of Jutland. Significant localities have been selected for checking in the field, and the features are discussed from a morphogenetic and a chronologic point of view. Suggestions for further approaches are given.

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With the objective of studying traces and identification possibilities of relict (fossil) permafrost structures and terrain elements fossilized by the melting out of ice (thermokarst processes) a survey was made 1975-78 for selected areas of Jutland.

The work was preceded by several years of studies of Danish air photo archives and benefitted from research experiences within periglacial geomorphology in other Nordic areas (northern Norway, Iceland and southern Sweden). Aspects of active periglacial processes were brought into the study from field work and excursions in present-day permafrost areas (Spitsbergen, Greenland and Jakutia). In the space available this paper will summarize some main aspects and ideas.

OBSERVATIONS AND IDENTIFICATION OF FOSSIL PERMAFROST STRUCTURES IN DENMARK

The first who mentioned features of this kind was Steenstrup (1897). He advanced the interpretation that funnel- or crack-like structures which he observed in sediments in Jutland had their origin in earthquakes. Steenstrup's short description was accompanied by a picture clearly indicating that the structure constituted a pseudomorph of an ice wedge, a phenomenon unknown in Steenstrup's time.

In Nordic areas, Nørvang was the first who correctly interpreted the structure as a permafrost feature during his studies in Jutland (Nørvang 1939 and 1942).

The possibility of identifying surface patterns of ice-wedge origin was advanced by the author (Svensson 1963) by using Danish air photos. This method was then practiced by Christensen in his research in Jutland (Christensen 1973, 1974, and 1978). Sjørring (1978) published an instructive series of ice-wedge casts and in her dissertation, Kolstrup (1980a) gave a detailed description of some sections and discussed the ice-wedge localities from a lithostratigraphic point of view. There also exist many observations of solifluction features in the Jutlandic landscape, but as they are not necessarily indicative of a permafrost environment, they will not be surveyed here.

METHOD AND MATERIAL

Decisive for the way of work and method of analysis is the type and possible occurrence of indications in the terrain or in other sources of information. As one has to take into account that the remnants of the ice containing permafrost forms, originally very week in relief, after the fossilization have for a long time been exposed to subaerial processes, one cannot expect the traces of them to be detected by a direct observation in the landscape. Therefore the overview necessary to get a conception of shape or pattern cannot be obtained from a point of observation in the mostly plain Danish landscape.

Topographic maps are, generally, an adequate tool for geomorphological analysis. In spite of having a large scale and very good equidistance properties the Danish maps are, however, not sufficient for an analysis of possible traces of a permafrost relief caused by the ice content of the ground.

Vertical aerial photographs combine the possibility of a good overview with the complete recording of terrain and surface details, and, viewed in stereo instrument, also low features stand out due to the relief exaggeration. The survey has benefitted from air photos in the good scale of 1:10,000, which turned out to be a most appropriate source of information about fossil periglacial phenomena. However, the large scale involves that the number of pictures necessary to cover an area must be large. In total, 3284 photos have been analysed in the air photo archives of Geodetic Institute and Landinspektørernes Luftfotoopmåling, Copenhagen. The analysis of existing air

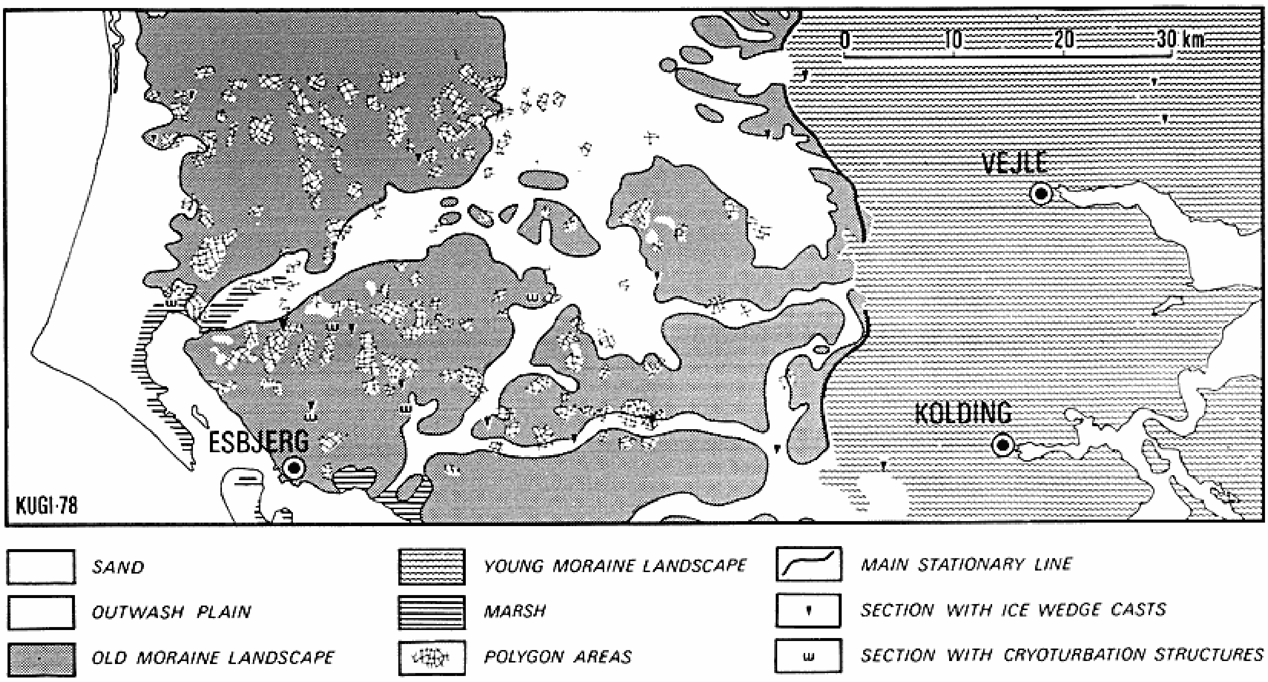

Fig. 1. Example of an inventory map of periglacial features in a west-east transection of Jutland.

Fig. 1. Registrering af periglaciale fænomener i et V-Ø tværsnit af Jylland.

photos was completed by reconnaissance and photography from a small aircraft for particular areas and gave the basis for selecting significant localities for field studies.

In order to judge possible changes in frequence and shape of fossil permafrost features through central Jutland, a regional analysis was initiated in west-east zones. Two students, Bodil Due Andersen and Birgit Sanderman Justesen co-operated with air photo interpretation and field work and completed a map for such a zone, Fig. 1.

I. ICE-WEDGE POLYGONS

1. Surface pattern

The whole scale, from very faintly to quite clearly (Fig. 2) outlined polygon patterns have been found in air photos from cultivated areas of western Jutland. Field-checked areas show no surface relief of polygons, and no linear soil contrasts are observed. The relief that once existed as a polygon system of low furrows was eliminated partly due to thermokarst processes, but principally by later erosion and accumulation in the ground surface. What possibly existed of the polygonal relief, when the reclamation of land started, was levelled during the cultivation and by eolian deposition.

The lack of a pattern, topographically printed in the ground surface as for instance in North-Norwegian areas of fossil ice-wedge polygons (Svensson et al. 1967), hampers a morphological identification and analysis of the polygon phenomena in the field.

2. Reproduction of polygonal network

From photo interpretation it was clear that the patterns were revealed by vegetation. Thus, there was sometimes a difference in pattern distinctness, bounded by field borders and dependent on crop type (cf. Fig. 2). There also existed an immediate connection with the degree of devel-

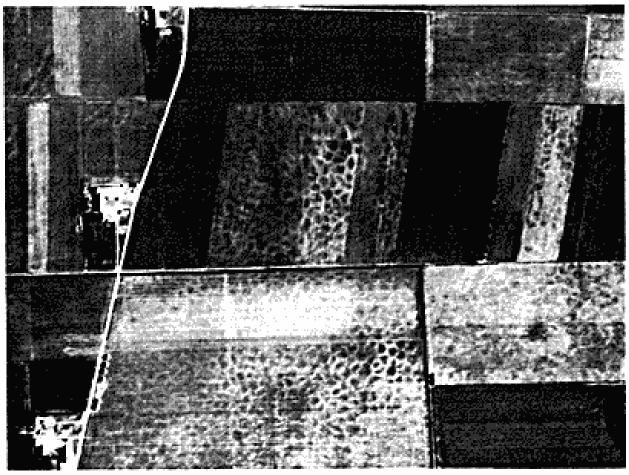

Fig. 2. Polygonal network in cultivated fields at Saedding. Approx. scale 1:8, 500. Air photo May 11, 1954. Copyright Geodetic Institute, Copenhagen.

Fig. 2. Polygon-net i dyrkede marker ved Sædding, målestok ca. 1:8.500.

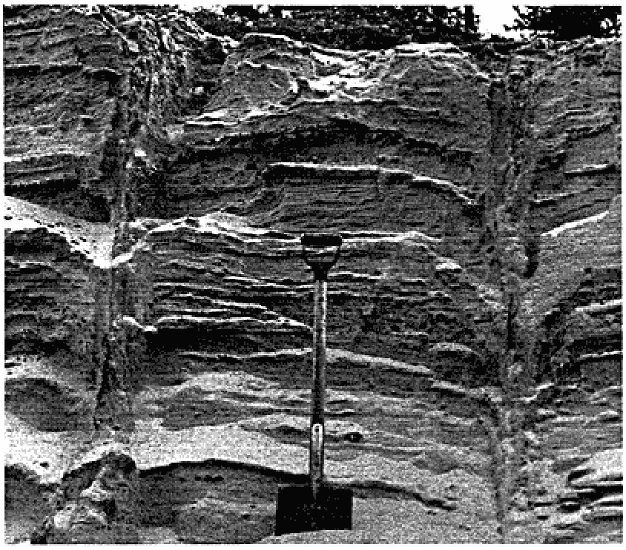

Fig. 3. Two ice-wedge pseudomorphs in a gravel pit at Alslev. Photo H. Svensson, Sept. 29, 1977.
Fig. 3. To iskile-afstøbninger i en grusgrav ved Alslev.

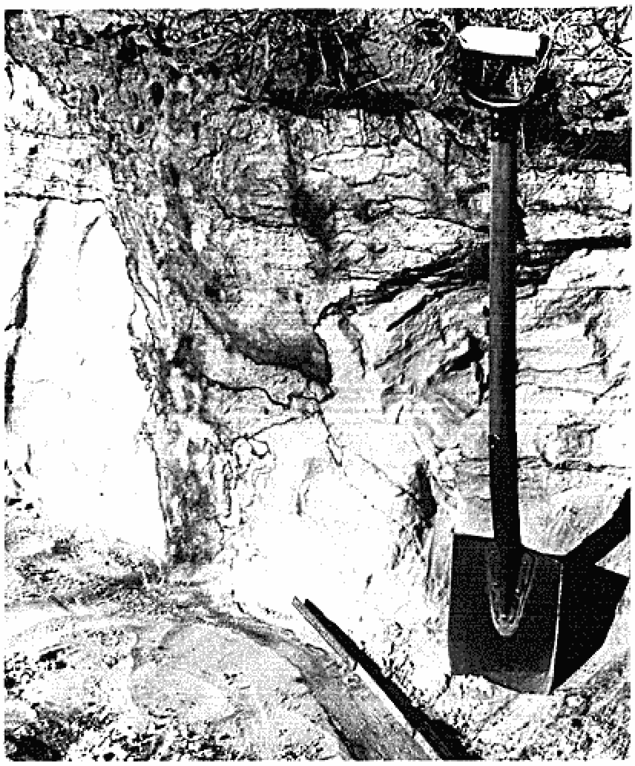

Fig. 4. Wedge cast in sandy host material at Videbaek. The asymmetry of the wedge is due to the fact that the wedge is obliquely cut; the folding rule indicates the horizontal direction of the wedge. Photo H. Svensson, May 14, 1971.
Fig. 4. Kileaftryk i sand ved Videbæk. Den asymmetriske form skyldes skrå overskæring af kilen. Tommestokken viser kilens horizontale retning.

opment of the crop during the season. For instance in an area photographed at the end of May the polygons were distinctly outlined in a bright grey tone, but ten days later, when the crop had grown higher, the pattern was not visible in photographs of the same area (Svensson 1972).

Even in other disciplines, especially in archaeology, the interpretation was later advanced that the line pattern had an anthropogenic origin. This is in a way not striking, as there are for many areas in Jutland indications of ancient fields in air photos. (Jeansson 1963). The problem was last brought up in the periodical SKALK 1977. By courtesy of the editor I got the possibility of analysing a large amount of pictures taken for SKALK from a small aircraft. In the picture series there were indications of archaelogical features, but the polygonal crop marks were without any doubt fossil ice-wedge polygons.

The polygon patterns are outlined due to a line-bound differentiation of the growth, either with a weeker or a more luxuriant growth in the lines. In the first case the pattern is marked by a bright, and in the second case by a dark grey tone in black-and-white pictures photographed in spring time. In potographs from late summer the originally dark pattern has passed into a bright one, due to the earlier ripening in the polygon lines (Svensson 1972 and Christensen 1974).

3. Vertical section

Test pits dug into polygon fields show disturbances of the type of ice-wedge pseudomorphs formed by infilling during the melting out (thermokarst) of the ice. Analogous observations have also been made in gravel pits, both in vertical and horizontal sections and in road cuttings. In fluvioglacial sediments the wedge character is emphasized by distinct interruptions in the stratification, or by a bending down of the beds against the wedge (Fig. 3). Sometimes small faults and secondary fissures occur in the host material close to the wedge cast and may, together with the properties of the wedge itself (contour and structure of the fill material), be informative of the fossilization process.

When the wedges occur in a homogeneous matrix such as eolian sand, the possibilities usually do not exist for a structure-based registration of the contour. The cast may, however, be recorded by chemical precipitation in the wedge and/or along the contour (Fig. 4).

Formed in a silt-clay matrix the outline of a wedge pseudomorph is usually less conspicuous (Fig. 5), a fact that may be due to:

1. The morphogenetic conditions of the permafrost stage; the wedge being branched in this type of material.
2. Mass movements in the watery material during the fossilization deforming the original contour of the wedge.

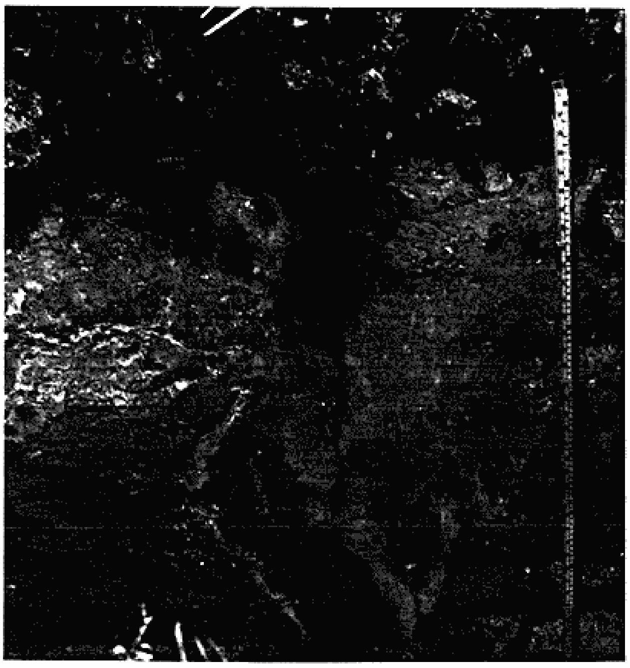

Fig. 5. Ice-wedge cast in a clayey host material at Borris. Photo H. Svensson, Sept. 3, 1971.
Fig. 5. Iskile-aftryk i leret materiale ved Borris.

The casts observed correspond to epigenetically formed wedges. In some deeper sections intersedimentary casts occur which may be considered to have a syngenetic origin.

4. External parametres significant for the vegetation-recorded patterns
Vertical sections have exposed a difference in structure and composition between the infilled wedge material and the host material. This condition constitutes the background for the outlining by vegetation and its dependence of moisture conditions. It is evident that external parametres that influence the water conditions may strengthen or exclude the registration. Local breaks in the pattern thus exist in surfaces with low depressions which, due to the grey tones, have a higher moisture content than the surrounding fields, or where sheets of wind-blown sand screen the pattern (Fig. 6). Besides such just local conditions, more general parametres like precipitation and temperature are important for the registration of the pattern. A check with climatic records reveals a clear connection between a well developed network and long periods of drought (Svensson 1972 and Christensen 1974).

As an indirect proof of the significance of soil moisture conditions for the showing up of polygonal patterns it can be mentioned that during the last years the increased artificial irrigation has caused a lower frequency of visible polygonal patterns in some districts of Jutland.

5. Form and dimensions
Generally the contour is composed of right, or nearly right lines, but sometimes it approaches a ring form, cf. Figs 2 and 6. The dimension of the polygons varies. A diameter of 10-15 m is usual. More rarely the cross section exceeds 25 m. The width of the contour (vegetation zone) lies between 1 and 3 m, measured in the aerial photographs. In one and the same area the polygons usually show only small variations in dimension and furthermore have nearly accordant shape.

Polygons of the larger dimension are usually characterized by a more rectilinear contour than the smaller polygons and often have the shape of tetragons (cf. Christensen 1974). The contour observed in the photographs is also thinner and rarely exceeds 2 m.

Visually there exists such a clear difference between the smaller ring-formed and the larger tetragonal polygons that, from a geometrical point of view, they seem to represent two types.

6. Type and age
The difference in shape and size may reflect an age relationship, but may also depend on divergence in material (cf. Christensen 1974). The fine-meshed type of rounded

Fig. 6. Polygons in cultivated fields at Videbaek. The legibility of the pattern is conditioned by ground relief and material properties. Approx. scale 1:3,500. Air photo May 10, 1954. Copyright Geodetic Institute, Copenhagen.
Fig. 6. Polygoner i dyrkede marker ved Videbæk. Overfladerelief og materiale påvirker linjernes tydelighed.

polygons and relatively wide contours no doubt constitutes a well-developed polygon net. Originally larger polygons have successively been divided into smaller individuals, and the uniform and regular network may be considered the optimal cell structure in permafrost, for a long time subjected to thermal contraction. These relations are known from present-day permafrost areas.

The other type constitutes a younger generation of polygons, for which the secondary division into minor units was not completed because of insufficient time span of formation. Unequal-sized polygons with this origin of their relative age difference are observed in raised terrasses in northernmost Norway (Svensson et al. 1967 and 1982a).

7. Age difference and pseudomorphs

In vertical sections, casts of various dimensions are found. Thin casts may be suspected to represent younger frost fissures dividing large polygons into minor individuals. This relation in age is, however, not a priori evident, but has to be considered from a lithostratigraphic point of view in each case. Concerning the lapse rate of the activity of the polygons, it may be postulated with a higher degree of certainty that a wide cast indicates a longer period of wedge formation than a thin one.

In some cases it has been possible to obtain a more distinct age relation between ice-wedge pseudomorphs, for example where two wedges interfere, such as shown in Fig. 7. A pseudomorph stands out both because of its wedge form and the precipitation of iron and manganese. To the left, a minor cast is seen which shows no chemical precipitation in the material in the levels corresponding to the large wedge. From the contour and the lacking precipitation it is evident that the smaller wedge is no branch of the larger one, but an independent wedge fossilized during a period when precipitation of iron and manganese was brought to an end. It means that the large wedge pseudomorph existed, when the minor wedge (cast) was formed. Other wedges in the the same gravel pit show the same characteristic.

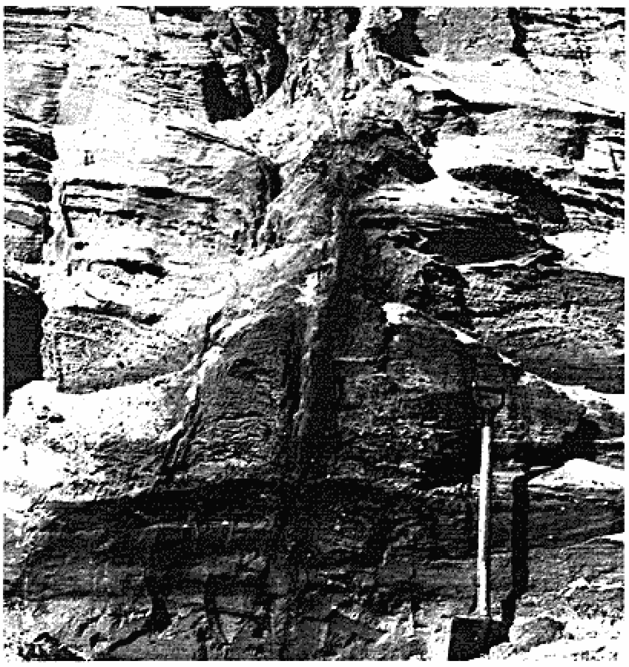

Fig. 7. Two generations of fossil ice wedges at Alslev. Photo H. Svensson, Sept. 29, 1977.

Fig. 7. To generationer af fossile iskiler ved Alslev.

Fig. 8. Section through a deposit of sandy material with an infilling of pure sand at Videback. The folding rule indicates the horizontal direction of the wedge. Photo H. Svensson, May 14, 1971.

Fig. 8. Tværsnit gennem aflejring af sandet materiale med en kile af rent sand ved Videbæk. Tommestokken viser kilens horizontale retning.

II. SAND-WEDGE POLYGONS

1. Present-day formation

Quite recently, the type sand-wedge polygons was identified in present-day permafrost areas (Péwé 1959). Morphogenetically, they have the same frost-crack origin as ice-wedge polygons, but belong to more arid areas, where cracks may be infilled also by blowing sand. Thus active sand wedges are a type of primary infillings not to be confused with ice-wedge pseudomorphs filled with sand, which are secondary infillings. In reality pure sand wedges are rare, because there is always some moisture present which contributes to the infilling and thus constitutes a composite wedge.

2. Fossil sand wedges

Classifying a cast of sand (Fig. 8) as a fossil sand wedge is not a priori evident, as it may also be an ice-wedge cast in a sandy matrix (secondary infilling). For the guidance of classification the facts may be used that 1) because of the low moisture content the formation of the sand wedge did not cause any strong wedging distrurbances laterally in the host material by the freezing (closing the crack) and, 2) due to the low ice content the wedge was not subjected to thermokarst processes to any high degree during the fossilization. This means that the adjoining strata are not, or only faintly, bending down against the wedge. The stratification shows a more abrupt vertical cutting than is the case for the funnel-formed ice wedge cast.

3. Fossil surface patterns?

As far as is known, a classification of a polygonal pattern only by shape or dimension as a fossil sand-wedge net has not been reported in literature. Therefore it was considered experimentally interesting to examine aerial photographs from areas outside the main stationary line of the last glaciation, which are rich in sand, for traces of polygonal patterns. In some areas, systems of thin lines were observed which possibly record a polygonal net of sand wedges (Fig. 9). The areas were visited more times in order to identify the lines, which would make it possible to dig test pits, but in vain. As long as no sections are analysed, the existence of a fossil surface pattern of sand-wedge polygons is still an open question.

Fig. 9. Faint polygon pattern in sandy soil at Barslund (Hoven). In the ground surface wind-blown stones are frequent. Approx. scale 1:2,500. Air photo May 9, 1954. Copyright Geodetic Institute, Copenhagen.

Fig. 9. Diffust polygonmønster i sandet jord ved Barslund (Hoven). I overfladen forekommer mange vindblæste sten. Målestok ca. 1:2.500.

Fig. 10. Cryoturbation structures at Saedderup. Photo H. Svensson. Aug. 17, 1978.

Fig. 10. Kryoturbationsformer ved Sædderup.

III. STRUCTURES OF CRYOTURBATION

1. Occurrence in vertical sections

Cryoturbation structures are seen in many Jutlandic gravel pits (Fig. 10). In periglacial works they are reported by Nørvang (1939) and Kolstrup (1980a), but more or less clear phenomena of the same kind appear in illustrations of papers on other items, especially quaternary geology. Sometimes the cryoturbate structures have a marked lower boundary some 1-2 m below the present ground surface. When not directly depending on lithostratigraphic conditions, this boundary may broadly reflect the thickness of the active layer and has thus a paleoclimatic significance.

2. Surface indications of cryoturbation structures

A vertical section is the general dimension for studying cryoturbatic phenomena. However, during the examination of air photos some observations were made that ought to be pointed to in this connection. In some particular areas a mottled surface structure shows up (Fig. 11). Certainly, closed units exist, but on the whole there is no direct geometric conformity with polygons. Nor can the irregular pattern be suspected to be a polygon pattern deformed by solifluction or erosion. The light and dark surfaces in the bare soil reflect a low (micro) relief hard to identify in the field.

This particular pattern is seen in photographs from areas of clayey soil; at the locality A in Fig. 11 there is clay

Fig. 11. Surface pattern of possible cryoturbation origin, visible in unvegetated fields at Uhre (Brande). Approx. scale 1:10,000. Air photo May 10, 1954. Copyright Geodetic Institute, Copenhagen.

Fig. 11. Overflademønster, muligvis forårsaget af kryoturbation, synlig i nogne marker ved Uhre (Brande). Målestok ca. 1:10.000.

to at least 7-m depth according to information from local people. As there is no possibility to relate the pattern to a deglaciation relief, it seems reasonable to take the starting point for an interpretation in material properties. The freezing of sediments with high silt-clay content causes an enrichment of ice and during a period of permafrost ice lenses and ice lacoliths develop. The freeze-thaw cycle results in a cryoturbation of the top soil. By this way of looking, the mottled pattern reveals traces of a surface relief formed during the definite disappearence of permafrost ice in the ground. Possibly, ring-formed elements have a morphogenetical relation to the degeneration of frost mounds related to the pingo type.

IV. PINGO

1. Form characteristics

The fossil form of a pingo has the nature of a collapse feature, caused by the disappearing of the ice content. Considering the good scale and equidistance properties of Danish maps, large collapse forms should have been noted long ago. For detecting small-scale, or levelled, forms the map material is, however, not sufficient and aerial photographs must be trusted.

Form characteristics that have been looked for are ring-shaped contours with a central lower part which is moist, overgrown, or filled with eolian sediments. The reason why these criteria were chosen is that during field work in northernmost Norway, excursions in Jakutia, Belgium, and Wales, the rampart was found to constitute the most certain indicium of a fossil pingo (cf. Pissart 1963, Maarleveld 1965, Watson 1974, Svensson 1964 and 1969).

The search for traces of pingos was accomplished contemporaneous with the examination of polygonal network in air photos and resulted in some possible indications, located in flat areas of the old (Saale) moraine and in the outwash plains of the last (Weichsel) glaciation.

2. Remnants of pingos

Generally rampart-like forms are not frequent. When, on air photos, clearly contoured individuals were checked in the field, they show a very faint relief, howerver, that easily escapes attention. The existence of a pond or wet area inside the ring may contribute to outline the form in the plain ground surface.

Out of the observations made, Fig. 12 has been chosen as an example. The pond is surrounded by a faintly marked ring which in the field has the character of a low, levelled wall, built up mostly by sand with some scattered stones in the ground surface. Outside the ring, moisture conditions indicate the existence of other low depressions. The height of the ring does not exceed 1 m above the water surface (Fig. 13).

It is a matter of fact that in cultivated areas ring-formed contours are successively diffused, and the relief smoothed. In areas of natural vegetation, e.g. heath, the form may be recorded by vegetation contrast such as grass- and fen vegetation in the center and ling on the ring.

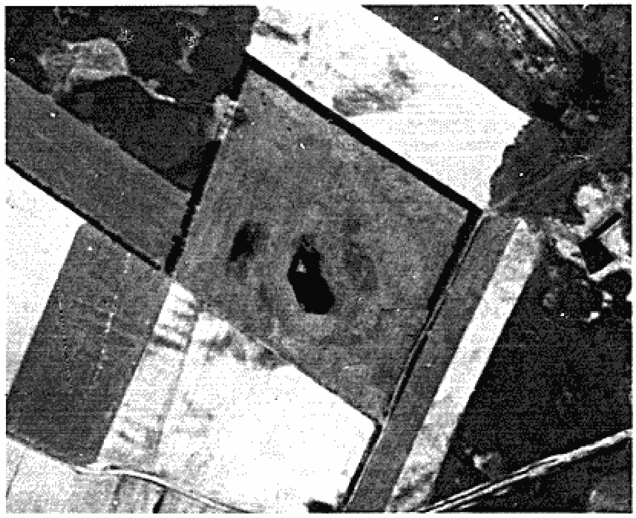

Fig. 12. Indication of a rampart-like form in a cultivated field at Hemmet. Approx. scale 1:2 500. Air photo May 10, 1954. Geodetic Institute, Copenhagen.

Fig. 12. Cirkulær voldform i dyrket mark ved Hemmet. Målestok ca. 1:2.500.

Fig. 13. Ground view of the locality in fig. 12. The low, levelled wall is encircling the pond. Photo H. Svensson. Aug. 18, 1978.

Fig. 13. Formen i fig. 12 set fra jorden. Den flade, lave vold omkranser et vandhul.

3. Comments to the interpretation

Even though the rampart character is a good criterion of a collapsed pingo, other possible processes forming similar features are to be considered. Due to the situation a glacial origin (dead ice) is out of question, so eolian activity seems to be the only alternative. Blow-out features exist in the study areas, but circular, closed depressions reaching below the ground-water level do not meet the geomorphological characteristics of eolian phenomena. The existence of ice-wedge polygons clearly indicates that the area once constituted a permafrost environment. Keeping these facts in mind makes it reasonable to interpret the rampart-like feature as remnants of periglacial frost mounds or pingos of a moderate size. Similar features, but in areas unaffected by man, are known from northernmost Norway (Svensson 1964 and 1969).

V. THERMOKARST DEPRESSIONS

1. Form and genesis

In arctic plains or river terraces built up by fine-grained sediments with high ice content, lakes often develop due to thermokarst processes. Usually the lakes are shallow and surrounded by a well defined bank, where thermoerosion is still active, as for instance in the Jakutian alaslakes. The depressions occur in groups and have dimensions from less than 100 m to several km in length. Because of the thermoerosive enlargement they sometimes interfere and get more irregular contours. Especially in coastal plains there is often a consistent long-axis orientation of the elongated lakes caused by wind-induced wave- and stream movements accelerating the thermoerosion.

2. Possible existence of fossil forms

As far as known traces of oriented lakes in present-day permafrost-free areas have not been reported in literature. Theoretically the permafrost zone outside the main stationary line of the last glaciation in Jutland constituted an area potential of thermokarst activity, especially surfaces underlain with fine-grained and accordingly ice-rich sediments. Furthermore, uniform wind systems (catabatic and cyclonal) ought to have existed in this real periglacial environment. From the morphogenetic point of view a development of thermokarst depressions including oriented lakes may quite well be imagined.

3. Indications of fossil forms

As the thermokarst lake in present-day permafrost areas is a relatively shallow basin, it is to be expected that if a fossil form exists, it will not show a sharply contoured water line, but be more or less filled up and overgrown. Cultivation and draining may also have influenced the outlines.

During the air photo analysis contours have been observed which may be considered possible indications of fossil thermokarst depressions. In Fig. 14 one such area is shown with two regular, oval contours (A and B) in the cultivated ground surface. Both have the same long-axis orientation (NNE-SSW) and now constitute very shallow depressions (< 1 m). Difference in ground moisture contributes in revealing the form in air photos. In close vicinity there is a third low depression (C) whose contour, however, is influenced by roads and a railway embankment. Most other indications observed are not so regular in shape, but in some cases there is a certain uniformity in orientation and they always appear in groups.

VI. CONCLUDING REMARKS AND PROPOSAL FOR FURTHER APPROACH

The development of periglacial forms is first and foremost a function of cold climate. Within the requisite climatic conditions a broad spectrum of periglacial phenomena may form dependent on parametres such as topography, ground material properties, soil water supply, and time. As the morphogenetic parametres seem to have been fulfilled to a high extent in the former arctic environment of western Jutland, it may be suspected that many members of the periglacial form group might develop.

It should be kept in mind, however, that after the development of the permafrost features and above all during and after their fossilization, the area was subjected to subaerial erosion and eolian accumulation. Later the area was also underlain human activity. These facts mean that relief is smoothed and contours are blurred, which hampers detection. In spite of these geomorphic and antroprogenic alternations of the original ground surface that sometimes render the true identification of the forms in question difficult, the assumption of West Jutland as a potential interesting area for studies of fossil periglacial features in loose material have been clearly confirmed. In this paper some periglacial features are identified and possible traces of others are hypothetically pointed at. To get a more reliable view of the diversification of elements and paleoclimatic significance of the periglacial form group, there is more work to do. Some problems considered as potentially interesting are listed below.

A. Fossil ice-wedge polygons

1. With starting point in variations in pattern character, polygon dimension, and geographic distribution.
   a. May the period of activity (duration of permafrost) be judged from pattern characteristics?
   b. Does there exist a clear connection between material properties and the geometric character of the polygon pattern?
   c. May the fine-meshed polygon system be formed during Weichsel?
   e. Has gelifluction/solifluction modified, or deformed, the original polygon pattern?
   f. What is the reason for the irregularity in the regional distribution of polygons?
   g. May fossil ice-wedge polygons be used to indicate the outer limit of the glaciation?

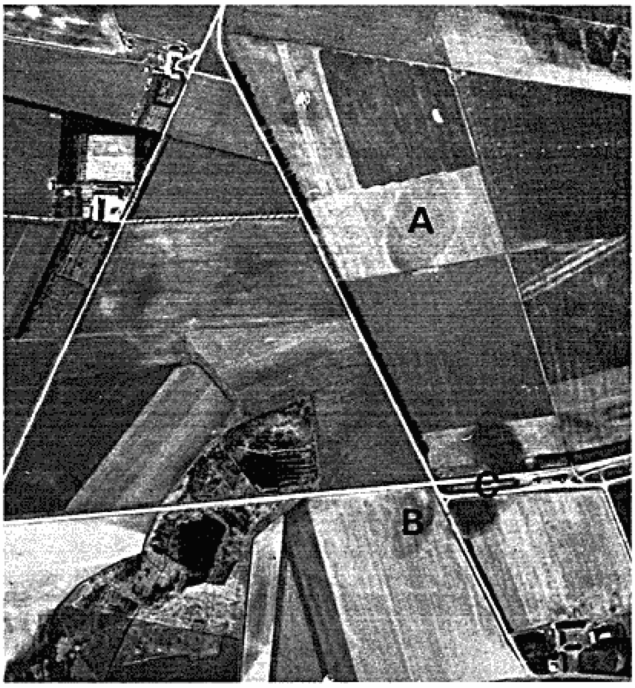

Fig. 14. Elliptical contours indicating low depressions at Eg (Grindsted). Approx. scale 1:5,000. Air photo May 9, 1954. Copyright Geodetic Institute, Copenhagen.
Fig. 14. Elliptiske omrids der viser lavninger i terrænet ved Eg (Grindsted). Målestok ca. 1:5.000.

2. With starting point in material properties and structures in horizontal and vertical sections.
   a. Influence of thermokarst processes on the wedge form in different host material.
   b. The possible use of intersecting ice wedges for judging age relations.
   c. Has a reactivation of ice wedges (»wedge in wedge«) occurred?
   d. What is the frequency of syngenetic and/or intersedimentary ice wedges?
   e. The possible occurrence of sand wedges (primary infillings)
   f. Sedimentologic characteristics of the fill- and host material.

B. Pingos and thermokarst depressions

a. Further search for morphologic traces in air photos and field studies of possible indications.
b. Boring for analysis of sediments in suspected collapse features.
c. Studies of material and structures in vertical profiles through ramparts.

C. Naledi, icings

a. Possible traces of icings in surface patterns and in sedimentary structures of vertical sections.

D. Periglacial valleys

a. Distribution of periglacial valleys.

b. Orientation and symmetry of periglacial valleys.

c. Is the formation of periglacial valleys intiated or facilitated by thermokarst processes in ice-wedge polygons?

E. Climatic parametres

a. Further collecting of observations on the thickness of the active layer (temperature factor).

b. Possible concordance in the orientation of thermokarst depressions (wind factor).

c. Do sand-wedge polygons occur (precipitation factor)?

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Resumé

På grund af sin beliggenhed uden for hovedopholdslinjen for sidste istid må den sydvestlige del af Jylland antages at give meget gode muligheder for studier af fossile arktiske frostjordsformer. Efter flerårige studier i danske flyfotoarkiver og foreløbige publikationer (1963, 1970 og 1972) startedes i 1975 et projekt for en registrering og kortlægning af fossile permafrostformer i Vestjylland. Arbejdet er udført som en analyse af flyfotos fra Geodætisk Instituts billedarkiv samt feltundersøgelser af udvalgte lokaliteter. I arbejdet deltog specialestuderende.

Trods naturlige processer i jordoverfladen (erosion og akkumulation) og menneskets påvirkning (f.eks. opdyrkning) er flere af den arktiske geomorfologis former i løse sedimenter blevet identificeret. Med erfaringer fra nutidige arktiske områder (Grønland, Svalbard og Jakutien) diskuteres formernes dannelsesmåde og kronologi ud fra aktualistiske principper; endvidere sammenlignes med fossile former i andre nordiske lande (Nordnorge, Island og Sydsverige). Undersøgelserne bekræfter formodningen om Vestjylland som et potentielt vigtigt område for analyse af fossile former i den arktiske formserie, og der fremsættes forslag om geomorfologiske problemstillinger, som bør tages op i de fortsatte undersøgelser.

References

Christensen, L., 1973: Fossile polygonmønstre i jyske landbrugsjorder. (Abstract. Fossil large-scale patterned ground in agricultural fields in Jutland). Ugeskrift. f. Agronomer og Hortonomer 2.

Christensen, L., 1974: Crop marks revealing large-scale patterned ground structures in cultivated areas, southwestern Jutland, Denmark. Boreas 3.

Christensen, L., 1978: Waterstress conditions in cereals used in recognizing fossil ice-wedge polygonal patterns in Denmark and northern Germany. Proc. 3. Intern. Conf. on Permafrost. Edmonton.

Jeansson, N.-R., 1963: Ancient fields in Himmerland, Denmark – an air photo survey. Svensk Geogr. Årsb. 39.

Kolstrup, E., 1980a: Climate and stratigraphy in north-western Europe between 30.000 B.P. and 13.000 B.P. with special reference to the Netherlands. Med. Rijks. Geol. Dienst. 32-15.

Kolstrup, E., 1980b: Frostkiler og hvad de kan bruges til. Dansk Natur – Dansk Skole. Årsskr. 1980.

Maarleveld, G. C., 1965: Frost mounds. Medd. Geol. Sticht. N.S. 17.

Norvang, A., 1939: Stenringe og frostspalter i Danmark. Naturhist. Tidende 3.

Norvang, A., 1942: Frostspalter i Jylland. (Abstr. Frost fissurers in Jutland.) Medd. Dansk Geol. Foren. 10:2.

Péwé, T., 1959: Sand-wedge polygons (tesselations) in the Mac Murdo Sound region, Antarctica. – A progress report. Amer. Journ. of Sci. 257.

Pissart, A., Les trace de »pingos« du Pay de Galles (Grand Bretagne) et du plateau des Hautes Fagnes (Belgique). Zeitschr. f. Geomorph. N.F. 2.

SKALK 1977: Kornets arkæologi.

Sjørring, S., 1979: Fossil kulde og varme. Varv 1979:1.

Steenstrup, K. J. V., 1897: Jordskælvsspalter? Dansk Geol. Foren. 4.

Svensson, H., 1963: Some observations in West-Jutland of a polygonal pattern in the ground. Geogr. Tidsskr. 62.

Svensson, H., 1964: Traces of pingo-like frost mounds. Svensk Geogr. Årsb. 40.

Svensson, H. 1969: A type of circular lakes in northernmost Norway. Geogr. Ann. 51A.

Svensson, H., 1970: Fossila skandinaviska frostmarksformer. En jämförelse med recent permafrost på Spetsbergen och i Jakutien. Abstract. Geol. Fören. i Sthlm. Förh. 92.

Svensson, H., 1971: Pingos i yttre delen av Adventdalen. Norsk Polarinst. Årb. 1969.

Svensson, H., 1972: The use of stress situations in vegetation for detecting ground conditions on aerial photographs. Photogrammetria 28.

Svensson, H., 1976a: Pingo problems of the Scandinavian countries. Biul. Perygl. 26.

Svensson, H., 1976b: Relict ice-wedge polygons revealed on aerial photographs from Kaltenkirchen, northern Germany. Geogr. Tidsskr. 75.

Svensson, H., 1982a: Age determination of fossil ice-wedge polygons in Nordic areas. Biul. Perygl. 29.

Svensson, H., 1982b: Valley formation initiated by ice-wedge polygonal nets in terrace surfaces. Biul. Perygl. 29.

Svensson, H., et al. 1967: Polygonal ground and solifluction features. Lund Stud. in Geogr. SerA 40.

Watson, E. and Watson, S., 1974: Remains of pingos in the Cletwr basin, southwest Wales Geogr. Ann. 56A.

D. Periglacial valleys

a. Distribution of periglacial valleys.

b. Orientation and symmetry of periglacial valleys.

c. Is the formation of periglacial valleys intiated or facilitated by thermokarst processes in ice-wedge polygons?

E. Climatic parametres

a. Further collecting of observations on the thickness of the active layer (temperature factor).

b. Possible concordance in the orientation of thermokarst depressions (wind factor).

c. Do sand-wedge polygons occur (precipitation factor)?

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References

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Kolstrup, E., 1980b: Frostkiler og hvad de kan bruges til. Dansk Natur – Dansk Skole. Årsskr. 1980.

Maarleveld, G. C., 1965: Frost mounds. Medd. Geol. Sticht. N.S. 17.

Norvang, A., 1939: Stenringe og frostspalter i Danmark. Naturhist. Tidende 3.

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Péwé, T., 1959: Sand-wedge polygons (tesselations) in the Mac Murdo Sound region, Antarctica. – A progress report. Amer. Journ. of Sci. 257.

Pissart, A., Les trace de »pingos« du Pay de Galles (Grand Bretagne) et du plateau des Hautes Fagnes (Belgique). Zeitschr. f. Geomorph. N.F. 2.

SKALK 1977: Kornets arkæologi.

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