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PINGO PROBLEMS IN THE SCANDINAVIAN COUNTRIES

Abstract

The northern part of Scandinavian peninsula reaches such high latitudes that permafost occurs, especially in peat bogs. The most typical and frequent form of permafrost in these northern regions is the palsa, a frost mound a few metres high and covered with peat. The interior structure of the palsa is mostly built up of segregated ice. The palsa does not require such hard climatic conditions for its formation as does the pingo. In northern Scandinavia palsas appear in different stages of degeneration and have been sometimes confused with pingos.

True pingos in active formation do not exist in the Scandinavian peninsula. Further northwards, in Spitsbergen, however, pingos can be found in different stages of development.

In aerial photographs of plateau areas in northern Norway, terrain features have been observed that from the geomorphological point of view show the characteristics of both the palsa and the pingo group. A type of circular lakes formed in minerogenic soil is interpreted as a fresh collapse stage of frost mounds that have originated as palsas or pingos. Ring-ridged depressions of a more stable character probably have the same origin but are of an older date.

In southern Scandinavia pingos may be suspected to have formed (1) in the periglacial environment of the retreating ice sheet of the last (Vistula) glaciation or (2) outside the margin of the ice cap, e.g. in western Jutland, Denmark.

During the deglaciation, periods of climatic deterioration occurred, as it is manifested by the vast areas of fossil ice-wedge polygons in southern Sweden. Some circular depressions filled with peat occur. However, as they lack a bordering ring wall, these depressions cannot be geomorphologically classified as collapse forms of pingos.

Western Jutland was not covered by the last glaciation and was for a long time exposed to a periglacial climate. In aerial photographs, low relief features of circular to oval shape have been observed in cultivated areas of Jutland. From the geomorphological point of view, their origin is hard to explain, except in terms of thermokarst processes in former frost mounds.

INTRODUCTION

From the point of view of permafrost or periglacial geomorphology, Scandinavia is of interest for two main reasons. (1) The northern part of the peninsula reaches such high latitudes and approaches the great Euro-Asiatic permafrost belt so closely that frozen-ground might exist. It may also be supposed that fossil forms appear which originated in periods of colder climate, when the border of the continuous permafrost zone in northern Russia may have migrated further westwards. (2) The southwestern part of Scandinavia (western Jutland) was not invaded by the last (Vistula) glaciation and formed for a long period a real periglacial environment.

These two considerations have been the basis for the study of permafrost topography, which was started in 1961. Aerial photographs were used for the inventory

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of the different forms, as well as for the planning of the field work. As regards the pingo forms in particular, aerial photographs turned out to be an indispensable tool, because the pingo problem in Scandinavia is a problem of detection.

This paper is intended to be a report of the observations of variants of permafrost mounds made during investigations on periglacial geomorphology, especially ice-wedge polygons, in the Scandinavian countries (Denmark, Norway and Sweden).

NORTHERN SCANDINAVIA

PALSA

In northern Scandinavia, discontinuous areas of permanently frozen ground exist. The most frequent topographic feature of the permafrost is the palsa, which occurs in bogs and stands out as a peat mound. The form of the palsas varies from singular, well-defined, individual mounds to complexes of hillocks. The peat cover is often more than 50 cm thick. Larger palsas usually contain a core of minerogenic material, interspersed with networks of segregated ice. The maximum height of a palsa observed in the northern districts is 7 m.

From the geomorphological point of view the characteristics of the palsas in the northeasternmost part of Norway may be described as follows:

1. Many palsas are surrounded by a small body of water, which is thought to have been formed by the weight of the growing palsa depressing the surrounding bog surface.

2. Palsas are eroded mainly by the thermokarst processes acting laterally. The erosion is accelerated by the presence of a body of water. The end stage of palsa degeneration is a circular or oval pond.

3. In the high palsas, the peat cover is dissected by vertical fissures. In summer, the fissures are open to a depth of 40—60 cm. Further down, they are filled with vein ice.

The possible causes of fissuring are: (a) an interior breaking force generated by the growing of the palsa, (b) thermal contraction, and (c) drying. The second possibility (b) is the most likely.

4. The dissection of the peat mantle is of great importance in the erosion of palsas. Blocks of peat burst or slide down from the flanks of the palsa.

5. Small, wind-eroded surfaces without any vegetation sometimes occur on the high palsas.

6. In the existing climate, the insulating peat cover is a necessary condition for the preservation of a palsa.

7. The growth of a palsa is caused by the segregation of ice, a process which is especially predominant in palsas containing fine-grained material.

This short survey of palsa morphology is given, because the palsas of northern Scandinavia are sometimes confused with pingos. In the analysis of other frost mounds it may also be useful to bear in mind some of these characteristics of the palsa morphology.

CIRCULAR LAKES

On the plateau of Finnmarksvidda in the northernmost part of Norway, there occurs a type of small lakes or ponds with a very regular and smooth shore contour of an often circular shape. These lakes or ponds always occur in groups. The diameters of the individual lakes usually do not exceed 50 m.

The lakes occur mostly in shallow depressions in areas of fluvioglacial deposits (SVENSSON, 1969). High moisture content is characteristic of the ground. The localities observed are situated at elevations of 400—600 m, well above the timber line.

The clear delineation of the lakes is often emphasized by an encircling ring-wall or ring-ridge. The rampart-like rings are not all equally distinct. The analysis of aerial photographs shows that the rings are in different stages of development.

As type locality, a depression in the upper part of the small river Corgosjokka (70°N, 20°E) was chosen. The lakes occur in a flat valley bottom on both sides of the river. The ring-walls vary in height and distinctness. The height only exceptionally exceeds 1.5 m.

The ring is built up of fine-grained material and in a vertical cut thin interrupted layers or lenses of peat appear in the fines. The surface layer of organic material on the ring is very thin. Except in some low rings, the outer slope of the ring is steep and differs clearly from the inner one. In the best developed rings, open fissures are to be seen, running along the top of the ring conformably with its contour. The fissures indicate that the inner part of the ring has slipped and moved inwards.

Some rings are steep and look newly developed. Other rings are greatly levelled, and the circular form is more emphasized by contrast in vegetation than by the relief on the ground. These rings are overgrown and in some cases partly covered by lichens. No open fissures are seen in the surface of the levelled rings.

One of the circular forms in the Corgosjokka locality differs from the others in that the area inside the contour is not occupied by water, except for a very small part. Like the other circularly shaped rings it is bordered by a low distal slope. However, the ring is not formed as a clear double-sided ridge, because the ground surface of the inner part is situated nearly at the same elevation, with the exception of the circle-sector-shaped area occupied by muddy water in the southern part of the form. Here a real ridge exists. Viewed at a distance, the ring gave the impression of a low tabular mound.

The composition of the soil in the mound is very homogeneous (90% silt). Because of the high moisture content, it was impossible to go deeper than 80 cm by digging. At this depth, the pit was filled by inflowing soil. The possible existence of a frost surface could not be confirmed.

The aerial photographs that drew the attention to the circular forms were taken in 1961. In these photographs, a small area of bare soil was seen in the tabular mound. Oblique aerial photographs taken in 1965 and 1967 indicated that the eroded central surface had grown larger. Obviously the tabular mound is in an advanced stage of collapse.

The existence of the tabular mound and its degeneration characteristics are of interest, as they illustrate a current aspect of the formation of the circular lakes. These lakes must be considered to show the collapse (end) stage of frost mounds in which thermokarst processes and mass movements have acted.

The geomorphological details of the Corgosjokka features, together with the fact that the rings and the tabular mound were formed in minerogenic material, may indicate that these features are a type of pingo remnants. The characteristics of the locality, a shallow, basin-like valley containing fine-grained material, are conditions suitable for pingo growth ("closed system", PORSILD, 1938, p. 55; MÜLLER, 1959, p. 97; and MACKAY, 1963, p. 69).

True recent pingos are not found in Scandinavia. The collapsed mounds that have been earlier observed in northernmost Norway (SVENSSON, 1962b, 1964a) are fossil forms dating from periods of more severe climate. The circular lakes in the Abisko area in northern Sweden, reported by RAPP and RUDBERG (1960, p. 150), are suspected to be "remains of small pingos".

The Corgosjokka area is undoubtedly situated in the district with the most severe climate in northern Scandinavia. Unfortunately, there is no weather station in the immediate neighbourhood. The mean annual air temperature and precipitation at the nearest station, Karasjokk (35 km to the south), are −2.1°C and 316 mm. The present climate seems to exclude the pingo alternative for the frost mounds.

Though they were not formed in a real bog, I am inclined to consider the initial form of the ring lakes, e.g. the low frost mounds, to be of the palsa type, formed by the upheaval of the surface due to segregation of ice. The possible existence of a hydrolaccolith cannot be denied but, from some detailed studies made in the frozen cores of palsas (SVENSSON, 1964b; WRAMNER, 1967, 1974; ÅHMAN, 1967), it is clear that the freezing of fine-grained supersaturated material with the suction of moisture to the zone of freezing, will result in an intense segregation of ice in the form of ice inclusions or lens-like ice-layers, which will cause an effective upheaval of the ground with the formation of a mound.

For the existence of palsas, a peat cover is necessary, because of its insulating effect during the summer. For the formation and especially for the preservation of a frost mound in minerogenic material without a peat cover, the insulating effect of the missing peat mantle must be compensated for by a lower summer temperature in the district where the mounds are situated. The ring-lake form may be a transitional form between the palsa and the pingo.

COLLAPSED MOUNDS

On the gently rolling mountain surfaces (Finnmarksvidda) of northern Norway (250—600 m above sea level), there is a terrain form of sparse occurrence that shows characteristics which indicate the destruction of former mounds by collapse processes. In aerial photographs, the form is delineated by its usually closed, circular-to-oval contour. Individual forms with a diameter of more than 100 m and a height of 8 m have been observed. Most of the forms, however, do not reach these dimensions and may easily be overlooked on the ground in flat mountain areas. The forms have developed in minerogenic material having the character of marginal deposits from a period of the deglaciation. Within the form group, there are variants from individual forms of a crater-like shape to a more ring-ridged form. Large-scale polygons are very often faintly delineated in the vicinity, but no active wedging is seen and no active thermokarst processes are observed in the mounds, which are covered with a sparse vegetation of mosses, lichens and scrub. Ring-ridged forms of the same characteristics have been described from northern Finland by SEPPÄLÄ (1972).

Two variants of the collapsed mound group have been observed (SVENSSON, 1964): (1) hillocks with a central depression and (2) ramparts enclosing a flat depression. In the first variant the mound character is obvious, but in the second case the ring form is the predominant feature. Both variants occur in groups.

It would have been of great interest to make a section through one of the hillocks, in order to get an idea of the structure and stratigraphy of the interior. Because of the very stony and hard ground, however, it was impossible to make a good section by using hand tools. Unfortunately, the hillocks are situated too far from any road to make it possible to transport mechanical equipment to the site.

The geomorphological details of the first type of mounds correspond in many respects with the degeneration features of hydrolaccoliths (pingos). In view of the situation of the mounds, i.e. in plateau areas or in slightly sloping ground, the interpretation of the collapse forms as remnants of pingos of the open system type seems to be the most likely.

Concerning the second type of collapsed mounds, i.e. the rampart-like type, there could be some doubt to classify it as a remnant of a real pingo. The ramparts seem to be more related to the ring-lake type described above.

SOUTHERN SCANDINAVIA

THE POSSIBLE OCCURRENCE OF PINGO REMNANTS

In southern Scandinavia, pingos may be suspected to have formed during periods when the climate was determined by the ice cap of the last Scandinavian ice sheet. If they exist, the remnants of frost mounds must have been greatly levelled by sub-aerial erosion down the ages.

For the detection of pingo features, it is, of course, desirable to use geomorphological criteria, such as circular contour, closed depression, and ring wall. The relief may, however, have been smoothed out, making the identification very problematic. From the existence of clusters of small ponds in south-eastern Zealand, CAILLEUX (1957) suspected the depressions to be remnants of pingos.

As regards the formation of pingos in southern Scandinavia, two periglacial environments must be considered: (1) areas adjacent to the receding ice front of the last glaciation, (2) areas outside the extreme limit of the Scandinavian ice sheet.

1. The recession of the ice sheet was interrupted by periods of climatic depression. Thus a severe periglacial climate prevailed during the Older Dryas and the Younger Dryas periods, as may be concluded from the formation of ice-wedge polygons over vast areas in southern Sweden. During dry summers, the polygon networks can be seen in their fossil stage in the form of crop marks.

Inside the polygon networks that are most distinctly impressed in former delta surfaces from the deglaciation, depressions are now filled with peat. In some places they have been drained and incorporated in the areable land. As the depressions lack a bordering rim, they cannot, on geomorphological grounds, be suspected to be remnants of pingos. The hollows may also be explained as depressions caused by the melting of ice blocks embedded in fluvioglacial material (dead ice). This is the origin of the topography of depressions in other parts of the raised delta area.

2. South-western Jutland was not covered by the ice sheet during the last Scandinavian glaciation. The terrain outside the ice margin constituted a low-lying area of glacial deposits from the Saale glaciation ("bakkeøer") and was supplied with fluvioglacial material from the (Vistula) ice sheet, forming vast outwash plains ("hedesletter"). This landscape had for a long time an arctic climate, judging not only from the true periglacial situation of the area at the time but also from the frequent occurrence of fossil ice-wedge polygons. No other district in Scandinavia shows such extensive areas of equally meshed polygons and deeply penetrating ice-wedge casts, indicating a long period of development, as does south-western Jutland.

The analysis of aerial photographs (1:10,000) has drawn attention to some surface forms of very low relief, often observable only because of vegetation differences or moisture contrasts. In clayey soil, the surface has a mottled appearance, with irregularly curving, bright zones enclosing darker (moister) parts.

Of great interest in this special connection are, however, the more regular, circular-to-oval depressions that may be distinguished in aerial photographs but easily escape attention on the ground. In some cases, the depressions are bordered by a very low, flat wall, giving the whole form the appearance of a collapse feature.

In other cases, the depressions have an elongated contour without any bordering rim. Individual forms of this type have been observed in groups, all of them elongated in the same direction in one and the same area. The situation in flat areas, the closed elliptical contour and, above all, the parallelism of the longitudinal axis, remind one of the specific type of depressions (oriented lakes) that is known from the coastal areas of recent arctic regions.

The observed features are situated in arable land. There is no exposure in the fields and it has, unfortunately, not been possible to perform a stratigraphic study, like that made by DYLIK (1963) on the now classical site at Józefów.

An interpretation of the observed features requires consideration of other possible processes. In the areas outside the ice margin, especially the wind must be considered. There is no doubt that eolian activity (that may still be very strong) was for a long time of very great importance in smoothing out existing low relief, as well as in moulding out surface details. More or less closed depressions, for instance, are well known as blow-out phenomena in recent deflation areas.

Taking these facts and the geomorphological characteristics into consideration in the interpretation of photographs and the field studies of the south-western Jutland areas, it seems very difficult to discuss these circular-to-oval features in any other terms than periglacial origin and later thermokarst degradation.

CONCLUSION

Northern Scandinavia

(1a) Under the recent climatic conditions, peat-mantled frost mounds (palsas) frequently occur in the peat bogs of northernmost Scandinavia.

(1b) The palsas have a cyclic development. The degradation goes on through thermokarst processes, creating transitional erosion forms.

(2a) Mounds of minerogenic, mostly fine-grained material without any peat cover, form in continental areas with a more severe climate.

(2b) Genetically, the minerogenic mounds are of the palsa type but constitute a transitional form to the pingo.

(2c) Thermokarst processes affect the minerogenic mounds, giving rise to the circular lakes as the end stage.

(3a) Collapse forms of a more crater-like shape occur in flat or slightly sloping areas in the interior of northernmost Norway.

(3b) No active degeneration processes are to be seen in these collapsed forms. The original mounds were probably pingos of the open-system type.

(3c) The pingos were formed in a severe climate, probably during intervals of climatic deterioration in the deglaciation period.

Southern Scandinavia

(4a) The low relief (micro-relief) of the mottled surfaces in Jutland outside the limit of the last glaciation was created by cryoturbation.

(4b) Groups of circular to oval depressions in western Jutland may be suspected to be fossil forms of pingos.

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