Matti Seppälä *
Helsinki

PRESENT-DAY PERIGLACIAL PHENOMENA IN NORTHERN FINLAND

Abstract

The northernmost part of Finland is located at the southern edge of the zone of discontinuous permafrost. The mean annual temperature of this region is somewhat below −1 °C and during the coldest season in January and February the temperature can fall down below −40 °C. In some favourable localities permafrost survives over the thawing season in mires under dry peat layers. Local permafrost concentrations raise the peat above the surface of the mire forming so called *palsas* which are frost cored peat hummocks rising up to 7 m in height in Finnish Lapland and the diameter can be some hundred metres.

In detailed palsa studies it has been found that their cyclic development is not caused by climatic changes. An experimental study of the formation of an artificial palsa has been carried out. This study has confirmed the hypothesis of the origin of palsas according to which the critical factor is the thickness of snow cover which is controlled by wind drift.

Many other periglacial phenomena occur in northern Finland, but all, with the exception of palsas, are connected with, and formed by seasonal frost. Such are turf hummocks, string bogs, patterned grounds of different types, sand and soil wedges, stone stripes, gelifluction terraces, frost weathering, deflation and dune formation, and phenomena produced by river and lake ice.

Introduction

Finland is located approximately between 60° and 70°N latitude as is the greater part of Alaska. The climate in Finland is much milder than in Alaska, however. The Gulf Stream affects most significantly the climate of Fennoscandian countries. It is the reason why there are not very favourable conditions for permafrost and periglacial phenomena in Finland which belongs to the zone of discontinuous permafrost and seasonal frost.

In southern Finland exists only seasonal frost, the lakes and the great part of Baltic Sea with its Gulfs are ice covered during the winter. The thickness of the frost layer depends of the air temperature and local factors, thickness of snow cover, type of soil, vegetation, and orientation of slope. Because of its practical meaning for human activities the thickness of seasonal frost has long been systematically recorded in Finland by several authorities (see e.g. Keränen, 1923; Soveri, Varjo, 1977).

Systematical soil temperature measurements have also been made by the Finnish Meteorogical Institute at seven sites covering the country from the south to the north (Results of soil temperature measurements in Finland 1961—1970).

* Department of Geography, University of Helsinki, Hallituskatu 11—13, SF—00100 Helsinki 10, Finland.

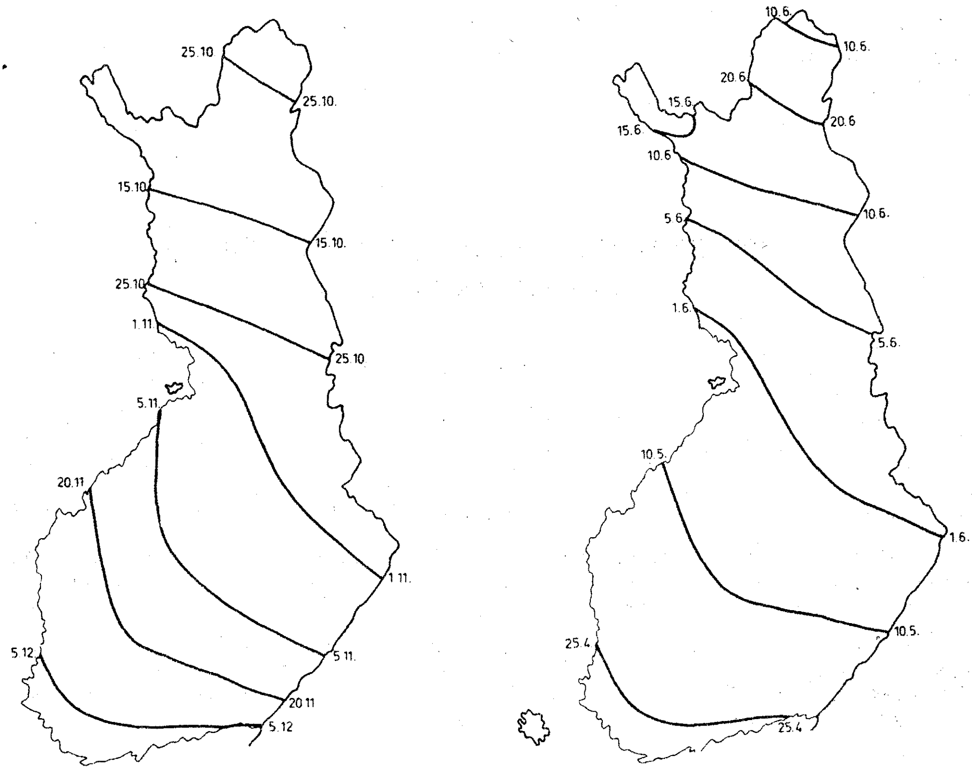


Fig. 1. Mean dates of first soil frost formation and of end of thawing in untouched sites in Finland for the period 1955 to 1975 according to SOVERI, VARJO (1977)

The ground is frozen in SW Finland no more than 4.5 months on average while the frost season in northernmost Finland lasts up to 8 months (Fig.1).

In northernmost Finland the mean annual temperature is somewhat below −1 °C and the monthly mean temperature of January is −14 °C and of July +13 °C (Atlas of Finland 1960; KOLKKI, 1966; SEPPÄLÄ, 1976a). During the coldest months (January and February) the temperature can fall down below −40 °C.

Of the previous reviews of the periglacial phenomena in Finland should be mentioned OKKO (1954), the introductory chapter of OHLSON's work (1964) and SEPPÄLÄ (1979b).

PALSAS

In the climatic environment of Northern Finland the formation of permafrost is possible in some favourable localities with a mean annual temperature below 0 °C. So far permafrost has been found only in mires in the cores of palsas. A palsa is a frost cored peat hummock rising up from the peat bog (SEPPÄLÄ, 1972b). Dry peat is very good isolator because of its low ability to conduct heat (*cf.* WASH-

BURN, 1979, p. 177). Therefore it protects the frozen core from thawing. The peat surface is cracked because of freezing and tension caused by uplift.

The morphology of palsas varies from small mounds with a diameter of a few metres and less than 1 m high to 7 m high (especially in Enontekiö, Fig. 2), to dome shaped palsas and palsa complexes also called peat plateaus with a diameter of hundreds of metres and rather flat character and containing thermokarst hollows and basins. Palsa complexes can be found especially in Utsjoki and Enontekiö (Fig. 2). The largest known palsa bog is Linkkiaapa, NW Utsjoki, with an area about 1 km² (Pl. 1). It is located typically in an interfluve area between two small rivulets.

The cyclic development of palsas (Fig. 3) has been found to be rather fast. Young palsas are rising at first 10—20 cm annually. When the frozen core touches the silty bottom of the bog then the palsa rises up more quickly. The mature palsas may stay 500—2000 years at their maximum height. These dates are based on radiocarbon datings of the surface layer of peat which does not grow much thicker after the rise of the mound.

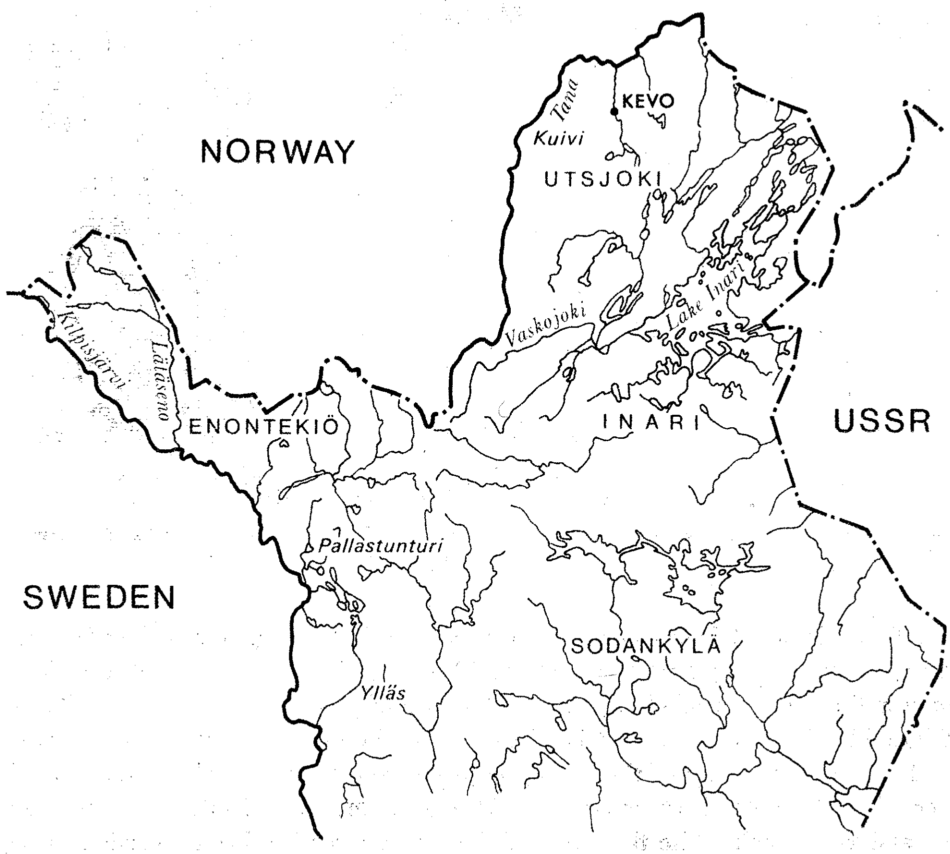


Fig. 2. Location of some place names mentioned in the text

The microenvironmental conditions on the palsas are completely different from the surrounding wet peat bog. During the winter the top parts of the palsas are uncovered by snow while the lower parts of the peat bog are covered by thick layers of snow (Seppälä, 1979 b; Pl. 2). The thickness of drift snow at the edges of palsas can be up to 2 m. The thickness of peat on the palsas does not increase any more because the vegetation is typical for a dry peat surface such as dwarf shrubs: *Betula nana*, *Empetrum hermaphroditum*, *Ledum palustre*, and *Andromeda polifolia*, etc., and lichens *Cladonia* and mosses *Polytrichum* and *Bryales*.

Old palsas start to degradate by wind erosion which deflates the peat surface, and by block erosion when peat blocks collapse along the open cracks from the edge into the surrounding water body. It has been observed how a 5 m high old palsa (Seppälä, 1971: Fig. 38; 1979 b: Figs. 2 and 3) collapsed completely in ten years. Degradation forms a circular pond which may have a circular peat rim ridge as a rampart of an earlier edge of the palsa.

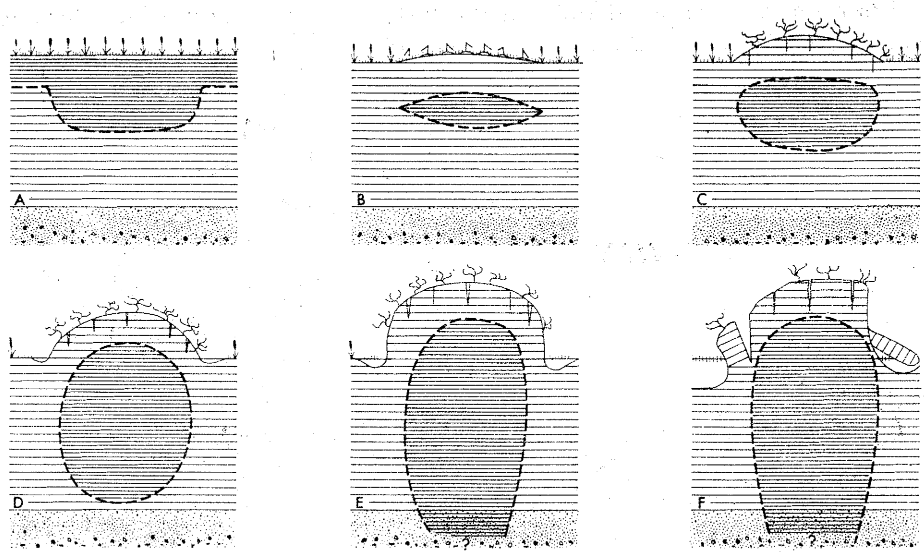


Fig. 3. Formation of the frozen core of a palsa

A — beginning of thawing season; B — end of thawing season; C — palsa embryo; D — young palsa; E — mature palsa; F — old, collapsing palsa

All developmental stages of palsas can be found on the same peat bog (Lundqvist, 1969, p. 209; Friedman, *et al.*, 1971, p. 141—144). These observations suggest that changes of climate are not necessarily the reason for the collapse of individual palsas, but that it is part of the cyclic development of these forms.

The annual thawing of the palsa measured from the top of the mound is, all over Finnish Lapland, at present 50—70 cm (Seppälä, 1976b). On some very low and young palsas the thickness of the active layer has been recorded to be less than 40 cm.

A hypothesis of the original reason palsa formation has been presented by FRIES & BERGSTRÖM (1910) and by SEPPÄLÄ (1976b). According to this idea the wind drift controls the thickness of snow cover on the bog surface. Where the snow cover is thin the frost penetrates deep into the peat. In these places frost does not disappear completely during the seasonal thawing but part of it remains under the insulating peat. The same process is repeated during the following winters and the unthawed layer of frost becomes thicker and the mound starts to rise. The wind carries away snow from the exposed hump more easily than before and the freezing process accelerates.

This hypothesis has been experimentally tested at Skallovarri palsa bog some 12 km NE of the Kevo Subarctic Research Station (SEPPÄLÄ, 1980). An area 5 by 5 metres of normal wet peat bog was several times during the winter cleaned of snow and the thickness of frozen layer and snow cover was recorded. By a thermograph the temperatures at different depths and in the open air above the peat were registered every hour the year round at 20 different points. It was found that in the experimental site the frost penetrated almost twice as deep as in the normal peat surface where the snow was not removed (Fig. 3). At the end of October when the thawing season finished there was still some 40 cm unmelted frost under the peat which had risen about 10 cm above the surface of peat bog and the normal vegetation (*Carex* and *Sphagnum*) had died. Snow clearing was continued during the second winter and the thickness of frozen layer grew some 20 cm to a total of about 100 cm at the beginning of the thawing season. The artificial palsa had started to grow. The details of the experiment will be published in a separate article (SEPPÄLÄ, 1980). With this experiment it was possible to confirm that the snow thickness is the critical factor in the beginning of palsa formation and it determines the sites where the palsas are formed.

STRING BOGS

South of the palsa zone it northern Finland as far as lake Oulujärvi peat bogs have special character with peat ridge patterns, in between which are depressions with shallow ponds. Ridges are transverse to the gradient. These so called string bogs are the most characteristic phenomena for the landscape of northern Finland (*cf.* RUUHIJÄRVI, 1960). We have to remember that mires cover more than 50% of the total land area in the lowland regions N and NE of the Gulf of Bothnia and in parts of North Central Finland (ILVESSALO, 1957).

String bogs can be easily identified from aerial photographs (Pl. 3). They belong to the boreal forest zone. For the origin of string bogs several explanations have been given which are reviewed by WASHBURN (1979, p. 174—176). There is no doubt of the role of seasonal frost in the formation of strings but the process has not yet been fully understood.

PATTERNED GROUND

TURF AND EARTH HUMMOCKS

Several types of turf and earth hummocks have been found in Finnish Lapland. Turf hummocks, in Finnish called *pounu*(s), are typical of peat bogs and palsa bogs (Fig. 4). Pounus have been described in detail by SALMI (1972). They are normally less than 1 m high and up to 1.5 m in diameter. The peat layer is often less than 60 cm thick and there may be a mineral core. Pounus occur normally in groups which are called in Finnish *pounikko* (RUUHIJÄRVI, 1960, p. 220—222).

Earth hummocks, the so called *thufurs* which are knobs with a height and diameter of ten centimetres to some decimetres, can be found in Finnish Lapland especially on the slopes of fells with silty material where the ground water is close to the surface.

The distribution of pounus or thufurs has not been systematically mapped in Finnish Lapland but they have been found normally in the fell regions in the favourable localities mentioned above. The difficulty in the regional mapping of most periglacial phenomena in Lapland is their small size which makes them unidentifiable with remote sensing techniques.

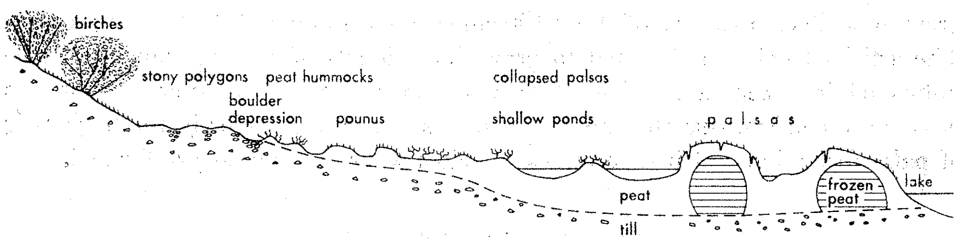


Fig. 4. Schematic profile of a palsa bog

SORTED STONE POLYGONS

Sorted stone polygons are found on the summits of many fells (*cf.* SEPPÄLÄ, 1972a). These irregular shaped polygons are 3—6 m in diameter, in some cases up to 10 m. Typical material of these large polygons is coarse till. At present on the fell summits most of sorted stone polygon fields at a lower altitude than 550 m are inactive. On high fells in the typical boreal forest zone there are large stone polygon fields; for example on Ylläs fell (718 m a.s.l.) and Pallastunturi fell (807 m a.s.l.) still partly active sorting processes have been found (Fig. 2).

In a second type of environment the sorting of stone polygons is more active than on high fells. This is on the bottom of very shallow ponds which are dried up part of the year. There the water level is very close the ground surface and many times it can be seen between the stones during the summer time. The bottom material is usually silty till with blocks. Frost activity is very strong in these spots even at low altitudes (100 m a.s.l.) in the birch forest zone (SEPPÄLÄ, RASTAS, 1980). Typical examples of this type of sorted polygons can be found for example at Skallovarri, on Ivvanasvarri (69°37′N, 27°15′E) and in Utsjoki river valley among the eskers some kilometres south of the Kevo Subarctic Research Station (Pl. 4).

A third site of stone polygon sorting is glaciofluvial gravel with some fine material in it. The stone are well rounded and very much of the same size. This type of polygons with a diameter up to 3 m have been found for example on a terrace of River Vaskojoki a few km W of Tirro (Fig. 2).

NONSORTED CIRCLES

In the fell region where silty till exists locally in the upper forestless zone (*regio alpina*) there are nonsorted circles with diameter up to 3 m without vegetation and formed of cracks on the surface, of similar character to those described by WASHBURN (1979, fig. 5.5) from NE Greenland. Some hundred of meters in diameter is one of the largest occurrences of nonsorted circles found from W Utsjoki north of the fell Kuivi (Fig. 2).

BOULDER DEPRESSIONS

In the regions of deep seasonal frost it is possible to find boulder depressions as evidence of frost sorting. Boulders have been uplifted to the ground surface in small basins where the ground water is close to the surface. The diameter of these block concentrations varies from a few up to hundred of metres. They have been found everywhere in Finland as shown by PIIROLA (1969) and AARTOLAHTI (1969). Large areas with boulder depressions exist in the Lake Inari basin. In most parts of the country they are inactive forms but in northern Lapland the blocks are still in motion. Inactive forms can be easily reactivated when the environmental conditions are changed and the frost penetrates deeper. Moving blocks normally lack lichens.

Active small size pits can be found on the edges of peat bogs with thin peat everywhere in the northern Lapland (Fig. 4).

STONE STRIPES

On the fell slopes it is possible to find large sorted stripes which can be several hundreds of metres long (e. g. SEPPÄLÄ, 1972a, fig. 4).

SORTED STEPS

Sorted steps formed by gelifluction are found on the slopes of higher fells for example on Kitsimalla (Kilpisjärvi) and Pyhäkero (Pallastunturit). The vertical height of these steps at their lower edge ranges from 1 to 1. 5 m. They are formed of downwards gliding till (Fig. 2).

FROST CRACK POLYGONS WITH SOIL WEDGES

Frost cracks and frost crack polygons in sand dunes in Finland were first reported by AARTOLAHTI (1972). Recent observations have been made by the author at Hietatievat (68°27′N, 24°43′E, 360 m a. s. l.) on a deflation surface lying between transverse dunes anchored by vegetation. The polygons are bounded by furrow-like depressions in the ground with a 5—15 cm deep open fissure in the middle of them (*cf.* SVENSSON, 1969).

The polygons are irregular in shape (Fig. 5). The length of their sides varies between 1 and 12 m. The largest polygons are to be found on the gently sloping

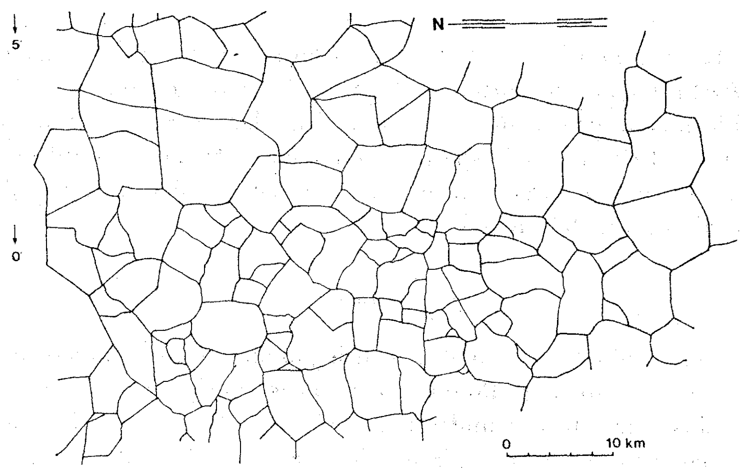


Fig. 5. Frost crack polygons with soil wedges in eolian sand on the basin between sand dunes on Hietatievat, Enontekiö. Mapped in June, 1973

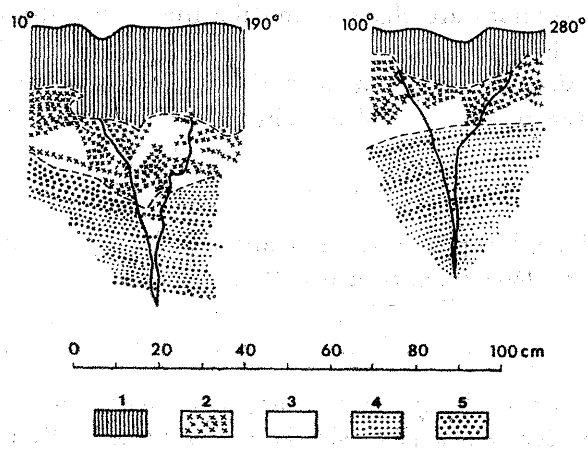


Fig. 6. Exposures of soil wedges in eolian sand on Hietatievat, Enontekiö

1. humus layer; 2. B horizon of podsol; 3. light brown sand; 4. fine sand strata; 5. coarse sand strata

side of dune (5 °W). At most of the junctions of the cracks the sides of three polygons meet.

The depth of the soil wedge is less than 70 cm. The soil layer (podsol) extends in places to a depth of only 40 cm (Fig. 6). Deeper down, the wedge could be distinguished from its surrounding by its darker colour caused by the humus.

The cracks show that the formation is still active. It is of great importance for the formation of the wedges that the ground water level lies close to the surface of the deflation basin during the spring.

SAND WEDGES

Another type of polygons (SEPPÄLÄ, 1966) are also found on Hietatievat esker. On the upper part of the esker exist many sand dunes with blow-outs. At the bottom of some blow-outs deflation has exposed stratified silt deposited in a late-glacial ice-lake. The silt surface has patterns formed by fissures filled with eolian sand (Fig. 7). On the surface, in the middle of the eolian sand are found open cracks with depths ranging from 0.5 to 2.5 cm. On excavation the wedge is found to be about 35—50 cm deep. Their width on the surface varies from 30 to 60 cm tapering rapidly downwards (Fig. 8). The origin of these sand wedge polygons is not yet fully explained (*cf.* SEPPÄLÄ, 1966) but it seems to be

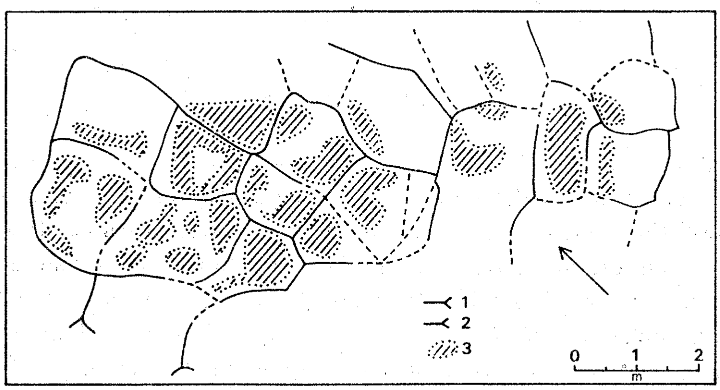


Fig. 7. Sand wedge polygons on silt with eolian filling on Hietatievat

1. open fissure; 2. recent fissure filled by eolian sand; 3. silt surface covered by vegetation. White areas indicate areas covered by sand. Mapped in July 1965, see SEPPÄLÄ, 1966.

most likely that they are connected with frost cracking of the silt and then the open cracks are filled with eolian sand transported on the surface of the blow-out. During the winter time the silt is deeply frozen but the sand wedge itself is dry and unfrozen (without frost). This was observed in November 1974. The interesting thing is that it is possible to get these forms in environments with only seasonal frost.

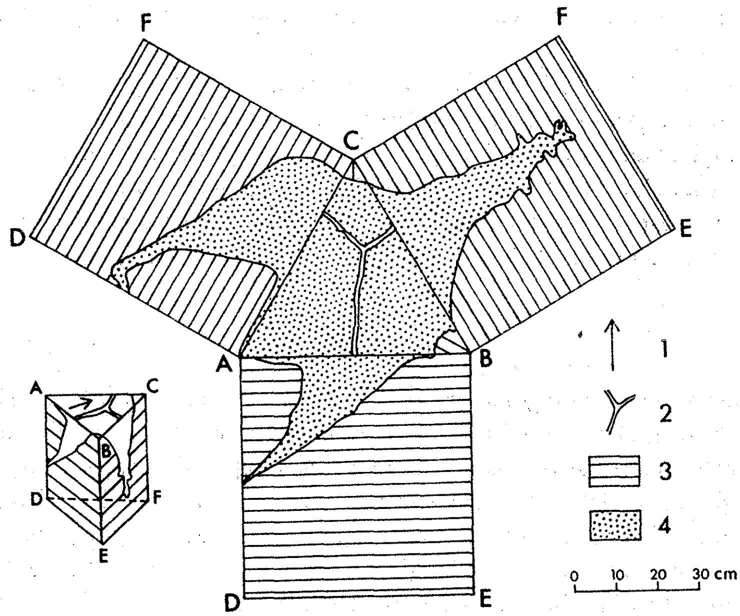


Fig. 8. Three dimensional exposure of the junction of open fissures on sand wedge polygon surface on Hietatievat (fig. 7)

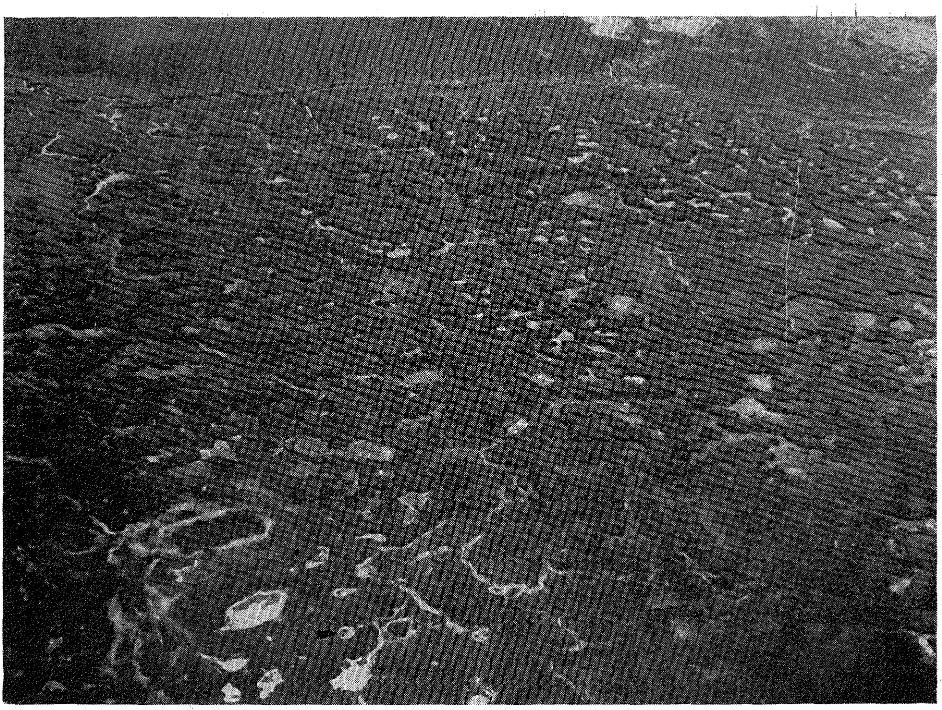
1. the north direction of the ABC surface; 2. open fissure; 3. silt; 4. eolian sand. In the great figure all the surfaces of the small figure have been drawn on the same surface level. See SEPPÄLÄ, 1966

FROST WEATHERING

Crystalline rocks in Finland are very compact. This means that they are not very sensitive to frost weathering but frost shattering is working very effectively by splitting barren rocks into block fields (*cf.* OHLSON, 1964; PIIROLA, 1969). The largest block fields in Finland are found on the summit areas of high fells in northern Enontekiö, Inari and Utsjoki (FOGELBERG, SEPPÄLÄ, 1979). In NW Enontekiö where the most part of region is higher than 800 m a. s. l. there are block fields hundreds of square kilometres in area.

On the steep slopes of fells the frost weathering forms talus and talus cones (OHLSON, 1964; PIIROLA, 1969). Recently has been measured the mass wasting on the talus slope of the Saana fell (Kilpisjärvi). According to the preliminary results the annual mass movement is 20—60 mm down the slope (SEPPÄLÄ 1979 a).

Well formed talus deposits can be seen in the deep valley of Utsjoki river and canyon-like valley of Kevo river. Several examples from Enontekiö are mentioned by OHLSON (1964, p. 73).

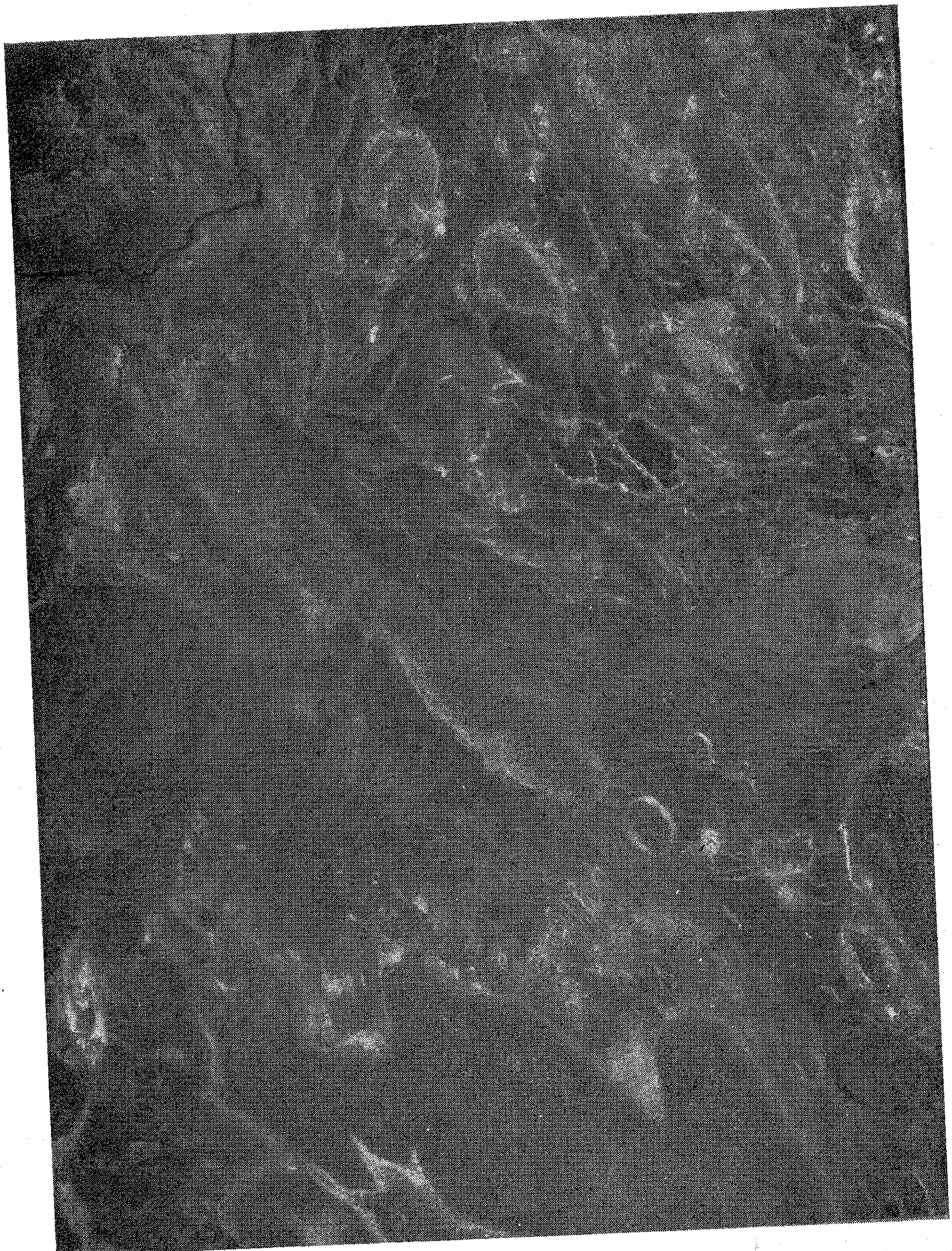


Photographed by K. Lundén on July 7, 1973. Published with the permission of Topografikunta

Pl. 1. Aerial photograph of a part of Linkkiaapa palsa bog in NW Utsjoki. Palsas are 2-5 m high and the picture covers about 0,5 km²

Photo by the author, April 24, 1969

Pl. 2. Suttisjoki palsa bog at the border of Inari and Utsjoki communes. In the foreground a low palsa partly covered by snow and in the background a 5 m high palsa



Pl. 3. Aerial photograph (nr. 5632 164, approx. scale 1 : 30 000) of string bogs east of Petkula village, Sodankylä, N Finland. Published with the permission of Topografikunta

Photo by the author, July, 1967

Pl. 4. Stone polygons on a bottom of a pond at Ivvanasvarri, Utsjoki

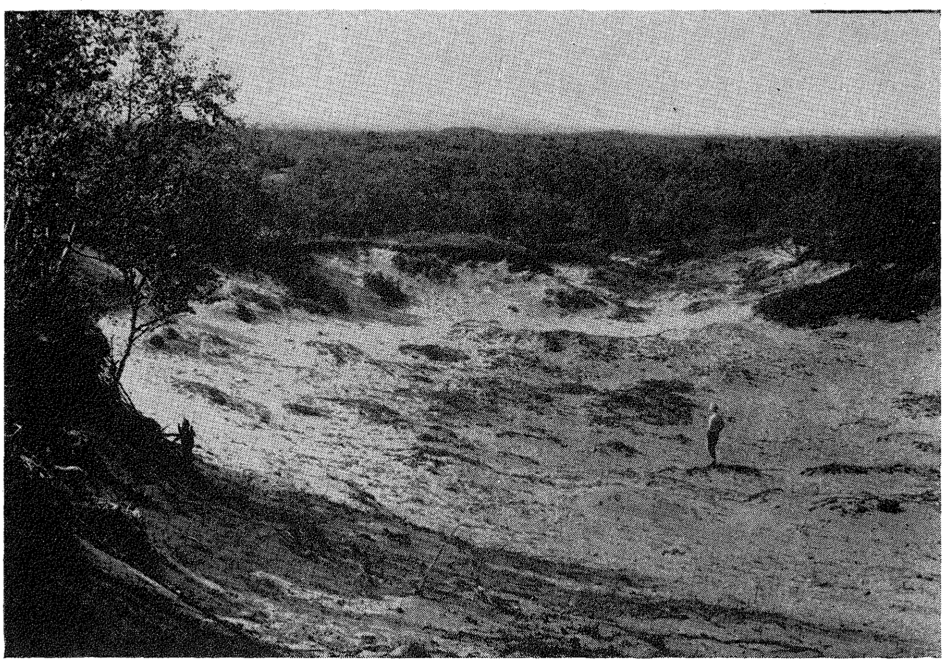


Photo by the author, July 18, 1967

Pl. 5. Large blow-out in a parabolic dune in the interfluve area of Kaamasjoki and Kielajoki rivers in Finnish Lapland. See SEPPÄLÄ, 1967

DEFLATION AND DUNE FORMATION

In the same region where palsas occur we can find active deflation on glaciofluvial and eolian sands as well as on the edges of eskers and deltas (SEPPÄLÄ, 1971). The larger deflation basins are about 10 m deep and hundred of metres in diameter (Pl. 5). Only small remnants of the edges of ancient parabolic dunes remain in many places (SEPPÄLÄ, 1973).

In many cases the deflation has started after a forest fire when the vegetation on the sand surface has been destroyed. To continue, the deflation need not be very strong and it keeps the blow-outs uncovered by vegetation. Only some centimetres of sand have to be moved annually (SEPPÄLÄ, 1974) and the sand surface stays uncovered.

Deflation takes place during the summer time when the basins are free of snow cover. On the summits of fells and edges of eskers and glaciofluvial deltas deflation works also during the winter time but it cannot be very effective because the ground is deeply frozen.

Only in very few places is wind drift sand still forming dunes. They can be found for example in the Hietatievat and Pöyrisjärvi regions (Enontekiö). They are typical parabolic dunes up to 10 m high lying among the early postglacial dune fields (Fig. 2).

PHENOMENA PRODUCED BY RIVER AND LAKE ICE

Many of the rivers in northern Finland have a typical subarctic character. Rivers are deeply frozen and the spring flood is formed rapidly when the snow melting starts; the water level rises high and moving ice blocks form dams in the channel. During the flood the river banks are heavily eroded and large bars of sand and gravel without vegetation are left in the river channel after the flood (*cf.* MANSIKKANIEMI, 1970; KOUTANIEMI, 1979). This type of river in fully natural conditions is represented by the Tana and Lätäseno (Fig. 2).

In special weather conditions the lake ice presses against the shores pushing up different types of small ridges (ALESTALO, HÄIKIÖ, 1979). Boulders and trees on the shores are moved, too. For example on the shores of Lake Inari it is possible to observe pavementlike boulder surfaces which are formed by ice pressure and the fine material is washed away by waves.

These phenomena produced by river and lake ice are typical of the periglacial environment although they are not formed by ground frost.

CONCLUSIONS

In regions with seasonal frost lasting at least 7 months it is possible to find quite a rich selection of geomorphological phenomena produced by ground frost. Most of these do not require permafrost to form.

Periglacial processes seem to be one of the most effective morphological agents in northern Finland.

The systematic mapping of the distribution of periglacial morphological phenomena has been started but because of the very large area and the few roads the work takes much time. The map of distribution of palsa bogs will be first ready for publishing.

Finnish Lapland is a relatively good region for studies of periglacial processes because many people live there and there exist some well equipped research stations. It is possible to organize all the year round measurements of frost phenomena. Some of these measurements have already begun but still much work is to be done on these regions close to southern limit of the discontinuous permafrost zone. In the future the studies should be directed to closer process measurements after which we should be able to understand better the formation of periglacial phenomena.

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