Nivation hollows and valleys in the fossil coast cliff Landborgen at Helsingborg, South Sweden

Gunnar Johnsson

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In the fossil coast cliff Landborgen at Helsingborg North-West Skåne (Scania), there are many hollows and broad valleys which begin blind with a semicircular back rim. These hollows and valleys were probably formed mainly by nivation in the bedrock of Lias sandstone and shale. The hollows mostly have a cirque form with an opening towards the cliff. Some of them continue as broad valleys containing a rill of water. Most of the main nivation hollows and valleys are older than the last phase of the Weichselian glaciation as indicated by the fact that they contain till or morainic boulders from the north eastern ice, the main ice stream in Skåne during the last glaciation. Hydro-thermal water has made hollows and rill water small valleys in the cliff where the nivation processes begun. The nivation processes were caused by drifting snow from the east during the Weichselian.

Keywords: *Coast cliff, Jurassic sandstone and shale, drifting snow, nivation, periglacial hydrothermal water, north-east till.*

Gunnar Johnsson, docent, Mellangatan 24, S-263 52 Höganäs, Sweden.

In two papers (Johnsson, 1984, 1985) I have described embryonic nivation hollows in the bedrock of Lias sandstone and shale on the highest shoreline at Tinkarp in the northern Helsingborg (fig. 1). Drifting snow from the east probably accumulated where hydro-thermal water and frost weathering once initiated depressions in the bedrock. This erosion must have taken place after deglaciation because its results are to be seen on the highest shore cliff. The bedrock belongs to the Helsingborg stage (sandstone and shale) from Ättekulla to Hittarp and farther north (fig. 1). These two stages belong to the lower Lias beds of the early Jurassic system (Troedsson, 1951).

The largest of these nivation hollows, 15 m deep, on the highest shore bank at Tinkarp has a reversed slope. The depression was once overdeepened to about 2 m before the hollow was dammed up to form a large dam (fig. 2). The back rim is steep and has a semicircular form. The whole depression (fig. 3) is elongated and the sides are smoothly concave. Such an overdeepened hollow can not have been formed by marine abrasion. The smooth concave form and the steep back rim is an indication that nivation has occurred. Hydro-thermal water runs out into the depression as in all of them.

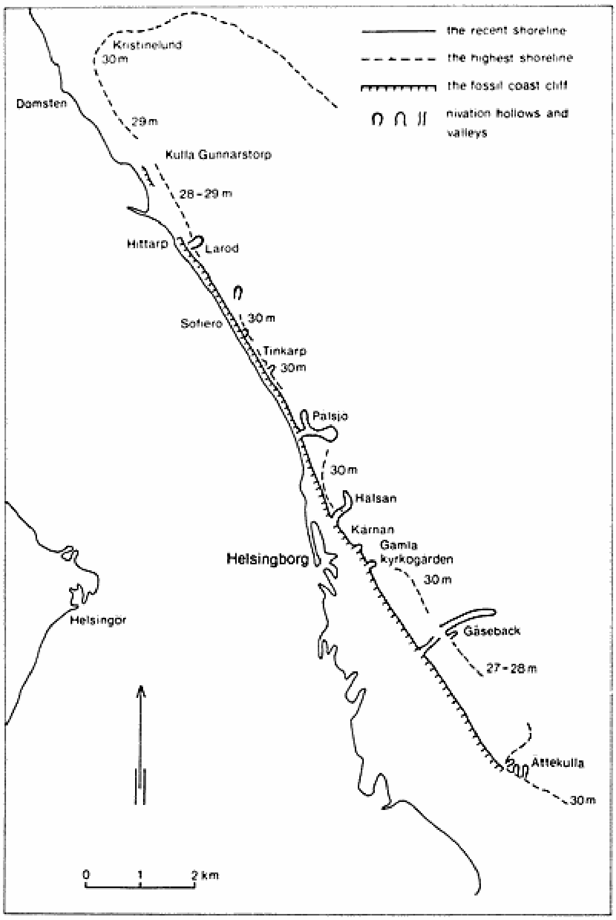

Fig. 1. Location map showing nivation hollows and valleys in the preglacial coast cliff at Helsingborg.

The sandstones and shales of the Helsingborg stage seem to have given rise to different forms of the nivation hollows. These depressen in sandstone are formed cirque-like, rather deep but small, the hollows in shale are more shallow and extended. They can not be classified as cirque-like.

When forms of nivation hollows are discussed, for instance, how much snowdrift of a certain thickness can overdeepen a hollow (Bowman, 1916; Brückner, 1921; Louis, 1960), different types of bedrock are not considered. Rockie (1951), Flint (1957), and French (1976) have pointed out that nivation goes much faster in sedimentary

Fig. 2. The steep back rim of the nivation hollow at Tinkarp. The water in the dam is hydro-thermal.

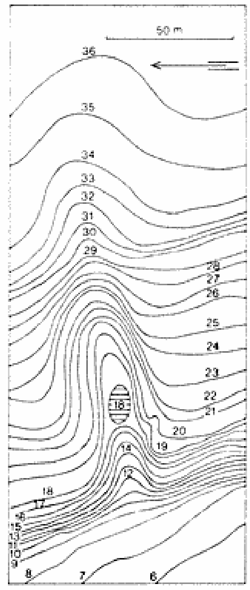

Fig. 3. The longitudinal nivation hollow on the highest shoreline at Tinkarp. Altitudes in meters above present sea level in this and following figures.

rocks. Rudberg (1954) is of the opinion that in the inclined schistose bedrock the most beautiful cirques with a steep back rim is formed. Vilborg (1985) has also discussed the importance of a schistose bedrock for the formation of nivation hollows. Both a horizontal and vertical structure of the bedrock favours the separation of flat fragments.

If the above is the case in the mountains of northern and central Sweden, it must be presumed that the frost weathering proceeded still faster in the loose Lias shales in the Helsingborg area. On the frost ridge Söderåsen, 20 km east of Helsingborg, where nivation hollows and glacial cirques have been found (Rapp, 1982a, 1982b, 1983, 1984; Rapp et al. 1984; Berglund & Rapp, 1988), the bedrock consists of gneiss. The large nivation cirques at low levels in northern and central Sweden (Agrell, 1979; Rudberg, 1984; Vilborg, 1984, 1985) are all situated in primary rocks.

The conditions for the formation of nivation hollows in the coast-cliff at Helsingborg are, therefore, different, especially as both the sandstones and shales are deeply preglacial weathered in many places. The extent to which such Lias shale and sandstone can be mechanically weathered is shown in fig. 9 and 13. These sections were frost weathered before the last glaciation because no frost splintering has been found in the younger cliff, which has been abraded by the sea after deglaciation.

Another factor, which has not been sufficiently discussed in connection with the formation of nivation hollows, is the influence of hydro-thermal water. This factor is not of current interest as regards the nivation in high mountains, but since nivation hollows have now been discovered also at lower levels, formed by drifting snow, this factor is relevant. Rapp et al. (1984) have also paid attention to the role of hydro-thermal water during the formation of nivation valleys in the horst ridge Söderåsen.

The best formed nivation hollows in the cliff are situated above and below the highest shoreline. They are filled with north east till, but beneath the uppermost postglacial shoreline the till has mostly been washed away by the sea and only boulders are left. Therefore these hollows must be older than the main phase of the Weichselian glaciation.

In his description of the geology in the Helsingborg region Sundelin (1925) noted these hollows and valleys. He described them as hanging valleys but was not able to explain their origin. At that time the former periglacial environment in South Sweden was not known. Sundelin does not try to explain their formation as being caused by the abrasion of the sea.

The fact that there must have been strong frost weathering before the main phase of the Weichselian glaciation has also been pointed out by Lundqvist (1971, 1986), Berglund & Lagerlund (1981), Rapp (1984), and Johnsson (1986). During these earlier periglacial periods there was also strong wind action from the east along the Swedish west coast (Hillefors, 1961, 1964, 1969, 1974, 1983), as there was in Jutland in western Denmark (Jørgensen, 1986). Wind eroded surfaces beneath Weichselian north east till have also been found in eastern Denmark (Jacobsen, 1984; Johnsson, 1984). After deglaciation easterlies were the prevailing winds in South Sweden, but a few localities with wind erosion from the west have also been found (Mattsson, 1951; Svensson, 1972, 1980, 1981; Johnsson, 1963, 1980; Rapp et al. 1984; Jacobsen, 1984; Johnsson, 1984) have also found wind eroded boulders on the surface of the ground in eastern Denmark, but the wind direction has not been established because the boulders are not earth-fixed.

The fossil coast cliff Landborgen

The cliff was probably formed as one or several fault escarpments mainly in the direction NNW-SSE and NW-SE in the Rhaeto-Lias bedrock (cf Norlin, 1978; Adrielsson et al. 1981). But later the sea abraded the present cliff both before and after deglaciation (Johnsson, 1984). The fossil cliff begins in the southern part of Helsingborg at Ättekulla (fig. 1) at a level of 11-12 m. Through Helsingborg the terrace level of the cliff is about the same, but near the present shore in the northern part of the town the level is about 7 m. This means that the cliff is older than postglacial time and that it is not shaped by the sea. The steep cliff ends at Hittarp but continues sporadically to Kulla Gunnarstorp (fig. 1).

The periglacial environment and the nivation processes

It was Matthes (1900) who introduced the term nivation, which means a process of erosion caused by snow. Matthes stated that the characteristic depressions of this type are smooth and round in contrast to erosion surfaces formed by running water. If such water is present under a snow patch the erosion must take place beneath the snow, therefore not making the depressions V-shaped. In the cliff at Helsingborg it is also easy to distinguish between steep ravines eroded by hydro-thermal or rill water and the oval and smooth nivation hollows.

As regards nivation processes it is very important to know whether the snow becomes thick enough to be changed into glacier ice. It is generally held that snow begins to form ice when subjected to a pressure of about 30 m or more of snow or firn (Embleton & King, 1975). As nivation, hollows and valleys described in this paper as mentioned are not more than 15 m deep there is no reason to believe that the snow accumulation turned into real glaciers. The hollows and cirques are all facing west and were at the time of their formation rather exposed for insolation. Much meltwater also ran out beneath the snow patches.

All hollows today have an outflow of hydro-thermal water. If spring water was present also in the periglacial environment frost weathering was evidently important at these places. But hydro-thermal water is not common in periglacial environments. Icing (naledi) probably caused depressions to form which were later enlarged by nivation (Akerman 1980). In sedimentary rocks such nivation processes go faster than in primary rocks as mentioned above.

Some of the nivation hollows described here are small, 20 x 30 m. In the literature such small nivation hollows are demonstrated by Ahlman (1919), McCabe (1933), Nichols (1963), Costin et al. (1964, 1973), Sparrow (1974), and Embleton & King (1976). On Söderåsen such small nivation hollows also exist (Rapp, 1982a, 1982b, 1983, 1984; Rapp et al. 1984; Berglund & Rapp, 1988).

Drift snow may deform and is then able to transport frost weathered material at the snow base (Odell, 1933; Russel, 1933; Imamura, 1937; McCabe, 1939; Haefeli, 1953; Costin et al. 1964, 1973; Jennings 1978). That the difference between transport by a snow drift and a glacier is small has also been pointed out by Watson (1966).

Protalus ramparts can be formed outside such snow drifts and have also been found outside some steep nivation hollows on Söderåsen (Rapp et al. 1984, 1986; Berglund & Rapp, 1988). These ramparts were probably formed as late as during the younger Dryas stadial when snow may have drifted over surfaces without vegetation at higher levels as on Söderåsen. Ramparts do not exist outside the hollows in the cliff because they are older than the main phase of the Weichselian glaciation and because embryonic hollows at the highest shoreline have been washed by the sea and later eroded by hydro-thermal water.

In this paper it is not possible to show if creep movements have formed small striae on the bedrock (cf Lewis, 1936; Dyson, 1937) or show such beautiful striation as described by Jennings (1979) because the bedrock is exposed only occasionally, and then in a loose and weathered state. In primary rocks on Söderåsen small striae have been found in a nivation valley at Åstorp (Johnsson, 1986) but here the snow drifts were 30-35 m thick. The thin snow patches in the cliff were probably not able to make any striae.

That the traces of wind erosion on bedrock and boulders in Skåne have been caused mainly by drifting snow has been demonstrated by Johnsson (1980, 1982a, 1982b, 1983, 1984). Wind eroded boulders have been found inside and in the close vicinity of the nivation hollows and valleys in the Helsingborg area. Unfortunately the difference between wind erosion by eolian sediments and by drifting snow has not hitherto been described in the literature. But on the highest shoreline at Helsingborg it seems that the wind erosion from the east was caused by drifting snow, and that from the west by eolian sand originating from the former shore. The eolian sand has not been found on the surface of the plateau to the east of the

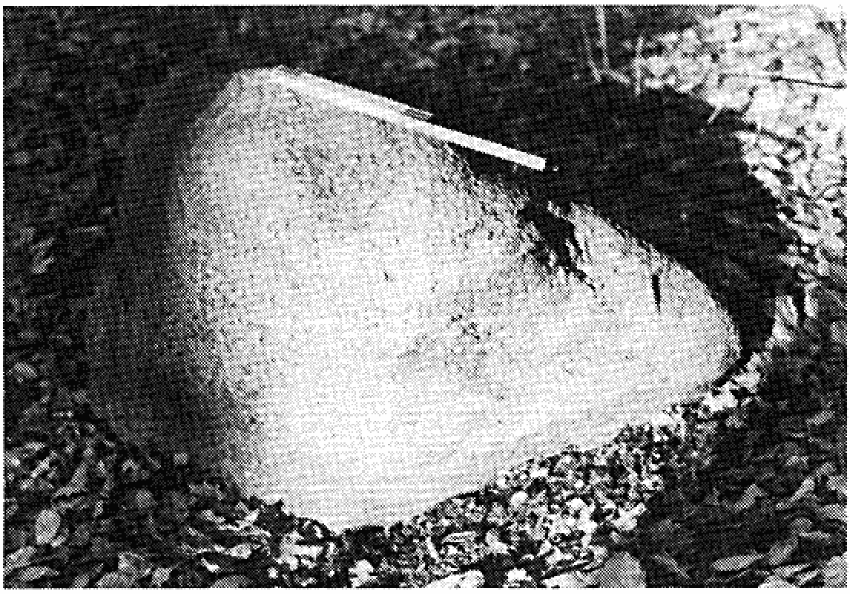

Fig. 4. Boulder eroded by eolian sand on the highest shore plane at Ättekulla. The wind direction was from the west (obliquely inwards from the left).

highest shoreline and has evidently only been moved a short distance.

In fig. 4 a granite boulder on the highest postglacial shore line at Ättekulla is shown. It is wind eroded from the west but only on the lower part and not at the top. The boulder is fixed in the ground. A thin stratum of eolian sand has been found in the vicinity beneath a tilted tree. However, no dunes have been formed. Along the highest shoreline westerly winds blow during the time of deglaciation, at least in the summer. The evident shore on the sandy

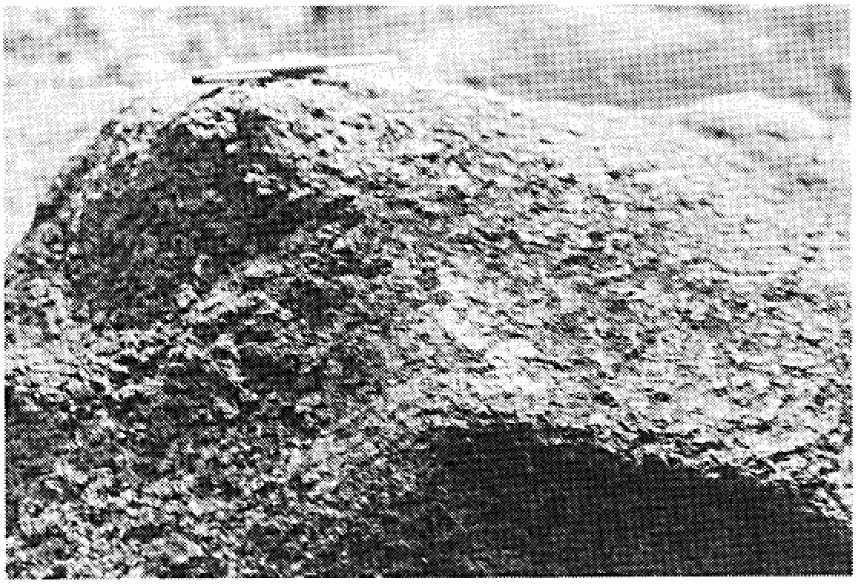

Fig. 5. Amphiboline boulder polished by drift snow. The wind direction was from the east (left).

plateau facing west also indicates this fact. The wind erosion probably took place when the permafrost in the shore sand had thawed on the surface and the sand was dry. Many boulders on this shore plane are wind eroded in this way (Johnsson, 1983).

Fig. 5 shows a boulder of amphibolite which also is fixed in the ground. It is situated in the southernmost periglacial valley on the sandy plateau Ättekulla. The valleys here are incised in the soil and are not nivation valleys as are the other ones (Johnsson, 1961, 1979). The cliff in the bedrock begins just to the north of Ättekulla.

Only patches on the surface of the boulder have been polished by wind erosion, indicating that the material instrumental in the polishing was very light. A few polished boulders have been found above the highest shoreline. In the eastern part of the town of Helsingborg some boulders have also been found which are wind eroded from the east over the entire surface and not only on the lower part as shown in fig. 4.

All these observations and the nivation hollows and valleys support the interpretation that there was much drifting snow in the winters during the time following deglaciation. The literature mentioned above also indicates that this was the case during older periglacial periods. Theoretically the prevailing winds at the southern border of the European inland ices must have been easterly at least in the winters (Lamb & Woodroffe, 1970; Liljeqvist, 1974). Strong winds also affect the structure of the snowdrifts by increasing their density compared to snow deposited by gravity fall alone (Nyberg, 1985).

Individual description of the localities with nivation formations

The southernmost valley adjoining the cliff is the Gåsebäck valley which was formed by rill water (fig. 1). The valley must be older than the main phase of the Weichselian glaciation because it contains large boulders of primary rock and was abraded by the sea after deglaciation. This is the only place where the sea has formed a broad shore plane and an evident cliff on the highest shoreline. Few meters to the south of this valley there is a little hollow in the cliff, where hydro-thermal water runs out. Gelifluction material has slided down onto the shore plane. The form can be described as an embryonic nivation hollow or gelifluction niche. It is reproduced in Johnsson (1979, fig. 3).

Just to the south of the well-known fortress Kärnan (the Kee fig. 1) is a very beautiful nivation cirque at the edge of the steep cliff (fig. 6 & 7). It begins at a level of 31 m above sea level and ends at about 18 m. It must have been formed before the main phase of the last glaciation, because there were once many boulders on the bottom, which had been washed out from the north eastern till.

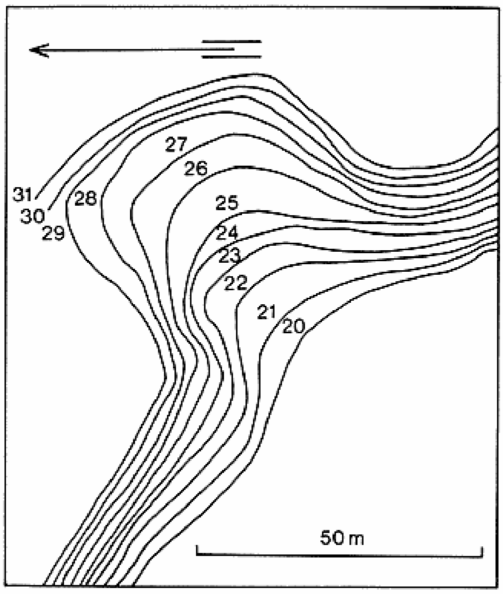

Fig. 6. The nivation cirque just to the south of Kärnan.

The cirque is much too large to have been formed by sliding in the bedrock. The form also excludes such an interpretation.

Such a regular cirque form cannot have been abraded by the sea. This is the only nivation depression described here to which hydro-thermal water erosion does not seem to have contributed. But lower down at the front of the cliff such water runs out in ample quantity, and it is probable that this water in a periglacial frost environment with permafrost ran out higher up at the permafrost table and gave rise to strong frost weathering in the upper part of the cliff.

The deep rill ravine called Hälsan (fig. 1) has a winding formation. In this valley there was once some watermills along the rill. In the upper part of the ravine there is a spring of mineral water called Hälsan (the Health). This valley was probably also first formed by erosion caused by hydro-thermal water and frost weathering. The valley begins on the plateau above the highest shoreline as an extensive hollow. It is possible that nivation processes have taken place here. The plateau rises as a real rim, and drifting snow from the east was probably left in this depression. Also in the Hälsan valley there were once many large boulders. Nowadays they have been removed to make room for the present main road.

The Pålsjö valley (fig. 1 & 8) is a rill valley but it begins as a large nivation hollow with a little escarpment in the bedrock. Hydro-thermal water runs along the hollow. This large valley contains a thick infilling of north east till with large boulders uppermost in the till. The beginning of the valley is situated far from the cliff and the postglacial

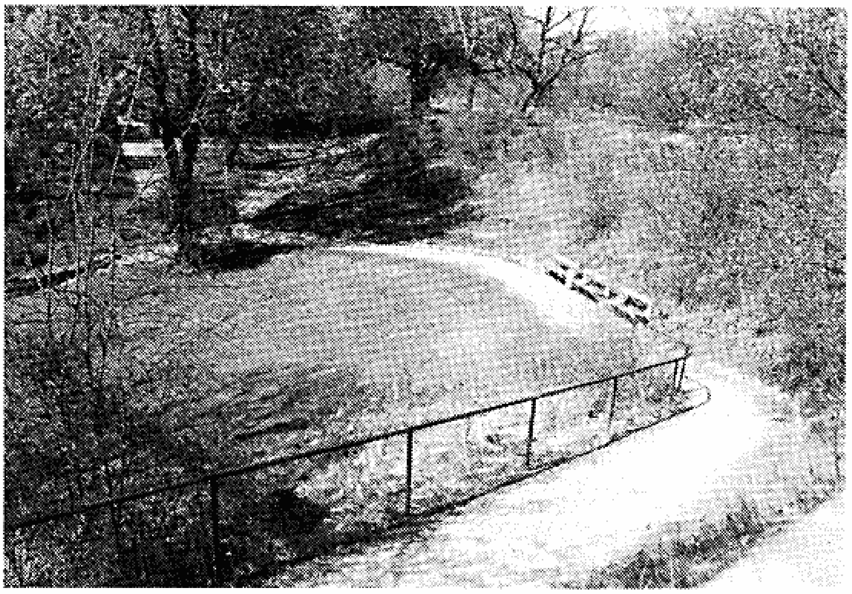

Fig. 7. the back rim of the nivation cirque in fig. 6.

sea has not formed a shore bank here. The plateau is at a level of 30-35 m and the valley begins at 32 m and ends at 7-8 m above sea level.

In the Pålsjö valley surfaces wind-polished from the east are also found on all parts of some boulders, mostly only on patches as at Ättekulla. Such wind polishing is also here a probable indication of former drifting snow, as eolian sand has not been found here.

The fact that the shale is deeply mechanically weathered can be observed in niches along the sides of the broad valley. In fig. 9 such a niche with weathered shale fragments on the sides and at the bottom can be seen.

Just to the south of Sofiero, the former royal summer residence (fig. 1), there is a small nivation hollow with an opening towards the cliff (fig. 10). Because the cirque formation and because it begins at a level of 35 m it cannot have been abraded by the sea. On the bottom there are many large boulders and traces of north east till. A very small stream of hydro-thermal water runs out at the end of the cirque. In the vicinity there are some mine-excavations, where coal was once mined, but their shape is entirely different.

A large shallow nivation hollow is found in the park of Sofiero (fig. 1). It ends at "the Old Kings garage" on the side of the present rill ravine (fig. 11). It is difficult to establish whether it was previously filled with north east

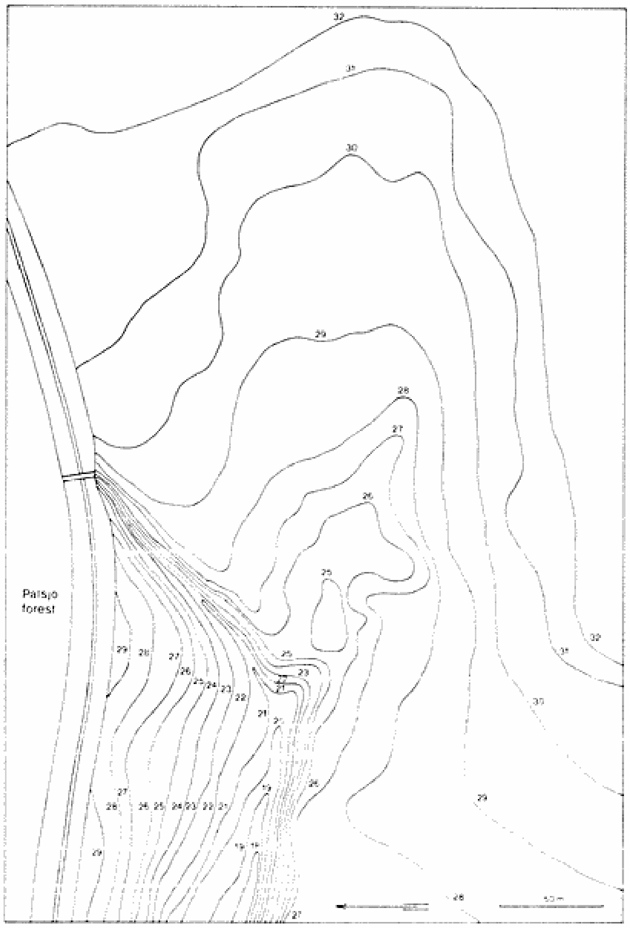

Fig. 8. The nivation hollow at the beginning of the Pålsjö valley. The railway ravine to the left (north) has been blasted in the bedrock.

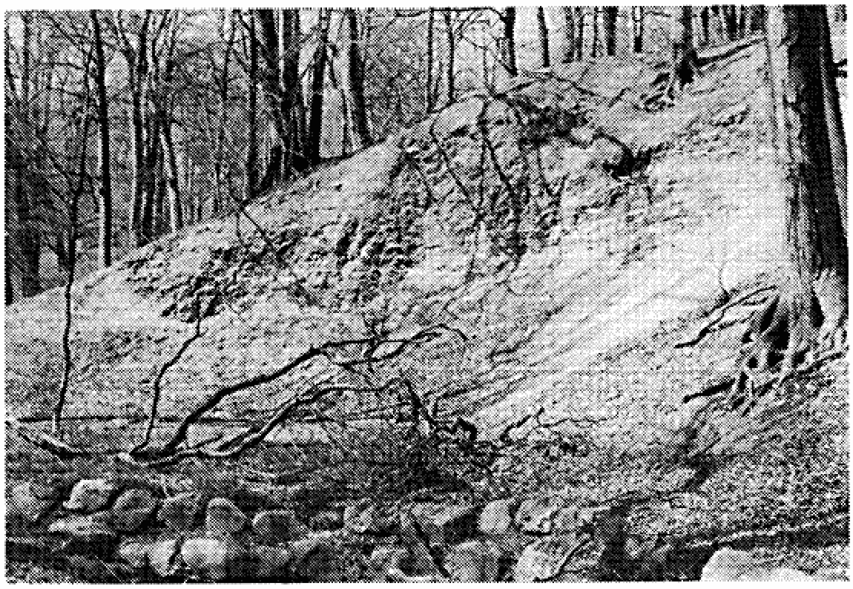

Fig. 9. A little niche in the Pålsjö valley with a strong, mechanically weathering of the shale.

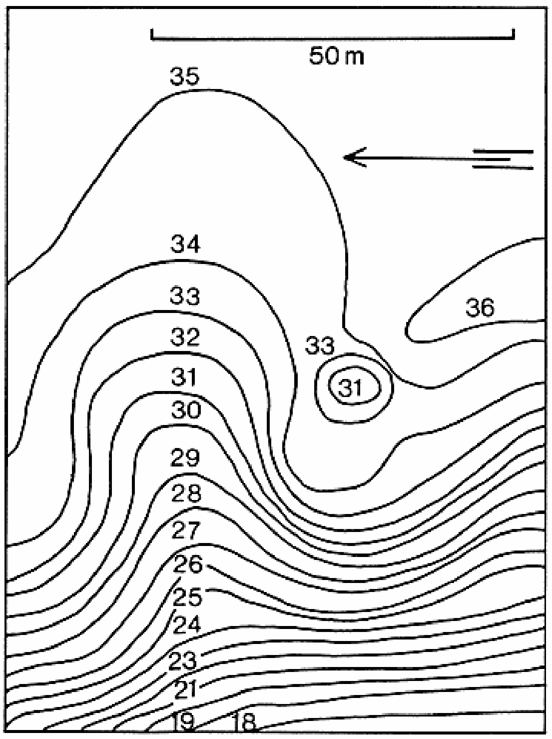

Fig. 10. The nivation cirque just to the south of Sofiero. The small isolated depression is man-made.

till because it is situated in the park, but earlier there were boulders on the ground. In any case it cannot have been abraded by the sea because it begins at a level of 35 m and because it is situated far from the cliff in a position protected from the sea.

At the beginning of this hollow there is a little rill which flows in a man-made ditch. This water must be hydrothermal because it does not begin as a rill. It is possible that the water contributed to the formation of the nivation hollow. Because of the higher bedrock surface towards the cliff, drifting snow can be given rise to the nivation processes particularly as the bedrock here consists of shale.

The inclination towards the present deep rill ravine is sufficient to have started gelifluction processes in the soil in a periglacial environment. On the whole, I think that such soil creep can have played a certain role during the formation of the more shallow hollows. Gelifluction also seems to play a certain role in the nivation processes (Rudberg, 1974; Strömquist, 1983). Especially Paterson (1951) has pointed out that gelifluction probably plays a more important role than the meltwater erosion beneath these snow drifts. On the whole thin snow patches in permafrost ground increase the nivation processes compared with thick snow drifts in a non-permafrost environment (Embleton & King, 1975).

The broad nivation valley at Hittarp-Laröd (fig. 1) begins at a large nivation hollow with a smooth semicircular

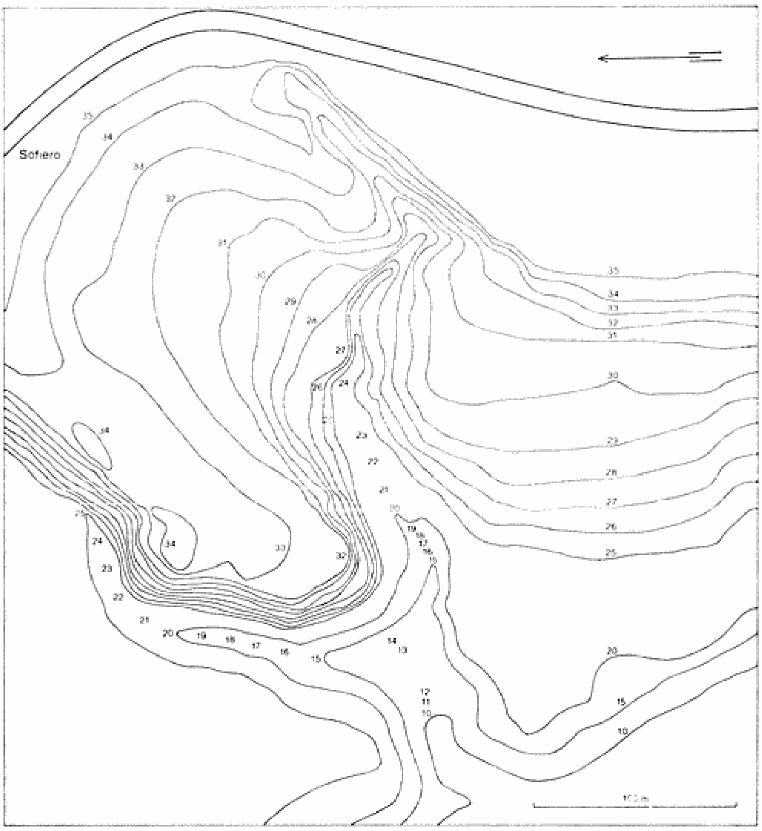

Fig. 11. The shallow extensive nivation hollow in the park of Sofiero. In the eastern part the road Laröd-Helsingborg is shown.

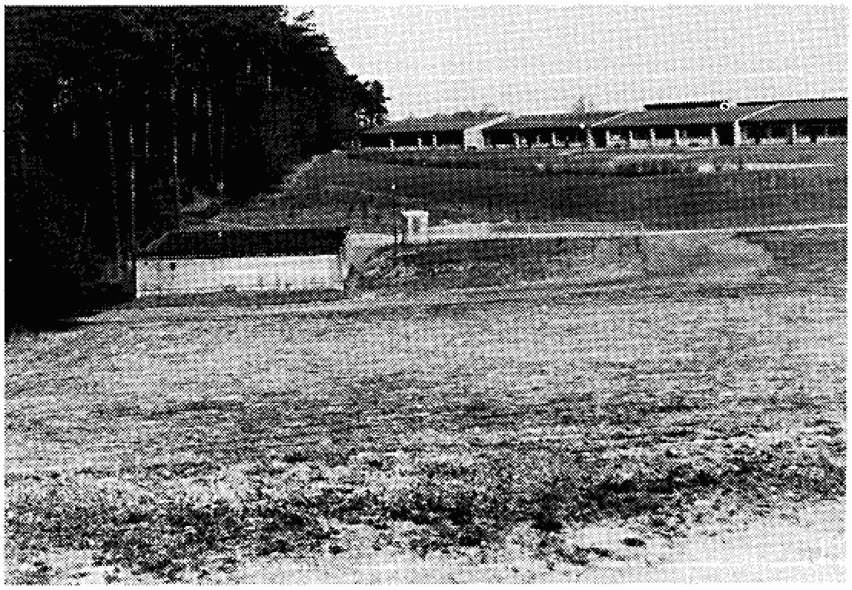

Fig. 12. The easternmost part of the nivation cirque at Hittarp-Laröd. In the center there is a pump station.

back rim (fig. 12). The hollow is filled with man-made filling-material and is formed in the bedrock of Döshult sandstone. Earlier there were boulders on the ground surface which have been removed when the rill ravine was filled up. The hollow is formed in a mechanical, deeply weathered sandstone (fig. 13) where the rill runs out. This rill has eroded a deep ravine in the cliff. The nivation hollow begins at about 33 m above sea level and ends at 23 m (fig. 14).

The cirque continues in a broad valley which in its northern side contains thick north east till, washed at the surface by the sea. The southern part of the valley has another, smaller hollow which forms a shallow cirque. At the bottom it is eroded into the bedrock. From there hollow hydro- thermal water runs out. The hollow is too shallow and has no back rim and, therefore, cannot be called a real nivation cirque. Frost weathering, gelifluction and hydro-thermal water have probably played a great part in producing such a formation.

Concluding remarks

As the fossil cliff faces west, is is evident from observations in other places as mentioned above, that there was drifting snow blowing from the east during several periods of Quaternary when the environment was periglacial. The abrasion of the sea when water level was higher must successively have eroded already formed nivation cirques and hollows. Those which still exist were probably formed before the main phase of Weichselian time. Possibly some of them may have been formed during the Saale glaciation. At the highest postglacial shoreline at about 30 m above sea level the nivation hollows are embryonic but are nevertheless an indication that nivation and frost weathering have taken place after deglaciation.

In Europe such nivation cirques and hollows have also been observed at low levels outside the border of the Quaternary ice sheets. Sekyra (1961) has described nivation cirques and hollows from Bohemia in Czechoslovakia. He mentioned that they are sometimes situated below 450 m above sea level. He called them "cirques embryonaux" or "pseudocirques". The semicircular hollow demonstrated by Sekyra (1961, photo 15) is very similar to the largest nivation hollows described here apart from the fact, that the latter are smaller and more shallow. Sekyra does not discuss the problem whether drift snow was instrumental in the formation of the hollows.

On the whole, wind directions in the periglacial environment on the continent have only been investigated in eolian sediments and not as trace of erosion on bedrock and boulders. Suitable bedrock to show evident wind erosion is almost lacking and according to the research reported the boulders have always been moved by cryoturbation (cf. Czajka, 1972). It is, therefore, important to point out that the suggested prevailing westerly winds in Late-Weichselian time on the continent, as shown by studies of eolian sediments (Maarleveld, 1964; Dylikova, 1969), had this direction during the summer when the ground was unfrozen and dry (cf. Åkerman, 1980).

At the southern border of the European ice sheet there should have been prevailing easterly winds, caused by a high pressure over the ice and low pressures passing farther to the south (Lamb & Woodroffe, 1970; Liljequist, 1974). Pressure gradients are largest and winds are expected to be strongest near the border of an ice sheet. An investigation in the region of Leipzig in Germany has also established, that the bedrock there was wind eroded by easterly winds (Händel & Hänsel, 1980).

In arctic and subarctic regions it is possible to find present environments which are similar to the fossil periglacial environment at the described coast cliff at Helsingborg.

In Spitsbergen the western coast cliff consists of an old sedimentary bedrock. Here are nivation hollows, some of them elongated (Dineley, 1954; Åkerman, 1980). There are also valleys, at first formed as rill valleys and later widened by nivation (Dineley, 1954). The valleys and nivation hollows were formed by accumulations of drift snow transported by north easterly winds (Åkerman, 1980). Snow patches sometimes only 4-5 m thick remain during midsummer and do not melt until late summer. The similarity between the two cliff areas seems to be great.

Acknowledgements

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References

Adrielsson, L., Mohrén, E. & Daniel, E. (1981): Beskrivning til jordartskartan Helsingborg SV. Sveriges Geol. Unders. Ae 16: 104 pp.

Agrell, H. (1977): A glacial cirque form in Central Sweden? Geogr. Ann. 59A: 215-219.

Ahlmann, H. W. (1919): Geomorphological studies in Norway. Geogr. Ann. I, 1-148: 193-252.

Berglund, B. E. & Lagerlund, E. (1981): Eemian and Weichselian stratigraphy in South Sweden. Boreas 10: 323- 362.

Berglund, B. E. & Rapp, A. (1988): Geomorphology and vegetation in NW Scania, Sweden, during the Late Weichselian. Geogr. Polonica (in press).

Bowman, I. (1916): The Andes of Southern Peru. New York: 295 pp.

Brückner, E. (1921): I. Bowman über Schnee-Erosion und die Entstehung der Kare. Zeitschr. Gletscherkunde 12: 57- 70.

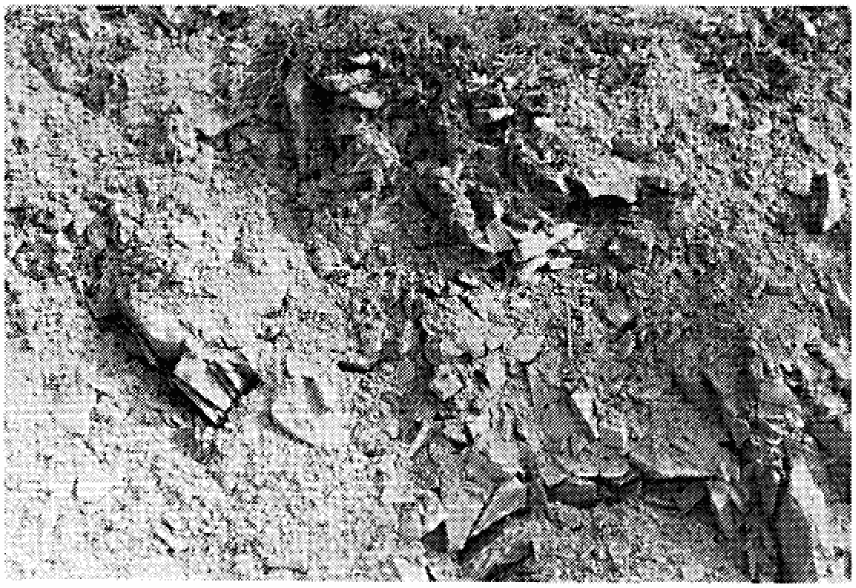

Fig. 13. The weathered Döshult silty sandstone in the northern part of the nivation cirque at Hittarp.

Costin, A. B., Jennings, J. N., Black, H. P. & Thomas, B. G. (1964): Snow action on Mount Twynam, Snowy Mountains, Australia. Journ. Glacial. 5: 219-228.

Costin, A., B., Jennings, J. N., Bantowich, B. C. & Wimbush, D. J. (1973): Forces developed by snowpatch action, Mt Twynam, Snowy Mountains, Australia. Arctic & Alpine Research 5: 121-126.

Czajka, W. (1972): Windschliffe als Landschaftsmerkmal. Zeitschr. Geomorph. N. F. 16: 27-53.

Dinley, D. L. (1954): Investigations in West- Spitsbergen. Journ. Glaciol. 2: 379-383.

Dylikova, A. (1969): Le probl me des dunes intérieures en Pologne á la Lumi re des études de structure. Biul. Peryglac. 20: 45-80.

Dyson, J. L. (1937): Snowslide striations. Journ. Geol. 45: 349-357.

Embleton, C. & King, C. M. (1975): Periglacial Geomorphology. E. Arnold, London: 203 pp.

Flint, R. F. (1957): Glacial and Pleistocene geology. John Wiley & Sons, New York: 553 pp.

French, H. M. (1976): The periglacial environment. Longman, New York: 389 pp.

Haefeli, R. (1953): Creep problems in soils, snow and ice. Proc. third intern. Soil Mechanics Found. Engin. Zürich 1953. Proc. 3: 238-251.

Hillefors, Å. (1961): Om vindslipade blockhorisonter i Dösebackagruppens bildningar. Gothia 9: 73-93.

Hillefors, Å. (1964): Vindslipat flyttblock från Ellesbo och Västsveriges glacialhistoriska utvickling. Göteborgs Naturh. Mus., Årstryck 1964: 29-42.

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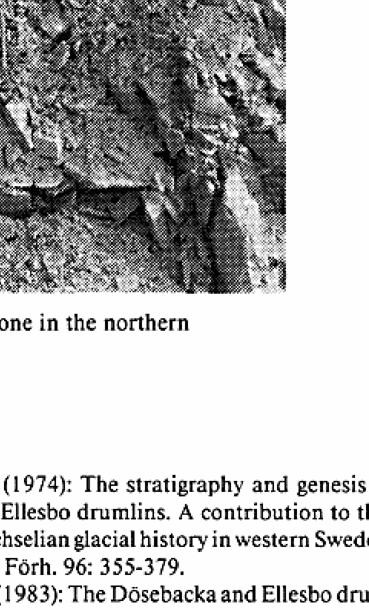

Fig. 14. The broad nivation valley at Hittarp-Laröd. The rill ravine in the northern part is very deep.

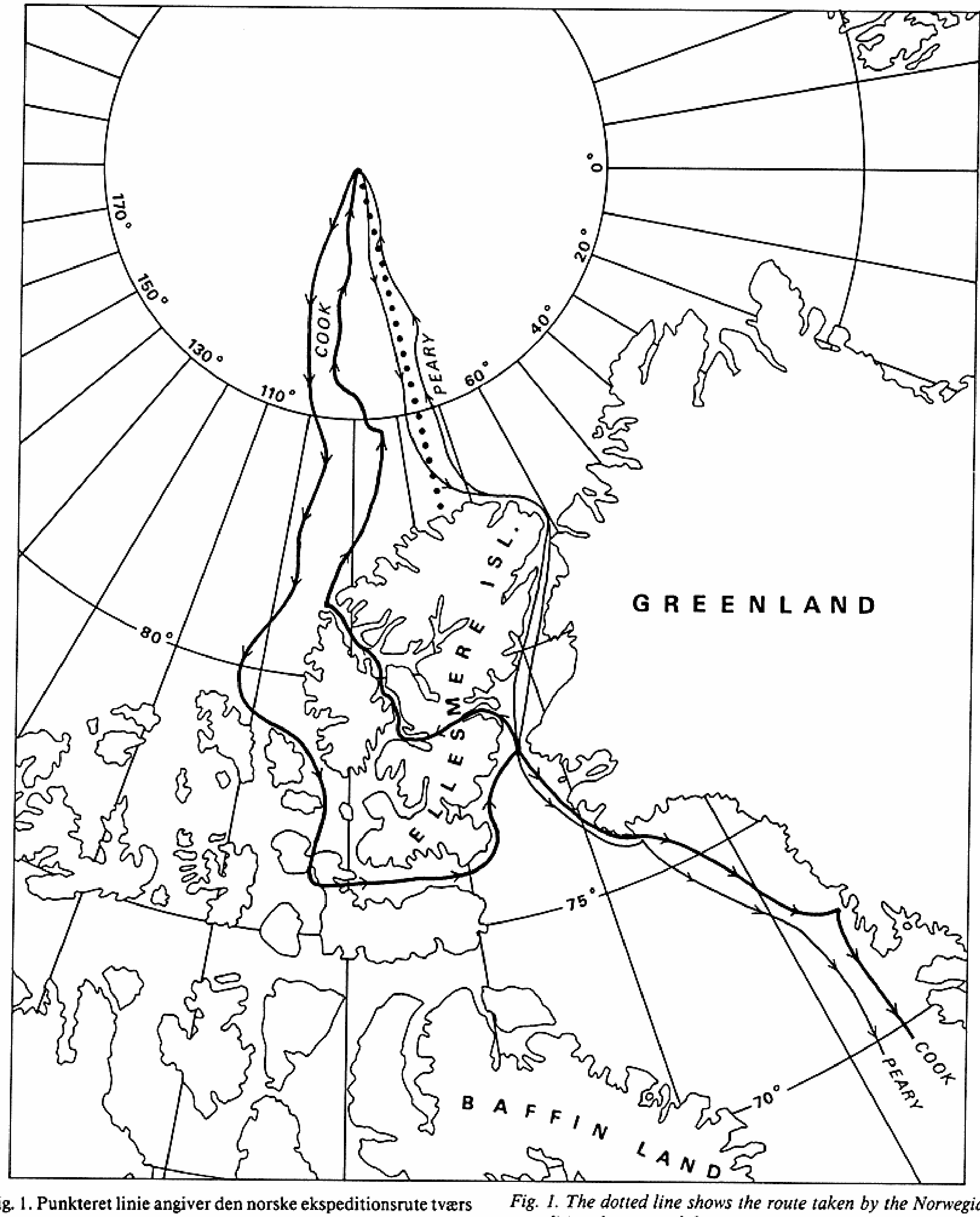

Fig. 1. Punkteret linie angiver den norske ekspeditionsrute tværs over Polhavet fra Ward Hunt Island (N for Ellesmere Island) til Nordpolen 8/3-4/5 1990. De tidligere ruter - Cook 1908 og Peary 1909 er ligeledes indtegnet.

Fig. 1. The dotted line shows the route taken by the Norwegian expedition that crossed the Arctic Ocean from Ward Hunt Island (north of Ellesmere Island) to the North Pole, 8/3-4/5 1990. The earlier routes taken by Cook, 1908, and Peary, 1909, are also indicated.

back rim (fig. 12). The hollow is filled with man-made filling-material and is formed in the bedrock of Döshult sandstone. Earlier there were boulders on the ground surface which have been removed when the rill ravine was filled up. The hollow is formed in a mechanical, deeply weathered sandstone (fig. 13) where the rill runs out. This rill has eroded a deep ravine in the cliff. The nivation hollow begins at about 33 m above sea level and ends at 23 m (fig. 14).

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References

Adrielsson, L., Mohrén, E. & Daniel, E. (1981): Beskrivning til jordartskartan Helsingborg SV. Sveriges Geol. Unders. Ae 16: 104 pp.

Agrell, H. (1977): A glacial cirque form in Central Sweden? Geogr. Ann. 59A: 215-219.

Ahlmann, H. W. (1919): Geomorphological studies in Norway. Geogr. Ann. I, 1-148: 193-252.

Berglund, B. E. & Lagerlund, E. (1981): Eemian and Weichselian stratigraphy in South Sweden. Boreas 10: 323- 362.

Berglund, B. E. & Rapp, A. (1988): Geomorphology and vegetation in NW Scania, Sweden, during the Late Weichselian. Geogr. Polonica (in press).

Bowman, I. (1916): The Andes of Southern Peru. New York: 295 pp.

Brückner, E. (1921): I. Bowman über Schnee-Erosion und die Entstehung der Kare. Zeitschr. Gletscherkunde 12: 57- 70.

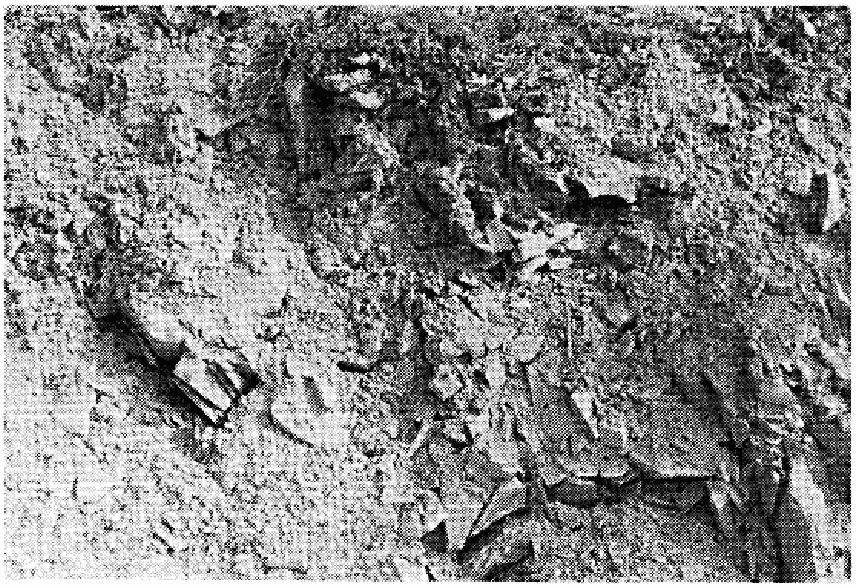


Fig. 13. The weathered Dôshult silty sandstone in the northern part of the nivation cirque at Hittarp.

Costin, A. B., Jennings, J. N., Black, H. P. & Thomas, B. G. (1964): Snow action on Mount Twynam, Snowy Mountains, Australia. Journ. Glacial. 5: 219-228.

Costin, A., B., Jennings, J. N., Bantowich, B. C. & Wimbush, D. J. (1973): Forces developed by snowpatch action, Mt Twynam, Snowy Mountains, Australia. Arctic & Alpine Research 5: 121-126.

Czajka, W. (1972): Windschliffe als Landschaftsmerkmal. Zeitschr. Geomorph. N. F. 16: 27-53.

Dinley, D. L. (1954): Investigations in West- Spitsbergen. Journ. Glaciol. 2: 379-383.

Dylikova, A. (1969): Le probl me des dunes intérieures en Pologne á la Lumi re des études de structure. Biul. Peryglac. 20: 45-80.

Dyson, J. L. (1937): Snowslide striations. Journ. Geol. 45: 349-357.

Embleton, C. & King, C. M. (1975): Periglacial Geomorphology. E. Arnold, London: 203 pp.

Flint, R. F. (1957): Glacial and Pleistocene geology. John Wiley & Sons, New York: 553 pp.

French, H. M. (1976): The periglacial environment. Longman, New York: 389 pp.

Haefeli, R. (1953): Creep problems in soils, snow and ice. Proc. third intern. Soil Mechanics Found. Engin. Zürich 1953. Proc. 3: 238-251.

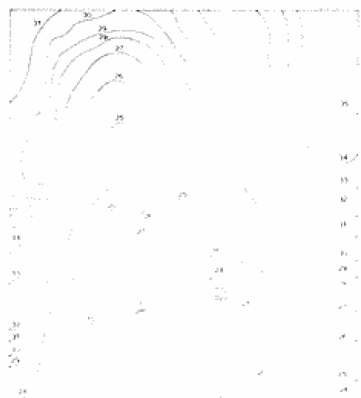
Hillefors, Å. (1961): Om vindslipade blockhorisonter i Dösebackagruppens bildningar. Gothia 9: 73-93.

Hillefors, Å. (1964): Vindslipat flyttblock från Ellesbo och Västsveriges glacialhistoriska utvickling. Göteborgs Naturh. Mus., Årstryck 1964: 29-42.

Hillefors, Å. (1969): Västsveriges glaciala historia och morfologi. Medd. Lunds Univ. Geogr. Inst. Avh. 60: 319 pp.

Hillefors, Å. (1974): The stratigraphy and genesis of the Dösebacka and Ellesbo drumlins. A contribution to the knowledge of the Weichselian glacial history in western Sweden. Geol. För. Stockholm Förh. 96: 355-379.

Hillefors, Å. (1983): The Dösebacka and Ellesbo drumlins. Morphology and stratigraphy. In: Ehlers, J. (ed): Glacial deposits in North-west Europe. A. A. Balkema, Rotterdam: 141-158.



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Händel, U. & Hänsel, Chr. (1980): Die windschliffe auf den kleinen Berg bei Hohberg (bezirk Leipzig) und ihre regionalklimatische Aussage. Geophys. und Geol. Geophys. Veröffentl. Karl Marx Univ. Leipzig 11: 239-245.
Imamura, E. (1937): Past glaciers and the present topography of the Japanese Alps. Science reports of Tokyo Bunrika Daigaba, Section C 2: 61 pp.
Jacobsen, E. M. (1984): Periglaciale fænomener på Sjælland. Dansk Geol. Foren. Årsskrift 1983: 81-87.
Jennings, J. M. (1978): The geomorphic role of stone movements through snow creep, Mount Twynam, Snowy Mountains, Australia. Geogr. Ann. 60A: 1-8.
Johnsson, G. (1961): Periglaciala dalar i sydligaste Sverige. Geol. För. Stockholm Förh. 83: 162-285.
Johnsson, G. (1962): Periglacial phenomena in southern Sweden. Geogr. Ann. 44A: 378-404.
Johnsson G. (1979): Högsta kustlinjen vid Helsingborg. Svensk Geogr. Årsbok 55: 19-34.
Johnsson, G. (1980): Periglacial vindslipning i Dalby- Lundområdet. Svensk Geogr. Årsbok 56: 13-22.
Johnsson, G. (1982a): Frostfenomen i tundratidens Blekinge. Blekinge Natur 1982: 85-106.
Johnsson, G. (1983): Periglacial klimat- och vädermiljö i Skåne. Svensk Geogr. Årsbok 59: 155-170.
Johnsson, G. (1984): Fossila periglaciala fenomen i Skåne och på nordöstra Själland – en jämnförelse. Dansk Geol. For. Årsskrift 1983: 55-63.
Johnsson, G. (1985): Landborgen – en naturens gåva. Helsingborg 900 år. Bokhuset, Höganäs: 18-21.
Johnsson, G. (1986): En nivationsdal i Åstorps stenbrott, NV Skåne. Svensk Geogr. Årsbok 62: 100-113.
Jørgensen, M. (1986): En periglacial afblæsningsflade fra Hobroegnen. Dansk Geol. Foren. Årsskrift 1985: 47-58.
Lamb, H. H. & Woodroffe, A. (1970): Atmospheric circulation during the ice age. Quatern. Research 1: 29-56.
Lewis, W. V. (1936): Nivation, river grading and shoreline development in south-east Iceland. Geol. Journ. 88: 431-447.
Louis, H. (1960): Lehrbuch der allgemeinen Geographie. I. Allgemeinen Geomorphologie. Berlin: 254 pp.
Liljeqvist, G. (1974): Notes on meteorological conditions in connection with continental land-ices in the Pleistocene. Geol. Fören. Stockholm Förh. 96: 293-298.
Lundqvist, J. (1971): The interstadial deposits at the Leveänimimine, Svappavaara, Swedish Lappland. Sveriges Geol. Unders. C 658: 163 pp.
Lundqvist, J. (1986): Deep-weathering in Sweden. Fennia 163: 287-292.
Maarlevald, G. C. (1964): Periglacial phenomena in the Netherlands during different parts of the Würm time. Biul. Peryglac. 14: 251-256.
Metthes, F. E. (1900): Glacial sculpture of the Bighorn Mountains, Wyoming. U.S. Geol. Surv. 21st annual Report 2: 173-190.
Mattsson, Å. (1957): Windgeschliffenes Gestein in südlichsten Schweden und auf Bornholm. Svensk Geogr. Årsbok 33: 49-68.
McCabe, J. M. (1939): Nivation and corrie erosion in West Spitsbergen. Geogr. Journ. 94: 447-465.
Nichols, R. L. (1963): Miniature nivation cirques near Marble Point. McMurdo Sound, Antarctica. Journ. Glaciol. 4: 477-479.
Norling, E. (1978): Berggrund. In: E. Daniel: Beskrivning till jordartskartan Höganäs NO/Helsingborg NV. Sveriges Geol. Unders. Aa 25: 92 pp.
Nyberg, R. (1985): Debris flow and slush avalanches in northern Swedish Lappland. Medd. Lunds Univ. Geogr. Inst. Avh. 97: 222 pp.
Odell, N. E. (1933): The glaciers and morphology of the Franz Joseph Fjord region of the N. E. Greenland. Geogr. Journ. 95: 246.
Paterson, T. T. (1951): Physiographic studies in north- west Greenland. Medd. Gr[00fe]nland 151: 60 pp.
Rapp, A. (1982a): Periglacial nivation cirques and local glaciation in the rock canyons of Söderåsen, Scania, Sweden. A discussion and new interpretation. Dansk Geol. Tidsskr. 82: 95-99.
Rapp, A. (1982b): Odensjön, Skäralid och Klövahallar. Ett nytt tolkningsförsök. Svensk Geogr. Årsbok 58: 131-142.
Rapp, A. (1983): Impact of Nivation on steep slopes in Lappland and Scania, Sweden. In: H. Poser & E. Schunke (eds.): Mesoformen des Reliefs in heutigen Periglazialraum. Abh. Akad. Wissenschaft, Göttingen, Math-Phys. Klasse, Dritte Folge 35: 97-114.
Rapp, A. (1984): Nivation hollows and glacial cirques in Söderåsen, Scania, south Sweden. Geogr. Ann. 66A: 11-28.
Rapp, A., Behrens, S. & Nyberg, R. (1984): Nivationsnischer vid Uggleröd, Röstånga. Svensk Geogr. Årsbok 60: 131-144.
Rapp, A., Nyberg, R. & Lind, N. (1986): Nivation and local glaciation in N and S Sweden. Geogr. Ann. 60A: 11-29.
Rockie, W. A. (1951): Snowdrift erosion in the Palouse. Geogr. Revue 41: 457-463.
Rudberg, S. (1954): Västerbottens berggrundsmorfologi. Geographica Uppsala Univ. Geogr. Inst. 25: 457 pp.
Rudberg, S. (1974): Some observations concerning nivation and snow melt in Swedish Lappland. In: M. Poser (ed.): Geomorphologische Prozesse und Prozesskombinationen in der Gegenwart unter verschiedenen Klimabedingungen. Vandemhoek & Ruprect. Göttingen: 263-273.
Rudberg, S. (1984): Fossil glacial cirques or cirque problematica at lower levels in northern and central Sweden. Geogr. Ann. 68A: 29-39.
Russel, R. J. (1933): Alpine landformes of western United States. Bull. geol. soc. America 44: 927-949.
Sekyra, J. (1961): La Carte periglaciaire du Massif Bohemian. Biul. Peryglac. 10: 43-52.
Sparrow, G. W. A. (1974): Non-glacial cirque formation in southern Africa. Boreas 3: 61-68.
Strömqvist, L. (1983): Gelifluction and surface wash, their importance and interaction on a periglacial slope. Geogr. Ann. 65A: 245-254.
Svensson, H. (1972): Vindaktivitet på Laholmsslättan. Svensk Geogr. Årsbok 48: 65-85.
Svensson, H. (1980): En fossil deflationsyta på den sydhalländska slätten. Svensk Geogr. Årsbok 56: 5-12.
Svensson, H. (1982): Vinderosion i bergblock. Svensk Geogr. Årsbok 57: 200-208.

Sundelin, U. (1925): Helsingborgstraktens geologiska historia. Helsingborgs historia I: 3-70.

Troedsson, G. (1951): On the Höganäs series of Sweden (Rhaeto-Lias). Lunds Univ. Årsskr. N. F. Avd. 2, bd. 47 nr. 1: 268 pp.

Watson, E. (1966): Two nivation cirques near Aberystwyth, Wales. Biul. Peryglac. 15: 79-101.

Wilborg, L. (1984): The cirque forms of Central Sweden. Geogr. Ann. 66A. 41-77.

Wilborg, L. (1985): Cirque forms in Northern and Central Sweden. A study focusing the mountain region. Medd. Naturgeogr. Inst. Stockholm Univ. STOU-NG 61: 72 pp.

Åkerman, J. (1980): Studies on periglacial geomorphology in West Spitsbergen. Medd. Lunds Univ. Geogr. Inst. Avh. 89: 297 pp.

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Berglund, B. E. & Lagerlund, E. (1981): Eemian and Weichselian stratigraphy in South Sweden. Boreas 10: 323- 362.

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Brückner, E. (1921): I. Bowman über Schnee-Erosion und die Entstehung der Kare. Zeitschr. Gletscherkunde 12: 57- 70.