

# Research Papers

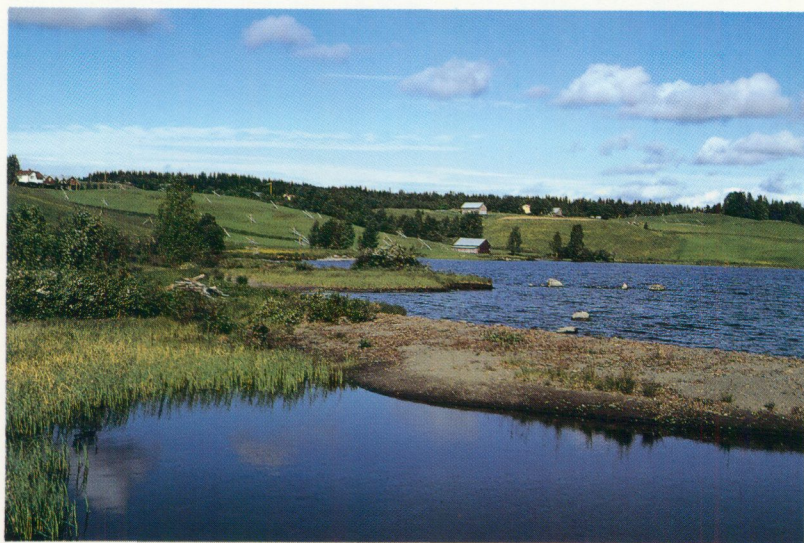
SGU series C 826

Forskningsrapporter

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## Weichselian stratigraphy and glaciations in the Tåsjö-Hoting area, central Sweden

Jan Lundqvist and Urve Miller



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*Sveriges Geologiska Undersökning*  
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Cover: The landscape at Lövvik consisting of sand and clay  
covered by a thin layer of till. Photo J. Lundqvist 1984.

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## ABSTRACT

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Complex lithostratigraphy in the Tåsjö-Hoting area, northern Ångermanland, Central Sweden, contains several stratigraphic units of diamicton. Most of them are interpreted as tills. The tills are interbedded by sequences of glacial sediments, indicating two ice-free stages after the deposition of the first till. Pollen and spore assemblage (PSA) spectra in the tills and sediments show five different types. The distribution of the spectra types in the lithologic units indicates that an interglacial preceded the deposition of the first till unit. The two sequences of glacial sediments correspond to two interstadials. On the basis of the PSA spectra the whole stratigraphy is interpreted as representing three Weichselian glacial stages, interrupted by interstadials corresponding to Brörup and Odderade. The oldest till contains redeposited early Eemian (or older) sediments.

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## INTRODUCTION

The central area of the Scandinavian glaciation has been deglaciated at least once during the Weichselian. A number of deposits, earlier interpreted as interglacial, are shown to be interstadial of Early Weichselian age (J. Lundqvist 1967). This interstadial was named Jämtland, after the province where its sediments are most abundant, and correlated with the Danish Brörup Interstadial (Andersen 1961). Later it has been shown that the so-called Jämtland Interstadial represents two ice-free stages (Lagerbäck 1988a, Lagerbäck & Robertsson 1988). The older one is still correlated with Brörup, while the younger Täreändö Interstadial probably corresponds to Odderade. In the marginal area of glaciation there is evidence of a younger, Mid-Weichselian, interstadial. This applies to southern Sweden (Brotzen 1961, Hillefors 1969, Miller 1977) and western Norway (Mangerud 1981).

On the Continent two warm Early Weichselian as well as at least four cool Mid-Weichselian interstadials have been identified (Behre 1989, Behre & Lade 1986). These discoveries are in good agreement with the key stratigraphy at, for instance, Grand Pile, France (Woillard 1978) and the classical deep-sea curve (Emiliani 1966, Shackleton 1969). This also implies that the Jämtland Interstadial and its correlatives in neighbouring countries should be divided into two Early Weichselian interstadials.

This fact as well is essential for better understanding of the entire glaciation model. In order to elucidate this problem projects have been carried out at the Department of Quaternary Research, Stockholm University. Part of this work is the following investigation of stratigraphic sequences in the northern part of Ångermanland, found during the geological mapping of the area (J. Lundqvist 1987). The lithostratig

carried out earlier has been completed for the present purpose by Lundqvist. Many of the first field observations were then made by Britt-Marie Ek and Jan-Olov Svedlund at the Geological Survey of Sweden. The work thus started during the mapping by the Geological Survey, but has continued also within our training programme of undergraduate students and their diploma works. The following work aims at a litho- and biostratigraphical investigation and interpretation of till beds and sediments, identified within these studies. Miller is responsible for the stratigraphical studies and results based on microfossil spectra. The analysis work was partly carried out by Karin Hedin (pollen analysis) and the staff of the Micropalaeontological Laboratory at the Geological Survey.

### REGIONAL AND TOPOGRAPHICAL CHARACTERISTICS

The area under consideration is situated in central Sweden, a short distance east of the Caledonian mountain range (Fig. 1). The topography is broken, with low mountains reaching slightly more than 700 m above sea-level and valley bottoms at about 250 m. All the investigated sites are located around Lake Tåsjön, in the Fjällsjöälven river system. Among the localities to be discussed is the so-called Tåsjö site (J. Lundqvist 1978).

The bedrock in the area consists of series of sedimentary rocks, including quartzites, arkoses, shales and tillites (see Gee *et al.* 1978, Th. Lundqvist 1990). Thrusting in connection with the formation of the Caledonian mountains has caused complex stratigraphies. In the strongly broken terrain this means that there is a very complicated pattern of distribution of different rock types. Indicator rocks therefore have a very limited use. Close to the southeasternmost sites is the north-south trending boundary between the sedimentary bedrock and the Precambrian shield, represented mainly by coarse granites and gneisses. In general, therefore, rocks of more westerly origin can be distinguished from more easterly ones. However, on the bottom of Lake Tåsjön the granites probably extend far west of this boundary.

The area has been glaciated repeatedly. Based on glacial striae and morphology the following ice movements across it have been identified (J. Lundqvist 1969, 1987). Most probably an oldest ice movement originating in the mountains in the west has traversed the region (J. Lundqvist 1969, 1974), although it has not been traced within the Tåsjö area. The oldest movement identified was from the east to eastnortheast, originating from an inland ice divide far east of the mountain range. After this the ice has continuously moved from the northwest, with a clockwise turning from WNW to NNW. The dominant traces show a northwesterly movement. The glacial morphology in the Tåsjö valley indicates that the last ice remaining there formed a lobe in the valley. No corresponding topography-controlled movement has been traced, but this may be due to the complete absence of striated outcrops in the valley. This ice body may

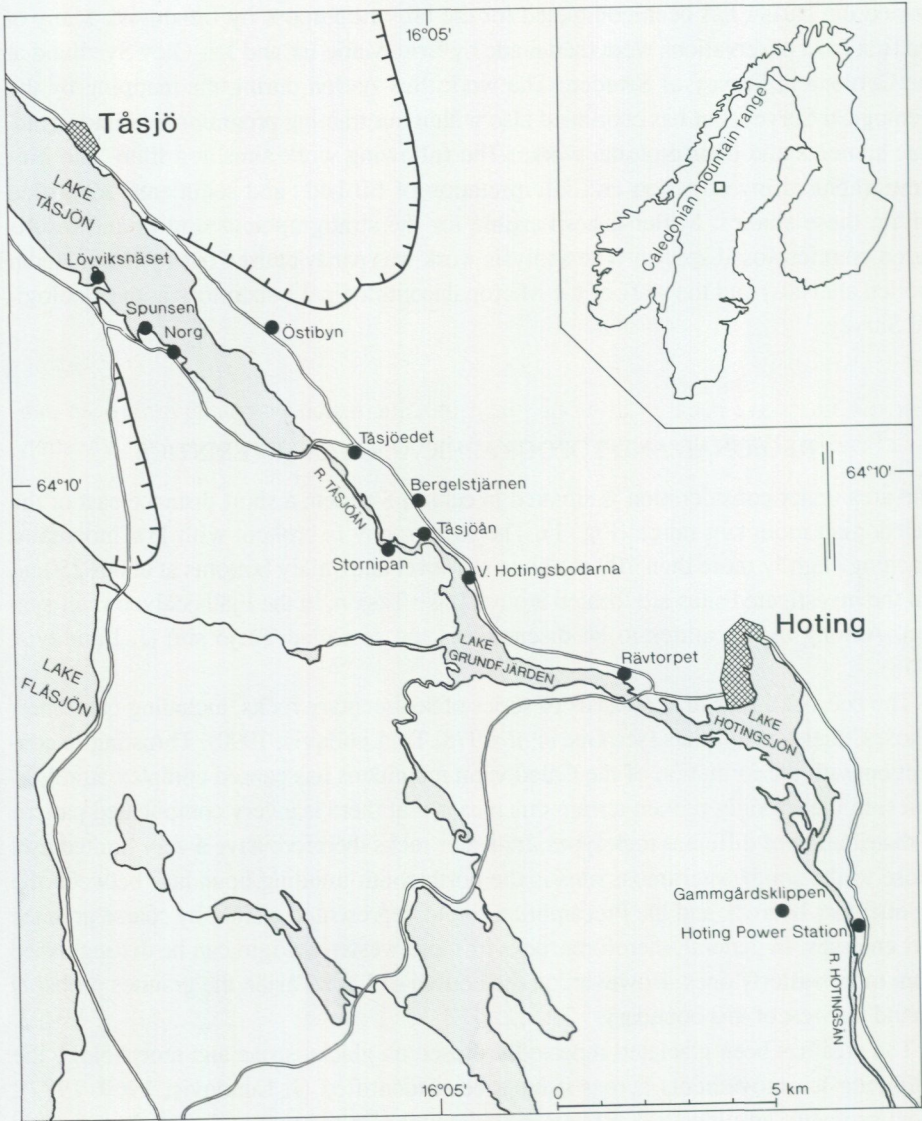


Fig. 1. Location map. Tåsjö site is situated 40 km NNW of Tåsjö. The hatched line indicates the western boundary of the Caledonian bedrock.

have been stagnant, but lateral erosion may be an indication of some activity (cf. J. Lundqvist 1973a).

The investigated area is almost entirely covered with till. Outcrops of the bedrock are few, and mainly in the highest hills. Glaciofluvial deposits occur, but they are small and do not form long eskers. Glaciolacustrine sediments occur as thin patches, indicating shallow, local dammings. The tills are probably mostly complex formations as can be seen in natural cliffs along the shores of Lake Tåsjön and at excavations. The following paper deals with stratigraphic sequences observed at such localities.

### DESCRIPTION OF THE SITES AND THEIR LITHOSTRATIGRAPHY

Thirteen sites have been used in our study. In some instances details have been published earlier. When this is the case only brief summaries are given. For lithostratigraphic units in the site descriptions arabic figures are used, to distinguish them from the units of the general stratigraphy, for which roman figures are used. The microfossil spectra of the different lithostratigraphic units are given in the next chapter.

#### TÅSJÖ SITE

The so-called Tåsjö site is situated in the Saxån valley, 7 km north of the northern end of Lake Tåsjön. It consists of a gravel pit in the valley side on the western side of the River Saxån. A description was published by J. Lundqvist (1978), of which the following is a summary.

The lithostratigraphy can be generalized to four different units. The main part is two series of glaciofluvial gravel, between which there is a thin bed of fine-textured organic and silty sediments. This sequence is covered with till.

*Unit 1.* The uppermost till bed is up to 3 m thick and very coarse-textured. It contains rounded boulders and stones and may be partly a redeposition of the underlying gravel. It is interpreted as an ablation till of local origin (J. Lundqvist 1978, Tab. 2). It has not been possible to determine its direction of transport.

*Unit 2.* Below the till there is a series of 7.6 m of glaciofluvial gravel. The petrographic character changes from one bed to another, but as a whole the gravel is typical outwash. Local rocks dominate, but rocks of distant origin are somewhat more abundant (12–15 % compared to 7) than in the till. Only at the bottom of the gravel bed is the percentage of distant lithologies considerably higher (40%). This fact may indicate that the gravel consists of reworked till of an origin different from that of the uppermost till.

*Unit 3.* In the gravel there is a series of 25 cm non-glacial, fine-textured sediments, mainly sand and silt, with about 5 cm of peat mixed with sand and silt. The organic layers contain microfossils – pollen, diatoms and insects. The flora and fauna indicate an open, treeless area with heath or tundra vegetation. The local environment is that of a river with bare gravel banks flowing through a valley with heaths, fens and small pools. The temperature corresponds to that of the mountain region today. Even during the warmest part of the time it was cooler than it has been in Holocene time. The time in question must correspond to an interstadial with cool continental conditions. It has been correlated with the Jämtland Interstadial, but after the recent development of our knowledge (Lagerbäck & Robertsson 1988) it is not clear whether it means the Brörup or Odderade Interstadial. Radiocarbon dating of the Tåsjö site has given about 55,000 B.P. (Lundqvist & Mook 1981). A new, unpublished dating (GrN-11.010; 55,900  $\pm$  1,200 B.P.) has confirmed the published result. This date agrees with the age that has earlier been assumed for the Odderade Interstadial (Grootes 1977). Unpublished (H. Heynis, pers. comm.) U/Th-datings of peat from Tåsjö at 75,000 $\pm$ 6,000 B.P. (GrN-91-135-138, 91-154-155) show even better agreement.

*Unit 4.* The lower gravel unit is very similar to the upper one (unit 2) but contains a larger amount of distant lithologies. In this respect it is more compatible with the lowermost part of unit 1. Possibly the lower gravel was derived by erosion of an unknown lower till bed. Since this stratigraphy was published, a boring through the gravel has been made. It showed the same gravel, partly more sandy, down to 7.5 m below unit 3. The lowermost part of the gravel could possibly be a till bed, from which the gravel has been derived by glaciofluvial reworking. There are some differences between the units 2 and 4 (J. Lundqvist 1978, Tabs. 1, 2) but they are not significant in terms of direction of transport.

#### LÖVVIKSNÄSET

The western side of the small peninsula Lövviksnäset (Fig. 1) in the southern part of Lake Tåsjön consists of a long bluff, up to 10 m high. The whole bluff shows a series of sandy sediments with a very irregular bedding (Fig. 2). Mostly the bedding is slightly undulating and gives a distorted impression. Folds occur, always indicating pressure from the northwest. Locally, ripples or small dunes occur in the sand, also showing stream direction from the northwest. The ripples often show a low-angle climbing and pass into more horizontal bedding, indicating a high flow regime. Especially the horizontal beds contain numerous clasts. Due to an often lenticular, flat-lying bedding this sediment may be rather similar to some of the Sveg tills in their type area. The Sveg till has been interpreted as a subglacial meltout till (Shaw 1979), formed partly of subglacially deposited glaciofluvial sediments (J. Lundqvist 1969).



Fig. 2. Proximal glaciofluvial sediments at Lövviksnäset show signs of glaciotectionic strain and pass into till. Photo J. Lundqvist 1976.

In some places, especially in the uppermost part of the bluff, the sandy sediments are replaced by stony, sandy diamicton. The boundaries between the diamicton and the sand are not always clear. The diamicton is interpreted as till, formed by partial reworking of the sand by a glacier moving along the valley from the northwest. The evidence may seem weak, but the assumption is supported by the appearance of clearly glacier-overridden sediments at, *e.g.*, Bergelstjärn (see below). In the northernmost part of the bluff diamicton pressed into the sand from the north indicates the same mode of formation.

A boring from the lake surface at the foot of the southern end of the bluff showed that from the lake level of that day down to 21.0 m below it there is a sediment sequence of dark, clayey silt. The boundary between the sand and the silt is rather sharp, occurring just a few centimetres below the lake level. A clay pit of a brickyard has been opened in the silt on the mainland close to the peninsula, but is no longer available due to damming of the lake. The silt is most probably of glacial origin, although no clear varves were identified.

The silt rests upon a boulder-rich diamicton, 1.0 m thick. Most probably this is a till, but no further study has been possible.

## SPUNSEN

At Spunsen, on the southwestern shore of Lake Tåsjön 1–2 km SE of Lövviksnäset (Fig. 1), there is a series of bluffs, up to about 8 m high, along the shore. The two main bluffs have been studied and described by Aldeborg & Holmquist (1983) and Edlund (1985), respectively. The stratigraphy is very complicated (see Figs. 3 and 4), and the description shall not be repeated in detail here. In outline the following units may be defined. The description follows the stratigraphic interpretation made by the above-mentioned authors, although the evidence for its validity is not proven in detail. The thickness of all beds varies within wide limits, and because the beds partly occur side by side no exact profile can be given. The following is a simplification with thicknesses given in general terms.

In the northern part of the Spunsen bluff (Aldeborg & Holmquist 1983; Fig. 3) there is an upper bed of unconsolidated sandy silt. Underneath it follows a complex bed of diamictons. Four different units (A–D in Fig. 3) can be identified. Beds A, B and D are interpreted as tills. Probably also C is a till, although a faint bedding and a different fabric (preferred orientation NE–SW) make it possible that this is a debris flow. Since the fabric does not agree with topographic conditions it is most likely, however, that even a debris flow originated from adjacent ice, and is thus rather a flow till (cf. Boulton 1972).

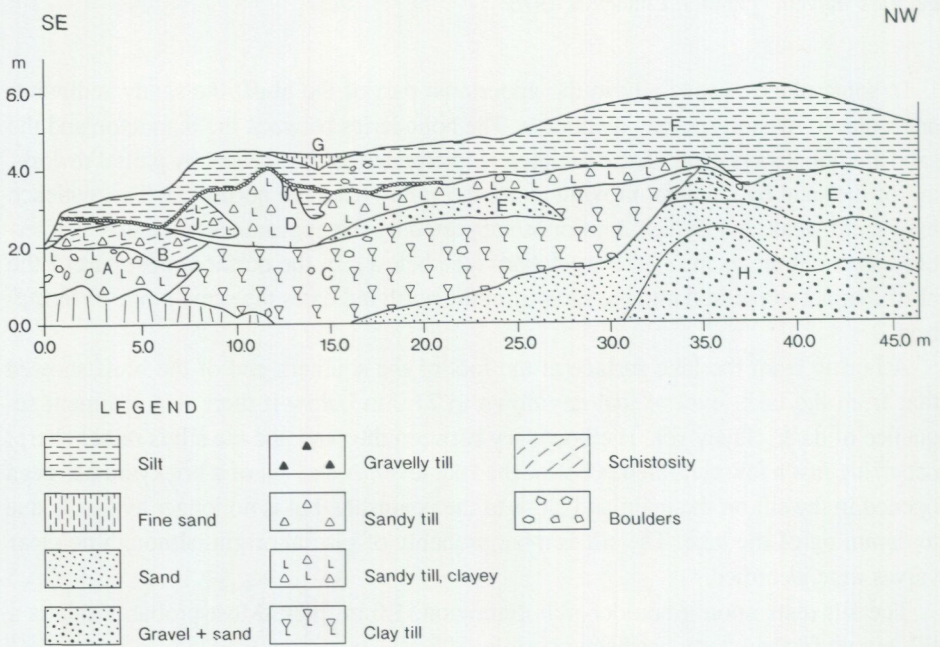


Fig. 3. Section from the northern bluff at Spunsen. Redrawn after Aldeborg & Holmquist (1983).

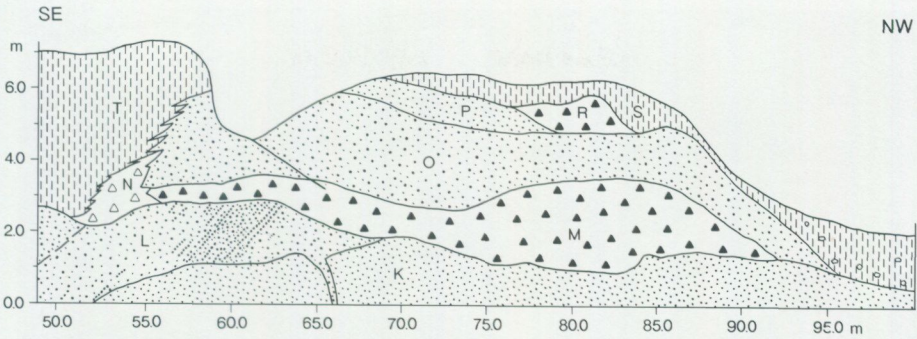


Fig. 4. Section from the southern bluff at Spunsen. Redrawn after Edlund (1985). Legend see Fig. 3.

The diamictons contain beds of sandy gravel, especially between units C and D. Northwestwards this sediment increases in volume (unit E) to completely replace the diamictons. This gravel unit (Fig. 5) then occurs as a separating bed between the upper silt and the lowermost unit, a highly lithified sand (unit I) and, lower down, sandy gravel (unit H). The beach processes have caused intense cavernous erosion of this unit, which gives it an appearance to be very old. It is true, however, that under favourable conditions consolidation may proceed quickly, so this alone is no proof of a high age.

Northwest of the bluff shown in Fig. 3 the formation of diamicton from the silty and sandy sediments can be studied in detail. This process has been described by J. Lundqvist (1985).

In the southern part of the Spunsen bluff units similar to those of the northern bluff can be identified (Fig. 4; Edlund 1985). However, there are only two diamictons (tills; M and N) between the two series of gravel and sand. There is also a diamicton, interpreted as till (unit R in Fig. 4) on top of the upper sand unit, and covered with stony, silty sand. This whole series is interpreted as tilted, which affects the fabric. Edlund (1985) made an attempt to correct the measured fabric for the tilting effect. Accepting this correction we may summarize the Spunsen stratigraphy with directions of transport in the following way, revised after Edlund (1985) and considering the stratigraphy from Aldeborg & Holmquist (1983). Only the main units from the published stratigraphies are included here.

*Unit 1.* Silty to sandy sediments, partly stony, representing flow tills and near-glacier meltwater sediments from the final deglaciation stage. Main direction of transport from the NE–ENE, probably as flows from adjacent ice. It cannot be excluded that the silty sediments have been overridden by ice. The uppermost part corresponds to bed F in Fig. 3 and S + T in Fig. 4.



Fig. 5. Sediments of unit E resting upon the highly lithified units I and H immediately to the right of the section, Fig. 3, at Spunsen. Photo J. Lundqvist 1980.

*Unit 2.* Tills representing the main Weichselian glacial stage. Transport mainly from the NE. Corresponds to beds N and R in Fig. 4 and probably D in Fig. 3.

*Unit 3.* Sediments representing an ice-free stage, an interstadial of unknown duration. It could be just a short-time oscillation of the ice margin. Corresponds to O and P in Fig. 4 and possibly E in Fig. 3.

*Unit 4.* Tills from an older glacial stage. Transport from the NE with some deviations in beds A and B. Corresponds to bed M in Fig. 4 and mainly C (incl. A and B) in Fig. 3.

*Unit 5.* Sediments representing an oldest ice-free stage. Possibly glaciofluvial, deposited in connection with the advance of the ice represented by unit 4, above, but their genetic character is not clear. Corresponds to bed K (Fig. 6) in Fig. 4 and H + I in Fig. 3.



Fig. 6. Lithified sand of unit K, with wedges of unit L, to the left of the section, Fig. 4, at Spunsen. Photo J. Lundqvist 1981.

#### NORG

At Norg, 0.5 km SE of Spunsen (Fig. 1), the bluffs continue but are less differentiated, and have not been studied in detail. They mainly contain a series of sandy sediments of glaciofluvial type. The sediments show dunes indicating a main direction of transport along the valley from the NW. A number of thrusts, dipping slightly towards the NW, cut the sand and indicate glacial overriding and shearing. A thin (less than 1 m) diamicton covers most of the sand. It may be a till or a debris flow. The same diamicton cuts the underlying sand as steep clastic dykes. This also indicates overriding by a glacier of a ground that may have been frozen. The sand is similar to the beds of unit 3 at Spunsen. Most probably they are correlatives, and the diamicton thus corresponds to unit 2.

#### ÖSTIBYN

On the northeastern side of Lake Tåsjön (Fig. 1), opposite to the Spunsen – Norg sites, the stratigraphy presented below seems to be predominant. The following beds of somewhat variable thickness have been observed in several places at Östibyn:

*Unit 1.* An uppermost bed, 0.5–2.5 m thick, of diamicton composed mainly of the local shales. No clear structures have been recorded, but the diamicton seems to represent the ordinary till of the area, of local origin.

*Unit 2.* 0.25–1.5 m of silty to clayey sediments with stones. They may be deposited in local, ice-marginal waters, but another explanation is possible. If we interpret the underlying diamicton as a debris flow, the silt-clay may be its uppermost part, separated during the flow.

*Unit 3.* Up to more than 2 m of stony, silty or clayey diamicton, sometimes with beds of pure clay. The stones are well rounded, and the deposit may be interpreted as a till of reworked glaciofluvial sediments or a debris flow. Which is the case is less important. It must in some way represent an older glacial phase – not necessarily much older than the phase of the upper diamicton. In the clasts the granite dominates, which forms the immediate substratum and the lake floor some distance upglacier. The two diamictons may represent just different phases of erosion, although the lake deposits or solifluction indicate a break in the glacial event.

#### TÅSJÖEDET

Around the southern end of Lake Tåsjön (Fig. 1) a stratigraphy similar to the one at Östibyn seems to be widespread. The upper diamicton is usually very thin, partly eroded by the river. It is underlain by up to 4 m of gravel to clay. The most fine-grained sediments are varved. The lowermost unit is a dark, clayey diamicton, most probably a till, with beds of clay. This till gives an impression to contain a lot of shale debris, but this applies to the fine fraction, only. The clasts are dominated by granite, as at Östibyn.

#### BERGELSTJÄRN – VÄSTER-HOTINGSBODARNA (TÅSJÖÅN)

The whole area on the eastern side of the River Tåsjöån between Lakes Tåsjön and Grundfjärden consists of coarse glaciofluvial gravel, forming slightly undulating fields or low, esker-like hills. The gravel is more than 15 m thick. In large gravel-pits it has been observed that the gravel mostly reaches the surface, but it is in some places covered with till. This till may be up to about 2 m thick, but decreases in thickness and disappears totally over short distances. Below the till, the gravel is often intensely folded (Fig. 7). Monoclinic or recumbent folds may be up to several tens of metres in "wavelength", and are interpreted as glaciotectonics. Fold axes indicate pressure from northwest to north. The till at the site Bergelstjärn shows a very strong fabric from the north. It is pressed like wedges into the gravel. Thrust planes cut the gravel in some places.



Fig. 7. Folded glaciofluvial sediments, to the right covered by thin till which wedges out towards the left. Väster-Hotingsbodarna. Photo J. Lundqvist 1978.

Even where the till wedges out and disappears such structures clearly indicate that the glacier has overridden the gravel. Whether this applies to all gravel in the area, or if there is also a younger set of gravel, not glacially overridden, is not clear. There are no structures to mark a possible hiatus between the generations. Only in one place, at Tåsjöån, there was a bed of 0.5 m clay in the gravel, which could be interpreted in this way. The upper part of the clay was rich in pollen and spores indicating an interstadial flora. Partly the clay bed was horizontal and undisturbed, but partly it was upraised and strongly broken, indicating some sliding or, probably, glaciotectionic disturbance.

The upper gravel unit at this place contained numerous rounded boulders of organic debris, up to 1–2 dm in diameter. No microfossils or other identifiable remnants were observed in them.

The stratigraphy of this area clearly indicates an older deglacial stage with deposition of proglacial outwash. Then followed an ice-free stage corresponding to an interstadial. During the following glacial stage the area was completely overridden by ice, but the erosive activity of this ice was surprisingly weak. Because the interstadial is probably a significant one, compatible with Brörup or Odderade, this means that the activity of the Late Weichselian ice was very weak in this area. We may compare with the well-preserved Pilgrimstad site in Jämtland (Kulling 1945, J. Lundqvist 1967, Robertsson 1988) and conditions in northern Lapland (Lagerbäck 1988a).

## STORNIPAN

On the eastern side of the River Tåsjöån, opposite to the area described above, there is a big bluff, here called Stornipan (Fig. 1). It reaches about 25 m above the surface of the adjacent river. The bluff is partly fresh, and the rest of it has been cleaned by excavation. It displays the following stratigraphy, shown also in Fig. 8 (simplified after Aldeborg & Holmquist 1983).

*Unit 1.* 116 cm brownish, clayey diamicton with foliation dipping  $20^\circ$  to the north. It contains thin laminae of silt and sand. The fabric may indicate movements both from the NNW and NE. This diamicton is probably a till deposited from the NNW, along the valley.

*Unit 2.* 2 cm dark gravel and sand separate units 1 and 3.

*Unit 3.* 150 cm yellow to grey sandy silt. Some laminae of sand and gravel occur, as well as a faint foliation dipping  $30^\circ$  N. The sorting is poor. This unit is interpreted as glacially reworked sediments.

*Unit 4.* 128 cm of a sediment similar to unit 3 but strongly folded and distorted. Orange or bluish layers of silt occur, as well as bands of gravel and sand. In the sand ripples have been observed, indicating stream direction towards the south.

*Unit 5.* 670 cm of alternating greyish blue diamicton and brown to orange sand bands. The unit is strongly folded and especially in the lower part distorted. The diamicton becomes schistous in the lowermost part. There is a fairly strong preferred orientation in NNW–SSE.

*Unit 6.* 190 cm dark bluish grey silty sandy diamicton with fissility dipping  $40^\circ$  N. It is interpreted as till. A fairly good fabric indicates transport from the NW.

*Unit 7.* 120 cm dark grey, slightly greenish sandy diamicton. Fissility dips  $30^\circ$  N. A good fabric indicates transport from about  $N60^\circ$  W. Probably this unit is a sandy sediment reworked by the glacier.

*Unit 8.* 50 cm yellow to brown coarse silt with varve-like bedding at its bottom.

*Unit 9.* 158 cm bluish grey fine silt, in the lower part sand-layered. Thin laminae of precipitated iron hydroxide.

*Unit 10.* 108 cm grey and brown fine sand with diffuse bedding.

*Unit 11.* 91 cm grey coarse sand with silt layers.

*Unit 12.* 15 cm grey to brown clay alternating with greyish blue silt and sand.

*Unit 13.* 118 cm grey, fine sand with ripples and cross-bedding indicating stream direction from the WNW.

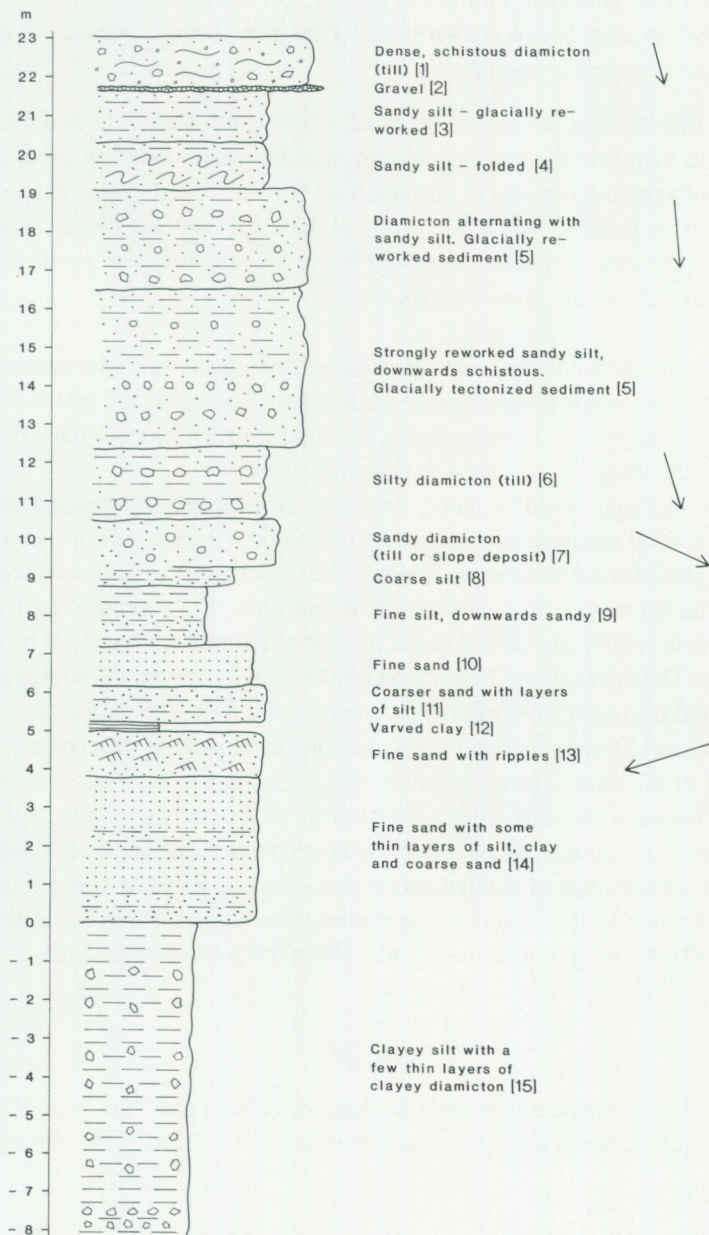


Fig. 8. Log from the Stornipan bluff. Numbers in brackets denote units. Arrows indicate direction of ice and stream movements.

*Unit 14.* 384 cm fine sand with thin layers of clay, silt and coarse sand. The colours change from layer to layer between dark greyish blue, grey, brown, orange and yellow, giving the unit a variegated appearance.

*Unit 15.* From this level, at the foot of the bluff, a boring has shown 13 m dark bluish grey clayey silt. Towards the bottom the clay-silt alternation may represent glacial varves. Pieces of varved sediments in this unit have been observed in clay blocks excavated from the river bottom. A few thin layers of dark, greyish blue clayey stony diamicton occur in the unit, especially around 7.5 and 12.5 m from the top of the clay. The silt seems to rest directly upon bedrock.

The lithologies in the whole sequence of strata are dominated by far-transported sedimentary rocks. Granites and gneisses make up about 10% or less in the gravel fraction. The clasts contain up to 50% of these rocks. No significant differences have been observed between the units (cf. Aldeborg & Holmquist 1983, Tabs. 2, 5).

The entire stratigraphy could be simply described as a series of diamictons, probably tills, with interbedded sandy to silty sediments resting on a thick series of fine-grained glacial, partly glaciofluvial sediments. It is not clear whether the diamictons represent one or more glacial stages. It is inferred here that units 1–7 represent two glacial events, resulting in folding and reworking of proglacial sediments overridden by the advancing glacier. The upper strata should probably be correlated with the stratigraphy at Lövviksnäset and the upper till-sediment sequence at Spunsen. The sediments overridden by the glacier at Stornipan are interpreted as the distal parts of the coarse-textured sediments east of the river. The assumption of two glacial events is based mainly on the similarity between the dark silty diamicton of unit 6 and the clayey till at the southern sites (see below) interpreted as representing an older glacial event. If we prefer to interpret the peculiar type of diamicton 6 as just a facies formed by reworking of the underlying dark strata 15 it is also possible to refer the entire sequence 1–7 to the same glacial event and consisting of folded and partly reworked parts of strata 8–15.

#### RÄVTORPET

At Rävtorpet, 6 km downstream the deposits described above and 2 km west of Hoting (Fig. 1), a boring has shown the following stratigraphy (B.-M. Ek, pers. comm.):

*Unit 1.* 3 m till

*Unit 2.* 12 m clay

*Unit 3.* 52 m sand

The stratigraphy was recorded at a drilling for water, but no further investigation has been made.

## AREA AROUND LAKE HOTINGSSJÖN

In the region south-southeast of Hoting till sequences have been recorded in many places. They usually show a thin uppermost brownish to grey sandy silty till upon a dark bluish grey more silty and clayey till. The stratigraphy is obviously very similar to the one described above from Tåsjöedet, but no further investigations have been made.

At Gammgårdsklippen, 5 km south of Hoting (Fig. 1), a lowermost diamicton passing into gravel was observed below the dark clayey till. It is extremely lithified, similar to concrete. It may correspond to a lowermost till, but is notably redeposited by a local stream. The lithologies of the clasts are not informative: 26 % of local origin, 74% from the northern sector. The fabric shows a distinct NW-SE maximum, indicating stream transport.

## HOTING POWER STATION

During the construction of a power plant in the River Hotingsån 6 km SSE of Hoting (Fig. 1) an important section was excavated. Unfortunately this key site was discovered too late. Only some sampling could be made whilst the bulldozers filled and covered the section. Time did not permit a complete sampling and fabric analyses. The following stratigraphy was recorded.

*Unit 1.* 2 m compact diamicton, rich in rounded boulders. Obviously this is a glacial redeposition of unit 2. The surface is reworked by fluvial erosion which has formed a boulder lag. The clasts are granites and gneisses, predominantly, with 6% of sedimentary rocks from the NW.

*Unit 2.* 2 m coarse gravel, rich in boulders and similar to unit 1 except for the compactness of the latter. Unit 2 is also better sorted, lacking the finer fractions abundant in 1.

*Unit 3.* 0-2 m dark bluish grey clayey diamicton. It formed a horizon of lenticular beds between units 1 and 3. The diamicton appeared to be rich in dark shales from the Tåsjö area, and these may have caused the dark colour of the fine fractions. In the gravel and coarser fractions, however, shale was absent. Granites and gneisses predominated, with only 3% of distant sedimentary rocks. The lenses of this unit may be up to 10 m in length. Between them unit 3 was replaced by a discordance.

*Unit 4.* 5 m gravel, wedging out towards the valley side. It showed delta foresets dipping towards the south.

*Unit 5.* 1-2 m sand with bedding like in 4. The sand is interpreted as an older phase of a delta formation in the valley.

*Unit 6.* 0.1 m greenish silt. This layer could be followed all over the section, more than 100 m in length.



SPUNSEN N Type 1

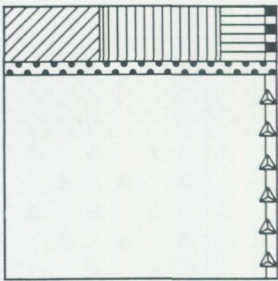


Fig. 10. PSA spectrum of type 1, characterizing the lowest Spunsen till.

HOTING P.S. Type 2

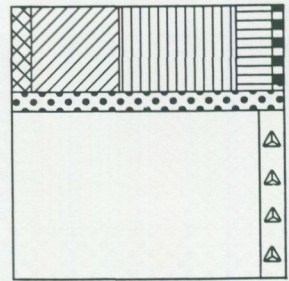


Fig. 11. PSA spectrum of type 2, characterizing the silty, greenish sediments at Hoting Power Station.

ÖSTIBYN Type 3

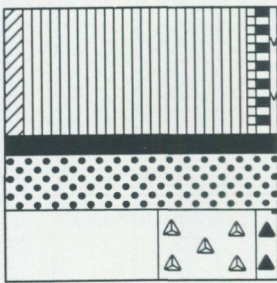


Fig. 12. PSA spectrum of type 3, characterizing the blue till and blue sediment at Östibyn.

TÅSJÖÅN Type 4

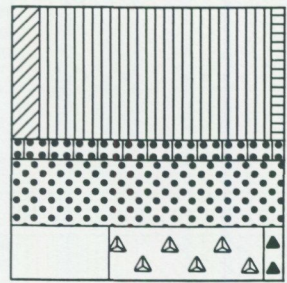


Fig. 13. PSA spectrum of type 4, characterizing the upper clay at Tåsjöån.

ÖSTIBYN Type 5

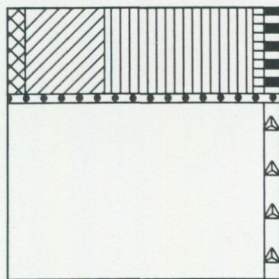
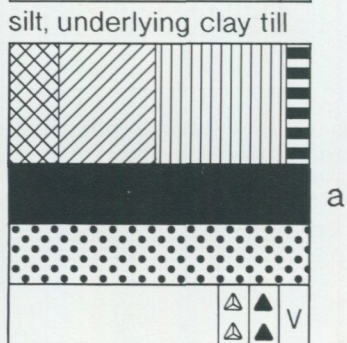
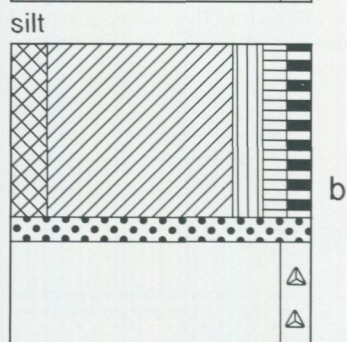
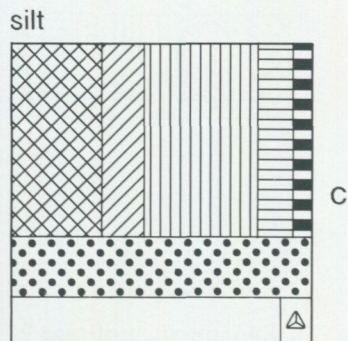


Fig. 14. PSA spectrum of type 5, characterizing the diamicton and normal till of the Tåsjö region at Östibyn.

## STORNIPAN Type 2



## TÅSJÖ SITE Type 4

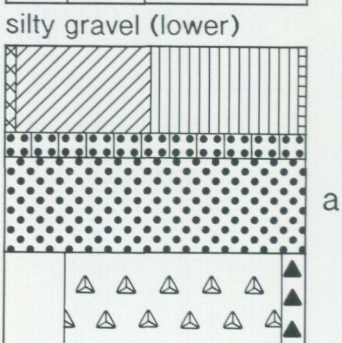
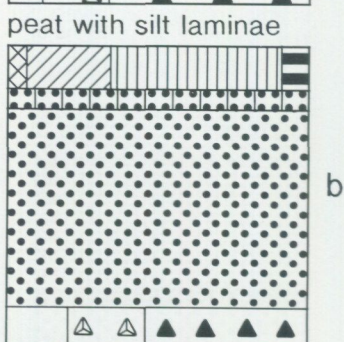
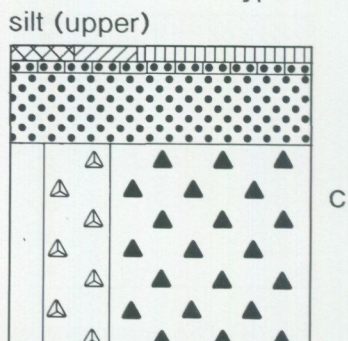


Fig. 15 a-c. PSA spectra of type 2, represented by sediment strata at Stornipan. a - silt, underlying clay till; b - silt; c - silt.

Fig. 16 a-c. PSA spectra of type 4, represented by sediment strata at Tåsjö site. a - silty gravel, lower; b - peat with silt laminae; c - silt, upper.

From left to right the percentages of different tree pollen taxa (*Picea*, *Pinus*, *Betula*, *Alnus*, *Quercetum mixtum* + *Corylus*, and others) are given. The shrubs are not divided, but consist mainly of *Betula nana*, *Salix* and *Juniperus*. Pre-Quaternary palynomorphs are architarachs and leiospherides of Palaeozoic age. Herb pollen consists of Gramineae, Cyperaceae, *Artemisia* and others. The group of spores is represented by Polypodiaceae, Lycopodiaceae, *Selaginella selaginoides* and others.

*Type 1* (Fig. 10). Rich in pollen and spores. Polypodiaceae spores predominate. *Alnus* pollen compose 15–30% of the pollen and spore assemblages. No *Picea* pollen present. Type 1 assemblages are characteristic for the tills of unit 4 in the Spunsen sequence. Connected to type 1 assemblages are also the sediments of Spunsen unit 5 and the lower till at the Hoting Power Station, unit 7. Absence of *Picea* pollen and predominance of Polypodiaceae spores are characteristic also for them, but they differ in being very poor in pollen and spores.

*Type 2* (Fig. 11). Sparse to poor in pollen and spores. Basic sums are low, about 100. *Picea* pollen and pre-Quaternary palynomorphs present. Type 2 assemblages occur in the greenish silt of unit 6 at the Hoting Power Station and in the silty sandy sediments of units 8–15 and dark to bluish clay till of units 5–7 at Stornipan. In the greenish silt there is a predominance of Polypodiaceae spores. In the tills and sediments at Stornipan the arboreal and herbaceous pollen predominate.

*Type 3* (Fig. 12). A sparse occurrence of pollen and spores with predominance of arboreal and herbaceous pollen. *Betula* pollen is common. Traces of *Picea* pollen. Type 3 assemblages are present in the blue till and sediment of unit 3 at Östibyn. The same type of assemblages but extremely poor in pollen and spores is characteristic of the sediments and tills of unit 2 at Östibyn and at Tåsjöån.

*Type 4* (Fig. 13). Pollen and spores are abundant. Among arboreal pollen *Betula* with some *B. nana* predominate. No *Picea* pollen. Spores are dominated by Lycopodiaceae. This type of assemblage occurs in the upper clay at Tåsjöån and in the interstadial deposits of Tåsjö site, where also some *Picea* pollen are present.

*Type 5* (Fig. 14). Pollen and spores are abundant. Assemblages are characterized by *Betula* pollen and traces of *Picea*. Predominance of Polypodiaceae spores. This type is present in the upper ordinary tills (diamicton) of the Tåsjö region represented by unit 1 at Östibyn.

For comparison the PSA spectra of the Stornipan (Fig. 15 a–c) and the Tåsjö site (Fig. 16 a–c) strata are shown. The different types of PSA spectra in tills and sediments of the Tåsjö region are summarized in Fig. 17.

## TÅSJÖ REGION

TYPES OF POLLEN AND SPORE ASSEMBLAGE (PSA) SPECTRA  
IN TILLS ( $\Delta$ ) AND SEDIMENTS

TYPE	P + SP CONTENT	SITE AND STRATUM	ORIGIN
5	Abundant <b>Betula</b> -rich with <b>Picea</b> Spores predominant (Polypodiaceae)	ÖSTIBYN Diamicton $\Delta$ , normal (Tåsjö region)	Reworking of interglacial + interstadial sediments S T A D I A L
4	Abundant <b>Betula</b> -rich (+ <b>B.nana</b> ) No <b>Picea</b> . Spores predominant (Lycopodiaceae) - TÅSJÖÅN Traces of <b>Picea</b> - TÅSJÖ SITE	TÅSJÖÅN Clay, (upper) TÅSJÖ SITE Peat, laminated with sand and silt	INTERSTADIAL Sediments, partly reworked
	Extremely poor	TÅSJÖÅN ÖSTIBYN Sediments + $\Delta$	Reworking of interstadial + interglacial sediments S T A D I A L
3	Sparse <b>Betula</b> . Traces of <b>Picea</b> AP + NAP predominant	ÖSTIBYN $\Delta$ , blue sediment in $\Delta$ , blue	
2	Sparse to poor With <b>Picea</b> + pre-Quaternary palynomorphs AP + NAP predominant	STORNIPAN $\Delta$ , blue silt $\Delta$ , clayey silt, laminated (clay)	Reworking of late interglacial (EEMIAN or older) and interstadial sediments S T A D I A L
	With <b>Picea</b> Spores predominant (Polypodiaceae)	HÖTING POWER S. Sediments, silty, greenish	(INTERSTADIAL?) L
1	Abundant No <b>Picea</b> <b>Alnus</b> (15-30% of AP) Spores predominant (Polypodiaceae)	SPUNSEN $\Delta$ , clayey, bluish grey	Reworking of early interglacial (EEMIAN or older) sediments S T A D I A L
	Extremely poor	SPUNSEN Sediments + "concrete" sand	
	Poor. No <b>Picea</b> Spores predominant (Polypodiaceae)	HÖTING POWER S. $\Delta$ , lower	(INTERGLACIAL?) L

UM - 91

Fig. 17. Types of PSA spectra in tills and sediments of the Tåsjö region, and the origin of the pollen and spores.

## TOTAL PLEISTOCENE STRATIGRAPHY OF THE TÅSJÖ-HOTING REGION

Summarizing the total stratigraphy of glacial deposits in the area under discussion we find the following to be the most reasonable interpretation. It is based on the lithofacies, considering the most probable environment of formation. In the following description of the summarized stratigraphy the postglacial Holocene deposits, such as subrecent fluvial sediments and peat, are excluded. We begin with the uppermost glacial units (cf. Figs. 18, 19).

*Unit I.* The uppermost unit is a till – or sometimes diamicton formed by slope processes but still in a glacial environment. This till is very thin, seldom more than 1 or 2 m thick and in many places wedging out to nothing. The till is of rather local origin, mostly formed by reworking of the underlying unit II. It is connected with strong glaciotectonics, which, in some places, are the only evidence of the glacier activity corresponding to unit I.

Only at Stornipan unit I may be considerably thicker if we prefer the second alternative given above. Its folding would actually then be caused by glaciotectonic processes. The unit is interpreted as composed of folded sandy to silty sediments, only partially reworked to till.

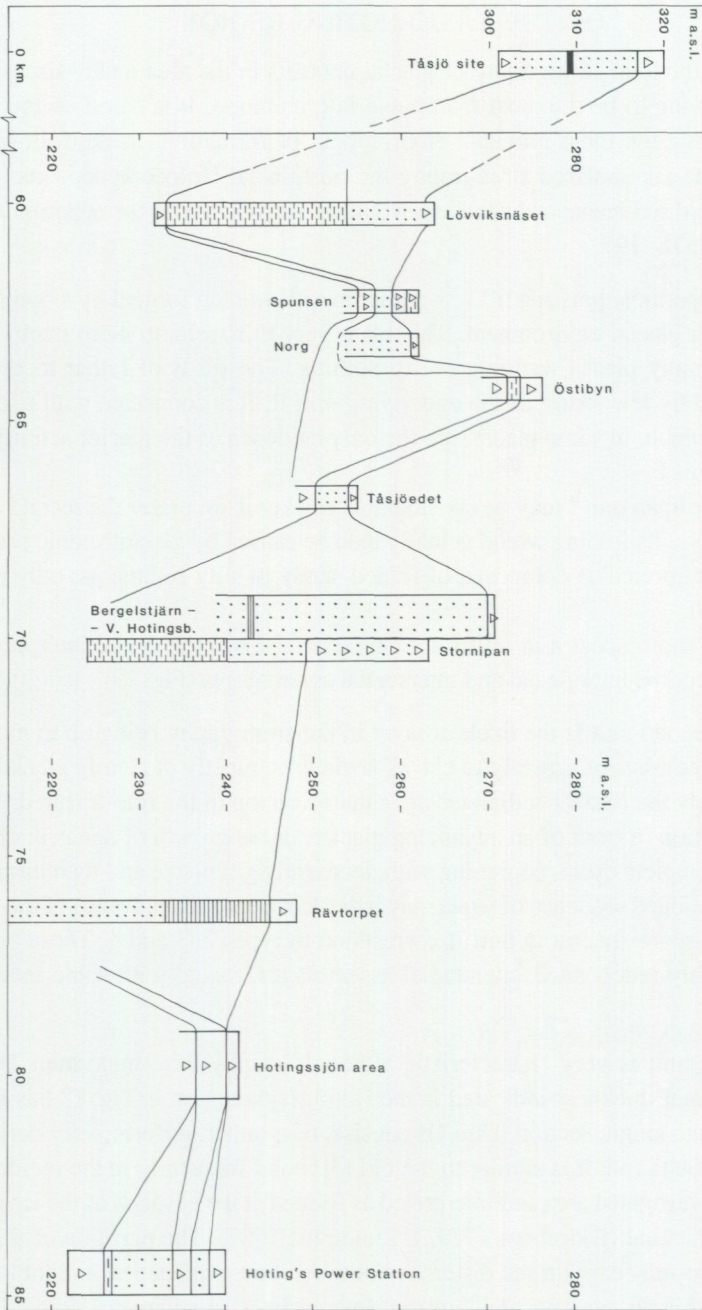
The pollen-spore spectra in unit I are characterized by type 5 and interpreted as a mixture of reworked interglacial and interstadial assemblages (Fig. 19).

*Unit II.* The second unit is the thickest layer in the stratigraphy being up to more than 30 m thick. It consists of gravelly to clayey sediments, mostly of clearly glacial facies. Most commonly the coarser sediments are situated on top of the fine-textured. This indicates exposition in front of an advancing glacier, or the growth of deltas in open water. A more complete cycle, beginning with decreasing grain-size and then turning into the above-mentioned sequence of strata may indicate retreat and readvance of the glacier.

The pollen-spore spectra in unit II correspond to types 2, 3 and 4. These are interpreted as mainly redeposited interstadial assemblages, mixed with some interglacial ones.

*Unit III.* This unit is very characteristic although usually thin, maximum 1 or 2 m thick. The greater thickness indicated in the Hotingsjön region in Fig. 18 has not been verified within a single section. Unit III consists of a rather uniform, very dark bluish grey, clayey diamicton. It is similar to the old till found frequently in the region east to south of the investigated area and interpreted as formed at the advance of the ice after the Jämtland Interstadial (Björnbom 1979, J. Lundqvist 1987). The partition of this interstadial into two may explain the difference between that explanation and the original, implying that this till pre-dates the Jämtland Interstadial (J. Lundqvist 1973b). The dark till should then represent the glacial stage between Brörup and Odderade. In our stratigraphy the character of a till has not always been verified. The diamicton may represent

Fig. 18. Summary of the lithostratigraphy from the Tåsjö site north of Lake Tåsjön to the Hoting Power Station. Triangles denote tills, dots = gravel and sand, lines = clay, broken lines = silt. The organic layer at the Tåsjö site is shown in black.



CHRONO-STRATIGRAPHY	GLACIAL EVENTS	HOTING POWER STATION	HOTINGSSJÖN	RAVORPET	STORNIPAN	BERGELSTJÄRN - V. HOTINGSBOD.	TÅSJÖEDET	ÖSTIBYN	NORG	SPUNSEN	LÖVVIKSNASET	TÅSJÖ SITE	GROSS-BIO- & LITHO-STRATIGRAPHY
Holocene	5 c Glacier retreat	Fluvial gravel	Upper till	Till	Upper till	Till	Upper till	Upper till	Till	N Sand F, G S silt S, T	(Till)	Upper till	Unit I PSA 5
Late & Mid Weichselian	5 b Glaciation	Till glacio-lect- onics	Upper till	Till	Glacio-lect- onics	Glacio-lect- onics	Upper till	Upper till	Till	Tills N, R	Glacio-lect- onics	Upper gravel	Unit II PSA 2, 3, 4
Tasjö, Tarendo, Odderade	4 Interstadial	Gravel			Sand silt	Clay PSA 4	Gravel -clay	Silt PSA 3	Sand O, P		Sand silt	Paat PSA 4	
2 nd Early Weichselian	3 c Glacier retreat	Dark clay till	Dark clay till	Clay, sand	Dark clay till	Lower gravel	Lower till	Lower till	Tills A, B, C		Lower gravel	Lower till ?	Unit III PSA 1, 2, 3
3 a Glacier advance	3 b Glaciation	Gravel sand			Dark clay till	Dark clay till	Lower till	Lower till	Tills A, B, C				
Pilgrinstad Parapholia, Brorup	2 Interstadial	Green silt PSA 2			Sand silt PSA 2	Glacio-lect- onics	Lower till	Lower till	PSA 1				Unit IV PSA 1, 2
1 st Early Weichselian	1 b Glacier retreat	Lower till PSA 1	Lower till, gravel		Lower till, gravel				Sand H, I, K, L				Unit V PSA 1
	1 a Glaciation												

Fig. 19. Litho- and biostratigraphy and glacial development in the studied area, with inferred correlation with the North European chronostratigraphy. A-C refer to the units in Figs. 3 and 4.

debris flows or material dropped from icebergs. This is of minor importance, however, because the glacial environment of formation seems to be clear.

The pollen-spore spectra in unit III are characterized by types 1, 2 och 3. These are interpreted as reworked assemblages corresponding to either an early part of an interglacial or an interstadial. The spectrum of the dark clayey diamicton at Stornipan belongs to type 2, a fact that supports our interpretation of this unit as separated from the uppermost Stornipan unit with spectrum type 5.

*Unit IV.* This unit is represented by the highly lithified sand and gravel at Spunsen, the thick lower sediment sequence at Stornipan, and the lower gravel to clay at Hoting Power Station. The sediment character at Spunsen is not clear. The sediments might be glacial, but there is no clear evidence of it. At the Hoting power plant most of the deposits represent a delta, which may be glaciofluvial. Most important is the thin greenish silt, which is certainly non-glacial, at least formed rather far from any glacier.

The pollen and spore spectra of the stratigraphical unit IV are of types 1 and 2, both interpreted as reworked interglacial.

*Unit V.* The lowermost unit is recorded only from the southernmost part of the area. It consists of a till, which looks like a typical basal till even if, unfortunately, no detailed investigation has been possible. At Gammgårdsklippen the till – or just diamicton – occurs together with better sorted gravel, interpreted as glaciofluvial.

The pollen-spore spectrum has been determined only at the Hoting power plant. It is of type 1, interpreted as an assemblage of reworked early interglacial origin, as there are no *Picea* pollen present. Polypodiaceae spores prove that the material is of terrestrial origin (exposed soil surface).

#### SEQUENCE OF GLACIAL AND ICE-FREE EVENTS

The following sequence of glacial events and interglaciations can be deduced from the general stratigraphy as interpreted by us in the Tåsjö-Hoting area (cf. Fig. 19). We then assume that there is no hiatus in the stratigraphy, which is probably mostly correct. Only in the case of Spunsen there is a possibility of a considerable hiatus between the two lowermost units. On the other hand, this may be a misleading impression caused by the fact that the lowermost unit is strongly lithified. This could be caused by a much higher age, but is certainly no evidence of it.

1. The oldest event was a glaciation (1a) – or probably just the retreat of a glacier (1b). The glacier reworked deposits from an interglacial. Which interglacial is unknown but the Eemian appears most likely. At the retreat of the glacier till and glaciofluvial sediments accumulated.

2. In an ice-free stage sediments were deposited in the Tåsjön basin and along the River Hotingsån. The valley of the latter must have been blocked somewhere south of the Hoting Power Station, probably in the narrow part 1–2 km south of it. In the ponded waters sediments were accumulated. They contain interglacial microfossils, but these are in secondary position and do not prove that this ice-free stage was an interglacial. More indicative is the predominance of resistant fern (*Polypodiaceae*) spores which are characteristic of soil surfaces.

3a. The delta represented by the main part of stratigraphic unit IV at the power station was probably formed in front of an advancing glacier in the lake ponded in the valley. This is the beginning of a second glacial phase.

3b–c. This glacial stage resulted in deposition of the dark clayey till. The glacial activity seems to have been weak, but it is difficult to explain unit III without the assumption of a glacier. Whether the diamicton was deposited directly by glacier ice or from icebergs or by debris flows is not clear, but it is so characteristic and partly far transported that it seems to be difficult to explain it without the assumption of transport by ice at some stage.

The retreat of the glacier also resulted in deposition of meltwater sediments. The lower part of the thick sediments between Hoting and Lake Tåsjön shows an upwards decreasing grain-size, and is in this respect similar to normal late Weichselian meltwater-sediment sequences. The lower gravel at the Tåsjö site is referred to this phase. The thin clay at Östibyn probably belongs to the same phase, being accumulated in a pond or small lake dammed by the shrinking ice in the Tåsjö basin.

4. It is not clear whether the thin clay at Tåsjöån is of glacial origin or not. There are no signs of glacial influence, like rhythmites or dropstones, and probably it is non-glacial. Its pollen and spore assemblages indicate interstadial conditions, compatible with those found in the peaty layer at the Tåsjö site. Therefore these deposits are referred to a stage 4, corresponding to an interstadial.

5a. The beginning of a third glacial stage is represented by thick proglacial meltwater deposits. These are the coarsening-upwards strata most typically developed at Lövviksnäset. The Tåsjö basin must have been occupied by a lake at this time, reaching a slightly higher level than the present-day lake level. The lake also must have extended much farther south. Most probably it reached as far as the narrow part of the Hotingsån valley, where the old blocking took place (cf. above).

On levels above this "Ancient Lake Tåsjön" supra-aquatic glaciofluvial deposits were accumulated. The upper gravel at the Tåsjö site belongs to them. Most important are the widespread deposits in the Bergelstjärn – Väster-Hotingsbodarna area. They were formed above and at the lake level. The corresponding distal facies of the sediments deposited in the lake are the sandy to silty, partly clayey, mostly reworked sediments at Stornipan.

5b. The activity of the ice during this glacial stage seems to have been rather weak. The ice may have been cold-based or just less active in the vicinity of the main ice divide. Fracturing of the deposits in front of the ice may be taken as an evidence that the ice advanced over at least partly frozen ground. Typically, the tectonic structures only reflect ice movements along the valley system studied. This corresponds to either the beginning or the end of the glacial stage. Indications of other ice movements demonstrated by striae are not evident. Some of the diamictons, if tills, at Spunsen may be such an indication but this is certainly not indisputable. It seems more probable that the different directions of transport reflect just differential movements within a glacier tongue in the valley, or even debris flows from the ice. We infer that only the local glacial conditions in the valley system influenced upon the formation of till and glaciotectionic structures. Other ice movements, for instance from an easterly ice divide, have been either too short-lived to have any noticeable effect, or they affected only areas less protected than the valley system studied.

5c. During the final deglaciation a thin till cover was left behind, and together with it thin meltwater sediments. They were deposited very close to the ice and may be mixed with debris flows and material dropped from icebergs, ice floes or a nearby ice margin. It is in many places hard to tell whether a certain meltwater deposit has been overridden by the glacier or just mixed with glacial debris in this way. The pollen and spore spectra contain reworked assemblages of interglacial and interstadial origin.

#### DATING AND CORRELATION OF THE GLACIAL STAGES AND INTERSTADES

In the foregoing we have identified three glacial stages and two interstades. Because there is no organic material – except at the Tåsjö site – *in situ* to be dated, any attempt to date these events must be somewhat speculative. The following can be stated, however.

If we accept the radiocarbon dates at about 55,000 B.P. or the U/Th date at 75,000  $\pm$ 6000 for the Tåsjö site it is clear that there was an ice-free stage in the area under consideration at that time, corresponding to the Odderade Interstadial of the European continent (cf. Grootes 1977). The environment in the area then was a mountain heath or tundra.

This environment corresponds fairly well to the environment indicated by the scanty pollen-spore assemblages of the upper non-glacial stage discussed above. The Tåsjö site has earlier been referred to the Jämtland Interstadial (J. Lundqvist 1978). After the partition of this interstadial in two (Lagerbäck & Robertsson 1988, Robertsson 1988, García Ambrosiani 1990) it seems most reasonable to refer the Tåsjö site to the Odderade Interstadial.

Several other interstadial deposits in central Sweden have been referred to the Jämtland Interstadial (J. Lundqvist 1967). From the till investigations by Björnbom (1979) it is obvious that at least some of these deposits are overlain by the very characteristic dark clayey till studied by him. Except the sites studied by Björnbom this applies to the Härnö (Munthe 1904, J. Lundqvist 1987, Robertsson 1988, García Ambrosiani 1990) and Långele (Sundius & Sandegren 1948) sites. In the Tåsjö-Hoting area there is a very similar till underlying some interstadial sediments and overlying others. It is true that there is no indisputable evidence that this till is a stratigraphic unit – as a matter of fact this is denied by many geologists. However, everywhere where the till occurs in a specific stratigraphic position its position is the same – that is, if we define the till correctly. Many tills formed by dark shales or dark marine sediments may look similar but we should use the definition of Björnbom (1979): The till is a clayey, basal till in which only the ordinary Precambrian crystalline rocks can be identified.

Provided we accept the dark till as a stratigraphic unit in the Tåsjö area we have to correlate also the sediments below it with the Jämtland Interstadial complex. The microfossils do not support such an assumption, but their evidence is not indisputable. The absence of *Picea* pollen in some deposits as well as the fact that the whole assemblages consist of redeposited material makes it possible that these sediments, too, show an interstadial environment, although there may be a contamination with older interglacial material. So far it seems most plausible to interpret also the older ice-free stage as an interstadial similar to Jämtland.

The consequence of this discussion is that also in the Tåsjö-Hoting area the Jämtland Interstadial should be divided into two units. The upper one, for which we can use the local name, the Tåsjö Interstadial, most probably corresponds to Odderade, while the lower could be correlated with Brörup. As a matter of fact, the possibility of an interpretation like this was the reason why J. Lundqvist (1967) preferred the name, Jämtland, for the interstadial instead of a more correct stratigraphic term. Most probably the sites used for the definition should be divided in two groups. Our investigation supports the division proposed by García Ambrosiani (1990). The two interstadials seem to be fairly similar, which agrees with what we know about two warm Early Weichselian interstadials on the European continent, defined at Grande Pile (Woillard 1978) and Örel (Behre 1989, Behre & Lade 1986). If we compare the general development found for the Tåsjö Interstadial with the conditions in adjacent areas we find the following. A similar development and environment is represented in Jämtland by the Storsjö basin sites (Vålbacken, Grytan, Frösön, and others) and the sites along Ströms Vattudal and the Flåsjö basin, adjacent to the Tåsjö basin (cf. J. Lundqvist 1967). East of the studied area a similar development has been found by Lindström (1971), and further north the Vilhelmina clay deposits (Granlund 1943, J. Lundqvist 1967) seem to indicate the same. In northernmost Sweden the same interstadial – there called Täreändö – has been considerably colder (Lagerbäck 1988b).

In Jämtland the Pilgrimstad site (Kulling 1945, J. Lundqvist 1967) seems to indi-

cate a slightly different development. The Långsele site east of it (Sundius & Sandegren 1948) is a correlative. Thus there might be reason to define a Pilgrimstad Interstadial (cf. Kulling 1967), separated from the Tåsjö Interstadial. It could be correlated with Brörup, although radiocarbon dates rather indicate a lower age than for the Tåsjö site (Robertsson 1988). However, a thermoluminescens date at 60 000 B.P. (García Ambrosiani 1990) may give some support. Our present observations do not allow further speculations in this respect. The conclusion, however, will be that in northern Ångermanland deposits from two Early Weichselian interstadials occur. Although the absolute ages differ from the time-scale obtained from the oxygen-isotope curve (cf. Behre 1989) we propose the following correlation:

Continent	Central Sweden	Lapland
Odderade Brörup	Tåsjö Pilgrimstad	Tärendö Peräpohjola

There is no indication that the described sites represent Mid-Weichselian interstadials. The sedimentation is quite continuous and no sub-till sediments are found above the Tåsjö Interstadial.

#### ACKNOWLEDGEMENTS

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## REFERENCES

- ALDEBORG, P. & HOLMQUIST, E., 1983: Moränstratigrafi i Tåsjöområdet, Ångermanland. University of Stockholm, Department of Quaternary Research, Report 2. 65 pp.
- ANDERSEN, S.Th., 1961: Vegetation and its Environment in Denmark in the Early Weichselian Glacial (Last Glacial). Danmarks Geologiske Undersøgelse II R. 75. 175 pp.
- BEHRE, K.-E., 1989: Biostratigraphy of the last glacial period in Europe. *Quaternary Science Reviews* 8, 25–44.
- BEHRE, K.-E. & LADE, U., 1986: Eine Folge von Eem und 4 Weichsel-Interstadialen in Oerel/Niedersachsen und ihr Vegetationsablauf. *Eiszeitalter und Gegenwart* 36, 11–36.
- BJÖRNBOM, S., 1979: Clayey basal till in central and northern Sweden. A deposit from an old phase of the Würm glaciation. *Sveriges Geologiska Undersökning C 753*. 62 pp.
- BOULTON, G.S., 1972: Modern Arctic glaciers as depositional models for former ice sheets. *Journal of the Geological Society of London* 128, 361–393.
- BROTZEN, F., 1961: An interstadial (radiocarbon dated) and the substages of the Last Glaciation in Sweden. *Geologiska Föreningens i Stockholm Förhandlingar* 83, 144–150.
- EDLUND, L., 1985: Södra Spunsen. En strandbrink med submoräna sediment i Tåsjöområdet, Ångermanland. University of Stockholm, Department of Quaternary Research, Report 4. 41 pp.
- EMILIANI, C., 1966: Paleotemperature analysis of Caribbean cores P6304-8 and P6304-9 and a generalized temperature curve for the past 425,000 years. *Journal of Geology* 74, 109–126.
- GARCÍA AMBROSIANI, K., 1990: Pleistocene stratigraphy in Central and Northern Sweden - a reinvestigation of some classical sites. University of Stockholm, Department of Quaternary Research, Report 16. 97 pp.
- GEE, D.G., Kumpulainen, R. & Thelander, T., 1978: The Tåsjön décollement, Central Swedish Caledonides. *Sveriges Geologiska Undersökning C 742*. 35 pp.
- GRANLUND, E., 1943: Beskrivning till jordartskarta över Västerbottens län nedanför odlingsgränsen. *Sveriges Geologiska Undersökning Ca 26*. 151 pp.
- GROOTES, P.M., 1977: Thermal diffusion isotopic enrichment and radiocarbon dating beyond 50 000 years B.P. Groningen. 221 pp.
- HILLEFORS, Å., 1969: Västsveriges glaciala historia och morfologi. *Naturgeografiska studier. Meddelanden från Lunds Universitets Geografiska Institution. Avhandling* 60. 319 pp.
- KULLING, O., 1945: Om fynd av mammut vid Pilgrimstad i Jämtland. *Sveriges Geologiska Undersökning C 473*. 62 pp.

- KULLING, O., 1967: Yttrande med anledning av J. Lundqvists föredrag: "Submoräna sediment i Jämtland". Geologiska Föreningens i Stockholm Förhandlingar 89, 123–125.
- LAGERBÄCK, R., 1988a: The Veiki moraines in northern Sweden - widespread evidence of an Early Weichselian deglaciation. *Boreas* 17, 469–486.
- LAGERBÄCK, R., 1988b: Periglacial phenomena in the wooded areas of Northern Sweden - relicts from the Tärenö Interstadial. *Boreas* 17, 487–499.
- LAGERBÄCK, R. & ROBERTSSON, A.-M., 1988: Kettle holes – stratigraphical archives for Weichselian geology and palaeoenvironment in northernmost Sweden. *Boreas* 17, 439–468.
- LINDSTRÖM, E., 1971: Submoräna sediment och isrörelser i nordvästra Ångermanland. Universitetet i Uppsala, Naturgeografiska institutionen, Rapport 10. 52 pp.
- LUNDQVIST, J., 1967: Submoräna sediment i Jämtlands län. Sveriges Geologiska Undersökning C 618. 267 pp.
- LUNDQVIST, J., 1969: Beskrivning till jordartskarta över Jämtlands län. Sveriges Geologiska Undersökning Ca 45. 418 pp.
- LUNDQVIST, J., 1973a: Isavsmältningens förlopp i Jämtlands län. Sveriges Geologiska Undersökning C 681, 187 pp.
- LUNDQVIST, J., 1973b: Dark bluish boulder-clay: a possible deposit from the first Würm glaciation. *Bulletin of the Geological Institutes of the University of Uppsala, New Series* 5, 19–20.
- LUNDQVIST, J., 1974: Outlines of the Weichsel Glacial in Sweden. *Geologiska Föreningens i Stockholm Förhandlingar* 96, 327–339.
- LUNDQVIST, J., 1978: New information about Early and Middle Weichselian interstadials in northern Sweden. *Sveriges Geologiska Undersökning C 752*. 31 pp.
- LUNDQVIST, J., 1985: Glaciotectonics and till or tillite genesis: Examples from Pleistocene glacial drift in central Sweden. *Palaeogeography, Palaeoclimatology and Palaeoecology* 51, 389–395.
- LUNDQVIST, J., 1987: Beskrivning till jordartskarta över Västernorrlands län och förutvarande Fjällsjö k:n. *Sveriges Geologiska Undersökning Ca 55*. 270 pp.
- LUNDQVIST, J. & Mook, W.G., 1981: Finite date of the Jämtland Interstadial. *Boreas* 10, 133–135.
- LUNDQVIST, Th., 1990: Beskrivning till berggrundskartan över Västernorrlands län. *Sveriges Geologiska Undersökning Ba 31*. 429 pp.
- MANGERUD, J., 1981: The Early and Middle Weichselian in Norway: a review. *Boreas* 10, 381–393.
- MILLER, U., 1977: Pleistocene deposits of the Alnarp Valley, southern Sweden - Microfossils and their stratigraphical application. University of Lund, Department of Quaternary Geology, Thesis 4. 125 pp.
- MUNTHE, H., 1904: Om den submoräna Hernögyttjan och dess ålder. *Geologiska Föreningens i Stockholm Förhandlingar* 26, 317–346.

- ROBERTSSON, A.-M., 1988: Biostratigraphical studies of interglacial and interstadia deposits in Sweden. Reinvestigations of the stratigraphy at Pilgrimstad, Öje and Boliden, and studies of the new sites Margreteberg and Seitevare. University of Stockholm, Department of Quaternary Research, Report 10. 135 pp.
- SHACKLETON, N.H., 1969: The last interglacial in the marine and terrestrial record. *Proceedings of the Royal Society of London B174*, 135–154.
- SHAW, J., 1979: Genesis of the Sveg tills and Rogen moraines of central Sweden: a model of basal melt out. *Boreas* 8, 409–426.
- SUNDIUS, N. & Sandegren, R., 1948: Interglacialfyndet vid Långsele. *Sveriges Geologiska Undersökning C 495*. 46 pp.
- WOILLARD, G.M., 1978: Grande Pile Peat Bog: A Continuous Pollen Record for the Last 140,000 Years. *Quaternary Research* 9, 1–21.



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