SVERIGES GEOLOGISKA UNDERSÖKNING

SER. Ca AVHANDLINGAR OCH UPPSATSER NR 79

BERTIL RINGBERG

LATE WEICHSELIAN CLAY VARVE CHRONOLOGY AND GLACIOLACUSTRINE ENVIRONMENT DURING DEGLACIATION IN SOUTHEASTERN SWEDEN

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ISBN 91-7158-504-4
ISSN 0348-1352

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Redigering och layout: Agneta Ek, SGU
Tryck: Offsetcenter AB, Uppsala 1991

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ABSTRACT

Ringberg, Bertil 1991: Late Weichselian clay varve chronology and glaciolacustrine environment during deglaciation in southeastern Sweden. Sveriges geologiska undersökning. Ser Ca, No. 79. 42 pp. Uppsala 1991.

The study presents floating clay varve chronology for the Late Weichselian deglaciation in northeastern Skåne and Blekinge.

From the 185 localities 67 new graphs are presented. The local chronology in the investigation area ranges from -325 to +315, or 640 years. Deglaciation occurred during the Bölling and the Older Dryas chronozones. The recession rate during the deglaciation period was, according to the clay varve chronology, 75–100 m per year.

The glaciolacustrine environment in the Baltic Ice Lake was studied on the basis of observation of the highest shoreline and the glaciofluvial and glaciolacustrine sediments. The varved clay has been divided into four varve types each formed in a particular environment. The first two varve types were formed by density underflows or more or less continous turbidity currents from melting stagnant ice masses. In open areas asymmetric ripples in the summer layers show that wave-generated bottom currents occurred. The third varve type, with diffuse varves, was formed during a temporary rapid melting period, 60–85 years long, when glaciofluvial delta plains situated 10 m below the highest shoreline were also formed. The third and the fourth varve types were formed by meltwater via overland streams. All the varve types except the third, have sharply defined boundaries between summer-winter and winter-summer layers. Generally, either the varves as units or the different layers are graded. The proximal varves in the bottomset beds of the glaciofluvial deltas have interseasonal lamination indicating the diurnal rhythm of the glaciolacustrine sedimentation.

Key word: Late Weichselian deglaciation, clay varve chronology, glaciolacustrine environment, diurnal rhythm.

Introduction

The purpose of this investigation is to establish a clay varve chronology and to describe the glaciolacustrine environment in the Baltic Ice Lake during the Late Weichseiian deglaciation in Blekinge and northeastern Skåne, in southeastern Sweden. The clay varve chronology of the investigation area was previously published in 1979 but without the varve diagrams and with no discussion of the deposition environment (Ringberg 1979). Since then the Geological Survey of Sweden has mapped most of the area covered by the Baltic Ice Lake in northeastern Skåne (Ringberg 1991a and b), and this has resulted in a more complete picture of the glaciofluvial and glaciolacustrine deposits.

The results of this investigation contribute to the IGCP project 253: Termination of the Pleistocene; subproject: History and drainage of large ice-dammed lakes.

Topography and geology

The investigation area comprises the province of Blekinge and the northeastern part of the province of Skåne below the highest shoreline of the Baltic Ice Lake, i.e. the coastal area below an altitude of 55–65 m (Fig. 1).

The area is largely lowland with a continous north–south slope. Some northern parts reach 100 m above sea level but most of the archipelago in Blekinge is below 20 m. The area belongs to the marginal part of the South Swedish Upland which reaches 100–150 m above sea level immediately north of the investigation area. In the southwest the area is bounded by faults against the ridges of Nävlingeåsen (100–125 m above sea level) and Linderödsåsen (150–200 m above sea level). Ryssberget, which is situated along the border between Blekinge and Skåne, reaches 150 m above sea level and is an offset from the South Swedish Upland.

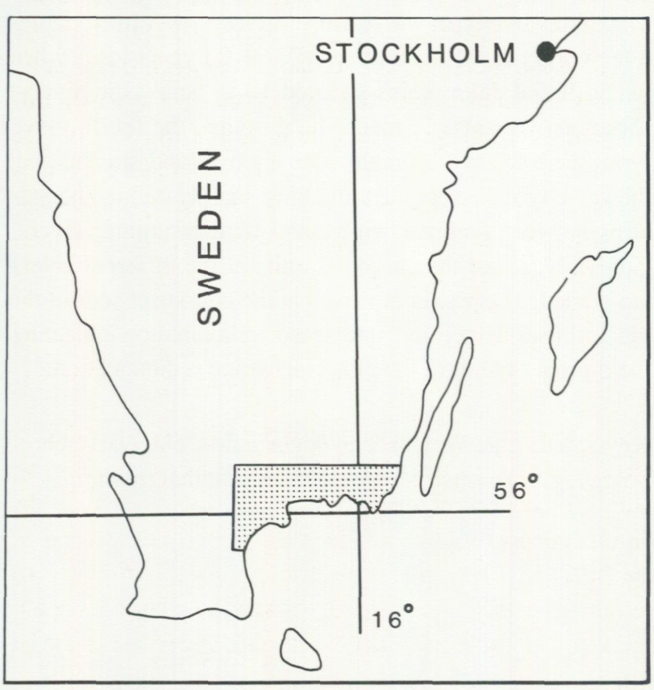

Fig. 1. Position of the investigation area.

Valleys cut into the landscape in mainly northerly directions and make the main part of the area mosaic. The area around Kristianstad (Pl. 1–2) is for the most part a plain with some hills and along the coast of Blekinge there is an archipelago (Pl. 3).

The investigation area is mainly composed of Archaean rocks, gneisses and granites. In northeastern Blekinge Cambrian sandstone overlies the older rocks, whilst on the Kristianstad plain kaolin deposits form a more or less continous layer on the Archaean surface. Limestones and sandstones from the Cretaceous period (Senonian) overlie the Archaean rocks and the kaolin deposits in the Kristianstad plain. Isolated Senonian and kaolin deposits have been found along the coast of Blekinge.

The youngest glacial striae in the area show an ice movement from N 5°–10° W in eastern Blekinge, from N–NNW in western Blekinge and from N–NE i northeastern Skåne (Pl. 1–3).

The bedrock is generally covered with sandy till which is clayey in certain areas. The till has generally medium boulder frequency and the bedrock content is dominated by Archaean crystalline rocks. The lime content of the till is generally low. In areas where limestones from the Cretaceous period overlie the Archaean rocks the lime content is high.

With the exception of drumlins in certain areas (Pl. 1–3), there are no morainic features in the investigation area that would suggest ice activity in a late phase of the Late Weichselian deglaciation.

The highest shoreline of the Baltic Ice Lake (Pl. 1–3) is situated about 65 m above the present sea level in eastern and central Blekinge, 60–65 m in westernmost Blekinge and 50–60 m above the present sea level in northeastern Skåne.

The glaciofluvial deposits of the investigation area consist of eskers, outwash fans and deltas which were formed at and below the highest shoreline of the Baltic Ice Lake (Pl. 1–3). Generally speaking, the glaciofluvial deposits follow the valleys and depressions of the bedrock. Near the coast and on the Kristianstad plain the directions of the deposits seem to be dependent on factors other than the topographical ones.

The glacial geology in parts of the investigation area has been most recently described by Hellberg (1971), Ringberg (1971, 1991a and b), Björck & Möller (1976, 1987), Hebrand (1978), Lagerlund & Björck (1979), Björck (1979, 1981), Schneider (1979) and Åmark (1984). The vegetation history and shore displacement was studied by Berglund (1966, 1979), Mörner (1969), Björck (1979, 1981) and Björck & Möller (1987). Palaeomagnetic studies were conducted by Mörner (1975b), Noël (1975) and Björck et al. (1987). The older literature relevant to this work is available in the above-mentioned works.

Glaciolacustrine environment in the Baltic Ice Lake

HIGHEST SHORELINE AND LITTORAL DEPOSITS

The highest shoreline and lower shorelines in the Baltic Ice Lake were formed in different environments during and after deglaciation. Most of Blekinge (Pl. 3) was an archipelago while northeastern Skåne (Pl. 1–2) had open coasts exposed especially to easterly winds. The different environments affected both the formation of the shore-marks and the glaciofluvial and glaciolacustrine deposits.

The highest shoreline in eastern Blekinge was determined at 25 localities as being an erosion boundary between non-washed till above and washed till below the shoreline. The 25 localities were selected without taking into consideration exposure to different wind directions. The highest shoreline in the area was determined to be 63.5–67.5 m above the present sea level. This shoreline is metachronous, formed during the ice recession, but since it was formed at nearly the same time over the whole area it can be designated approximately synchronous (Ringberg 1971, pp. 30–38).

The shore-marks of the highest shoreline in most of Blekinge are indistinct and the littoral deposits, gravel and sand, are of very limited extent. The abrasion of the Baltic Ice Lake was not very strong because most of the coast was protected by an archipelago during and after deglaciation.

In westernmost Blekinge, on the eastern slopes of Mt. Ryssberget and on the drumlins of the Listerlandet peninsula there are well developed shore-marks and littoral deposits such as cobbles, gravel and sand. The littoral deposits of the Baltic Ice Lake occur from the highest shoreline at 55–60 m to 16–17 m above the present sea level (Hellberg 1971, pp. 25–62). The shore-marks of the highest shoreline lie some metres lower and are much smaller on the western than on the eastern side of Mt. Ryssberget (Hellberg 1971, p. 63). The impressive shore-marks on the eastern side were caused by heavy abrasion of the Baltic Ice Lake on an open coast during strong easterly winds, while the western side of Mt. Ryssberget was more protected. The heavily abraded, flat landscape below the highest shoreline in easternmost Blekinge, northeast of Jämjö (Lundqvist 1946, p. 9) and the deposition of littoral sediments 25–40 m above the present sea level at Häljarum (Ringberg 1971, pp. 22–23) were also formed by easterly winds.

In northeastern Skåne the highest shoreline is situated 50–60 m above the present sea level (De Geer 1889, pp. 82–83; Hellberg 1971, pp. 63–64; Ringberg 1991a, p. 54 and 1991b, p. 50). Especially the southern part of the Kristianstad plain (Pl. 1–2) was heavily abraded following deglaciation. Littoral deposits, consisting of cobbles, gravel and sand, are common below the highest shoreline. Primary forms of till and glaciofluvial deposits were wave-washed and sediments were redeposited at all levels from the highest shoreline to the present sea level. The glaciofluvial outwash fans and eskers very often have asymmetric intersections caused by abrasion during easterly winds and littoral deposition on the western lee-sides of the primary deposits. Littoral lee-side deposits were also observed on the partly till-covered bedrock hills (Ringberg 1991a, p. 55; 1991b, p. 51–52). The northern part of the Kristianstad plain is situated on the western lee-side of Mt. Ryssberget and there the abrasion of the Baltic Ice Lake during and after deglaciation was less than in the southern part of the plain.

GLACIOFLUVIAL DEPOSITS

The glaciofluvial deposits below the highest shoreline in the investigation area (Pl. 1–3) can be roughly classified as outwash fans, eskers, deltas, kames and kame terraces. The different deposits were formed in different environments of the Baltic Ice Lake. These environments were primarily affected by the bedrock morphology and the nature of the ice dynamic during the recession of the ice sheet. Secondarily, the environments were affected by the water level fluctuations in the Baltic Ice Lake.

Outwash fans

The outwash fans (Ringberg 1991a, pp. 46–48; 1991b, pp. 40–47) are situated on the Kristianstad plain with their surfaces 10–45 m below the highest shoreline (Pl. 1–2). The fans are generally 0.1–3 km wide and 5–20 m high. The deposits follow the lowermost parts of the bedrock and till morphology. The widths of the outwash fans seem to be related to the amount of space available in the depressions of the underlying, comparatively flat, Cretaceous bedrock morphology during deglaciation.

The outwash fans usually have a flat or undulating form. In their more proximal and narrow parts they are ridge-like. One of the outwash fans, the so-called Helgeåsen, has holes and hilly forms 20-30 m above the present sea level. The latter forms indicate deposition in or on dead ice 20–30 m below the highest shoreline. Observed faults in the outwash fan also give the same indication.

Boulders of crystalline bedrocks and aeolian sand dunes are common on the surfaces of the outwash fans.

According to exposures and corings the outwash fans are generally constructed as in Fig. 2, modified after Shaw (1985, Fig. 2–39 *in* Ashley et al. 1985). Several corings in the deposits show that till is missing in the central parts of the outwash fans where the glaciofluvial sediments lie directly on the bedrock. Flow till was observed as layers in the glaciofluvial sediments. Boulders were observed in the sediments. The boulders have fallen from the ice front or dropped from icebergs. Pieces of till up to 1–2 m in diameter were observed in the outwash fans. The ice in the till pieces

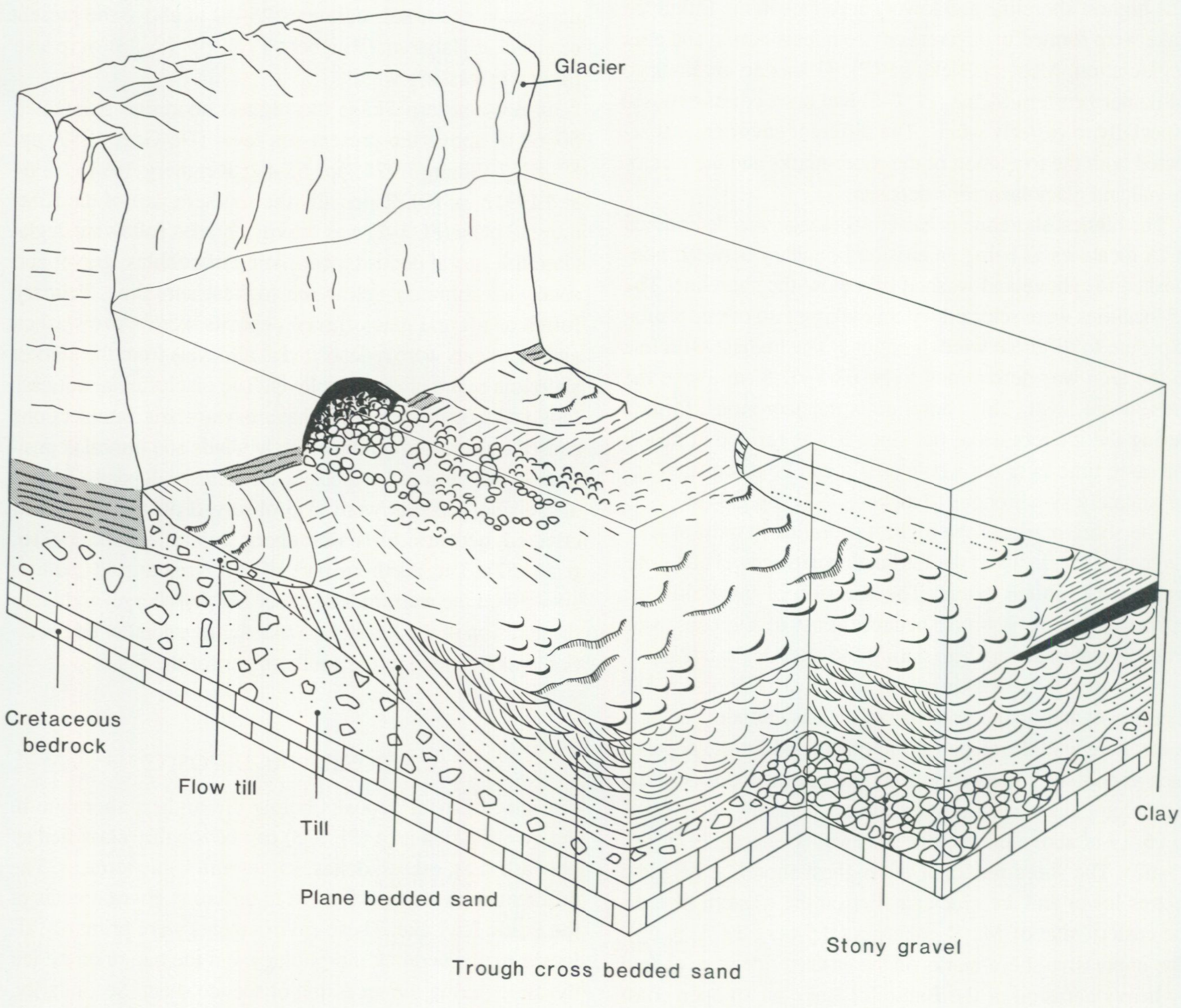

Fig. 2. Outwash fan at Vä, 5 km SW of Kristianstad (Pl. 1). From Ringberg 1991a, Fig. 17.

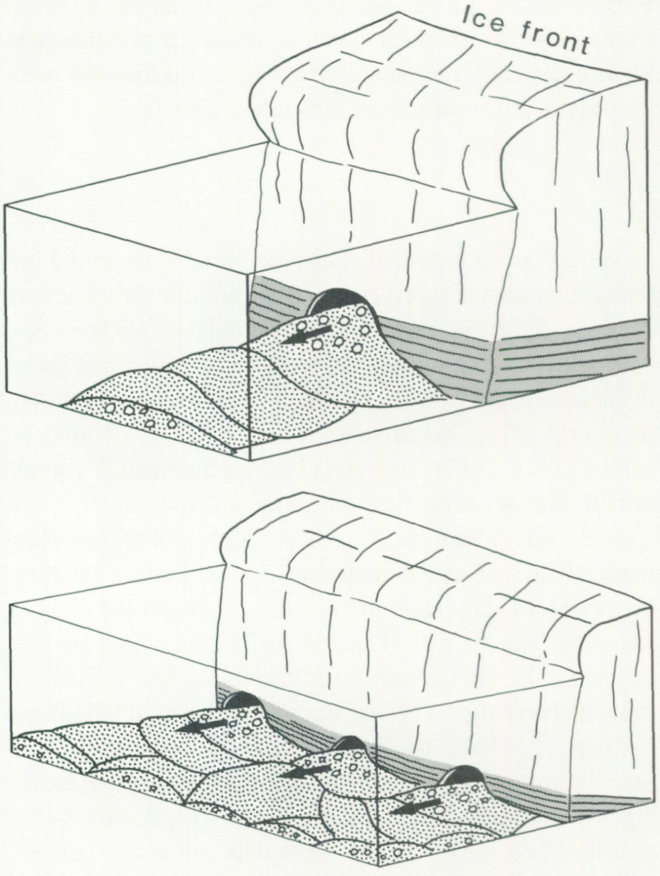

Fig. 3. Annual deposits in subaqueous esker (upper picture) and outwash fan (lower picture). After Rust & Romanelli 1975, Fig. 14. From Ringberg 1991a, Fig. 14.

melted during the glaciofluvial sedimentation and caused minor syngenetic faults. At one locality, a structure which was interpreted to have been formed by a dragging iceberg was observed.

Varved glaciolacustrine clay was found locally in exposures and corings on top of and generally on the sides of the outwash fans ending the uppermost part of the primary deposit (Fig. 2). Littoral sediments, gravel and sand, generally lie discordantly on the glaciolacustrine clay or glaciofluvial sediments. However, at a few localities Åmark (1984, pp. 94–99) found a gradual contact between varved clay and beach deposits (wave ripples). The gradual contact indicates wave action at the bottom of the Baltic Ice Lake on the Kristianstad plain as early as during the sedimentation of the varved clay. The localities are not correlated to the local varve chronology, so it is not possible to tell when the wave action affected the sedimentation.

The littoral sand deposits overlying the glaciolacustrine clay, are thickest on the western sides of the outwash fans and the latter often have asymmetric intersections. The sand was deposited during strong easterly winds. On top of the deposits 1–2 m of beach gravel is common and generally cuts other units discordantly. The littoral sediments were deposited during the general regression after deglaciation.

From the ridge morphology and the exposures it can be deduced that the outwash fans were deposited from 1–3 tunnels in the ice. The position of the outwash fans (see above) indicates that the deposition occurred subglacially. The outwash fans seem to be composed of annual deposits formed at the ice front where the glacial stream discharged from the tunnel into the Baltic Ice Lake (Fig. 3). The fining upwards of the sediments in the fans (Fig. 2) indicates that the deposition occurred at and outside the ice margin. The ridge-like deposits seem to have been formed at and inside the ice margin. Whether the deposition occurred at a straight ice margin or in estuaries (Åmark 1984, p. 101) has not been possible to determine. The ice recession lines of the varve chronology are straight (Pl. 1–2) but may hide smaller estuaries.

Eskers

The eskers (Ringberg 1971, pp. 47–67; 1991a, pp. 50–51; Lagerlund & Björck 1979, pp. 10–34) are situated at all levels between the present sea level and the highest shoreline. The deposits are located in the Archaean bedrock valleys which cut into the landscape in mainly northerly directions north of the Kristianstad plain (Pl. 1–2) and in Blekinge (Pl. 3). Their directions follow the directions of the valleys even when the latter diverge up to 45° from the direction of the last ice movement. In the coast area of Blekinge, which is a disjointed tableland without distinct valleys, the eskers follow the lower parts of the landscape but their directions seem mainly dependent on non-topographical factors.

There is also generally a connection between the width of the valleys and the width of the eskers. The southern parts of the bedrock valleys are widest and it is in these areas that the widest and most rounded eskers occur. In the narrow valleys the eskers form more or less continous and narrow ridges. The eskers are generally 30–300 m wide and usually 5–15 m (but up to 20–35 m) high. The influence of the topography makes it clear that the esker streams flowed at the base of the ice.

The typical esker of the investigation area situated below the highest shoreline has a coarse central part with layers of stony gravel and boulders alternating with layers of gravel and sand. This primary part of the esker ends at the upper portion with glaciolacustrine varved clay, the layers being convexly deposited (Fig. 4). Above the varved clay, littoral sand and gravel occur, deposited during the regression of the Baltic Ice Lake. The varved clay which covered the whole esker was abraded at its upper surface at that time. Locally the clay slid down and was folded along the sides of the esker. At the top of the esker a layer of coarse stony shallow-water gravel or sand was finally formed, lying discordantly on the other layers. Boulders are common on top of the eskers.

The eskers seem to be composed of annual deposits formed at the ice front where the glacial stream discharged from the tunnel into the Baltic Ice Lake. According to available exposures the eskers were deposited from only one tunnel (Fig. 3, upper picture). The annual "beads" or subaqueous fans (De Geer 1940, pp. 45–77; Banerjee & McDonald 1975, Fig. 28) are, in one valley in Blekinge, visible as eight hills in the esker lying 90–110 m from each other. Close to the coast the "beads" are not visible at the ground surface. Owing to abrasion during the regression the eskers in the coast area are broad and flattened while the eskers in the valleys are more narrow and marked as a result of protection against wave action. The narrowness of the valleys limited the fetch required for significant wave action. Björck (1979, pp. 202–206; 1981, pp. 77–79, 82) does not agree with this theory and prefers an explanation related to the 30–40 m altitude above sea level and to a transgression of the Baltic Ice Lake.

An essential condition for the composition of the type of esker below the highest shoreline described above seems to be that the esker formed near the mouth of a subglacial meltwater stream or at least in an area where the ice had lifted from the ground and allowed space for sedimentation of glaciolacustrine clay. These conditions were present in the coastal area and the broad valleys of the investigation area. Such conditions were not present in areas without broad valleys where the surroundings are near the level of the highest shoreline and where the base of the esker is situated more than 30-40 m above the present sea level. Dead ice remained there since it could not be carried away as in the wide valleys. The dead-ice prevented or delayed deposition of glaciolacustrine sediments along the sides of the esker (Lagerlund & Björck 1979, pp. 15–20; Schneider 1979, pp. 25–29) and protected it from abrasion. This type of esker has a sharp-edged ridge morphology down to about 25 m below the highest shoreline and cannot be distinguished from the morphology of the eskers above the highest shoreline.

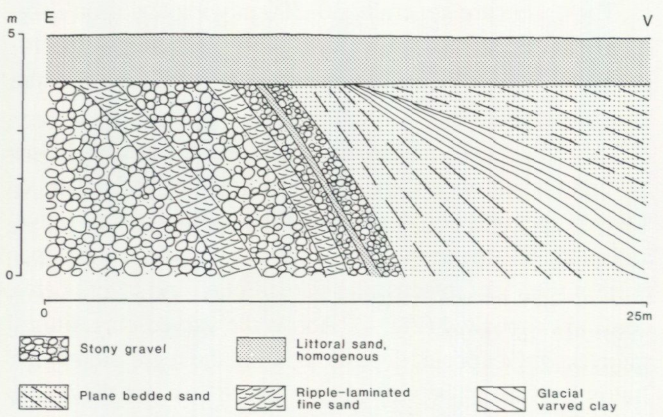

Fig. 4. Exposure in the western part of a subaqueous esker at Råbelöv, 7 km NNE of Kristianstad. From Ringberg 1991a, Fig. 19.

Deltas

Deltas and small sediment plains are found in the entire investigation area at levels between the highest shoreline and 10–40 m below it. The glaciofluvial deltas have been described and discussed in relation to deglaciation and shore displacement by Mörner (1969, 1975a), Hellberg (1971), Ringberg (1971), Rydström & Stjernkvist (1972), Björck & Möller (1976, 1987), Hebrand (1978), Lagerlund & Björck (1979), Björck (1979, 1981) and Åmark (1984).

The deltas close to the level of the highest shoreline were formed both with and without contact with dead ice and may be a result of stagnation in the ice recession at the highest shoreline (Ringberg 1971, p.46). In Blekinge there are few exposures in the uppermost delta plains. The exposures show a coarse topset bed of stony gravelly sand (Ringberg 1971, p. 129; Hebrand 1978, Fig. 20–21). In northeastern Skåne there are exposures in some of the deltas close to the highest shoreline (Hellberg 1971, p.75–77; Åmark 1984, p. 110). The exposures show delta deposits with a composition typical of the classic Gilbertian delta (Gilbert 1890; Fig. 5).

The large delta plains situated 10–15 m below the highest shoreline in Blekinge are composed of topset, foreset and bottomset beds, in the western part of the province, overlying glaciolacustrine varved clay (Hebrand 1978, Fig. 38–39, 55–57; Lagerlund & Björck 1979, pp. 15–32). Lagerlund & Björck have described delta plains with underlying varved clay at different levels down to 40 m below the highest shoreline (see also Björck & Möller 1976). The relation between the delta sediments and the glaciolacustrine varved clay is discussed in the final chapter (p. 18).

Kames and kame terraces

Kames and kame terraces with forms and stratigraphy indicating support of stagnant ice were observed on levels from the highest shoreline down to at least 10–15 below it (Ringberg 1971, p. 51, 62; Lagerlund & Björck 1979, pp. 10–14; Björck 1979, pp. 155–161, 168–169, 185).

GLACIOLACUSTRINE DEPOSITS, VARVES

The fine-grained glaciolacustrine deposits in the investigation area were formed in various environments below the highest shoreline in the Baltic Ice Lake. The description and

Fig. 5. Glaciofluvial delta at Marieholm, 20 km N of Sölvesborg (Pl. 2). Bottomset and foreset beds are visible. The 0.5–1.0 m thick topset bed is difficult to see in the photo.

interpretation of the glaciofluvial deposits show that the formation of the latter was considerably influenced by the nature of the ice dynamic, the changing bedrock morphology and the water-level fluctuations. The deposition of the glaciolacustrine sediments was affected by the same factors but also by the closely related neighbouring glaciofluvial deposits.

Extension and thickness

The varved glaciolacustrine sediments at the ground surface are not usually found higher than 25 m above the present sea level in Blekinge and not higher than 15 m above sea level in northeastern Skåne. Locally, however, the sediments reach up to c. 30 m in northeastern Skåne and 50–55 m in Blekinge.

The glaciolacustrine deposits lie on bedrock, till or glaciofluvial sediments and are overlain by littoral gravel or sand and postglacial fine-grained and organic deposits. Only small areas of surficial fine-grained glaciolacustrine deposits are found in Blekinge (Pl. 3) and the most extensive area where these sediments are observed at the surface is situated in northeastern Skåne around and northwest of Kristianstad (Pl. 1).

Local variations in the thickness of the fine-grained glaciolacustrine sediments are considerable as a result of varying bottom morphology. The thickest sediments are generally situated in the central parts of the valleys and basins and the deposits thin off towards the edges of the basins.

In Blekinge, a maximum of 10–15 m of fine-grained glaciolacustrine sediments in the form of varved clay have been found in the central part of the province whilst on the east coast of the province no thicknesses more than 1.5 m have been observed. The small thickness there may be due to the absence of appropriate basins in the flat landscape. Another reason may be that extremely small amounts of primary glaciofluvial deposits occur because crevasses in the ice available for the meltwater streams were not as easily formed in the flat landscape on the east coast as in other parts of Blekinge where the relief is much higher.

In northeastern Skåne (Pl. 1–2) 10–25 m of fine-grained glaciolacustrine sediments are common in the central part of the basin in the Kristianstad plain. In general the sediments thin off towards the edges of the basin but local variations in thickness are considerable (Ringberg 1971, pp. 72–73; 1991a, pp. 51–52; 1991b, p. 48).

Appearance, composition and genesis

The fine-grained, varved glaciolacustrine sediments along the southern coast of Blekinge (Pl. 3) have a general stratigraphy which is regional and can also be observed in northeastern Skåne (Pl. 1–2). These varve series range between -100 to +315 (415 years) in the 640-year long local chronology (Ringberg 1971, pp.73–77; 1979, pp. 213–214).

In exposures and cores from the investigation area (Fig. 6a) where complete varve series of the fine-grained glaciolacustrine sediments have been studied, it is possible to make a lithofacies dividing of the series into four varve types. The division is made on the basis of relative thickness of silt and clay layers and on the basis of the general appearance of the varves.

From the bottom to the top of the varve series the following four varve types can be distinguished and related to a particular glaciolacustrine environment:

(1) *The bottom or proximal varves.* The thickness of the bottom varves varies between 1 cm and 30 cm. The light summer layers are generally thicker than the winter layers and consist of silt and fine to medium sand. Asymmetric ripples and draped lamination occur in thick summer layers (Schneider 1979, Fig. 15). The winter layers consist of heavy clay (more than 60% clay). Thin layers of diamicton were observed in the summer layers close to the bottom varve at three localities (Ringberg 1971, p. 132, 139; De Geer 1905, unpubl. diagram, see p. 15).

The thickness of the bottom or proximal varves seems to vary considerably depending on the proximity to the glaciofluvial deposits. Thus it is proposed that the thicker summer layers are due to the nearness of the subglacial tunnel mouths where the meltwater streams entered the Baltic Ice Lake. It is also proposed that the suspended sediment content of the inflowing meltwater entered the lake as density underflows or continuous turbidity currents which was the major mechanism of sediment distribution (Gustavson 1975, p. 261).

(2) *The varves above the bottom varves.* Their thickness generally varies between 0.5 and 2.0 cm. The winter layers are generally thicker than the summer layers, which may be very thin. The summer layers consist of medium and fine silt while the winter layers consist of heavy clay.

The thinner varves and summer layers of this varve type seem to be due to a longer transport distance from the subglacial tunnel mouths where the meltwater discharged into the lake as density underflows or continous turbidity currents.

(3) *60–85 varves of a diffuse appearance* (Fig. 7). These varves are dated to +88 – +173 in the local varve chronology. The varves are during a part of, or during the whole time period, thicker than those which were formed just before or just after this period (Ringberg 1971, Fig. 35), generally 1–3 cm. The diffuse appearance of the varves can be explained by the grey laminae of clay observed both below and above the red-brown winter layers of heavy clay. The grey laminae, which have a smaller clay content than the red-brown layers, form the summer layers together with the light silt laminae. Very thin silt laminae occur in the red-brown winter layers of heavy clay. The summer layers are generally thicker than the winter layers.

The thicker diffuse varves break the normal thinning and fining upwards of the varve series into a temporary reverse trend. As there are no indications of a glacial advance in the area, the sudden change and increase in the glaciolacustrine sedimentation is proposed to be due to an increase in the drainage into the Baltic Ice Lake via overland streams. This increase may be caused by a temporarily more rapid melting of stagnant ice in the region. During this period the wide delta plains 10–15 m below the highest shoreline and the varves of diffuse appearance were formed (Björck 1979, p. 227). Possibly the meltwater from the overland streams altered the earlier temperature balance and the earlier steady underflow conditions to a more variable environment in which the diffuse varves were deposited.

(4) *Distal varves in the upper part of the sections.* The thickness of these varves varies between a few millimetres and 1 cm in the varve series observed close to the coast of Blekinge. At a higher level inland from the coast and in the inner part of the Kristianstad plain (Pl. 1–2) the varves are 1–5 cm thick. The summer layers consist of medium and fine silt and are thickest, which results in a light appearance of this varve type (Fig. 6, uppermost part of cores a–b). The thin winter layers consist of heavy clay.

This varve type is proposed to be the result of successively shallower water depths owing to the regression of the Baltic Ice Lake and to meltwater discharged from melting stagnant ice via overland streams (Ringberg 1971, p.77). This varve type includes the uppermost and youngest varves in the investigation area.

With the exception of type 3 (Fig.7) the varves of the different types consist of two distinct layers, the summer and the winter layer. The varves are not graded as units. Thus sharp limits exist between both the winter and summer layers of the varves as well as inside the varves. The summer and winter layers are generally not graded. The

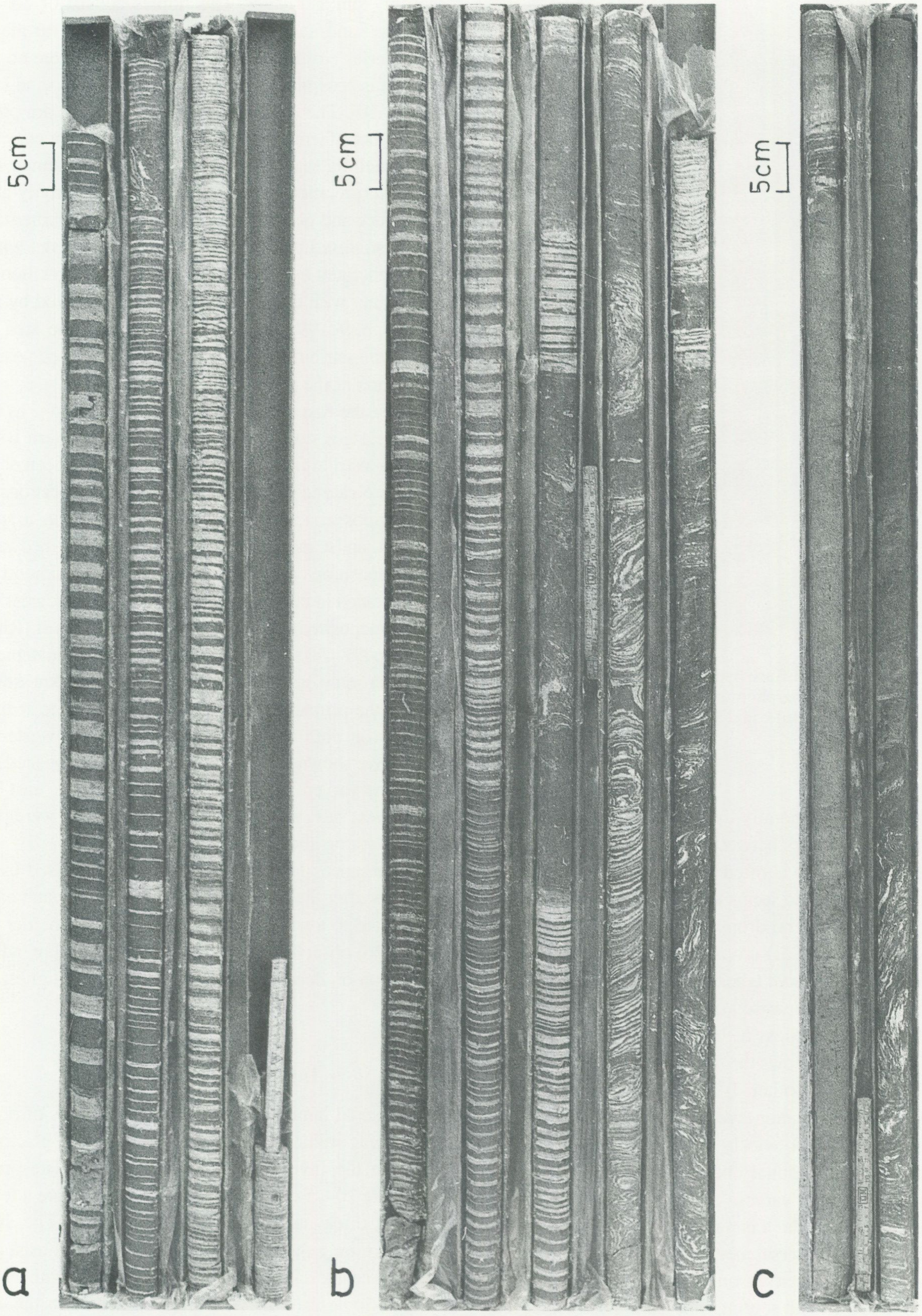

Fig. 6. Three cores from Blekinge. The bottom varves can be seen at bottom extreme left of the cores. – *a*. Core from loc. No. 127 Karlshamn with varved clay and silt. *b*. Core from loc. No.128 Horsaryd near Karlshamn (Pl. 3). Varved clay and silt partly disturbed. *c*. Core from loc. No. 133 Björkelund east of mount Ryssberget. Disturbed and re-deposited clay and silt. From Ringberg 1979, Fig. 2.

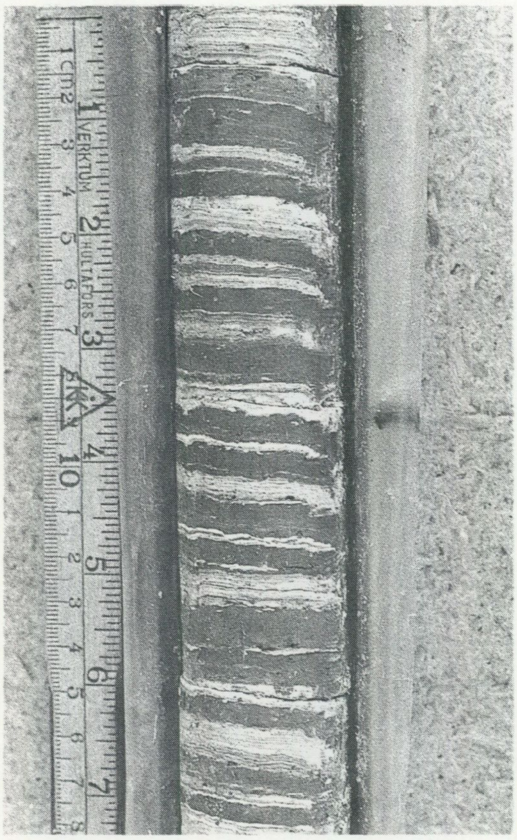

Fig. 7. Varves with a diffuse appearance in the core from loc. No. 127 Karlshamn. The photo shows a detail of the core immediately left of the rule in Fig. 6a. From Ringberg 1979, Fig. 3.

summer layers are generally light grey while the colour of the winter layers varies between red-brown and grey-blue. The red-brown colour is often more frequent in the upper part of the sediment and seems to be caused by oxidation after deposition. In general dropstones are rare but according to Schneider (1979, p. 21) dropstones of crystalline bedrock occur in all the four varve types.

Fig. 8 shows a comparison of individual layer thickness with total varve thickness at locality No. 127 Karlshamn (Pl. 3). The diagram shows the different varve types 1–4 and their relation to each other. It is also possible to see that thicknesses of the summer layers follow the thicknesses of the total varves more obviosly than the winter layers. The latter have a more gradual change in thickness from the proximal to the distal varves. This difference between the two seasonal layers, which is regional, may be explained by more effective silt dispersal mechanisms, particularly underflow, during the summer season. The clay thickness is especially a function of both settling time during the winter season and basin depth (Smith & Ashley, 1985, p. 198).

In northeastern Skåne the varve series which range between -325 and +90 belong to varve types 1 and 2. In varve type 2 asymmetric ripples occur in the uppermost part of the silty summer layer. The ripples consist of coarse silt and fine sand and are common for instance in the whole varve series No. 141 A. Klabbarp (Pl. 1). Where no ripples occur it is possible in many varves to see thin sand laminae (Fig. 9–10). The ripples and the sand laminae are proposed to have been formed by wind-generated bottom currents late in the melting season, possibly during late summer storms. This interpretation is concordant with the heavily abraded till surface and glaciofluvial deposits in the southern part of the Kristianstad plain which was open to waves with long fetch generated by easterly winds. The interpretation is also concordant with the symmetric ripples observed by Åmark (1984, pp. 94–99) on the outwash fans in the area (p. 7). The asymmetric ripples are rare in the described position in other parts of the investigation area.

Along the east and southeast coast of Blekinge as well as on the eastern side of Mt. Ryssberget in western Blekinge glaciolacustrine fine-grained sediments have been observed which are varved only in certain parts of the sections. From the composition, appearance and situation in a strongly abraded landscape, the formation can be ascribed to a primary deposition of glaciolacustrine varved sediments which were abraded in the Baltic Ice Lake during the regression and then re-deposited together with sand and gravel (Ringberg 1971, pp. 77–78). The re-deposition occurred in depressions where, in some cases, it formed secondary thicknesses greater than the primary deposits of glaciolacustrine sediments. Corings on both sides of Mt. Ryssberget in western Blekinge have shown that the disturbed and re-deposited glaciolacustrine varved sediments (Fig. 6c) lie on the east but not on the west side, where the primary sediments were protected from strong abrasion by the lake.

Disturbances in the varved sediments, caused by slides during or after the sedimentation, are common and have not been dated to a particular time (Fig. 6b). Schneider (1979, pp. 25–26) observed faulted glaciolacustrine clay indicating deposition on dead ice remaining below the highest shoreline.

Interseasonal lamination

Interseasonal lamination in the summer layers of proximal varves was studied in the bottomset beds of glaciofluvial deltas in the investigation area (Fig. 11). The proximal varves are 20–75 cm thick. The winter layers are a few millimetres thick and consist of heavy clay. The summer layers, forming the main part of the varves, consist of sublayers of coarse silt and fine sand, alternating with sublayers of silt. Ripple-drift cross-lamination occurs in the coarse-grained sublayers which vary more in thickness than the fine-grained sublayers (Ringberg 1971, pp. 78–84; 1984, pp. 57–62). From observation, the summer layers are not graded as whole units but seem to be multiple graded. The

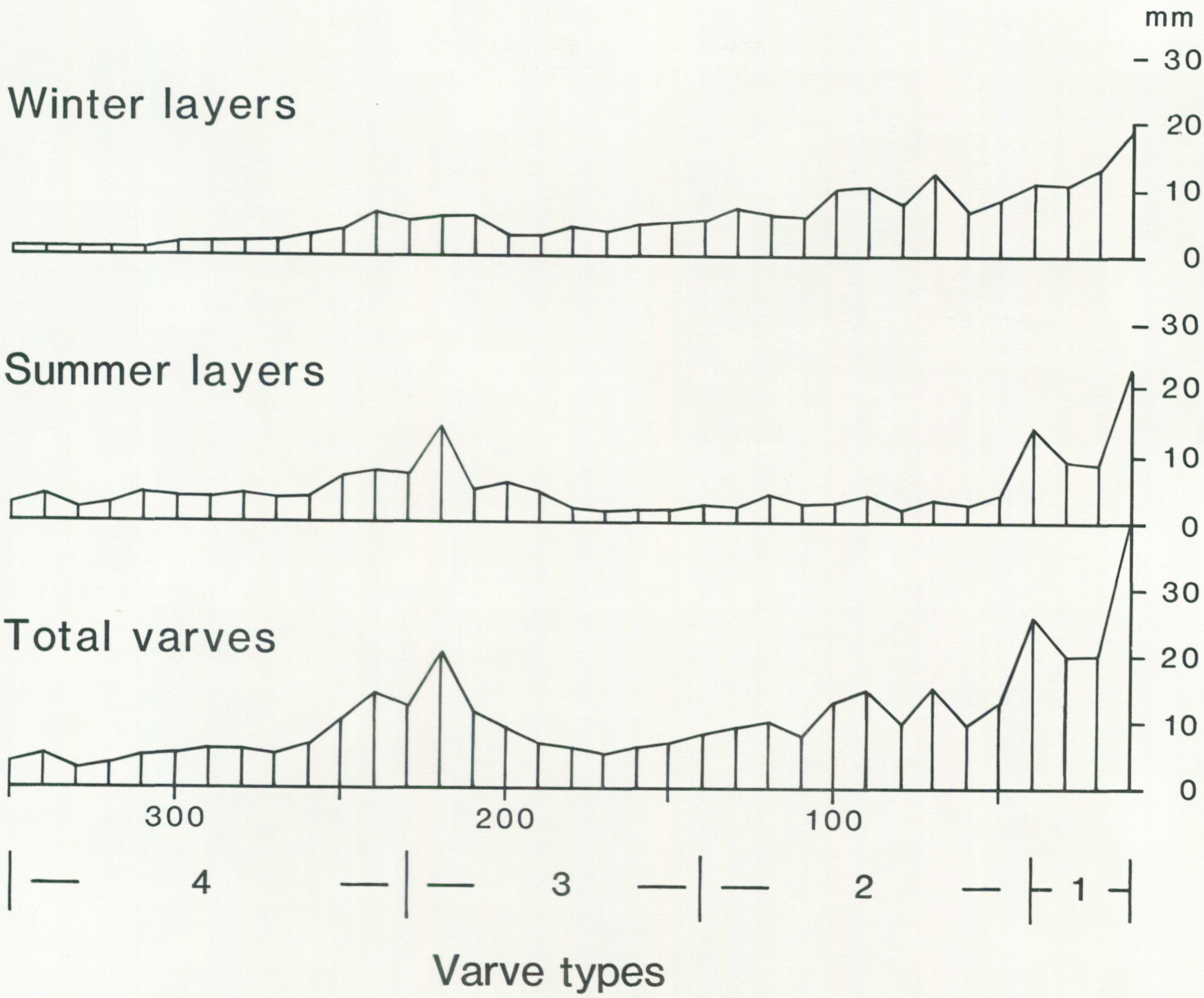

Fig. 8. Comparison of individual layer thickness with total varve thickness at the loc. No. 127 Karlshamn (Pl. 3, Pl. 7). Diagram of 10-year means.

lamination above and below the ripple-drift cross-lamination in Fig. 11 is draped over the underlying bedform and called draped lamination. The relationship of the laminae consisting of sand, silt and clay to the underlying bedforms of ripples suggests deposition from suspension (Gustavson et al. 1975, p. 266).

The observed lamination in the summer layers is believed to correspond to the diurnal rhythm in the transportation of material and its sedimentation in the meltwater streams. The layers of coarse silt and fine sand were deposited during daytime and those of silt were deposited at night. The number of day varves (one day and one night layer) varies between 43 and 56 in the studied varves (Ringberg 1984, p. 60).

The proximal varves in the bottomset beds of the deltas are not dated in the local varve chronology and they cannot therefore be related definitely to one of the described four varve types. There is, however, reason to believe that the proximal varves, studied in the large delta plains formed 10–15 m below the highest shoreline in Blekinge, were formed contemporaneously and proximal to the diffuse varves (varve type 3). The latter varves are proposed to have been deposited mainly by overland streams during melting of stagnant ice in the area (see above). Such an environment, with comparatively small drainage areas of the glacial streams, may explain the pronounced diurnal rhythm of the glaciolacustrine sedimentation registered in the proximal varves in the delta bottomset beds.

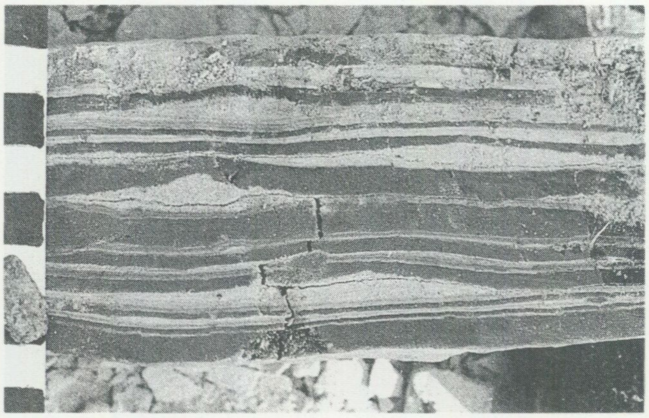

Fig. 9. Assymmetric ripples in the summer layers of varved clay at loc. No. 141 A Klabbarp (Pl. 1), 3 km SW of Kristianstad. Scale in centimetres.

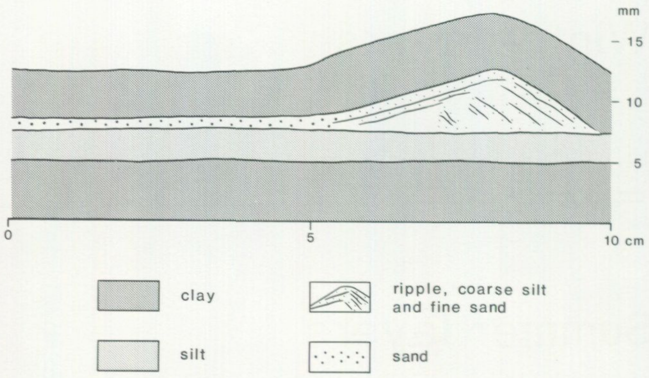

Fig. 10. Assymmetric ripple and sand layer in the uppermost part of the summer layer.

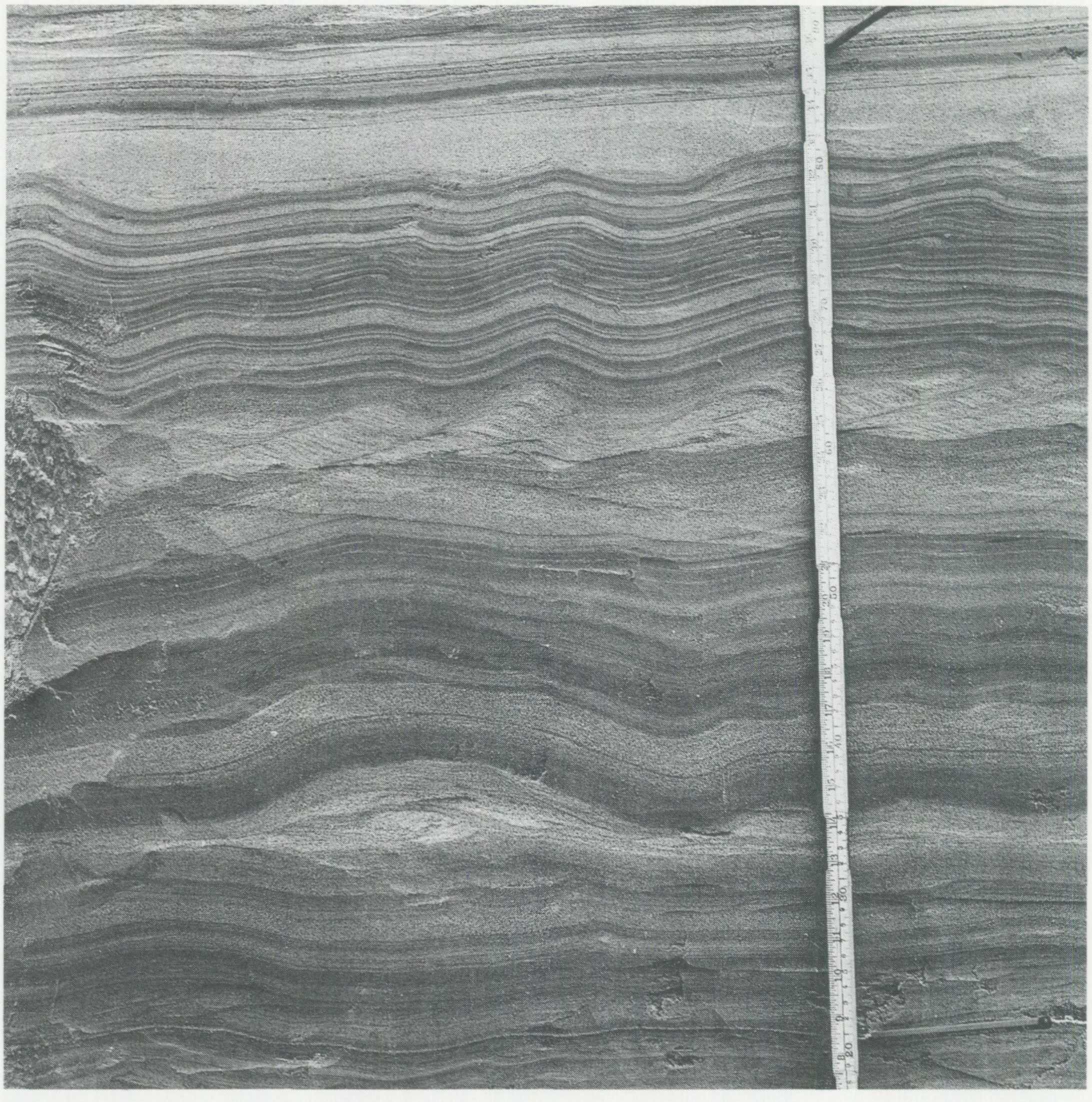

Fig. 11. Interseasonal lamination in summer layer of proximal varve at Östafors, 19 km N of Sölvesborg (Pl. 2). The pens are placed at under- and overlying winter layers of heavy clay, only a few millimetres thick. From Ringberg 1971, Fig. 33.

Clay varve chronology

METHODS AND TIME SCALE

The present investigation is based on observation in a number of localities of which 185 are presented in Pl. 1–3 and Table 1. Forty of these localities, situated in eastern Blekinge, have already been described and the varve diagrams published (Ringberg 1971, Pl. 1–3). In this study the latter localities are numbered 146–185 on the maps and in the table and have been related to the local varve chronology. These forty localities consist of seven cores taken with a metal-foil corer, and 11 profiles from natural exposures, roadcuts, excavations in connection with building etc. The remaining 22 localities were taken from De Geer's unpublished reports of the area. The varved glaciolacustrine sediments in eastern Blekinge were investigated by De Geer and his colleagues between 1905 and 1915 and the varve chronology of the area was, according to these unpublished reports, linked with the Swedish geochronological time scale (Järnefors 1966).

From the localities in western Blekinge and northeastern Skåne, 15 cores were taken with the metal-foil corer in 1969. The glaciolacustrine sediments were also studied in exposures during the current mapping of the Geological Survey of Sweden in the region (Ringberg 1991a and b). Four localities in northeastern Skåne were added to this investigation from the work of E. Nilsson (1968). Most of the localities in western Blekinge and northeastern Skåne, 126 in all, are represented in Antevs' work. Of them, 116 were published, but without the varve diagrams and without information as to how many varves were used from each locality (Antevs 1915). Antevs and colleagues used profiles from natural cuts, roadcuts, excavations for houses, brickyard pits etc. for their work in western Blekinge and northeastern Skåne between 1906 and 1916. The diagrams of the varve series from the localities in western Blekinge and northeastern Skåne are presented in Pl. 4–7. Where the diagrams continue from one plate to another they overlap each other with ten years.

The main part of the present investigation has been to work on the varve series and unpublished diagrams of Antevs, and to correlate the diagrams with each other and with the varve series taken with the metal-foil corer. A preliminary report of this work has been published (Ringberg 1979). The method developed by De Geer (1940) was used in the investigation of the varved glaciolacustrine sediments at the various localities, whereas that described by Järnefors (1963) was used when taking cores with the metal-foil corer. The method developed by De Geer was used in constructing the varve chronology as was his definition of correlation (De Geer 1940).

In my earlier work (Ringberg 1971), the varve series in eastern Blekinge were linked with the revised Swedish geochronological time scale (Nilsson 1968). The revised Swedish geochronological time scale was, however, criticized by, among others, Mörner (1969), Lundqvist (1975) and Berglund (1976). Antevs' (1915) local "floating" chronology was therefore used in my work of 1979 and is also used here since the most recent revision of the Swedish time scale has not yet been completed. As mentioned above, the localities from eastern Blekinge (Ringberg 1971) have been redated in Table 1. The local chronology in this investigation ranges from -325 to +315, or 640 years.

CORRELATIONS IN THE LOCAL CHRONOLOGY

The general classification of the varve series into four varve types has been useful during the correlation work. In general the varve series belonging to varve types 1 and 2 are easy to correlate with each other even over long distances, due to the fact that they have an equal regional thickness variation. Their common genesis (deposition from density underflows discharged from subglacial tunnels in the ice) is the reason for this easily recognizable variation. The annual variation in the varve thicknesses seems to be a result of regional climatic variations which influenced the melting of the ice. Surface melting of the wide area of stagnant ice in the region may have had a direct climatic influence on the sediment deposition.

The varve series belonging to varve types 3 and 4 are difficult to correlate with each other, as is obvious from Pl. 5 and 7. Those parts of the varve series belonging to the latter varve types were therefore excluded in the diagrams from eastern Blekinge and only examined, measured and described (Ringberg 1971, pp. 86–88). The reason for the correlation problems with types 3 and 4 seems to be that their genesis depends on local variations in the amount of suspended material deposited from the overland streams.

Varve series 103, Västanå (Pl. 6b), is not particularly reliably correlated. An alternative correlation could be made by dating the bottom varve -64.

During the correlation work, Antevs' thick varve No. -100 and saw-blade pattern 43–51 varves above No. -100 which he described in 1915, have been of special value. This constellation of varves is easy to recognize in the varve series of the whole investigation area (Pl. 5–7).

The varve No. -100 was proposed by E. Nilsson (1968, p. 28) to be a secondary drainage-varve which was formed at a supposed drainage of the Baltic Ice Lake at Tyringe, 35 km WNW of Kristianstad. Mörner (1969, pp. 118–126) proposed that the varve was formed by a small ingression of saltwater through Öresund into the Baltic Ice Lake. Antevs (1915, pp. 365–366) describes the varve No. -100 as a normal but thick varve with an especially thick winter layer of clay. The present investigation supports Antevs' hypothesis and in this work the discussed varve is regarded as a thick but normal varve belonging to varve type 1 or 2 depending on wether the varve is proximally or distally deposited in front of the ice margin. In varve serie No. 141.A Klabbarp (Pl. 6) the varve No. -100 has a thicker summer than winter layer which indicates a more proximal sedimentation.

Antevs (1915, p. 365) described a colour boundary in the varved glaciolacustrine clay at varve No. -120. The clay below the limit is, according to Antevs, grey–greybrown and above the limit there are red-brown winter layers. This boundary can be seen in varve series No. 139 Kiaby (Pl.6) but the few observed varve series from the relevant time span have not made it possible to use this colour change for correlations.

REGIONAL CORRELATIONS

Some attempts have been made to extend the local varve chronology in the investigation area to areas outside this area. Mörner (1975a and b, 1976) attempted to extend the Fjärås line (The Gothenburg end moraine) from the west coast of Sweden to the Bredåkra delta in Blekinge and tried to establish a correlation mainly on palaeomagnetic grounds. This was criticized by Ringberg (1976).

Stay (1979), Duphorn et al. (1979, Fig. 2), and Duphorn et al. (1981, Fig. 6) made connections between varve series in northeastern Skåne and varve series in the Bornholm basins, situated in the Baltic southeast of Skåne. Stay used the varve diagrams and the colour limit between grey and red clay described by Antevs (1915, see above) to make correlations. The varve diagrams of the varve series at Bornholm and in northeastern Skåne show similarities especially in the lower parts of the the diagrams. The layer with high organic content, described and ^{14}C-dated to more than 39,500 years B.P. by Stay (1979, p. 43), is situated at the colour boundary. Stay ^{14}C-dated also what he assumed to be varve -100, just above the organic layer, and calculated an age of 28,000 B.P. The organic layer has not been found in Skåne but in the Baltic a similar stratigraphy was found in the Hanö bay east of Skåne (Björck et al. 1990, pp. 271–273). Future investigations in the area between Blekinge and Bornholm will show whether the long distance correlations made by Stay are reliable or not.

Ringberg & Rudmark (1985) made an attempt to extend the local varve chronology in Blekinge to the Kalmar area in the province of Småland northeast of Blekinge (Rudmark 1975). The work resulted in two alternative correlations and continued investigations in the area will show which is the most reliable alternative. At present the ice recession chronology in the area can be definitely dated to whithin a margin of 85 years.

An attempt was made to connect the varve serie No. 127 Karlshamn (Pl. 7) directly with varve series from southeastern Småland, north of the Kalmar area (Björck & Möller 1987, Table 6; Björck et al. 1988, pp. 40–41). In cooperation with the present author the year +100 was preliminary connected with the local year 2,800 in Småland (Kristiansson 1986). Future detailed investigations in the area north of Kalmar will show whether the preliminary long distance correlation is reliable or not.

Conclusions about ice recession and changes in the glaciolacustrine environment on the basis of the local clay varve chronology

Several publications during recent years have shown the usefulness of clay varve chronology in dealing with the nature of deglaciation and glaciolacustrine environment. The latest of these publications also gives a short historical review and the present state of the revised Swedish time scale (Strömberg 1989).

Unfortunately it was not possible to extend the local clay varve chronology in the present work to the Swedish time scale. However, the information from the varved glaciolacustrine sediments appear to have been useful in dealing with the deglaciation pattern, the ice recession rates and the changes in the glaciolacustrine environment during the time span studied.

DEGLACIATION PATTERN

The youngest striae directions, the directions of the drumlins and the general regional pattern of the glaciofluvial deposits in northern Skåne and Blekinge show that the last ice moved from an ice culmination over southern Sweden (Ringberg 1988, Fig. 11 F). The position of the culmination may be from the model suggested by Boulton et al. (1985, Fig. 22).

Some factors indicate that no ice activity occurred in eastern Blekinge subsequent to the formation of the youngest glacial striae and the drumlins formed by the last ice movement. It is proposed that the ice in large parts of the area simultaneosly lost contact with the accumulation area and turned into stagnant ice. One of the factors indicating that this happened simultaneously is the direction of the youngest ice movement which is the same over the entire area with no deviations caused by the influence of the topography. A second factor is the absence of end moraines whilst a third is the locally considerably deviating directions of the glaciofluvial deposits from the direction of the youngest ice movements (Ringberg 1971, p. 97). Finally, nowhere in the investigation area is there any indication of ice oscillations during the deposition of the glaciolacustrine varved clay.

Åmark (1984, p. 102) observed indications of an active ice terminus during the recession on the Kristianstad plain in northeastern Skåne (Pl. 1–2). He proposed that some of the glaciofluvial deposits were formed when subglacial meltwater flowed in an up-slope direction. This together with observations of folded, stratified drift, including strata of clay, lead him to suggest an active, receding ice sheet.

During the current, geological mapping in northeastern Skåne attention was paid to other indications supporting Åmarks hypothesis. Off the coast north of Åhus (Pl. 2) there is an area with moraine ridges. The ridges lie in a NW–SE direction (Tunander 1982) which is perpendicular to the direction of the nearest outwash fan on the mainland. These ridges seem to represent late activity of the ice during the recession. Also the shape and depths of the lakes in the northern part of the Kristianstad plain indicate late ice activity (De Geer 1889, p. 57; Ringberg 1991b, p. 59).

However, as in the whole of Blekinge (Pl. 3), there are in northeastern Skåne also several indications of dead ice remaining below the highest shoreline. These indications include observed meltout-till, faults in an outwash fan and forms in the glaciofluvial deposits indicating deposition on dead ice and a wide area where glaciolacustrine sediments are of very limited extent as a result of remaining dead ice. All the observations were made at levels down to 20–40 m below the highest shoreline (Ringberg 1991a, pp. 38–39, 46–47, 60–61).

ICE RECESSION RATES

The localities of connected and unconnected varve series have been marked in Pl. 1–3, together with a selected number of glacial striae, drumlins, glaciofluvial deposits and localities where the highest shoreline in the Baltic Ice Lake has been determined. The equicesses (isolines between localities deglaciated during the same varve year) in the local chronology have been drawn for every 20th year. Especially in areas where only few or no varve series have been found, the equicesses have been based on the directions of the glacial striae and drumlins. The equicesses generally represent ice recession (ice border) lines.

The recession lines have been drawn more or less straight. There are indications of dead ice remaining below the highest shoreline in several areas (see above). The dead ice delayed, or in certain areas, prevented the deposition of glaciolacustrine deposits. Therefore there are reasons to believe that the ice recession lines are not in detail as straight as they have been drawn in Pl. 1–3. With the available number of localities it has not been possible, however, to draw the recession lines in regard to the dead ice areas.

The ice recession lines show that small calving bays existed in the area close to Ronneby at localities No. 150–165 in Pl. 3 (Ringberg 1971, Fig.10 and pp. 93–94). De Geers opinion that a calving bay existed in the Kalmar Sound was confirmed in easternmost Blekinge as regards the western side of this calving bay (De Geer 1912, Pl. I and p. 248).

The existence of calving bays in certain areas may be compared with the amount of ice-dropped material in the glaciolacustrine clay. Ice-dropped crystalline boulders have been observed in eskers and outwash fans but in the glaciolacustrine clay ice-dropped particles of any size are rare. The boulders in the glaciofluvial deposits can, at least in some cases, have fallen directly from the ice edge or tunnel. The reason for the small amount of ice-dropped material in the clay is either that the icebergs carried small amounts of material or that dead ice remained below the highest shoreline and that the calving occurred only in restricted areas.

The ice recession rate calculated from the equicesses is 86 m/year in northeastern Skåne during the years between -300 and -80 (Pl. 1–2). The value corresponds to that calculated by Antevs (1915, p. 361) namely 89 m/year. The ice recession rate between the yaers -300 and -200 is 100 m/year and between the years -200 and -80 it is 75 m/year. The decreasing ice recession rate towards the highest shoreline is proposed to be due to reduced calving intensity of the ice owing to decreasing water depth.

The ice recession rate in Blekinge was calculated close to Ronneby (at localities No. 146–173) where most of the localities are situated (Ringberg 1971, p. 86). The recession rate is 90 m/year between the years -100 and +20. The recession decreases from 100 m/year (years -100 to -20) to 80 m/year (years -20 to +20). The reason for the decreasing recession rate towards the highest shoreline is proposed to be, as in northeastern Skåne, reduced calving intensity of the ice. In the area at and north of Karlskrona (Pl. 3) the localities are too few to allow reliable calculations and the equicess -100 was necessarily drawn with insufficient data.

CHANGES IN THE GLACIOLACUSTRINE ENVIRONMENT

The glaciolacustrine environment of the Baltic Ice Lake in the investigation area changed character during the 640 year long-period which is documented in the record of varves.

During the deposition of varve types 1 and 2 between the years -325 and +90 in the local varve chronology the proximity to the mouths of the subglacial meltwater streams in the ice was important for the genesis of the sediments and the sedimentation rates. Sediment was carried to the Baltic Ice Lake directly from stagnant ice masses as density underflows or more or less continous turbidity currents. Dead ice delayed or prevented deposition in certain areas. The ice recession was slow, 75–100 m/year during the years -300 to +20 with decreasing recession rates towards the highest shoreline owing to the reduced calving intensity of the ice. In this investigation area, it is not possible to calculate the ice recession rate after the year +20 as no younger bottom varves have been found. The ablation of the stagnant ice proceeded mainly through minor calving and melting at the surface. During the deposition of varve types 1 and 2 in the southern part of the Kristianstad plain (Pl. 1–2) asymmetric ripples and sand layers were deposited late in the summer seasons formed by wind-generated bottom currents in a water depth of 30–40 m.

In the year +90 the glaciolacustrine environment suddenly changed. After c. 10 years of deposition the varve changes to varve type 3 and the 60–85 varves with a diffuse appearance. These varves, dated +88 to +173 in the local varve chronology, are proposed here to have been formed during a temporary more rapid melting of stagnant ice and a meltwater drainage mainly via overland streams. During this period the wide delta plains 10 m below the highest shoreline were formed. The diffuse varves, which are easiest to identify close to the glaciofluvial deltas, were, however, earlier proposed by Ringberg (1971, pp. 89–90) to be the result of wave abrasion of the low delta plains 10 m below the highest shoreline. In the same work, Ringberg also calculated the shoreline displacement to be maximum 7 m per 100 years from this assumption.

Mörner opposed Ringberg's earlier idea of the genesis of the diffuse varves and proposed that the wide lower delta plains were formed during an 85-years long climatic deterioration leading also to deposition of the diffuse varves during the Fjärås Stadial. The dating of the diffuse varves was done on palaeomagnetic grounds (Mörner 1975a, pp. 294–297; 1975b, pp. 298–301) which was criticized by Ringberg (1976, pp. 82–84). Björck (1979, pp. 185–193; 1981, pp. 70–73; Björck & Möller 1987, p. 23) also correlates the genesis of the delta plains 10 m below the highest shoreline with the 60–85 varves of diffuse appearance.

The above hypothesis that the diffuse varves were formed during a period of rapid melting (compare Björck & Möller 1987, p .23) affects the assumptions for the calculations of the shoreline displacement. An additional forty years must be added into the calculations (Ringberg 1971, pp. 89–90, p. 136) which gives a shoreline displacement of c. 5–6 m per 100 years during the beginning of deglaciation.

After the formation of the varves of diffuse appearance the distal varves in the upper parts of the sections, varve type 4, were deposited between the years +175 and +315. This varve type was deposited at successively shallower water depths owing to the regression of the Baltic Ice Lake and from meltwater discharged from melting stagnant ice via overland streams. When the varves ceased to form between the years +290 and +315 (localities No. 73 and 127) the last dead ice had disappeared away from the drainage area.

The glaciolacustrine varved clays in Blekinge were, according to Björcks investigations and calculations, formed c. 12,900–12,050 radiocarbon years B.P. which correspond to the Bölling and the Older Dryas chronozones. The varved clay ceased to form when the shoreline had regressed to more than 15 m below the highest shoreline (Björck & Möller 1987, Fig. 16–18)

ACKNOWLEDGEMENTS

Some field work and the drawing of the maps and graphs has been financially supported by the Swedish National Science Research Council. Most of the field work and the printing has been financed by the Geological Survey of Sweden. My colleagues at the head office in Uppsala and at the branch office in Lund have provided all possible support during the work. The manuscript was read and commented by Bo Strömberg at the Department of Physical Geography in Stockholm, Svante Björck at the Department of Quaternary Geology in Lund and by Esko Daniel at the Geological Survey in Lund. Drawing of the graphs was done by Siri Bergström and the maps and some of the graphs by Christine Andréasson at the Geological Survey in Lund. The English text was corrected by Merk Produktinformation. The table was typed by Eva Janselius at the Geological Survey in Lund. To all those mentioned and to everybody who has assisted my work I wish to extend my sincere thanks.

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TABLE 1

VARVE SERIES

Datings according to Antevs (1915) local chronology (- and + before dating year means: - = neg. year; + = pos. year)

+ after dating year means proximal varves are missing
Graphs in this work numbered Pl. 4-7. Graphs I-III from Ringberg 1971.
Unpubl. series from: AL. = Alsén, D.G. = G. De Geer, E.A. = E. Antevs, H. = Hamberg, H.J. = H. Johansson, N.N. = N. Nilsson, E.N. = E. Nilsson 1968. No signature means investigated by Ringberg.
Co-ordinates in the national Swedish grid

	Site	Inv. by	Plate Map	Plate Graph	Year	Location	Co-ordinates	
1.	Vidtsköfle tegelbruk	H.J.	1	-	-	1.9 km SSW Vittskövle slott	61913	13948
2.	Borrestad märgelgrop	H.J.	1	-	-	900 m ENE Borrestad	61941	13907
3.	Skogsma	H.J.	1	-	-	300 m NE Skogsma gård	61957	13887
4.	Sönnarslöf S lertag	E.A.	1	-	-	900 E Ö. Sönnarslöv k:a	61966	13890
5.	Sönnarslöf S lertag	H.J.	1	-	-	900 m E Ö. Sönnarslöv k:a	61966	13890
6.	Sönnarslöf N lertag	H.J.	1	-	-	650 m ENE Sönnarslövsg.	61975	13889
7.	Sönnarslöf g. lertag	H.J.	1	-	-	800 m WNW Sönnarslöfsg.	61976	13876
8.	Köpinge tegelbruk	H.J.	1	4a	-325+	550 m ESE Köpinge k:a	62021	13976
9.	Ugerup tegelbruk	E.A.	1	-	-	300 m ESE Ugerups säteri	62034	13952
10.	Hofby S	H.J.	1	-	-	500 m E Hovbygård	62044	13991
11.	Hofby E	H.J.	1	4a	-300+	600 m SE Björkhäll	62049	13996
12.	Hofby W	H.J.	1	-	-	300 m SE Björkhäll	62052	13994
13.	Hofby N	H.J.	1	-	-	1.5 km E Trädgårdslund	62066	13983
14.	Åsum	H.J.	1	4a-c	-221+	1.3 km SE N. Åsum k:a	62071	13977
15.	Åsum grustag	E.A.	1	-	-	500 m N N.Åsum k:a	62085	13967
16.	Åsumtorp lertag	E.A.	1	4a-b	-228+	300 m SW Majbacken	62093	13960
17.	Herkules tegelbruk	E.A.	2	4a-c	-256+	800 m SE Gustav Adolf k:a	62096	14034
18.	Kvarnäs tegelbruk	E.A.	2	4a-b	-233+	400 m SE Kvarnäs	62099	14013
19.	Håslöf	H.J.	2	-	-	300 m NNW Kvarnäs	62105	14010
20.	Hammar	H.J.	1	4a	-279	1.3 km SSW Hammarshus	62107	13994
21.	Hattabacken	H.J.	1	-	-	1.2 km S Kristianstad k:a	62115	13970
22.	Kristianstad	H.J.	1	4a-b	-256	850 m SE Kristianstad k:a	62122	13976
23.	Cellfängelset, K-stad	H.J.	1	-	-	600 m E Kristianstad k:a	62128	13975
24.	Öllsjö	E.A.	1	-	-	300 m SW Åkersholm	62116	13927
25.	Lillö	H.J.	1	-	-	250 m SW Lillö Kungsgård	62128	13946
26.	Isgrannatorp	E.A.	1	-	-	1.4 km WNW Lillö Kungsgård	62132	13935
27.	Nosaby lertag	E.A.	1	5a	-225	600 m WSW Nosaby k:a	62146	13991
28.	Näsby	H.J.	1	5a	-215	300 m SW Näsbygård	62150	13958
29.	Vinnö	E.A.	1	-	-	600 m WSW Araslöv	62155	13933
30.	Näsby	H.J.	1	5a	-225	500 m NNE Näsbygård	62157	13962

Site		Inv. by	Plate Map	Graph	Year	Location	Co-ordinates	
31.	Rödaled märgeltag	E.A.	1	-	-	600 m SE Fårarp	62159	13990
32.	Vrangelsdal	E.A.	1	-	-	450 m S Wrangelsdal	62159	13917
33.	Araslöf	E.A.	1	-	-	700 m NNW Araslöf	62163	13937
34.	Listernäs	H.J.	1	-	-	1.9 km WNW Tvedegård	62165	13954
35.	Karl-Anders	H.J.	1	-	-	1.1 km WSW Fredriksdal	62170	13960
36.	Fredriksdal	H.J.	1	-	-	350 m NW Fredriksdal	62177	13969
37.	Åby	E.A.	1	-	-	200 m SE Ängagården	62174	13940
38.	Önnestad prästgård	E.A.	1	5a	-202	1.0 km NE Önnestad k:a	62166	13898
39.	Lovisero	E.A	1	-	-	200 m SW Nydala	62171	13895
40.	Önnestad lertag	E.A.	1	-	-	500 m WNW Nydala	62173	13892
41.	Rålambsdal	E.A.	1	-	-	1.0 km SW Rålambsdal	62182	13891
42.	Roalöf	E.A.	1	-	-	500 m ESE Ulriksdal	62186	13918
43.	Hamiltonhill	E.A.	1	-	-	200 m SW Hamiltonhill	62191	13947
44.	Fredriksdal	H.J.	1	-	-	1.0 km NNW Fredriksdal	62182	13966
45.	Torseke	H.J.	1	5a	-186	450 m NW Gårrya	62192	13964
46.	Ebbetorp	H.J.	1	5a-b	-182	1.0 km ENE Hamiltonhill	62195	13957
47.	Sofiedal	E.A.	1	-	-	750 m NNW Hamiltonhill	62198	13944
48.	Skoglösa	E.A.	1	5a	-180	500 m SW Dockarp	62189	13881
49.	Brogården	E.A.	1	5a-b	-173	50 m NE Brogården	62198	13889
50.	Strö gamla lertag	E.A.	1	-	-	1.4 km WSW N. Strö k:a	62209	13885
51.	Strö lertag	E.A.	1	5a-b	-169	650 m S N. Strö k:a	62209	13896
52.	Roalöf	E.A.	1	-	-	1.0 km WSW Adinal	62199	13908
53.	Adinal	E.A.	1	-	-	700 m NW Adinal	62205	13914
54.	Adinal	E.A.	1	5a	-176	300 m NE Adinal	62203	13920
55.	Torsebro	H.J.	1	-	-	500 m S Torsebro Bruk	62208	13955
56.	Stubbarp	H.J.	1	-	-	At Stubbarp	62219	13953
57.	Hesslekärr	H.J.	1	-	-	1.0 km SW Hässlekärr	62222	13972
58.	Ballingstorp	H.J.	1	5b	-106	300 m WSW Ballingstorp	62234	13956
59.	Öfvarp	E.A.	1	-	-	1.5 km W Mossadal	62236	13893
60.	Hörröd	E.A.	1	5a-b	-123	500 m NE Hörröd	62248	13897
61.	Källeshuset	E.A.	1	5b	-108	450 m ESE Källehuset	62262	13909
62.	Nydala	E.A.	1	5b-c	-99	800 m SSW Kviinge k:a	62268	13925
63.	Krabbegården	E.A.	1	-	-	1.1 km S Kviinge k:a	62263	13931
64.	Krabbegården	E.A.	1	5b-c	-94	1.1 km SSE Kviinge k:a	62265	13935
65.	Hanaskog tegelbruk	E.A.	1	-	-	700 m ESE Hanaskog gård	62257	13954
66.	Hanaskog tegelbruk	D.G.	1	-	-	750 m SE Hanaskog gård	62256	13955
67.	Hanaskog kanal	E.A.	1	5b-c	-79	1.3 km NE Hanaskog gård	62269	13959
68.	Hanaskog badhus	E.A.	1	-	-	1.0 km NNE Hanaskog gård	62270	13954
69.	Truedstorp	D.G.	1	-	-	450 m W Truedstorp	62272	13941
70.	Kviinge	N.N.	1	5b-c	-89	350 m E Kviinge k:a	62274	13933
71.	Västerslöf	E.A.	1	-	-	At Västerslöv	62278	13922
72.	Ålsåkra	E.A.	1	-	-	700 m NNW Ålsåkra	62275	13909
73.	Spånga lertag	E.A.	1	5b-d	-79	850 m ENE Spånga	62289	13912
74.	Almö	D.G.	1	-	-	200 m NNW Almö	62288	13939

Site	Inv. by	Plate Map	Graph	Year	Location	Co-ordinates	
75. Knislinge tegelbruk	E.A.	1	5b-c	-64	250 m S Tegeborg	62298	13932
76. Knislinge tegelbruk	D.G.	1	-	-	250 m SW Tegeborg	62299	13931
77. Knislinge	D.G.	1	-	-	1.2 km SE Knislinge k:a	62298	13941
78. Hjärsås Lilla	E.A.	1	-	-	1.1 km ENE Knislinge k:a	62309	13942
79. Hjärsås lertag	E.A.	1	-	-	450 m S Hjärsås k:a	62318	13974
80. Balsby	E.A.	2	-	-	1.2 km SW Niklasberg	62173	14008
81. Hästa S lertag	E.A.	2	-	-	250 m NW Sturedal	62180	14035
82. Hästa N lertag	E.A.	2	-	-	50 m S Nybodal	62192	14032
83. Österslöf märgeltag	E.A.	2	6a-b	-179	750 m SW Österslöv k:a	62196	14027
84. Tommarp	E.A.	2	6a	-153	750 m SSE Tommarp	62219	14022
85. Sjödala lertag	E.A.	2	6a-b	-157	800 m ESE Helmershus	62222	14032
86. Ekestad	E.A.	2	-	-	800 m NE Helmershus	62231	14030
87. Kjelkestad	E.A.	2	6a-b	-136	1.1 km W Knutstorp	62237	14031
88. Gårrö lertag	E.A.	2	6a-b	-98	500 m NE Gårrö gård	62258	14041
89. Spegelvik	E.A.	2	-	-	1.1 km NE Gårrö gård	62261	14046
90. Allarp	E.A.	2	-	-	1.1 k NNE Gårrö gård	62265	14041
91. Mannestad	E.A.	2	6a-b	-99	850 m E Smedstorp	62277	14054
92. Arkelstorp	E.A.	2	6b	-87	1.3 km NE Smedstorp	62285	14055
93. Gualöf tegelbruk	E.A.	2	-	-	250 m N Gualöv k:a	62145	14130
94. Kjuge	E.A.	2	6a	-204	1.0 km NE Kiaby k:a	62168	14093
95. Bäckaskog	E.A.	2	-	-	500 m NNE Bäckaskog slott	62188	14095
96. Bäckaskog	E.A.	2	6a	-189	900 m NNE Bäckaskog slott	62191	14097
97. Plageboda	E.A.	2	-	-	950 m SW Odratorp	62199	14102
98. Hofgården	E.A.	2	-	-	200 m N Hovgården	62199	14140
99. Homna Udd lertag	E.A.	2	-	-	150 m SSW Sjödala	62209	14117
100. Kapellet	E.A.	2	-	-	1.1 km ESE Kapellet	62227	14110
101. Klagstorp tegelbruk	E.A.	2	7a	-118	300 m S Fridhem	62249	14158
102. Västanå sandtag	E.A.	2	-	-	500 m NNE Klagstorp	62271	14164
103. Västanå	E.A.	2	6b	-81	1.6 km WNW Näsum k:a	62281	14171
104. Grödby	E.A.	2	-	-	1.6 km ESE Grödby	62173	14214
105. Håkanryd tegelbruk	E.A.	2	-	-	1.1 km SE Håkanryd	62183	14217
106. Leingaryd	E.A.	2	7a	-125	400 m SSE Leingaryd	62235	14210
107. Axeltorp	E.A.	2	-	-	800 m NW Leingaryd	62245	14204
108. Axeltorp	E.A.	2	7a	-111	1.5 km NNE Pigehuset	62250	14202
109 Näsum tegelbruk	E.A.	2	-	-	1.0 km SSE Näsum k:a	62263	14191
110. Ryedal lertag	E.A.	3	-	-	700 m WNW Möllebjörke	62241	14273
111. Pukavik	E.A.	3	7a	-69	1.4 km ENE Halleborg	62260	14290
112. Björkenäs	E.A.	3	7a-b	-47	750 m W Stensnäs	62273	14308
113. Stensnäs	E.A.	3	-	-	400 m N Stensnäs	62278	14318
114. Svenstorp	E.A.	3	-	-	1.0 km NE Svenstorp	62286	14329
115. Galleryda lertag	E.A.	3	7a-b	-35+	150 m NW Perstorp	62292	14332
116. Gillabro lertag	E.A.	3	7a-b	-21	2.0 km ENE Mörrum k:a	62309	14362
117. Stilleryd	E.A.	3	7a-b	-59	250 m N Stilleryds skola	62278	14388
118. Sternö	E.A.	3	7a	-80	350 m ENE Solhem	62258	14402

Site	Inv. by	Plate Map	Graph	Year	Location	Co-ordinates	
119. Munkahus	E.A.	3	7a	-72	300 m NE Munkahus	62264	14403
120. Drösebro	E.A.	3	7a	-67	900 m E Stilleryd gård	62268	14401
121. Asarum tegelbruk	E.A.	3	-	-	500 m WSW Strömma	62299	14403
122. Gustafsborg	E.A.	3	7a-b	-48	500 m WNW Karlshamn stn	62282	14413
123. Häggarp	E.A.	3	7a-b	-41	400 m NE Häggarp	62310	14447
124. Trensum	E.A.	3	7a	-48	1.1 km SSW Hällaryd k:a	62302	14466
125. Siggarp	E.A.	3	-	-	500 m NW Siggarp	62290	14472
126. Skyekärr	E.A.	3	7a-b	-60	800 m SSW Skyekärr	62290	14476
127. Karlshamn		3	7a-d	-41	250 m SW Stampen	62294	14405
128. Horsaryd		3	7a-d	-49	450 m SW Horsaryd hpl	62283	14381
129. Perstorp		3	7b-d	+60+	300 m S Perstorp	62289	14333
130. Agerum		3	7a-b	-74	250 m WSW Halleborg	62253	14274
131. Sandbäck		3	7a-b	-53	350 m NW Sandbäck stn	62273	14271
132. Hultagård		3	-	-	600 m NE Hultagård	62173	14265
133. Björkelund		3	-	-	1.1 km W Björkelund	62163	14274
134. Leingaryd		2	7a-b	-126	400 m S Leingaryd	62235	14208
135. Axeltorp		2	-	-	700 m SE Garnanäs	62251	14207
136. Valhem		2	-	-	750 m SSE Valhem	62263	14192
137. Klagstorp		2	6a-b	-99	600 m NE Klagstorp	62270	14167
138. Vånga		2	6a-c	-104	1.6 km SE Vånga k:a	62280	14124
139. Kiaby		2	6a-c	-210	950 m ENE Kiaby k:a	62166	14092
140. Herkules tegelbruk		2	-	-	350 m SW Rosendal	62090	14035
141AKlabbarp		1	6a-c	-138+	600 m W Klabbarp	62102	13945
141BHärlöv		1	5b-d	-86+	1.2 km SSE Vallunden	62115	13957
142. Hanaskog tegelbruk	E.N.	-	5b-d	-77	Not exactly localized		
143. Rinkaby	E.N.	2	4a-c	-303	800 m NW Rinkaby k:a	62078	14035
144. Lillön	E.N.	-	4a-c	-258	Not exactly localized		
145. Flötö	E.N	2	4a	-321+	1.2 km ESE Svaneholm	62040	14015
146. Vieryd 1	D.G.	3	I	-103	1.5 km SSV Krokskvarn	62270	14592
147. Hjälmseryd 2	D.G.	3	I	-80	200 m E Hjälmseryd	62289	14607
148. Saxemara 3	D.G.	3	I	-73	400 m NW Svedala	62297	14633
149. R. Fornanäs 4		3	I	-102	150 m SE Fornanäs Skjutb.	62287	14685
150. R. Lindkullen 5	D.G.	3	I	-97+	300 m ESE Droppemåla	62278	14677
151. R. Angelskog 6	D.G.	3	I	-100	350 m N Angelskog	62286	14693
152. R. Busstorp 7	D.G.	3	I	-82+	300 m NW Busstorp	62292	14667
153. R. Silverberget 8	D.G.	3	I	-90+	400 m SW Ronneby Brunn	62295	14677
154. R.Folkets hus 9		3	I	-86	1.2 km SSE Ronneby k:a	62306	14678
155. R. Persborg 10	D.G.	3	II	-85	200 m W Persborg	62306	14668
156. R. Fridhem 11	D.G.	3	II	-74	450 m N Ronneby Brunn	62303	14680
157. R. Hulta 12	E.A.	3	II	-66	750 m NNE Ronneby brunn	62305	14681
158. R. Långkärra 13	E.A.	3	II	-79	1.2 km E Långkärra	62289	14664
159. R. Snäckebacken 14	D.G.	3	II	-73	600 m SW Ronneby k:a	62312	14670
160. Torneryd 15	E.A.	3	II	-79	At Torneryd	62300	14652

Site	Inv. by	Plate Map	Graph	Year	Location	Co-ordinates	
161. R. Herstorp I 16	H.	3	II	-65	900 m NW Ronneby k:a	62322	14666
162. R. Silverforsen 17		3	II	-63	1.0 km NNW Ronneby k:a	62325	14668
163. R. Herstorp II 18	H.	3	II	-52	1.7 km NW Ronneby k:a	62330	14662
164. R. Herstorp III 19	H.	3	II	-48	2.3 km NNW Ronneby k:a	62336	14661
165. Kjettorp I 20	E.A.	3	II	-37	100 m SW Kättorp	62347	14641
166. Trofta 21	E.A.	3	II	-22	300 m ESE Trofta	62354	14619
167. R. Sörby 22		3	III	-49	2.0 km NNW Ronneby k:a	62333	14662
168. Kallinge Järnv. 23		3	III	-31	600 m W Kallinge k:a	62350	14675
169. Skarup 24		3	III	+46+	1.2 km NNW Bredåkra k:a	62373	14649
170. R. Lugnet 25		3	III	+82+	1.2 km NW Ronneby k:a	62324	14664
171. Härsjölund 26	E.A.	3	III	-11	250 m NE Röetorp	62364	14614
172. Tubbarp I 27	E.A.	3	III	-11	1.7 km ENE Röetorp	62365	14628
173. Möllenäs 28	E.A.	3	III	+26	At Möllenäs	62394	14631
174. Jämsunda 29		3	III	-19	600 m ESE Jämsunda	62391	14786
175. Tving 30		3	III	+26	900 m SSE Tving k:a	62415	14793
176. V Rödeby 31		3	III	-37+	1.2 km SW Rödeby k:a	62363	14878
177. Johanneberg 32	AL.	3	III	-47	1.2 km SW Rödeby k:a	62363	14878
178. Rosenholm 33		3	III	-74	1.0 km SSW Rosenholm	62315	14874
179. Lyckeby 34		3	III	-85	700 m NE Slottsängen	62301	14909
180. Björkelycke 35		3	III	-91	450 ENE Törneryd	62426	15131
181. Högaryd 36		3	III	-91	200 m S Högaryd	62428	15132
182. Senoren 37		3	-	-	700 m SW Östernäs skola	62215	14966
183. Eriksholm 38		3	-	-	500 m WNW Eriksholm	62379	15128
184. Annedal 39		3	-	-	300 m WNW Annedal	62412	15126
185. Kabbetorp 40		3	-	-	400 m W Grönadal	62467	15147

Plate 1

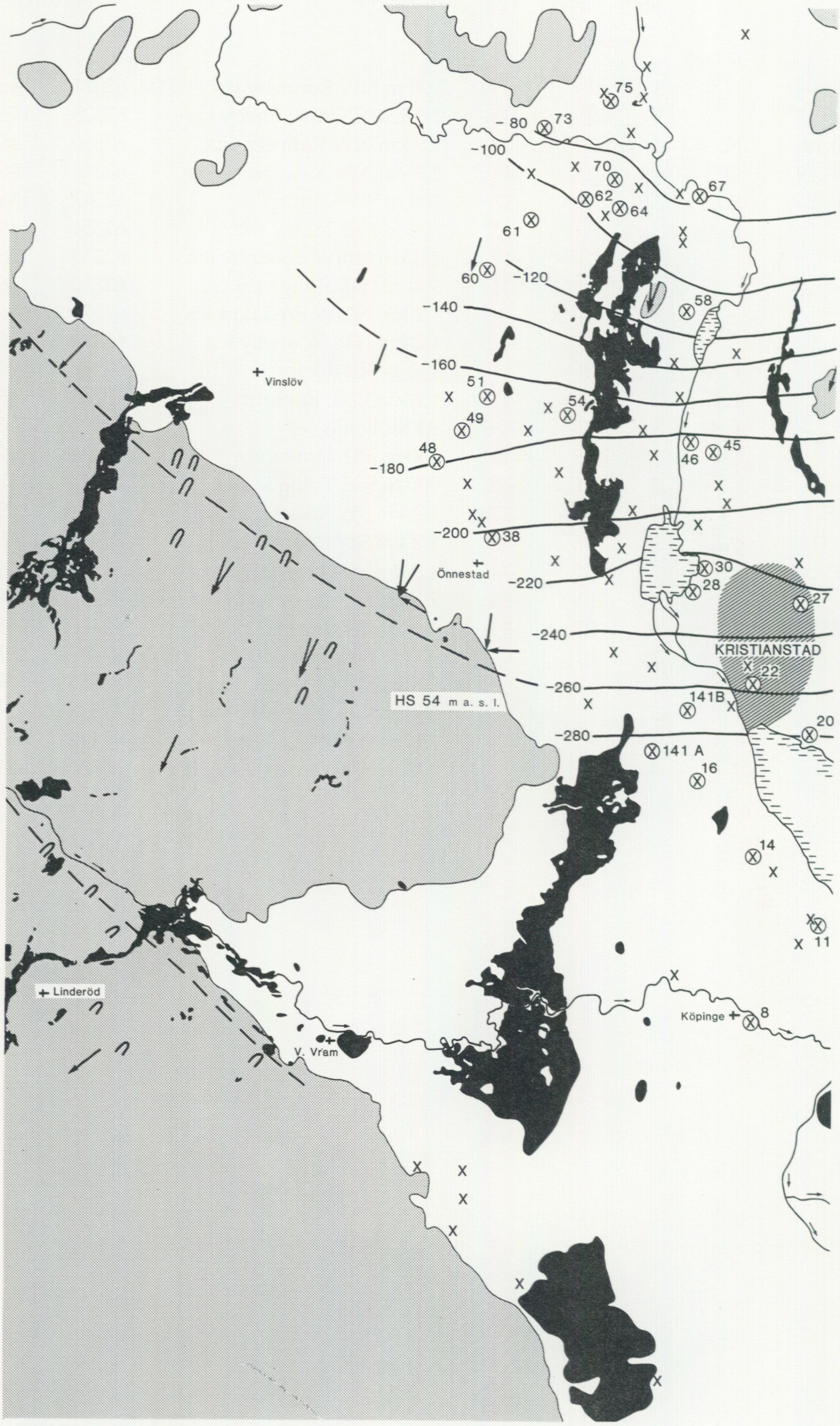
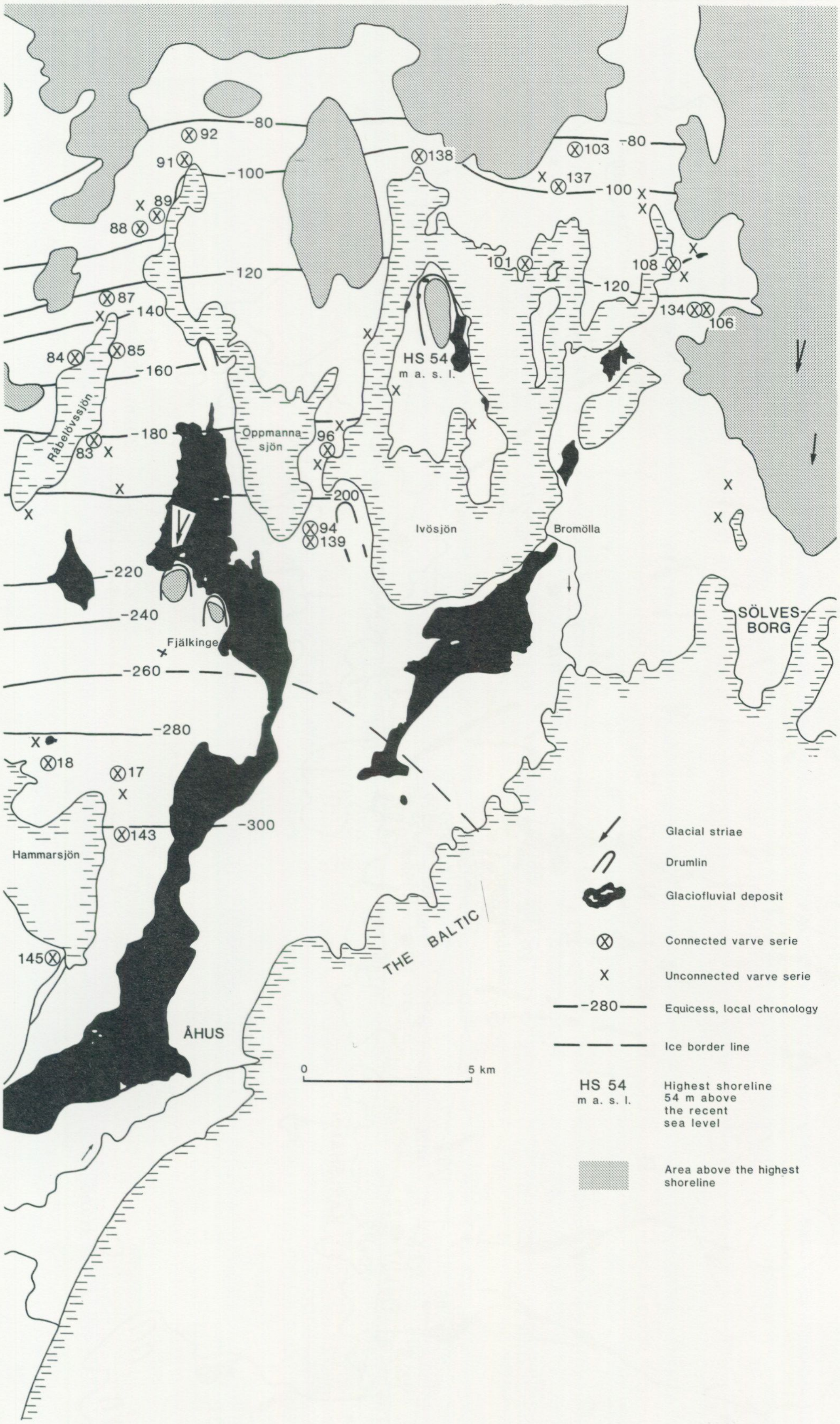
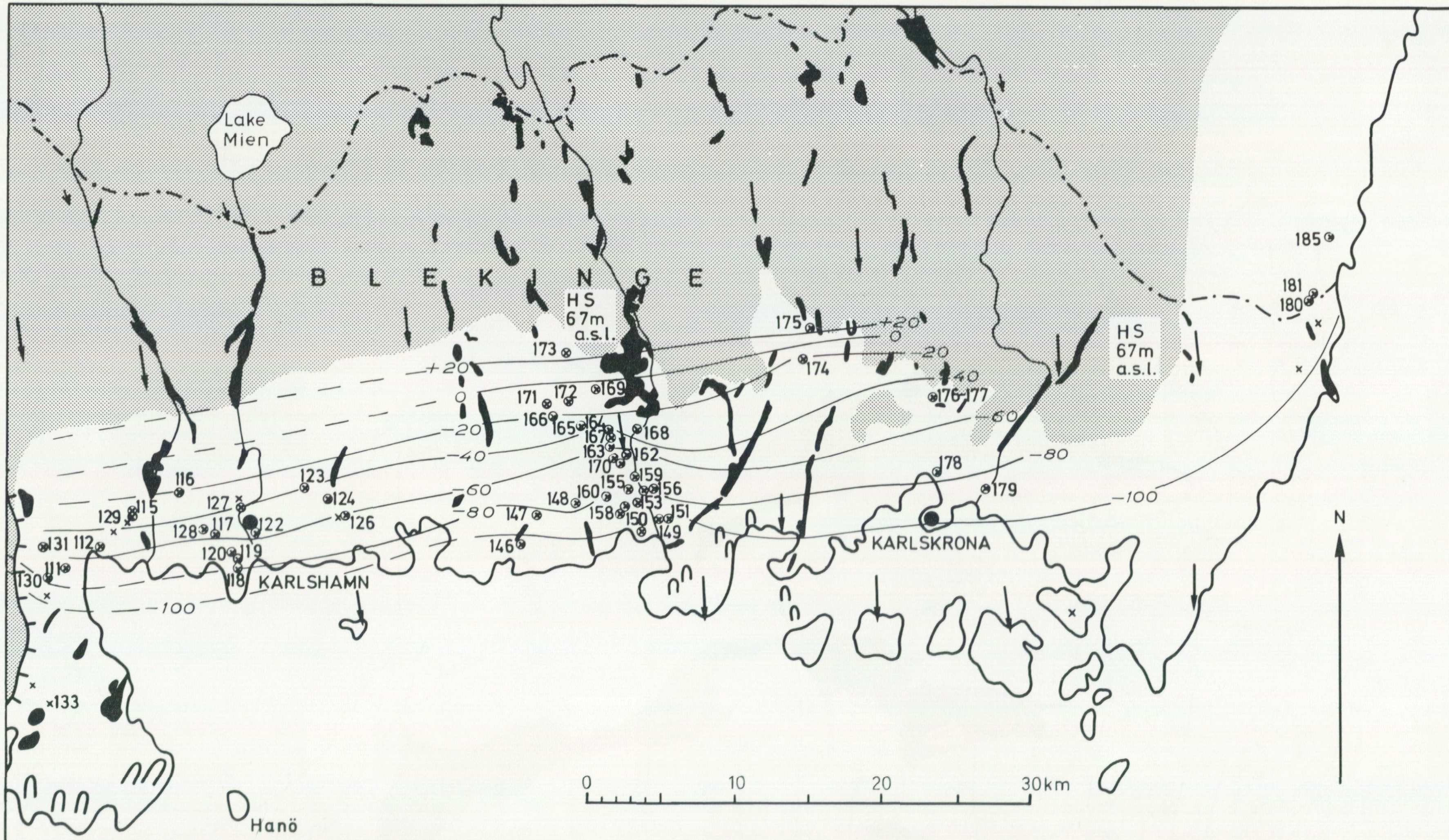

Vinslöv
Önnestad
KRISTIANSTAD
HS 54 m a. s. l.
Linderöd
V. Vram
Köpinge
- 80
-100
-120
-140
-160
-180
-200
-220
-240
-260
-280
75
73
70
67
62
64
61
60
58
51
54
49
48
46
45
38
30
28
27
22
141B
141 A
20
16
14
11
8

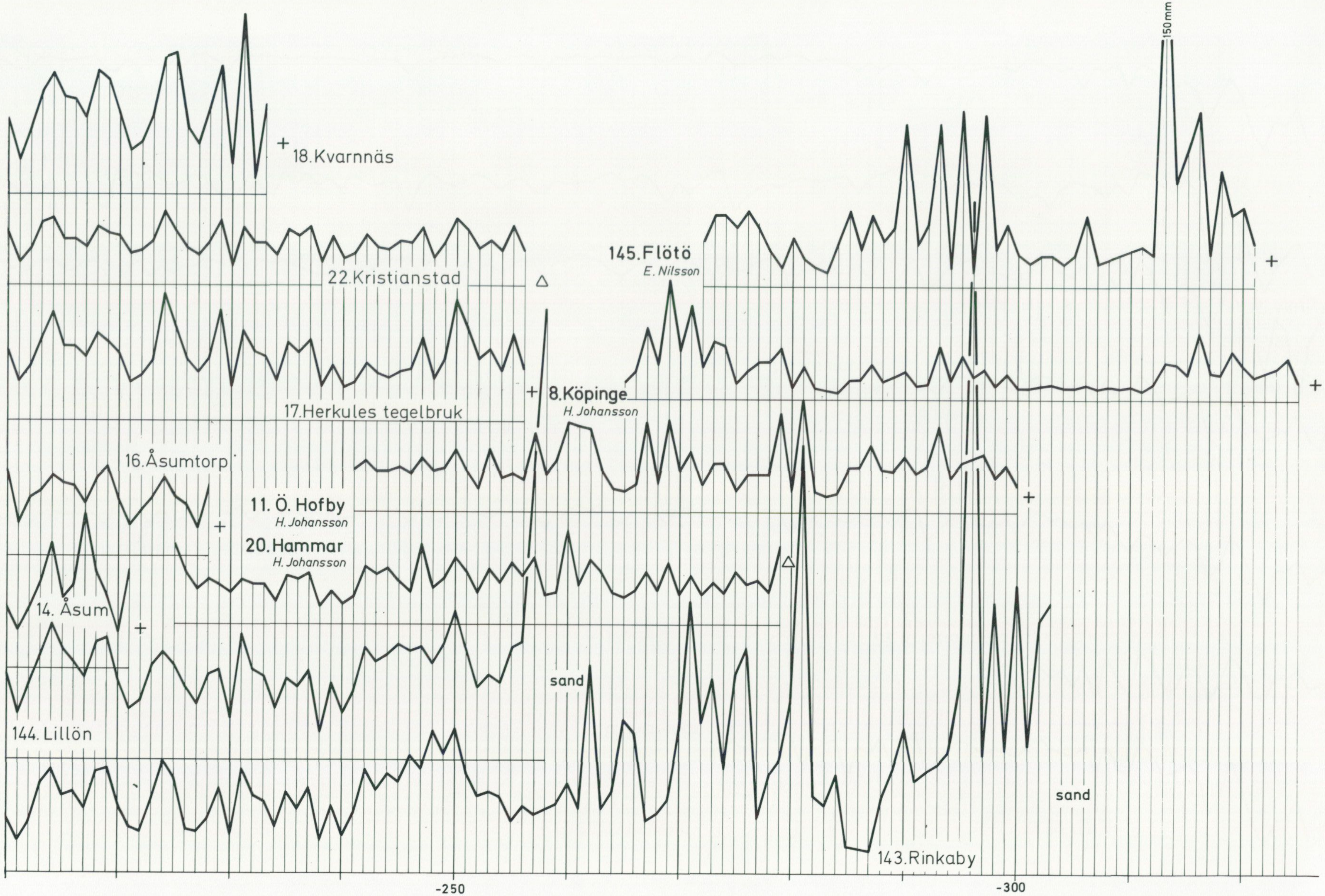
Plate 2



-80
92
91
-100
138
103
137
89
88
-120
101
108
87
-140
134
106
84
85
-160
HS 54
m a. s. l.
Råbelövssjön
-180
83
Oppmanna-
sjön
96
200
94
139
Ivösjön
Bromölla
-220
-240
SÖLVES-
BORG
Fjälkinge
-260
-280
18
17
-300
143
Hammarsjön
145
THE BALTIC
ÅHUS
0
5 km
Glacial striae
Drumlin
Glaciofluvial deposit
Connected varve serie
Unconnected varve serie
-280
Equicess, local chronology
Ice border line
HS 54
m a. s. l.
Highest shoreline
54 m above
the recent
sea level
Area above the highest
shoreline

Plate 3


Lake Mien
B L E K I N G E
HS 67m a.s.l.
HS 67m a.s.l.
KARLSHAMN
KARLSKRONA
Hanö
N
0
10
20
30km
+20
0
-20
-40
-60
-80
-100
111
112
115
116
117
118
119
120
122
123
124
126
127
128
129
130
131
133
146
147
148
149
150
151
153
155
156
158
159
160
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
185


150 mm
18. Kvarnnäs
22. Kristianstad
145. Flötö
E. Nilsson
17. Herkules tegelbruk
8. Köpinge
H. Johansson
16. Åsumtorp
11. Ö. Hofby
H. Johansson
20. Hammar
H. Johansson
14. Åsum
sand
144. Lillön
sand
143. Rinkaby
-250
-300

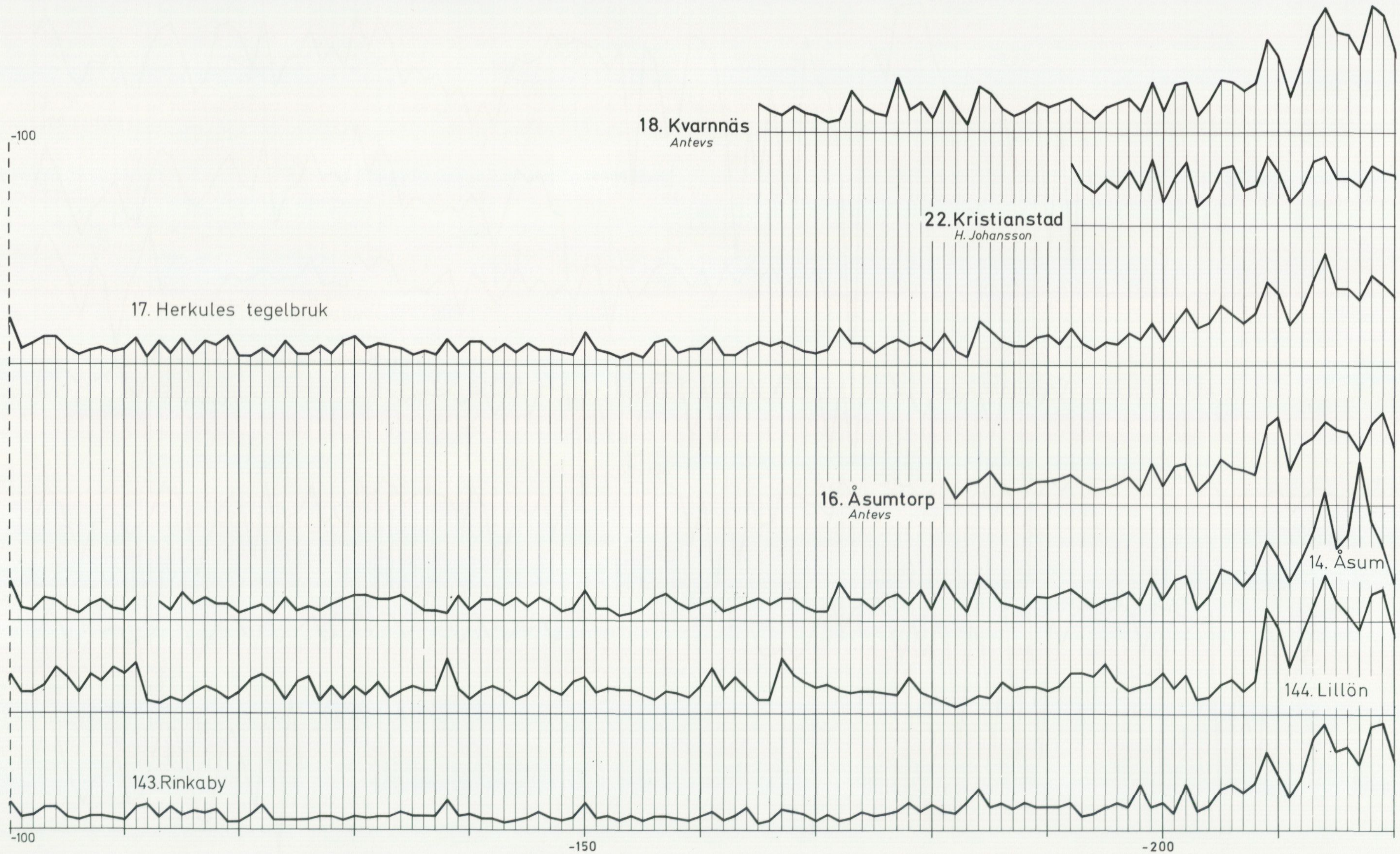
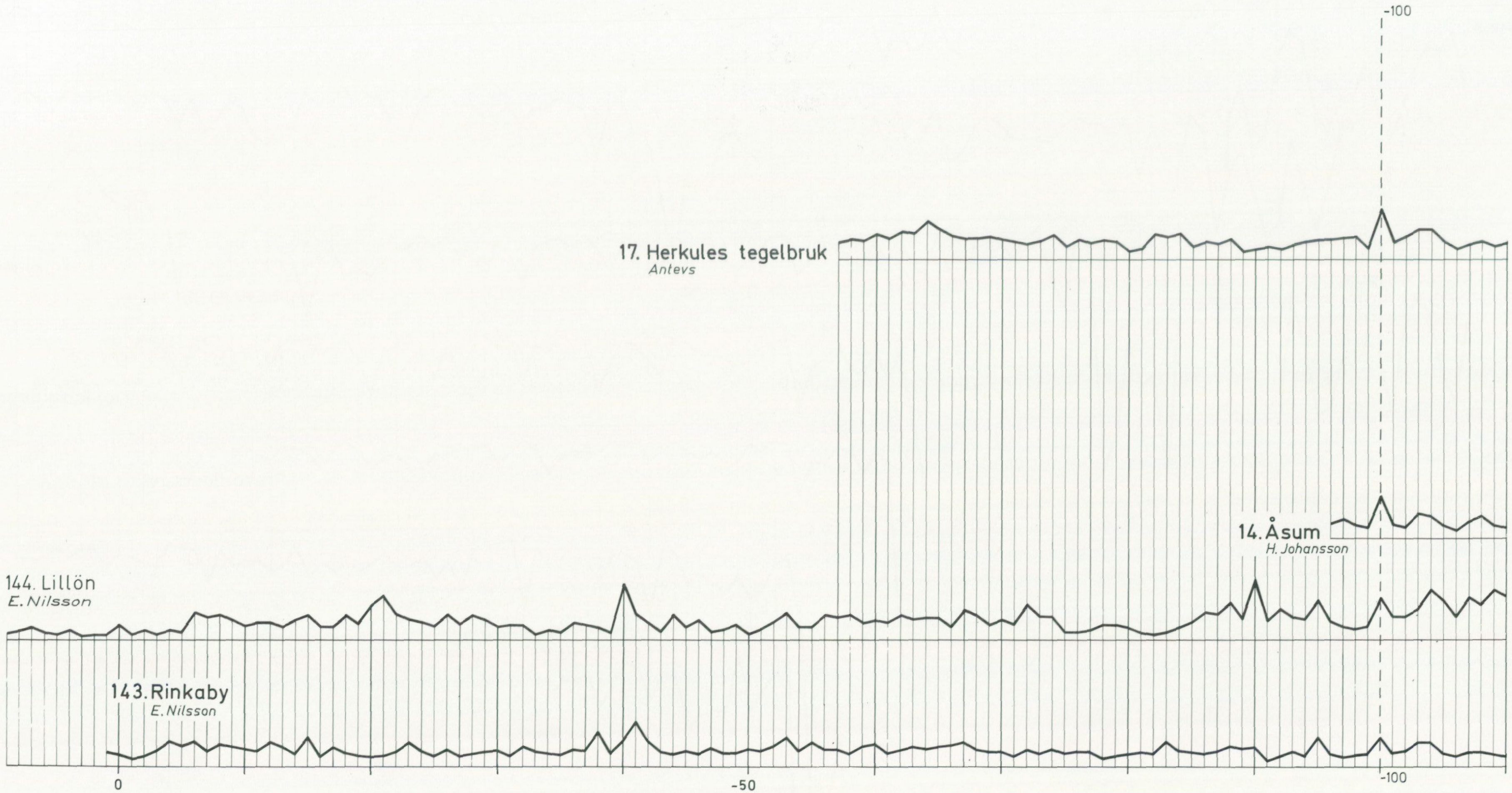
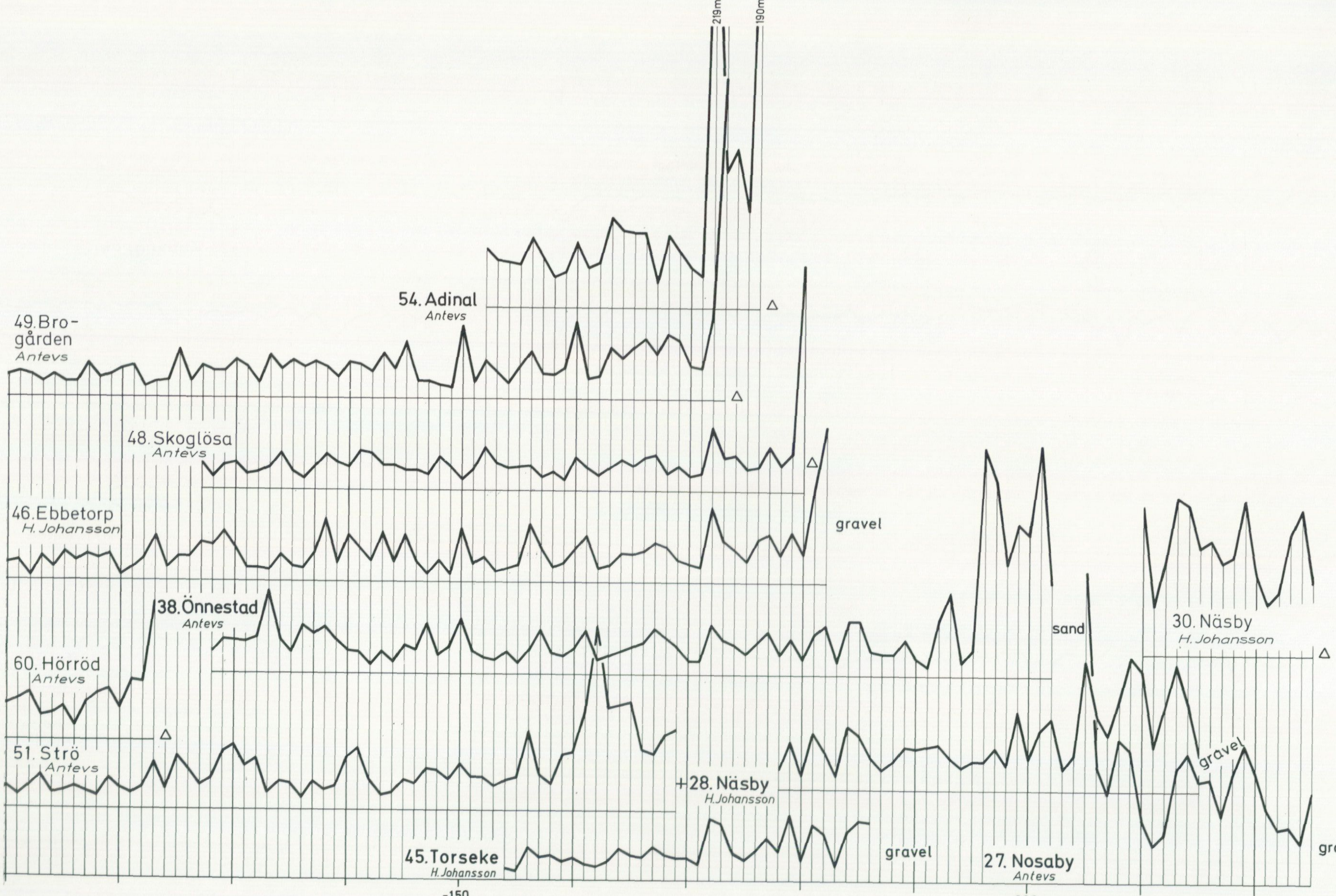

18. Kvarnnäs
Antevs
22.Kristianstad
H. Johansson
17. Herkules tegelbruk
16. Åsumtorp
Antevs
14. Åsum
144. Lillön
143.Rinkaby
-100
-100
-150
-200

Plate 4c


-100
17. Herkules tegelbruk
Antevs
14. Åsum
H. Johansson
144. Lillön
E. Nilsson
143. Rinkaby
E. Nilsson
0
-50
-100


219mm
190mm
54. Adinal
Antevs
49. Bro-
gården
Antevs
48. Skoglösa
Antevs
46. Ebbetorp
H. Johansson
gravel
38. Önnestad
Antevs
sand
30. Näsby
H. Johansson
60. Hörröd
Antevs
51. Strö
Antevs
+28. Näsby
H. Johansson
gravel
45. Torseke
H. Johansson
gravel
27. Nosaby
Antevs
gravel
-150
-200

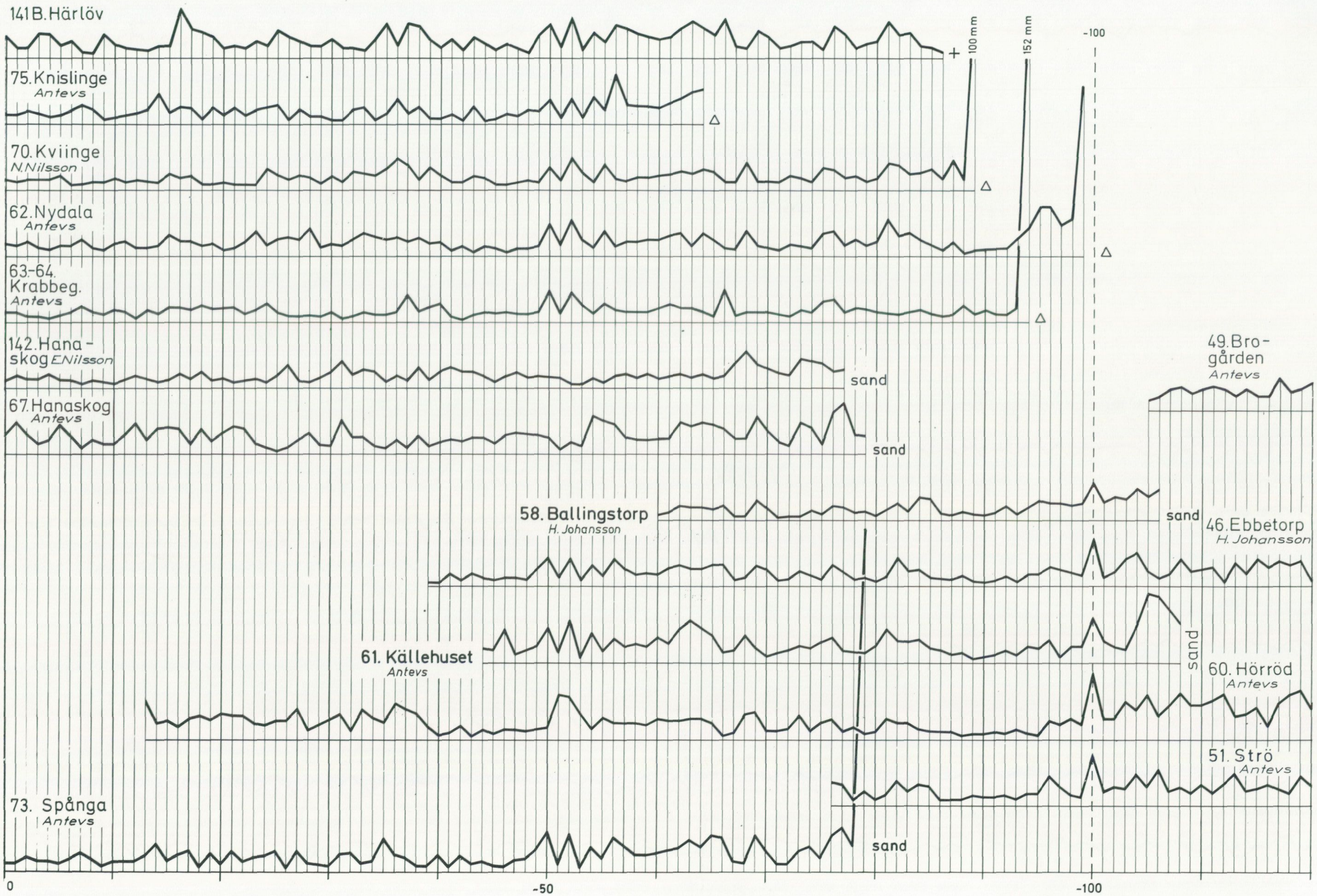

141B. Härlöv
100 mm
152 mm
-100
75. Knislinge
Antevs
70. Kviinge
N. Nilsson
62. Nydala
Antevs
63-64. Krabbeg.
Antevs
142. Hanaskog E. Nilsson
sand
49. Brogården
Antevs
67. Hanaskog
Antevs
sand
58. Ballingstorp
H. Johansson
sand
46. Ebbetorp
H. Johansson
61. Källehuset
Antevs
sand
60. Hörröd
Antevs
51. Strö
Antevs
73. Spånga
Antevs
sand
0
-50
-100

Plate 5c


141 B. Härlöv
141 B. Härlöv
75. Knislinge
Antevs
70. Kviinge
N. Nilsson
62. Nydala
Antevs
63-64. Krabbeg.
Antevs
142. Hana-skog E. Nilsson
67. Hanaskog
Antevs
73. Spånga
Antevs
+100
+50
0

Plate 5d

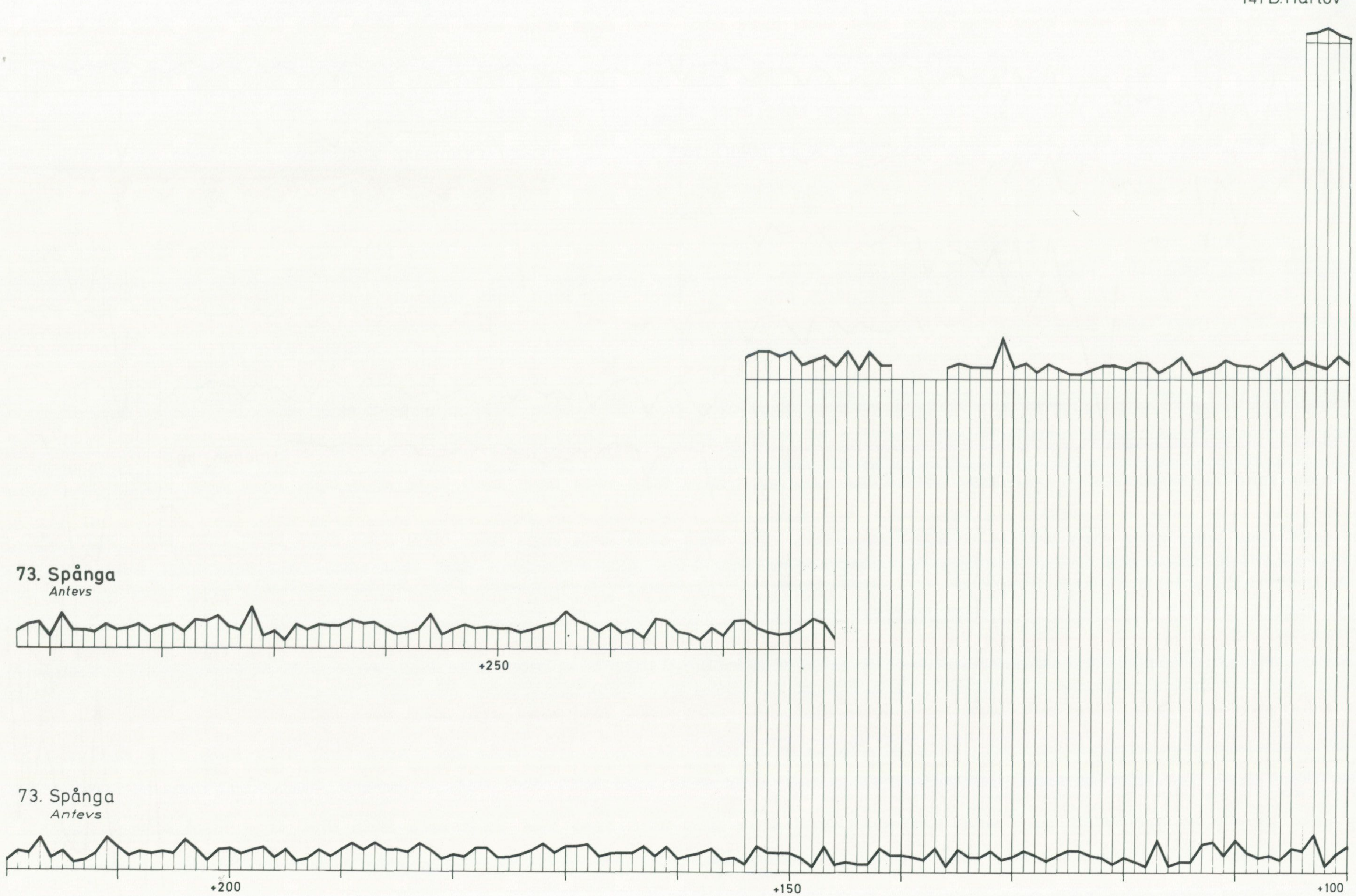
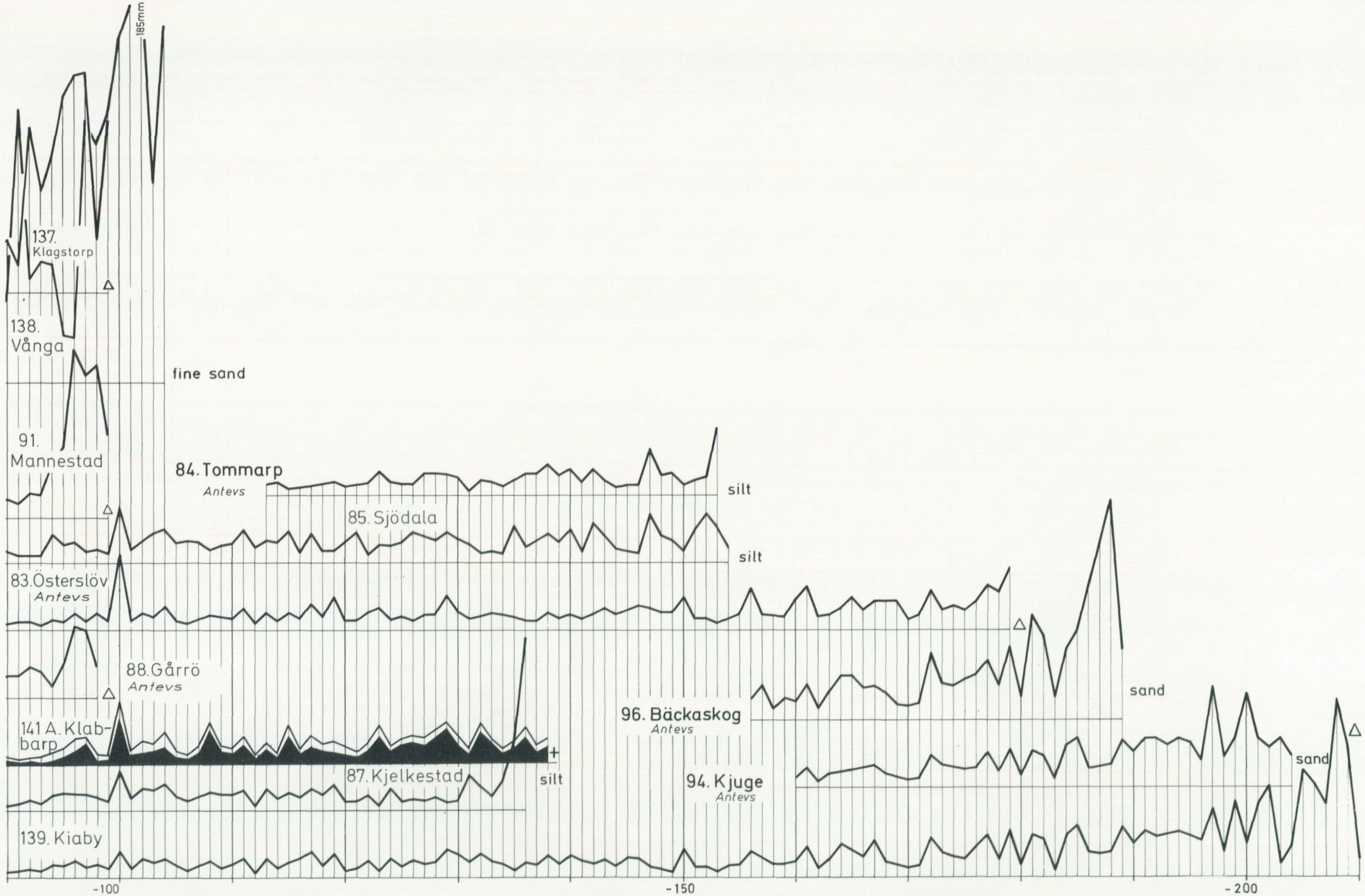
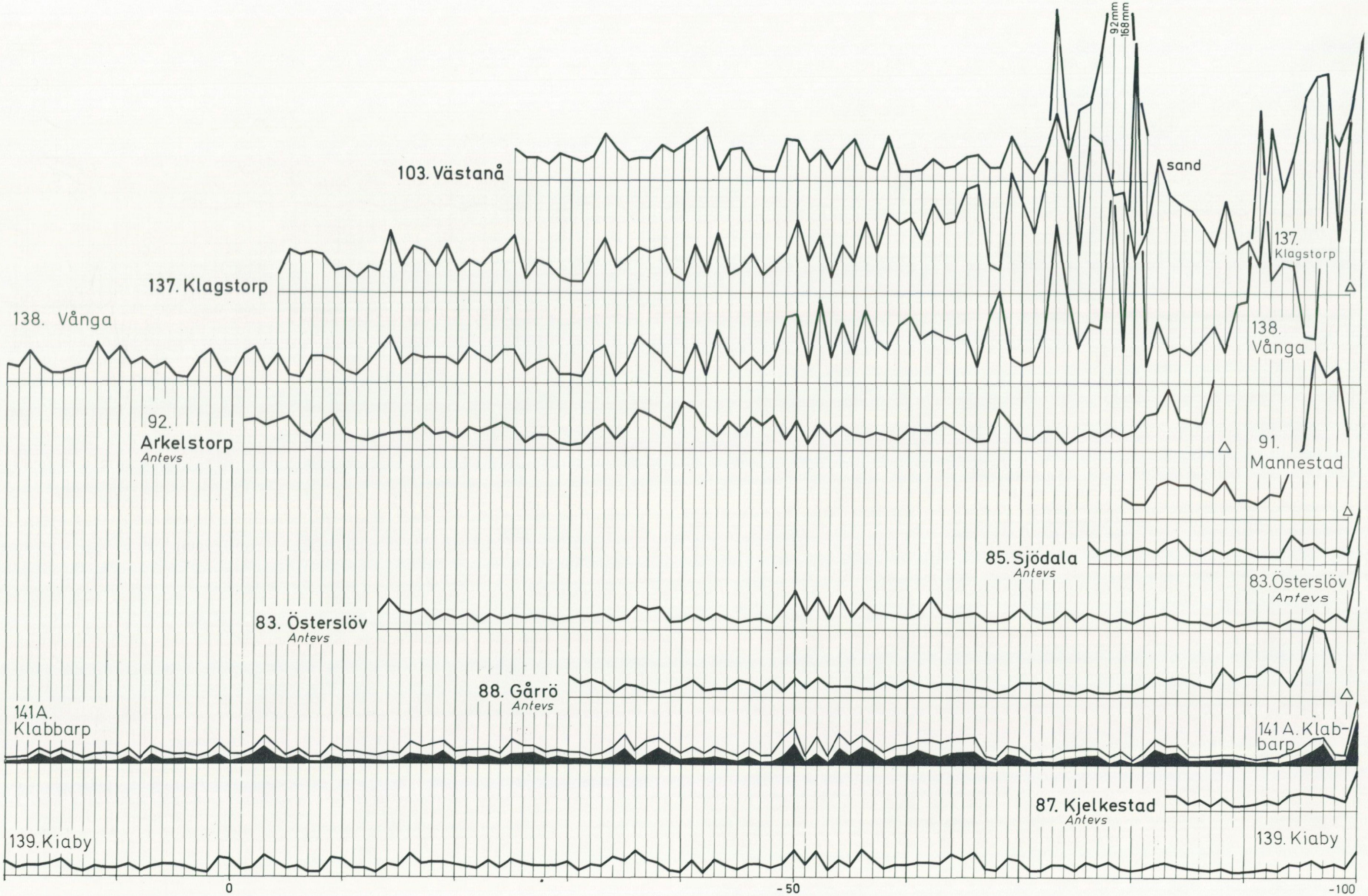
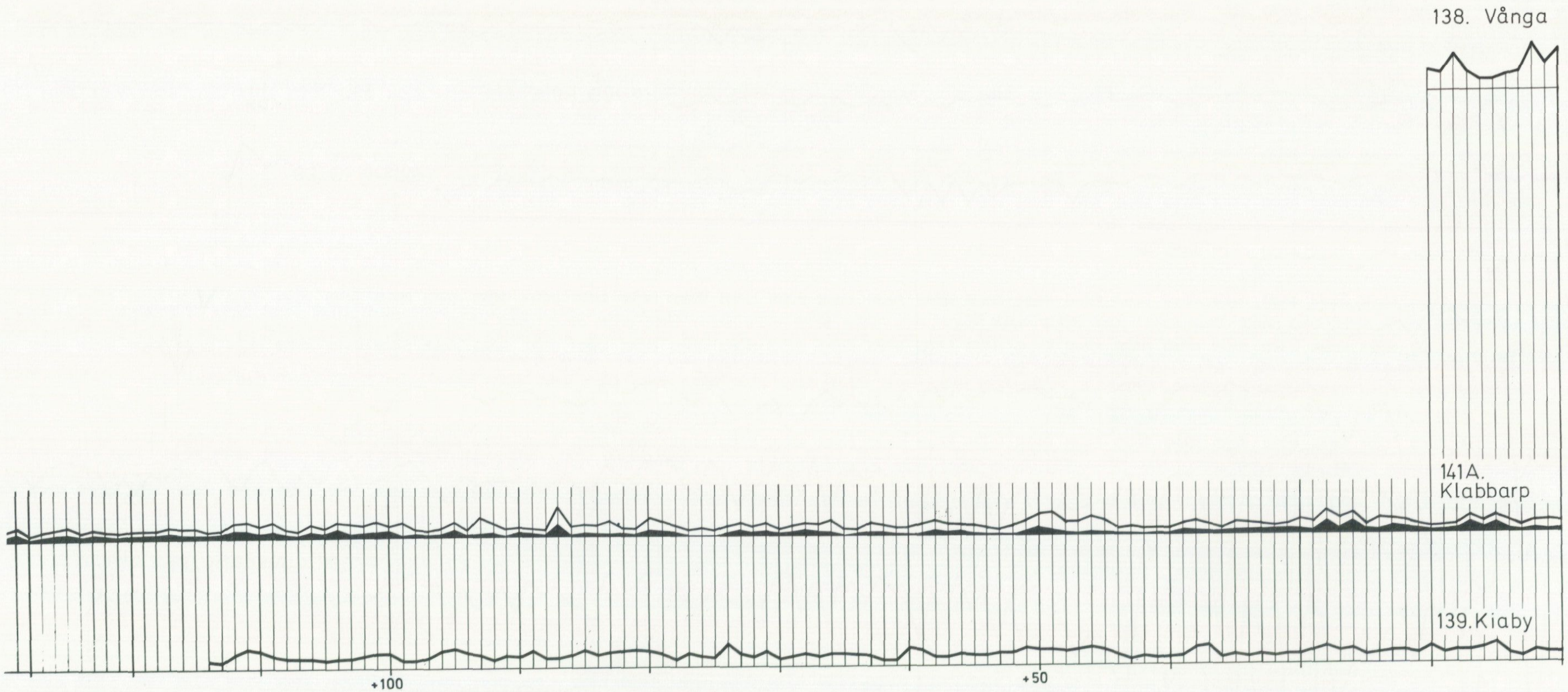

141 B. Härlöv
73. Spånga
Antevs
+250
73. Spånga
Antevs
+200
+150
+100

Plate 6a


185mm
137. Klagstorp
138. Vånga
fine sand
91. Mannestad
84. Tommarp
Antevs
silt
85. Sjödala
silt
83. Österslöv
Antevs
88. Gårrö
Antevs
sand
96. Bäckaskog
Antevs
141 A. Klabbarp
+
87. Kjelkestad
silt
sand
94. Kjuge
Antevs
139. Kiaby
-100
-150
-200


92mm
168mm
103. Västanå
sand
137. Klagstorp
137. Klagstorp
138. Vånga
138. Vånga
92. Arkelstorp
Antevs
91. Mannestad
85. Sjödala
Antevs
83. Österslöv
Antevs
83. Österslöv
Antevs
88. Gårrö
Antevs
141A. Klabbarp
141 A. Klab-barp
87. Kjelkestad
Antevs
139. Kiaby
139. Kiaby
0
-50
-100


138. Vånga
141A. Klabbarp
139. Kiaby
+100
+50

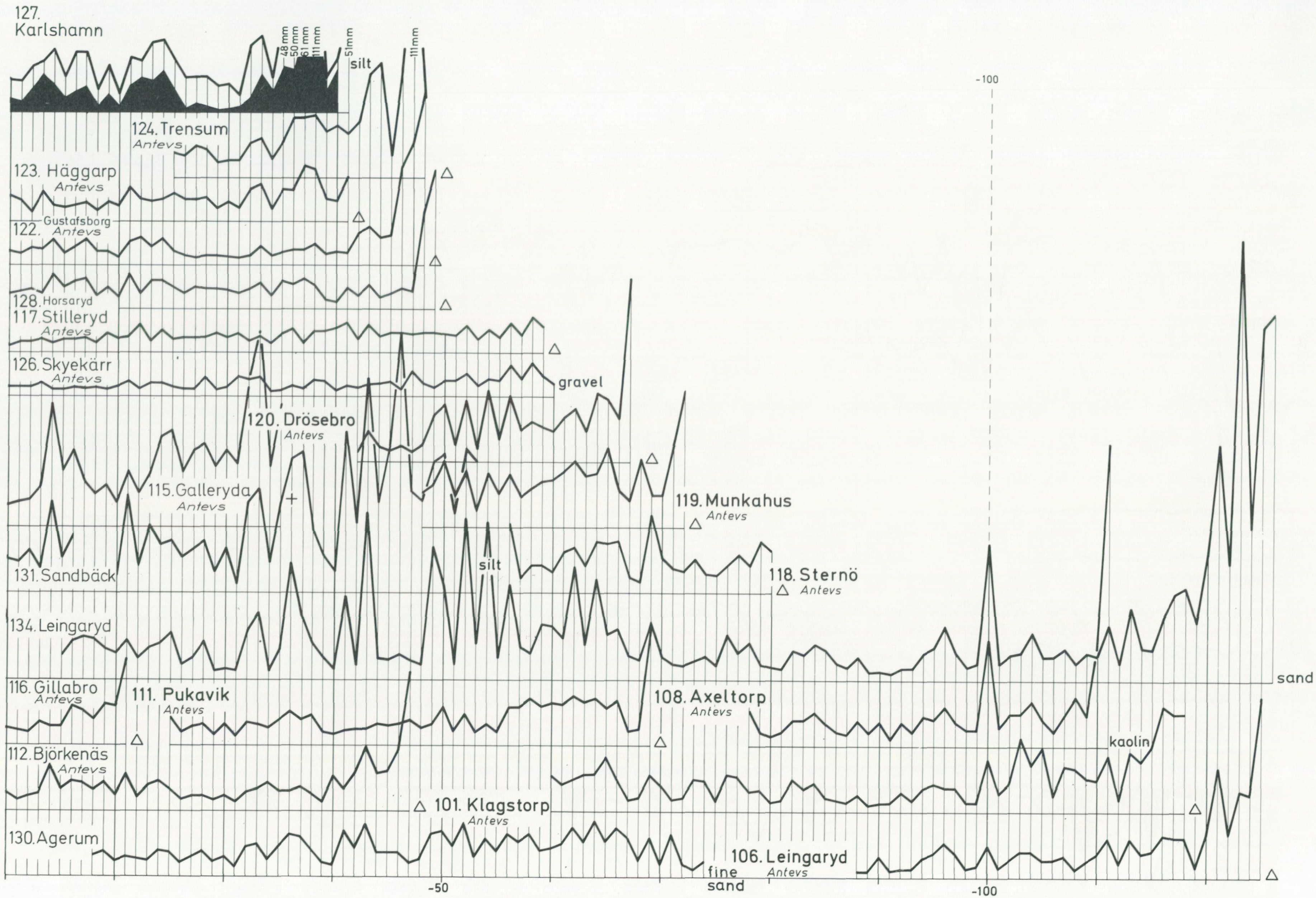

127. Karlshamn
48mm
50mm
61mm
111mm
51mm
silt
111mm
124. Trensum
Antevs
123. Häggarp
Antevs
122. Gustafsborg
Antevs
128. Horsaryd
117. Stilleryd
Antevs
126. Skyekärr
Antevs
gravel
120. Drösebro
Antevs
115. Galleryda
Antevs
119. Munkahus
Antevs
silt
131. Sandbäck
118. Sternö
Antevs
134. Leingaryd
sand
116. Gillabro
Antevs
111. Pukavik
Antevs
108. Axeltorp
Antevs
kaolin
112. Björkenäs
Antevs
101. Klagstorp
Antevs
130. Agerum
fine sand
106. Leingaryd
Antevs
-50
-100

Plate 7b

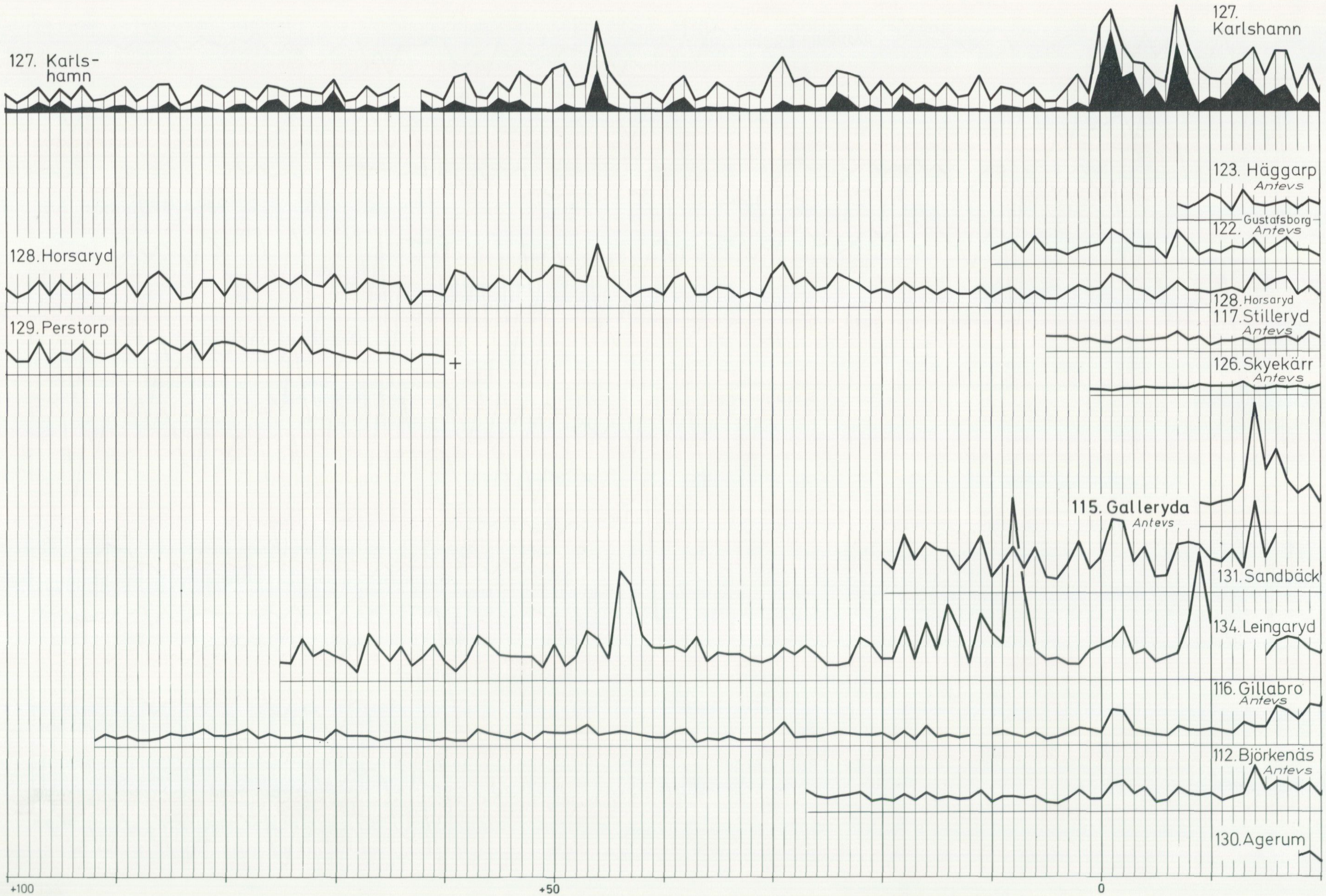
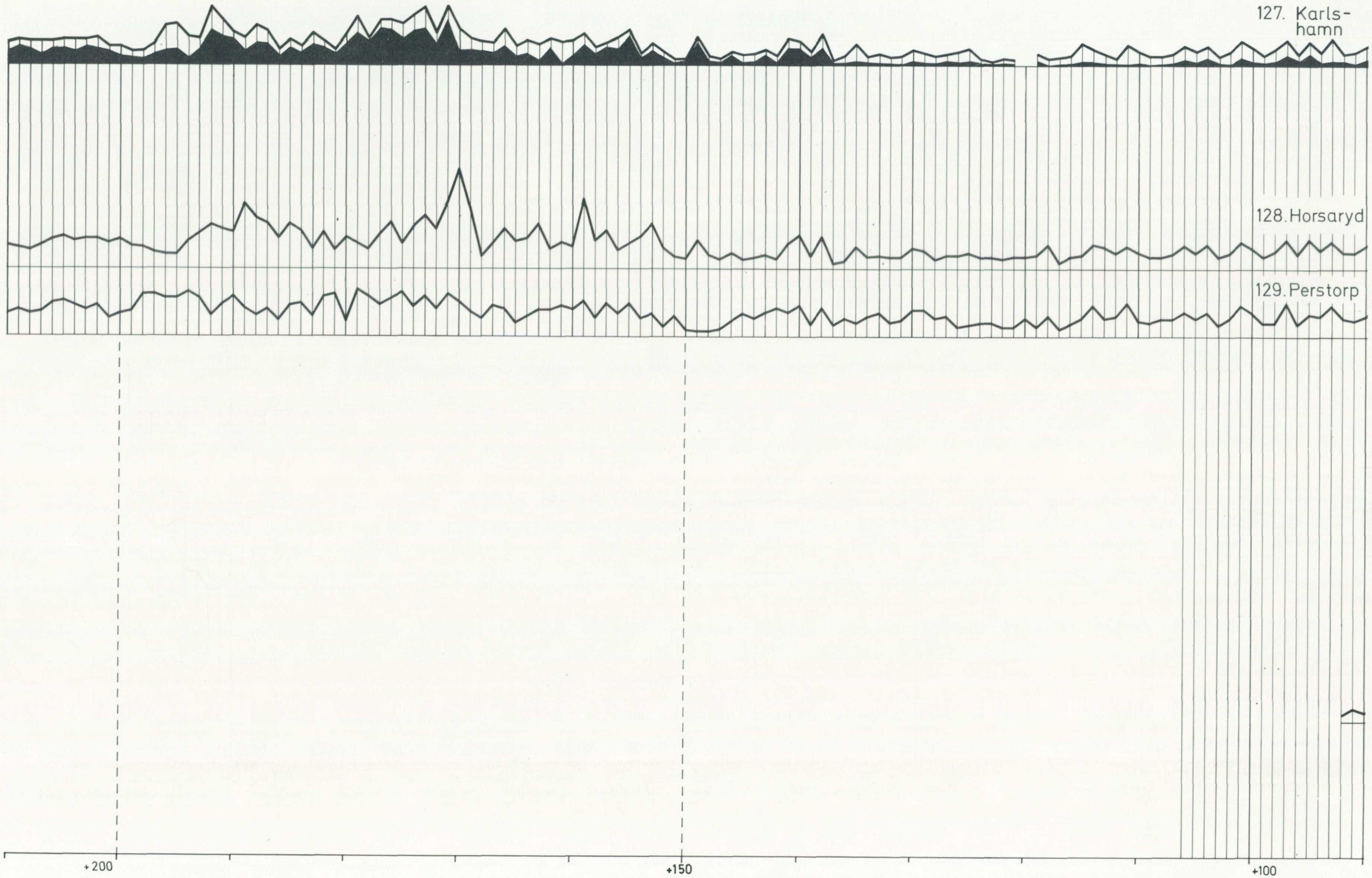
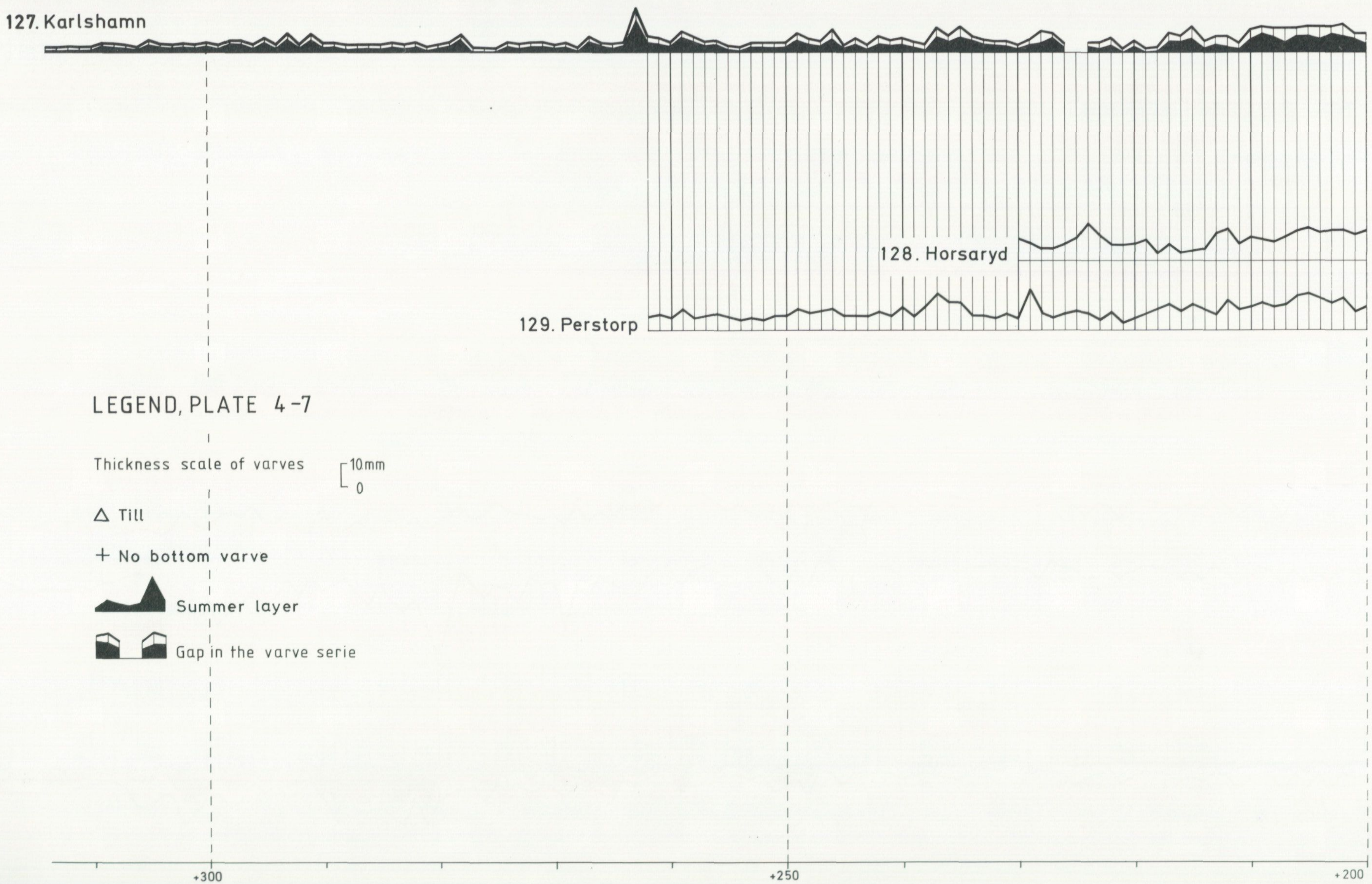

127. Karls-hamn
127. Karlshamn
123. Häggarp
Antevs
122. Gustafsborg
Antevs
128. Horsaryd
128. Horsaryd
129. Perstorp
117. Stilleryd
Antevs
126. Skyekärr
Antevs
115. Galleryda
Antevs
131. Sandbäck
134. Leingaryd
116. Gillabro
Antevs
112. Björkenäs
Antevs
130. Agerum
+100
+50
0

Plate 7c




127. Karlshamn
128. Horsaryd
129. Perstorp
LEGEND, PLATE 4-7
Thickness scale of varves
10 mm
0
Till
No bottom varve
Summer layer
Gap in the varve serie
+300
+250
+200

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ISBN 91-7158-504-4
ISSN 0348-1352