SVERIGES GEOLOGISKA UNDERSÖKNING

SER C NR 640 ÅRSBOK 63 NR 3

NILS-AXEL MÖRNER

THE LATE QUATERNARY HISTORY OF THE KATTEGATT SEA AND THE SWEDISH WEST COAST

DEGLACIATION, SHORELEVEL DISPLACEMENT, CHRONOLOGY, ISOSTASY AND EUSTASY

WITH 10 PLATES

SUMMARY IN RUSSIAN

STOCKHOLM 1969

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Fig. 19, 24, 26, 29, 34, 43, 58, 75, 95, 100 och 102 är för spridning godkända i rikets allmänna kartverk den 21 februari 1969.

LAHOLM 1969 · TRYDELLS BOKTRYCKERI AB

To

My father Professor Stellan Mörner, the artist
who has given me a free and unrestrained life
with artistic sensibility

My son Jonas Mörner, 5.5 years old
who followed me in the field
with inspiring enthusiasm

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Abstract

The intensity of land upheaval, the direction of tilting, the distribution of sediments, the almost negligible tide, the good pollen chronology, etc. all make the Swedish West Coast and the Kattegatt Sea extremely suitable for a detailed investigation of shorelevel displacement. Older investigations are marred by the absence of good dating methods. Thus one main purpose was to bring C^{14} dates into the history of deglaciation and shorelevel displacement. 108 samples were C^{14} dated. The Kattegatt Sea has hitherto been a "white spot on the map" preventing correlations between Denmark and Sweden or leaving the field open to loose hypotheses.

The present investigation is here given a thorough description containing the following: 1) the main lines of the Weichselian Glaciation prior to the last maximum at about 18,000 BC, 2) a detailed description of the ice recession across Kattegatt and the Swedish West Coast after the last maximum, 3) a discussion of the chronology, 4) an extensive and detailed description of the shorelevel displacement from about 11,750 BC to 1,400 BC (200 BC), and, as a content of the whole investigation a calculation of the isostatic and eustatic fluctuations.

The picture of land upheaval obtained is fairly simple, though the sensitivity to minor changes in the load of ice (= glacio-isostasy) and water (=hydro-isostasy) turned out to be very high. The eustatic curve obtained is highly fluctuating, though with a likely amplitude.

Acknowledgements

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Introduction

Kattegatt and the Swedish West Coast were entirely covered by the ice during the last, Late Weichselian, glaciation maximum. By the load of the ice the earth's crust was pressed down. At the same time the sea level was eustatically lowered to about –85 m. When the ice receded the isostatic land upheaval started in order to restore the equilibrium in the earth's crust. At the same time the sea level started eustatically to rise. In the beginning the isostatic effect was stronger than the eustatic and there was a more or less uniform regression. In early Postglacial time the turning point was reached and a eustatically caused rise of relative sea level started. Finally the slow isostatic land upheaval brought the shore level down to its present position. As the intensity of the land upheaval increases towards NE, all older shorelines are tilted from NE to SW. The intersection between the tilted shoreline of the regression maximum and the present sea level is found at the mouth of River Viskan on the Swedish West Coast. Consequently the whole investigation of shorelevel displacement can here be made on land. This means that a very detailed study is possible, in contrast to entirely submarine studies of "stable areas". Still the area is situated so near the periphery of the isostatic land upheaval that also minor eustatic fluctuations are registered as positive shorelevel displacements.

My intention has been to work out a very detailed, well fixed and closely dated shoreline diagram over a large area, giving shorelevel displacement curves from several different isobase latitudes, from which the isostatic and eustatic causes could later be calculated.

In 1963 I started a very detailed investigation of the shorelines (ALV) in the Viskan Valley during the transition period between Late Glacial regression and Postglacial transgression. This meant taking up von Post's old investigation of this area with the help of new and better methods, above all radiocarbon dating. In 1964 the investigation of the Viskan Valley was extended in time and space to Kattegatt and the rest of the Swedish West Coast. First the continuations of the ALV shorelines were investigated. Later the PTM shorelines, the Late Glacial shorelevel displacement and the deglaciation were investigated. The ALV shorelines, their gradient and age, and the direction of tilting were closely determined within the Viskan Valley and formed an ideal base for the amplified investigation.

I hoped to achieve a good result in this way of combining a detailed investigation in one area, the Viskan Valley, with a lot of observations scattered over a very big area, the Swedish West Coast, Kattegatt and the Danish Coasts, i. e. 300—350 km in the direction of tilting.

The area investigated is extremely suitable for investigation of the shorelevel displacement for many reasons:

1) Kattegatt is a marine continuation of the Atlantic Ocean. The investigated area is situated outside the Swedish-Danish Sounds which have intermittently been situated above the sea level, damming up a lake in the Baltic area.

2) The area has been lifted up isostatically but cannot be situated on a better isobase latitude because of the fact that the shoreline of the regression maximum (ALV-1) intersects the present sea level at the mouth of the Viskan Valley (cf. above). Further south more and more of the evidence is submerged below the sea level and further north the intensity of the land upheaval increases so that the eustatic transgression waves are no longer registered as positive shorelevel displacements.

3) A long and broad river valley, the Viskan Valley, opens into Kattegatt just where the ALV-1 shoreline intersects the present sea level. The Late Glacial sea fjord reached about 65 km inland and the Postglacial about 30 km inland giving a long investigation area. The width of the valley meant that abundant sediments have been deposited at different times, and also that these sediments have not been subsequently eroded away, as happens in narrower river valleys.

4) The isobases have a NW—SE orientation and the Swedish West Coast has a WNW—ESE orientation, i. e. the direction of tilting is very suitable for a shorelevel displacement investigation.

5) Kattegatt is a shallow sea which is hardly anywhere deeper than 100 m. The submerged shorelines can be followed in many places: in a NNW—SSE direction along the Swedish West Coast, in a NE—SW direction along the Sjaelland—Skåne—S Halland coasts, in a N—S direction along the Jylland coast and around the islands and shoals in Kattegatt. This also means that it is easy to compare the isobase latitude of different localities and work out a good isobase system.

6) Together the Swedish West Coast, Kattegatt and the Danish coasts offer a very big area across which one and the same shoreline may be followed. The shorelines were followed 250—350 km in the direction of tilting.

7) The tide is negligible within this area. This is very important for a detailed fixing of the shorelevel and the formation of a shore marks.

8) The pollen chronology is well established and offers a necessary double check of the radiocarbon dates.

9) The immigration of the shell-bearing fauna gives information about the climate. The shells also give material for C^{14} dating of the earliest part with arctic climate and poorness of organic deposits.

10) The glacial drift deposits as well as the younger sediments have a wide distribution in this area. The glacial, Late Glacial and Postglacial deposits can usually easily be distinguished already in the field.

11) The presence of synchronal ice marginal lines gives a possibility also to fix synchronal shorelines of the corresponding Marine Limit (ML).

12) The area has not been disturbed by neo-tectonic activities.

13) The whole Swedish West Coast south of Gothenburg has had roughly the same Late Quaternary history. The Late Glacial sea reached some 20—30 km inland up to the highland of Småland (in the valleys still further inlands). North of Gothenburg, on the other hand, an arm of the Yoldia Sea reached across Middle Sweden as the Närke Sound right to the Baltic Sea. And towards the south inside the Swedish-Danish Sounds there is the Baltic area which at least twice has been separated from the sea, as the Baltic Ice Lake and as the Ancylus Lake with water levels above the corresponding sea level. This can be significant as hydro-isostatical movements are to be expected (p. 420, Fig. 146; cf. also Higgins 1965 and Nansen 1922).

When publishing this, my intention has been not only to present the results and theories but also the whole basic material. In this way everyone can form his own opinion — affirmative or negative — about this investigation, and does not have to wait for a possible paper in the future. All too often only the results are published. For still further perticulars I invite personal communication.

Parts of this investigation have earlier been described in lectures, viz. at the INQUA Subcommisson for Baltic (and Northsea) Shorelines (1965 in Uppsala, 1968 in Haarlem), at the VII and VIII "Nordiska Geologiska Vintermötet" (1966 in Åbo, 1968 in Lund) and at the meeting of "Nordisk Maringeologisk Kommission" (1966 in Stockholm). The chapter about the ALV shorelines in the Viskan Valley was presented in 1965 at the University of Stockholm as a thesis (in Swedish).

Throughout this paper, I have consciously tried to keep the language easy and up-to-date. I have used the first person singular, by this taking the responsibility for statements and interpretations given. This mode of expression is, in my opinion, more true and honest — and is thus in fact the most scientific. I would very much have liked to get rid of the italics of the specific names in Latin — in order to save the italics to stress the importance of certain words or sentences. However, this reform (though sooner or later necessary) could not yet be realized.

Numerous stratigraphies are listed and discussed in this paper. In order to shorten and simplify the text, different layers are often denoted by the names of the stages, shorelines or ice marginal lines during which they were formed, by a sign of equality (=), though a certain deposit in fact cannot be equal to a certain period, shoreline or ice marginal line.

Material and methods

Kattegatt has never before been investigated from geological point of view (except in the straits of Lille Belt, Store Belt and Öresund). From the Swedish West Coast and adjacent areas there are several older more or less important descriptions. However, they are all limited by the absence of good datings (except T.Nilsson's works in Skåne, e. g. 1935) and they do not offer any solution either of the deglaciation or the shorelevel displacement on the Swedish West Coast. The Swedish time scale, i. e. De Geer's method of counting the annual varves of the glacial clay, has possibly now been extended to Southern Bolmen (E.Nilsson 1968), but definitely not further south (though this was stated by E.Nilsson 1968). The pollen zonation is very well established in Skåne by T.Nilsson (e. g. 1935) and partly also in the area of the Viskan Valley by von Post († 1968 and unpublished).

The field work is extensive and contains: 849 "boring points" with samples brought home from 398 boring points, mapping of the ice marginal lines (in Kattegatt and on the Swedish West Coast), levelling of 24 sections across the PTM shore marks, studies of all available cuttings (gravel pits, ditches etc.) and measurement of ML and Late Glacial shore marks (in NW Skåne and S Halland). Von Post's sections and pollen diagrams (von Post † 1968) were used as basic material for the investigation in the Viskan Valley. The archives of most of the Swedish geotechnical firms were gone through concerning all borings on the Swedish West Coast. Often very important information was obtained from these borings. Many earlier described localities with known stratigraphy or pollen content were returned to and sampled for C^{14} dating and pollen analysis.

The field and laboratory methods are below dealt with one by one.

The borings and samples

All B numbers in the text and figures refer to my borings (or observations in cuttings), while the BP numbers refer to von Post's borings in the Viskan Valley.

Several sections were bored in the Viskan Valley with the Hiller auger. Later, samples were taken in these as well as in von Post's old sections. The stratigraphy and depth of sampling were determined with a Hiller auger. For preboring a post hole auger was used. The samples were taken with a piston corer of the type used by the Swedish State Railways, having an inner diameter of 44.5 mm and being 60 cm long. The cores were immediately rolled up in

plastic foil. Usually four cores were taken of the same level in order to get the thickness of the C^{14} dated sampes down to 1.0—1.5 cm.

Eight continuous cores in four boring points in the Viskan Valley were taken with the Swedish piston sampler with metal foils (Kjellman *et al.* 1950), having an inner diameter of 38 mm and being capable of taking quite undisturbed and continuous samples of up to 11 m length.

Later a very useful helical auger (the G-sond of Geoscandia) was put to my disposal. The screw is 100 cm long and the diameter is 60 mm (or 40 mm). The helical auger is screwed down as well as pulled up with the help of a motor. With the helical auger the stratigraphy was easily determined 10—20 m down. Also hard sandy layers or buried ground crusts could be penetrated. It was also used for preboring. In a few exceptional cases samples (below sand or very deep down) were taken for pollen analysis and even C^{14} dating (B 711) without any contamination.

The method of sampling described above, i. e. determination of the stratigraphy with a Hiller auger, preboring with a post hole auger and sampling with a piston corer, were also used at many places on the rest of the Swedish West Coast. However, the helical auger here soon replaced the Hiller and post hole augers. Also, the old piston corer was later replaced by a lightweight modification of the standard piston corer (of the Swedish Geotechnical Institute), giving cores of 70 cm length and 4.6 cm diameter. A plastic tube divided longitudinally into two halves was used in order to get unbroken cores that could be studied in the field and be rolled up in plastic foil. As C^{14} dating was the main purpose of sampling, four (sometimes six) cores were always taken of the same horizon (cf. above).

Samples were also taken by digging in many cuttings in ditches, gravel pits, clay pits, pits for house foundations, cliffs, etc. Some B numbers refer, to such observations.

The methods of sampling the seabed of Kattegatt are described on p. 22. Usually a piston corer but also different types of dredgers were used.

All samples were immediately and carefully rolled up in plastic foil and kept in a cold cellar. Clay samples from 1963 are still quite loose.

The levellings

The levelling of the sections and the boring points in the Viskan Valley were made with a theodolite, a Wild instrument and a Kern instrument.

The important levellings of the sections across the PTM shore marks, all were made with the Kern instrument (Kern GK 1). This is an extremely good levelling instrument where the source of error concerning the horizontal setting is avoided by the presence of a telescope level with coincidence prisms.

All measurements of the altitude of ML were made with an aneroid barometer. However, the time (half an hour or less) and distance (a few km) to a fixed point were always short. Furthermore a measurement was always checked to more than one fixed point. Usually more than one measuring was made in each locality.

The altitude of boring points in secluded bogs, etc. were derived from the maps, from older levellings and measurings by von Post or from new measurings with an aneroid barometer. The pass thresholds were always closely determined, which was usually not difficult. The boring points in Gothenburg were all kindly levelled by Stadsbyggnadskontoret in Gothenburg.

At Stenshuvud and Borstahusen a rough and rapid "levelling" of PL was made with a mirror and a measuring rod. As the distances were short the margin of error is still not more than 1—2 dm. The altitude of B 328 and B 840 was determined in the same way.

The soil identification

The first summer every soil determination in the field was made under the microscope. Later when I was closely familiar with the different sediment in this area, this was no longer necessary. The samples brought home to the laboratory were closely examined under the microscope. The first year Dr. Wenner checked and helped me with the identification of important organic layers. The mud content was always carefully determined, as an increase of mud is significant at the isolation level and the mud content is important for a possible C^{14} dating. In several samples the loss on ignition was determined.

The following terms are used in the following sense:

mud (muddy) = gyttja, content of fine detritus (organic material)
clayey mud = a clay containing 6—30 % mud
muddy clay = clay containing 3—6 % mud
dy (dyey) = sapropel, oxidized humus deposited in water
pitchy soil = dopplerite, humus horizon, Sw: "beckjord"
drift peat = alloctonous or alluvial peat, Sw: "svämtorv"
drift clay = alluvial clay, (also "Dryas clay"), Sw: "svämlera"
"mo" = fine sand + coarse silt, Sw: "mo"
fine sand = grain size 0.2–0.06 mm, Sw: "grovmo"
coarse silt = grain size 0.06—0.02 mm, Sw: "finmo"
fine silt = grain size 0.02—0.002 mm, Sw: "mjäla"
drift = till and glacifluvium
till = unstratified drift (= Sw: "morän")
moraine = accumulation of drift
glacial clay = varved and unvarved clay showing influence of the melting ice

The name pitchy soil (Sw: "beckjord") was introduced by von Post (the English name in von Post † 1968, the Swedish name in von Post and Granlund 1926). This is an important soil, which is well worth a closer description. This soil is very common along the beaches of ALV time in the Viskan Valley.

Pitchy soil is a coal-black, "fatty" soil, which is found as thin layers or as impregnation in the upper part of another layer (clay, sand, peat, etc.). Sometimes the black material decreases downwards. Microscopically, pitchy soil consists of black formless lumps and aggregates in a varying matrix. Pitchy soil is composed of humus residues from a decomposed vegetation layer. Very often the humic acids have impregnated the layer below. Pitchy soil is formed by chemical precipitation of humus in the upper part of a buried layer. Boiled in alkaline solution pitchy soil (like dy) gives the solution a dark brown colour.

Pitchy soil is formed when an overgrown land surface is buried. This can happen at a transgression (as along the ALV shorelines) but also by artificial burying. It frequently occurs below eolian sand. On the Bjäre peninsula I have a locality with pitchy soil below sand that less than 50 years ago was thrown by man on a land surface. According to observations in Washington State, USA, pitchy soil is also formed when an ash layer buries an overgrown land surface. In the Netherlands I have observed pitchy soil in the top of some organic sequences below tidal flat deposits. When pitchy soil is found below a shore deposit or marine deposit, this gives evidence of a transgression.

The important thing about the pitchy soil is that it consists of residues of the vegetation which grew on the land surface just when it was buried, i. e. a C^{14} dating gives a very good date of the event in question. This is demonstrated by my C^{14} dates. Pitchy soil seems to give very exact dates (better than peat, which usually has a slow growth rate) of transgressions and other burying events.

The pollen analysis

Totally 360 samples from 89 different boring points were pollen analysed. In many boring points only a few samples were analysed in order to check the relation to the distinct pollen index horizon A^0 (or sometimes C^0), the content of *Hystrix* or the presence or absence of gaps (hiatus) at transgression and isolation contacts.

A core taken with the piston corer was split up longitudinally and the samples for pollen analysis were taken from the centre of the core and put in small glass specimen tubes. This means that contamination with air borne pollen was avoided. The samples were carefully treated to avoid contamination and to get good preparations. The completely organic samples (not so many) were

treated according to the acetolysis method. The samples containing inorganic material (most samples) were first treated with hydrofluoric acid and than treated according to the acetolysis method.

The samples were almost all analysed by Mrs Irene Holm. As a principle 200 tree pollen (AP) were counted (excluding *Corylus*). In some Late Glacial and marine samples very poor in pollen only about 150 AP were counted (in a few exceptional cases only 110—120 AP). Some pollen and spores were kindly checked or classified by Dr. J.Praglowski. Besides the AP pollen, NAP pollen, aquatic pollen, spores, *Pediastrum* and *Hystrix,* were counted. *Corylus* was not included in the AP sum. Fragments of *Pinus* and *Picea* were counted as half a pollen. The counted microfossils are all expressed as a percentage of the AP sum. The NAP sum is sometimes given as a percentage of the total sum of AP, *Corylus* and NAP. The cumulative area diagrams of Late Glacial samples are given as a percentage of the total sum of AP, *Corylus* and NAP, and includes the following four groups (shrubs and dwarf shrubs sometimes together):

1. trees = AP (excluding shrubs) + *Corylus*
2. shrubs = *Salix Hippophaë, Juniperus (Betula nana* not identified)
3. dwarf shrubs = *Ericaceae, Empetrum*
4. herbs = NAP (excluding dwarf shrubs)

The occurrence and distribution of *Hystrix (Hystricosphaeridae,* incerta sedis) in this material is interesting. According to Iversen (e. g. 1937) *Hystrix* is entirely redeposited from older beds. However, Erdtman (1949) found *Hystrix* in the water of Gullmarsfjorden, Bohuslän, and thus concluded that *Hystrix* must still live in Kattegatt. According to the distribution of *Hystrix* in the sediments in Bohuslän M.Fries (1951) found *Hystrix* to be an indicator of haline environment. Concerning the occurrence and distribution of *Hystrix* in this material, I find it quite obvious that *Hystrix* has lived in Kattegatt in Late Glacial and Postglacial time. In lacustrime sediments *Hystrix* is absent or occurs as a few (0.5—2.0 %) percent, which apparently is connected with the clay content (= redeposition from older marine clay beds). In brackish or marine sediments *Hystrix* is common (5—60 % of the AP sum). In the Late Glacial clays the percentage seems to be somewhat lower (5—20 %) than in Postglacial sediments (10—60 %). The percentage of *Hystrix* seems often to be higher in the shallow sea deposits (60 % in the Viskan Valley) than in the open sea deposits far from the coast (7—15 %). In the samples of the lacustrine stage of Ancient Lake Veselången in the Viskan Valley (muddy clay) just a few or no *Hystrix* was found, despite the strong redeposition of older marine clay. When the transgression at 5,800 BC created a sea fiord of the Viskan Valley, the content of *Hystrix* rapidly rose to high percentages, 24—60 % in the clayey mud as far inland as in Section 1 (p. 223). This can definitely not be ascribed to redeposition in connection with erosion, but must be ascribed to the salinity of the water and to the presence of *Hystrix* in marine water.

The C^{14} datings

108 samples were C^{14} dated at the Radioactive Dating Laboratory in Stockholm (St—). Further more, one C^{14} date from Professor I.Hessland and eight from Mr. S.Widell were kindly put at my disposal. The C^{14} dated samples consist of the following material: 2 of bone, 12 of shells and the rest (94) of organic deposits (muddy, dyey or peaty). See Table 3 (p. 476).

In order to avoid contamination in the field and in the laboratory very much care was devoted to the sampling. Oiled corers were never used. The cores from one and the same horizon were split up longitudinally and closely synchronized with soil identification and stratification. In order to get the thickness of the dated horizon down as much as possible, the samples were divided in one main sample and several reserve samples, which were burned one by one until gas enough was produced for a determination (e. g. in the following way: the 0.4 cm containing the horizon in question in four cores were used as main sample, and the next 0.2 cm in each core were combined to give seven reserve samples, together representing a 1.8 cm thick sample divided into eight minor samples). The outermost part of the cores was not used. Every trace of roots was removed. All this is a very time-consuming procedure, but I find it necessary and it gives much more reliable dates.

However, several C^{14} datings gave results that do not fit with the age of deposition. This can usually be ascribed to redeposition of older carbon (also suggested by the clay content in the samples). Some samples have been contaminated by younger carbon, e. g. younger roots, humus or carbonate (B 228:II, B 228:III). In two cases the explanation is difficult, viz. B 95:4, a detritus mud about 3,000 years too old (cf. p. 41) and B 675, a mud about 4,000 years too young (cf. p. 345).

The C^{14} dates are all given in years BC (except some very old samples). The value 5,568 $\pm$30 years has been used as the half-life of C^{14}, though 5,730 $\pm$40 years is more likely. The technique used at the laboratory in Stockholm has been described in the date list Stockholm V.

The C^{14} datings of organic deposits were always combined with pollen analysis. This gives a necessary double check, i. e. the reliability of the C^{14} date can be checked with pollen and vice versa.

Concerning the C^{14} dating of marine shells, the age obtained must be corrected according to the retarded carbon cycle in the sea (the "sea correction"). However, this correction is not finally established. The following C^{14} datings of sea water (Fonselius and Östlund 1959) and organisms living in the sea are of interest for a calculation of the "sea correction" in the Kattegatt area and give the following figures of the correction:

1. Broecker (1957), average of North Atlantic surface water 1956 –320
2. St-322, the Gulf Stream, surface water 1957 –330 $\pm$56

3.	St-458, the Norwegian Sea, surface water 1959	–278 ±88
4.	St-460, the Norwegian sea, surface water 1959	–320 ±72
5.	St-459, the Norwegian Sea, water at –1000 m	–328 ±56
6.	St-421, the Bay of Biscay, surface water 1958	–179 ±56
7.	St-369, Skagerak, surface water 1958	–280 ±56
8.	St-370, Skagerak, bottom water (–20 m) 1958	–115 ±56, bomb?
9.	St-365, Skagerak, *Fucus* 1905 at 0.5–5.0 m	–255 ±56, –45 years
10.	St-363, Skagerak, *Fucus* 1950 at 0.5–5.0 m	–385 ±56
11.	St-355, Skagerak, *Fucus* 1958 at 0.5–5.0 m	–278 ±48
12.	St-364, Skagerak, *Laminaria* 1958 at –20 m	– 55 ±48, bomb
13.	St-428, Skagerak, *Fucus* 1959 at –0.5–5.0 m	+, bomb
14.	U-607, *Patella vulgata* 1935	–530 ±72, –15 years
15.	T-199, Trondheimsfjord, *Mytilus edulis* 1957	–400

C^{14} datings of shells (T-139) and wood (T-138) from the same layer in Blomvåg (Trondheim II) gave a difference of 500 years (excluding the statistical error of ±350 years in each sample). The shells in B 287 gave 6,785 ±105 BC, while the clay contains a pollen flora of earliest zone VI (A^0 = 6,550 BC). This indicates a correction of about –250 years. In Vendsyssel shells of *Cardium edule*, K-895, have been C^{14} dated at 6,330 ±140 BC (Copenhagen II). As the shells were probably deposited at the onset of the second Postglacial transgression at 5,800 BC, this suggests a correction of about 500 years.

If these dates are considered together, most of them fall within –330 to –280 years (–305 ±25). However, the variations are much bigger. The upper limit is at about –500 years, while the lower limit is hard to fix as the samples may have been influenced by the atomic bombs (probably at about –200–150 years). Arctic water from the East Greenland Current seems to be about 200 years older than the Atlantic water (Fonselius and Östlund 1959). In the Baltic Sea on the other hand the sea correction is very small according to the following dates by Berglund (Stockholm VI):

St-1467, *Chara horrida* 1888–1896	130 ±80 BP, –60 years
St-1468, *Chara aspera* 1888–1896	30 ±56 BP, –60 years
St-1469, *Ulva lactuca* 1910–1917	75 ±120 BP, –35 years
St-1474, *Fucus verticulosa* 1936–1939	170 ±64 BP, –13 years
St-1517, *Zostera marina* 1900	115 ±56 BP, –50 years

According to these dates the sea correction for the Baltic area seems to be about –60 ±90 years, i. e. more or less negligible.

The sea correction for Kattegatt, Skagerak and the North Atlantic Sea seems to be about –500 to –200 years, with most dates falling within –305 ±25 years. In this paper a sea correction of –305 ±25 years are used and marked with an asterisk (*) behind the age figure.

The hard compact shells are most suitable for a C^{14} dating. Thus I prefered to use shells such as *Neptunea despecta, Balanus hammeri, Litorina, Mytilus,* etc. but avoided less compact shells such as *Saxicava* or shells with its surface enlarged by a lot of structures.

The pollen zones

In this paper K.Jessen's (1935) and/or T.Nilsson's (1961) pollen zone system are used. For comparison with my dates, T.Nilsson's (1964a) and Berglund's (1966) C^{14} dates of the pollen zones, in Skåne (Scania) and Blekinge, respectively, have to be converted back to "uncorrected" dates. The pollen zones and their ages are given in the table below (the Late Glacial chronology is closely dealt with on p. 167).

pollen zones		dates of the pollen zones		
K. Jessen 1935	T. Nilsson 1961	T. Nilsson 1964a	Berglund 1966	this paper
Ia	DR-1			10,300
Ib	BØ			9,950
Ic	DR-2		9,750	9,800
II	AL		8,600	9,000—8,950
III	DR-3	8,000	8,000	8,050—8,000
IV	PB	7,600	7,400	7,750 (7,330)
V	BO-1	6,550	6,750	6,550
VI	BO-2	6,000	6,000	5,800
VII	AT-1	4,400	4,300	4,400
	AT-2	3,150—3,100	3,150—3,100	3,100
VIII	SB-1	1,700—1,600	1,700	1,650
	SB-2	250—200 BC	250—200 BC	200—250 BC
IX	SA-1	700 AD	700 AD	700 AD
X	SA-2			

Zone boundary IV/V (PB/BO—1) is in the pollen diagrams put at the onset of the *Corylus* curve and/or rise of the *Pinus* curve. However, the immigration of *Corylus* to the Swedish West Coast is unusually early. The climatic (real) counterpart of the Preboreal/Boreal boundary in Northern Europe must be put at 7,330 BC — where the eustatic curve begins rapidly to rise, indicating a distinct amelioration of the climate (in the pollen diagrams from the Swedish West Coast the *Corylus* curve rapidly increases here) — and the Preboreal must thus be divided into at least two parts (cf. p. 403). This division of the Preboreal is obviously a counterpart of Behre's subdivision of the Preboreal (Behre 1967). The subdivision of the Preboreal and Boreal is given in the table on p. 424.

Different mechanical, chemical and physical analyses

Determination of the grain size distribution

The grain size distribution was determined in 63 samples, 35 of which are derived from the bottom of Kattegatt and are listed in Table 2 (p. 475). The

particles between 16 mm and 0.074 mm grains size were determined by screening and the particles smaller than 0.074 mm with hydrometric analysis. The particles bigger than 16 mm are given in three groups as: abundant, many and few.

Geotechnical analyses

Under this name I include the following analyses (the symbols here given are used in the figures and the text):

$H_1 = \tau_R$, shear strength of remoulded samples determined by the Swedish fall-cone test

$H_3 = \tau_K$, shear strength of undisturbed samples determined by the Swedish fall-cone test

S_t = sensitivity, the ratio $H_3:H_1$

V = water content in weight per cent of natural state

W = water content in weight per cent of dry substance

W_F = fineness number

In this way 179 levels in 10 boring points were analysed. These analyses were made of samples from buried ground crusts in the Viskan Valley and submarine ground crusts in the seabed of Kattegatt.

According to the consistency of the clays the following four main types can be distinguished:

1. A real ground crust formed by weathering of a land surface: It is hard and weathered. It contains precipitation of rust, roots in situ and vertical sand filled cracks. The H_3 value is high and the water content (W) is low compared to the fineness number (W_F).
2. A "grainy" clay (Sw: "grynlera"): This is a mixture of hard pieces of weathered clay and quite loose clay. The hard pieces of clay have distinct forms; rounded, if they have washed in littoral zone (= erosion in a ground crust, + redeposition), or angular, if they have not been washed (= maceration of a transgressed ground crust).
3. A lumpy clay (Sw: "klimplera"): The loose clays often contains somewhat harder formless lumps of clay. Von Post thought that these lumps were the remnants of transgressed and macerated ground crust. I do not use a lumpy clay as an indication of an old ground crust.
4. A loose, homogeneous clay: This is the normal consistency of clays that never have been situated above the sea level or never have been exposed for weathering processes. The H_3 and H_1 values are low and slowly increases downward. The water content (W) is high compared to the fineness number (W_F).

The presence of buried ground crusts is quite clear evidence of an old land surface that later was transgressed. The absence of a ground crust may suggest that the surface has not been situated above the sea level, but it may also depend upon local circumstances, such as the ground water, preventing formation of a ground crust above the sea level.

It has often been stated (e. g. Alin 1934, von Post † 1968) that a sand layer above a ground crust is evidence of a transgression. This may be true in some cases, in other cases a ground crust formation may have taken place below a covering sand. If a 10—20 cm thick sand layer rests upon a clay surface this is usually not enough to prevent a ground crust formation. The relation between the weathering of a clay surface and the thickness of a covering sand layer has, as far as I know, never been investigated.

Loss on ignition

In connection with the geotechnical analyses the loss on ignition was often determined. However, this test was also made in several other samples in order closely to determine the content of organic material (often befor a sample was C^{14} dated).

Determination of the mineralogical composition of clays

In order to compare the mineralogical composition of weathered and unweathered clays I had five samples of submarine ground crusts analysed at the Geotechnical Institute of Norway (p. 261). The meaning was to compare these samples with the results from a continuous series down through a ground crust in the Viskan Valley (B 695). Unfortunately this could, of economical reasons, not be realized.

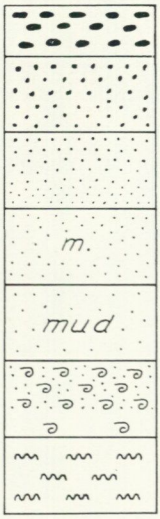
Symbols and explanations to the illustrations

In the sections and stratigraphical columns I have used a mixed system of symbols and names. The symbols employed are all given in the list. The words clayey and muddy are sometimes abbreviated to c. and m., respectively. When other symbols are used these are always specially explained in the figures or in the text to the figures.

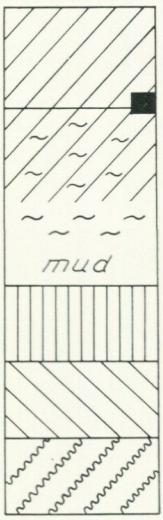
Altitudes, depths and distances are always given in metric scales. The vertical scales are referred to mean sea level (= the Swedish zero level), and + = above and − = below.

In the pollen diagrams all curves, except for QM, are drawn on the same scale.

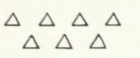
The time scales are usually given in years or thousands of years BC and refer to the C^{14} chronology.



shingel
gravel
sand
muddy sand
sandy mud
shell bank
shells
alluvial clay



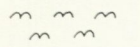
peat
C^{14} dated sample
coarse detritus mud
fine detritus mud
pitchy soil
dy
drift peat



till, moraine



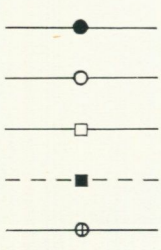
ground crust



dunes, eolian sed.



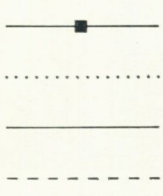
pitchy soil



Pinus
Betula
Alnus
Corylus
Salix



wood, strumps, etc.



Quercetum Mixtum (QM)
Ulmus
Quercus
Tilia

The investigation of the seabed of Kattegatt

I started the investigation of Kattegatt in 1964 in order to follow the shorelines from the transition between Late Glacial regression and Postglacial transgression (i. e. the ALV shorelines), which from the investigation in the Viskan Valley were found to intersect the present sea level at the mouth of River Viskan, out on the bottom of Kattegatt. Later, when I had found that the ice marginal lines in Kattegatt were mostly very easy to follow (much information had already been gathered) and that it was impossible to determine the Late Glacial shorelevel displacement without first knowing the deglaciation, I took up the problem of deglaciation in Kattegatt.

Material and methods

Six major expeditions were made for sampling and echo sounding in Kattegatt: with MS "Skagerak" (a research vessel of the National Swedish Board of Fisheries) in 1964, 1965 and 1966 and with MS "Sagitta" (research vessel of the Swedish National Science Research Council) in 1965, 1966 and 1967. Furthermore samples were taken (B 702—705) from a trawler from Bönnerup, an echo diagram was made from the Grenå—Varberg ferry and minor points were investigated with echo soundings and diving in Skälderviken and outside Torekov. Fishermen from Bönnerup, Hals, Frederikshav, Laesö, Anholt, Dragör, Glomma and Torekov were interviewed about their knowledge of the bottom of Kattegatt (checked by borings, dredgings and echo soundings and found generally to be extremely reliable).

The position was always closely determined with a Decca navigator.

The echo sounded lines and the sampling sites are marked on the map, Fig. 1. The names mentioned in the text, the topography, ice marginal lines and geology of Kattegatt are given in the map, Pl. 1.

"Skagerak" has a Kelvin Huges echo sounder and "Sagitta" an Atlas echo sounder. An Elac echo sounder was put in a portable "fish" and used in shallow water in Skälderviken. These echo sounders have a frequency (30 Kc), which unfortunately gives little or no penetration of the sediments. However, the main features of the bottom can still be studied with these echo sounders: rock, till and glacifluvium, dune sand, silt, loose clay, etc. give different bottom lines (e. g. Figs. 17, 18, 22 and 109). Terminal moraines and shore features can be mapped. But of course the echo sounding must be supplemented with sampling. An echo sounder with a frequency of 5—10 Kc would have given a very suitable penetration for this investigation. I have tried, but unfortunately not yet succeeded, to get the necessary money. This is a pity, as I now only know the material at the surface

of the bottom. And this is the weak point in my mapping of terminal moraines in Kattegatt, at least along the Swedish side, where Archaean rock is to be expected.

Along the Swedish West Coast the fundamental charts in the scale 1:20,000 (upon which the published nautical charts are based) were used for studies of the seabed (by permission of the National Swedish Board of Shipping and Navigation).

The sampling of the seabed was made in the following ways. Of totally 300 samples, 242 were taken with a piston corer (Kullenberg 1947) and 58 with different dredgers (usually a pipe dredger, in some cases a clamshall bucket and in a few cases an ordinary dredger). The most useful length of the piston corer turned out to be 3 m, so this length was used in most cases (199), but 1 m, 5 m and 7 m length were also used. The samples of the seabed of Kattegatt are all listed in Table 4.

The dredgings only give samples of the surface. The pipe dredger (a pipe 1 m long and 30 cm in diameter, with a perforated bottom plate) is specially useful as it gives a much more powerful scraping effect, which means that even pieces of outcropping rock can be torn away.

The sampling with the piston corer is worth a closer description, as there are several possible sources of error connected with this corer. The principle of the piston corer is a falling heavy corer which penetrates the sediments while a piston prevents compaction and stops the sample from falling out. It has earlier been pointed out that minor loose layers can be pressed away by a piston corer (Kallstenius 1963, p. 123). In the sediments of Kattegatt this source of error is of little or no importance. Of very great importance on the other hand are two other sources of error here described:

1. *Sucking by a corer falling over:* On hard bottoms where the corer is not able to penetrate down into the sediments, or only penetrates so little that it cannot remain standing, it falls over. As the piston during this fall is pulled to the upper end of the corer, sediments in front of the head are sucked into the corer. By this sucking the sediments are graded from coarser at the bottom to finer at the top. In this way a full corer may in reality only represent a sample of the surface. In the literature there occur several statements of long cores of sandy sediments. Apparently they only correspond to surface samples and the gradation is due to the sucking. In coarse silt there is almost no penetration, unless this layer does not rest upon loose layers — 20 cm is the thickest layer I have penetrated in Kattegatt. Very often I received quite full cores of sandy sediments. However, this was always due to sucking by a corer falling over. If the piston was taken away no sample at all was obtained. In other cores surface sand was sucked in below thin parts of older sediments (e. g. hard Late Glacial or glacial clay). If the corer falls over, there is a second pull in the wire. Thus this source of error can easily be avoided, if one watches carefully.

2. *The vacuum effect:* If the corer only penetrates a little into a hard clay but reamins standing a vacuum is created in the corer when the hoisting up starts and the piston is pulled to the upper end. When the corer is then hoisted up through the sediments, loose layers are sucked by the vacuum into the corer. As I have taken many samples of buried ground crusts, this source of error has often given surprising results. In Laholmsbukten where the old ground crust is covered by loose mud, dy and peat, I often got muddy-dyey sediments also below the hard, weathered Late Glacial clay. Several borings in the same area, pollen analyses and C^{14} datings have clearly shown that the organic layers below the clay are sucked in from the layers above the clay. In B 290 a living species of *Buccinum* sp. was found below 35 cm of hard glacial clay (furthermore the clay was sucked to the uppermoast end of the corer). This source of error is very hard to avoid. Often it can only be detected by datings. B 292 is a good example: not until the pollen analyses were made did I realise that the loose clay below the hard glacial clay really was sucked in from above.

The grain size distribution was determined in 35 samples of the seabed (screening + hydrometric analysis). They are all listed in Table 2 (p. 475).

The petrographical composition was closely determined in B 657, while other samples have as yet only been preliminarily analysed.

In order to show the weathering of the submarine ground crusts, which were found at several places in Kattegatt, geotechnical analyses (H_3, H_1, V, W, W_F and loss on ignition were made in 8 boring points (B 500, B 501, B 502, B 504, B 630, B 633, B 634 and B 635). Five clay samples of submarine ground crusts were mineralogically analysed.

Pollen analysis was made of samples from 23 different boring points in Kattegatt. C^{14} datings were made of 15 submarine samples.

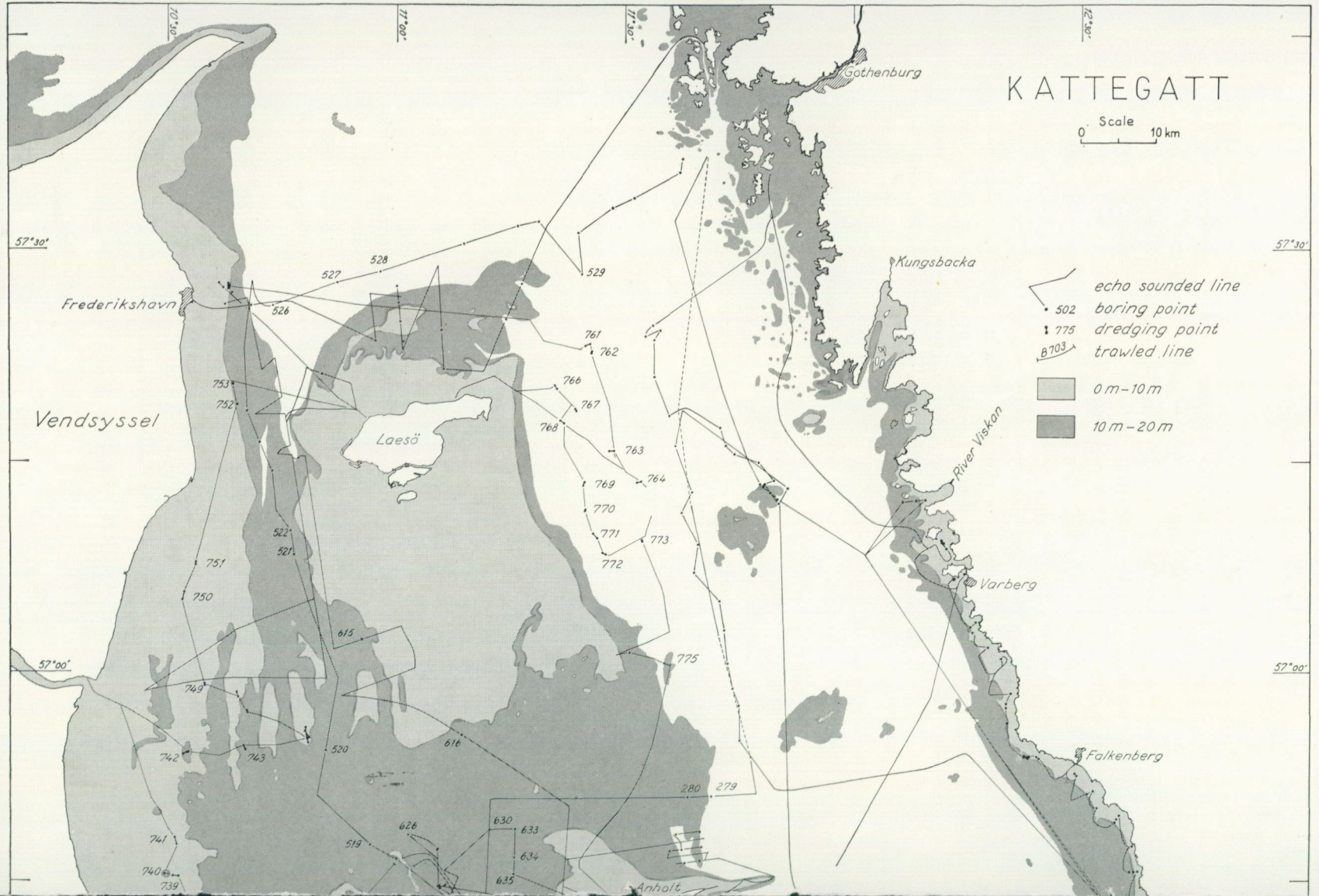
Topography and soil regions

Concerning the topography and bottom conditions (Pl. 1), Kattegatt can be divided into four main regions (Fig. 2).

I: *The eastern clay-rock (-drift) area:* This area is characterized by thick layers of Late Glacial and Postglacial clays, broken through by steep peaks of Archaean rock, i. e. monadnocks. Large accumulations of drift occur arranged along lines in NW-SE direction. It is not known to what extent sedimentary rocks occur (cf. below).

II: *The southwestern silt-till area:* The area is characterized by flat silty areas and shoals of moraine arranged in curves from NE-E (in the Store Belt area with other directions).

III: *The western "mo"-till area:* This area is characterized by till and, from the till outwashed, "mo", fine sand (in the more shallow parts) as well as coarse


KATTEGATT
Scale
0
10 km
Gothenburg
Kungsbacka
Varberg
Falkenberg
Frederikshavn
Vendsyssel
Laesö
River Viskan
Anholt
10°30'
11°00'
11°30'
12°30'
57°30'
57°00'
echo sounded line
502 boring point
775 dredging point
B703 trawled line
0 m–10 m
10 m–20 m
528
527
529
526
761
762
753
752
766
767
768
763
769
764
770
771
773
772
522
521
751
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740
739
635

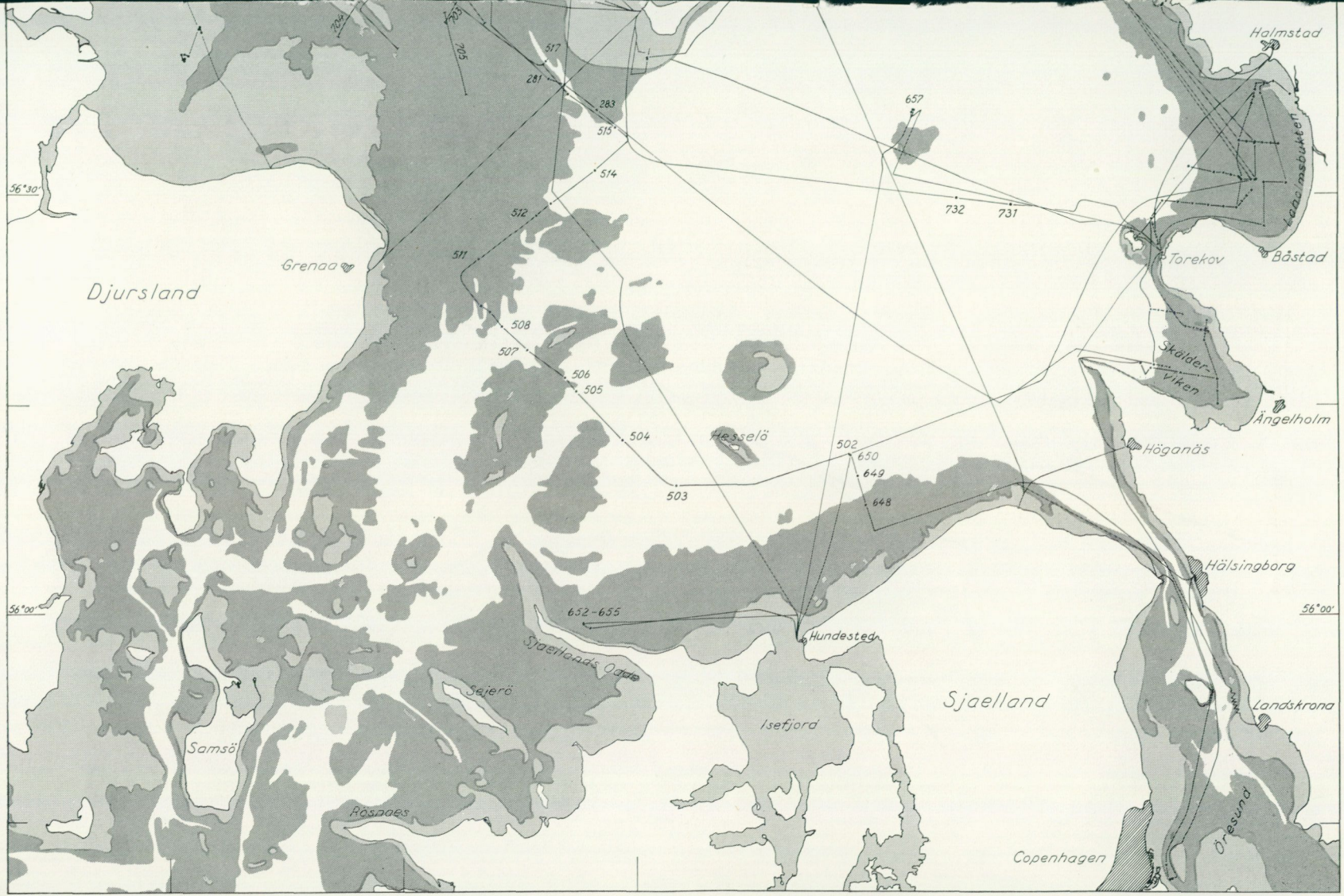


Fig. 1. *Areas in Kattegatt investigated by echo sounding (lines) and sampling of the seabed (black dots).*

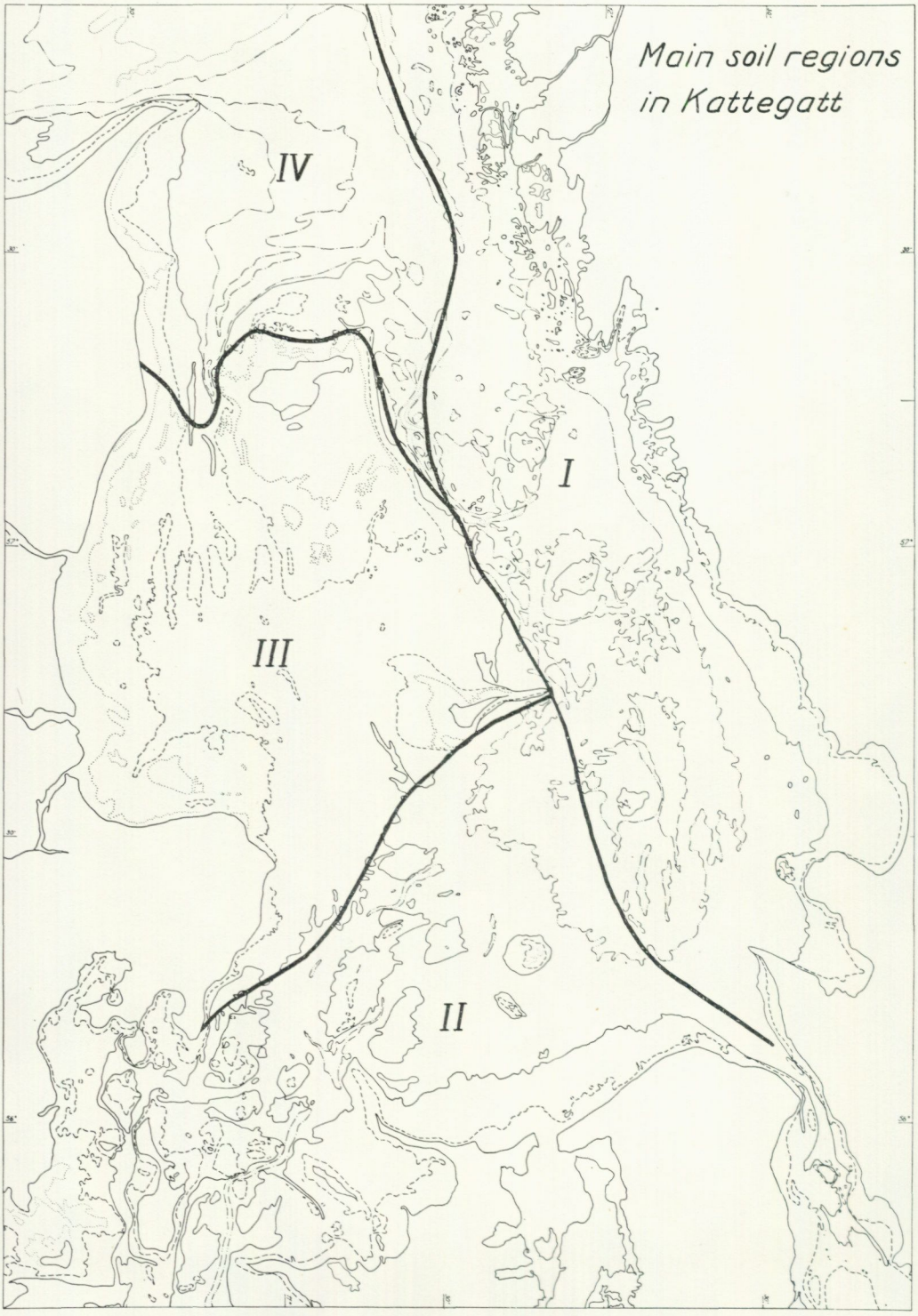


Fig. 2. *According to the bottom conditions (Pl. 1) Kattegatt can be divided into four main soil regions. Scale 1:1250000.*

silt (in the deeper parts). Along the coasts submarine dune ridges are common. As the area was dry land in early Postglacial time peat occurs at several places (Pl. 7). The Quaternary deposits are very thick in this area and apparently are not only derived from the last deglaciation (p. 37).

IV: *The northeastern silt-clay-moraine area:* This area is characterized by large flat areas of clay (in east) and silt (in west), broken through by shoals of moraine.

A more detailed picture of the bottom surface is given in a special geological map, Pl. 1, which was based upon information from borings, dredgings and echo soundings, supplemented by informations from interviews with fishermen and from the bottom conditions marked on the nautical charts.

Grain size, sedimentation and facies

The grain size of the till is as a rule coarser on the Swedish side (gravelly sandy till) and finer on the Danish side (sandy clayey till). This has to do with the fact that the ice, coming from the Archaean rocks of the Swedish West Coast, in the middle of Kattegatt passed out over older drift and probably also sedimentary rocks. This is also shown by the presence of double maxima in the grain size distribution curves of samples from middle and western Kattegatt (e. g. B 769 with one maximum in the sand fraction and one in the pebble fraction).

The glacial clay is deposited under the influence of the melting ice. It is of two main types: 1) varved or semivarved (diatact or semidiatact) clay, where varves or at least traces of varves are seen, and 2) unvarved (symmict) clay, containing sand, silt and often stones dropped from icebergs, and having a pinkish-brownish colour. The varves do not always correspond to one year, but often to minor units such as sunny days or days and nights. In Vendsyssel there occur partly varved to semivarved *Yoldia* clay not containing shells, and partly unvarved *Yoldia* clay containing shells, which are said to be quite synchronous and merely deposited under different geophysical conditions (A. Jessen 1936, p. 105). On the Swedish West Coast NW of Halmstad the glacial clay is mostly unvarved and does not allow any varve chronology, but in some places varved to semivarved clay occurs (Caldenius 1951, Asklund 1935). In Skälderviken and Laholmsbukten varved clay occurs with annual varves (Fig. 88). This clay was found down to –20 m (B 150) in Laholmsbukten. In the middle of Kattegatt, glacial clay was not found.

The Late Glacial clay is deposited as a normal marine clay. It is characterized by its light grey to bluish grey colour (also in the sandy-silty facies). On the Swedish West Coast the farmers have given it the expressive name blue-clay, a name that I have used in this paper. The blue-clay is often silty and contains FeS and shells. On the Swedish West Coast it is very thick (up to several tens of

meters). In Laholmsbukten (48 borings) at −10—20 m it is not more than 1 m thick. At Torekov at ±0 m (B 674) it was only 1—2 dm tick and at +5 m (B 695) about 0.5 m thick, though now in another facies, viz. bluish-grey silty sand to sandy silt. In Skälderviken (25 borings) it was not found. West of Anholt the facies is silty clay and the thickness at least more than 0.4 m (B 630—635). It was probably found at Höganäs (p. 354) at +3.8 m as a silty clay. On the Danish side of Öresund it is said to be absent and instead the clay there is classed as lacustrine Dryas clay. However, the marine Late Glacial clay apparently occurs, at least in some places, e. g. in Nivaa at −1.75 m (K. Jessen 1920) and in Rungsted at −4.7 m (K. Jessen 1923). Outside Sjaellands Odde at about −15 m (B 651—655) the facies is clayey silt to sandy silt and the thickness is at least more than 0.4 m. Outside Northern Sjaelland the facies is sandy clayey silt to sandy silt and the thickness at least 1.5 m (B 502, 504, 649 and 650). It is evident that the blue-clay and its equivalents in other facies on the whole have the following distribution from NE towards SW: thick clay — less thick silty clay — thin clayey silt — very thin sandy silt. A change in facies can of course also be seen vertically with finer sediments at low altitude and coarser sediments at higher altitude or towards the extremities of the river valleys. These changes in facies mainly depend upon the tilting of the Late Glacial shorelines and the discharge of loaded river water. As the direction of tilting is NE-SW, there was deep water in NE when it was shallow water or even land in SW.

The isostatically caused regression brought the shorelevel to low altitudes in the late Late Glacial and early Postglacial. During the lowest shorelevel (ALV-1) at the transition between Late Glacial regression and Postglacial transgression, large areas of Kattegatt were dry land. Shore marks, weathered land surfaces, peat layers and shore deposits were found from this time (dealt with in detail in connection with the shorelevel displacement).

From the Late Glacial/Postglacial boundary the finer sediments contain mud. However, this is seldom seen until the Postglacial transgression, as the early Postglacial shorelevel is mostly marked by a hiatus or shore deposits. In the inner parts of the Postglacial sea fiords on the Swedish West Coast *Ruppia* mud (i. e. mud containing macroscopic fruits of *Ruppia maritima*) was deposited. In the outer parts a clayey mud with shells was deposited. Still further out a muddy clay was deposited. The change in facies is evident. In SW Kattegatt, main area II, a clayey muddy silt of 1—2 m thickness is the characteristic Postglacial sediment. In the shallow main area III, the characterestic Postglacial sediments are partly a pure fine sand (in more shallow parts) and partly a muddy coarse silt (in deeper parts), usually of small thickness (some dm). In main area IV the typical Postglacial sediment is a somewhat muddy silty clay to clayey silt of great thickness (more than 3—5 m) and with shells of *Turritella tenebra* as a characteristic fossil indicating a high Postglacial temperature of the

sea water. In Laholmsbukten a greyish-brownish silty muddy clay to clayey mud was deposited. In Skälderviken there is a grey somewhat muddy and silty clay. In the deeper parts in the middle of Kattegatt, main area I, a very loose somewhat muddy silty clay was deposited. Outside the Swedish West Coast, where several big rivers debouche, the Postglacial sediments are usually evenly sloping downwards into the deeper parts, where a steeper slope is seen, giving a deltaic picture (e. g. Fig. 3).

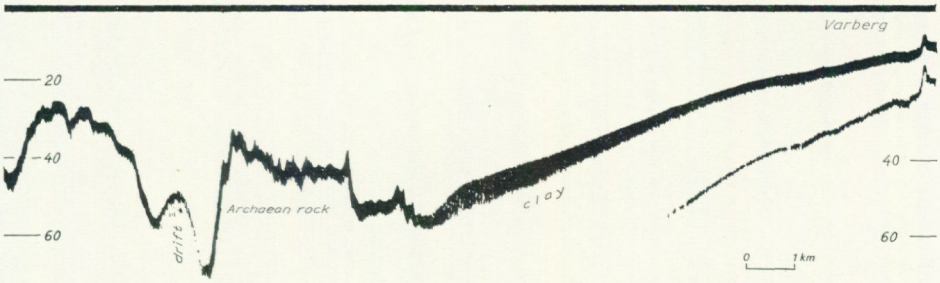


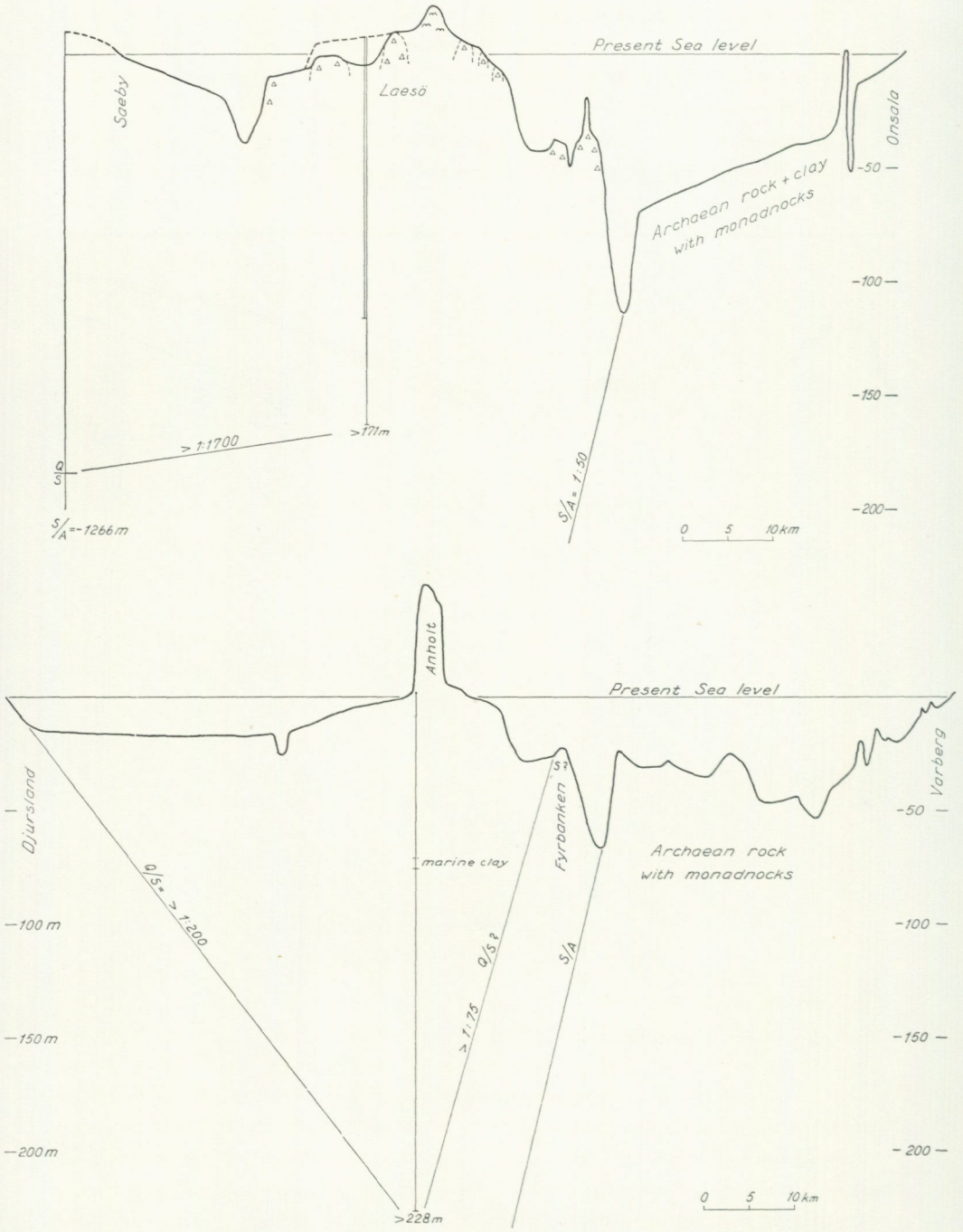
Fig. 3. *Echo diagram of the area between Anholt and Varberg.*

The distribution of the sediments is interesting, especially in the hilly topography of main area I. The tops of the shoals are almost never covered by younger sediments, either Late Glacial or Postglacial. Instead I usually found a more or less unwashed till, at the surface containing arctic as well as recent shells. This is important as it means that we have to give up the classical view of the uplifted seabeds, for example in Bohuslän, where clay layers are said originally to have covered the hills as well as the valley floors, but where the clay on the tops of the hills later were eroded away and redeposited in the valleys. Between the shoals there seem to be very thick layers of clay. In the deep channels the bottom is often hard (e. g. Fig. 14) and does not contain any young clays, which should be due to the strong bottom currents that follow the deep channels and keep them more or less clean.

Recent changes of the sedimentation due to pollution (p. 270) and tipping of dredge material have also been observed, but will not be described here.

General geological structure

Kattgatt is a shallow marine continuation of the Atlantic Ocean. On the Swedish side we have the Archaean rocks which dip down towards SW into the Danish-Polish Geosyncline, which has a NW—SE direction. On the Danish side we have sedimantary rocks, often buried under a very thick Quarternary. Two sections (Figs. 4 and 5) have been drawn, based upon the facts from the echo soundings and bottom samples and the stratigraphy in some deep drillings in Denmark (Danmarks Geologiske Undersögelse).



Figs. 4 and 5. *Principal sections across Kattegatt showing the general geological structure.* Q = *Quaternary deposits,* S = *sedimentary rocks,* A = *Archaean rock (bedrock).*

The Vendsyssel—Laesö—Onsala line (Fig. 4) shows the following:

1. The Archaean rocks dip from Onsala, with some monadnocks in eastern Kattegatt, with a gradient of 1:50 to –1,266 m in Vendsyssel, where the Archaean rock was found in a drilling near Frederikshavn.
2. The sedimentary rocks were found 291 m down in Vendsyssel and do not seem to occur in eastern Kattegatt (unless the layers do not form a syncline).
3. The Quaternary is very thick in Vendsyssel (291 m) and at least more than 171 m thick on Laesö. It apparently forms the submarine cliff between Anholt and Laesö, which gives the position of the ice margin during the Anholt Stadial (cf. p. 37).

The Djursland—Anholt—Varberg line (Fig. 5) shows the following:

1. The Archaean rocks dipping down towards SW. The gradient cannot be fixed here. It is at least steeper than 1:120, and may roughly be the same as in the northern line.
2. The Cretaceous (Danian) chalk is in the surface on Djursland, dips down towards NE to at least below 229 m on Anholt and probably rises again and outcrops in Fyrbanken (as it does in St. Meddelgrund further towards SE, which would have roughly the same position in the section). This gives a picture of a syncline.
3. The Quaternary is at least 228.8 m thick on Anholt and formed not only during the last deglaciation but also as ice marginal deposits during the Anholt Stadial of Lower Pleniglacial age (cf. p. 37).

Do sedimentary rocks occur in eastern Kattegatt?

In view of the occurrence of flint on the Swedish West Coast, Wieman (1873) pointed out that outcropping Cretaceous limestone was very probably present at the bottom of Kattegatt. The present investigation has brought forward some interesting facts concerning this question.

The till from shoals east of the Anholt—Laesö line as well as west of this line contains flints, not many, but almost always some. As the ice streams here came from NE, it suggests the presence of sedimentary rocks east of the Anholt—Laesö line. No outcropping sedimentary rock has yet been found in this area. However, the flints may also have been dropped from floating ice (icebergs or younger winter ice). On Anholt (B 779) the boulder clay which probably was deposited from NE, E or SE, is very rich in flint and chalk, indicating outcropping sedimentary rock somewhere east of Anholt. Flints seem to occur in practically the whole of central Kattegatt — but amount only to a few percent. On three shoals the picture is quite different and flint occurs in such masses that it is quite predominating. These shoals are Fyrbanken, Rödebank and

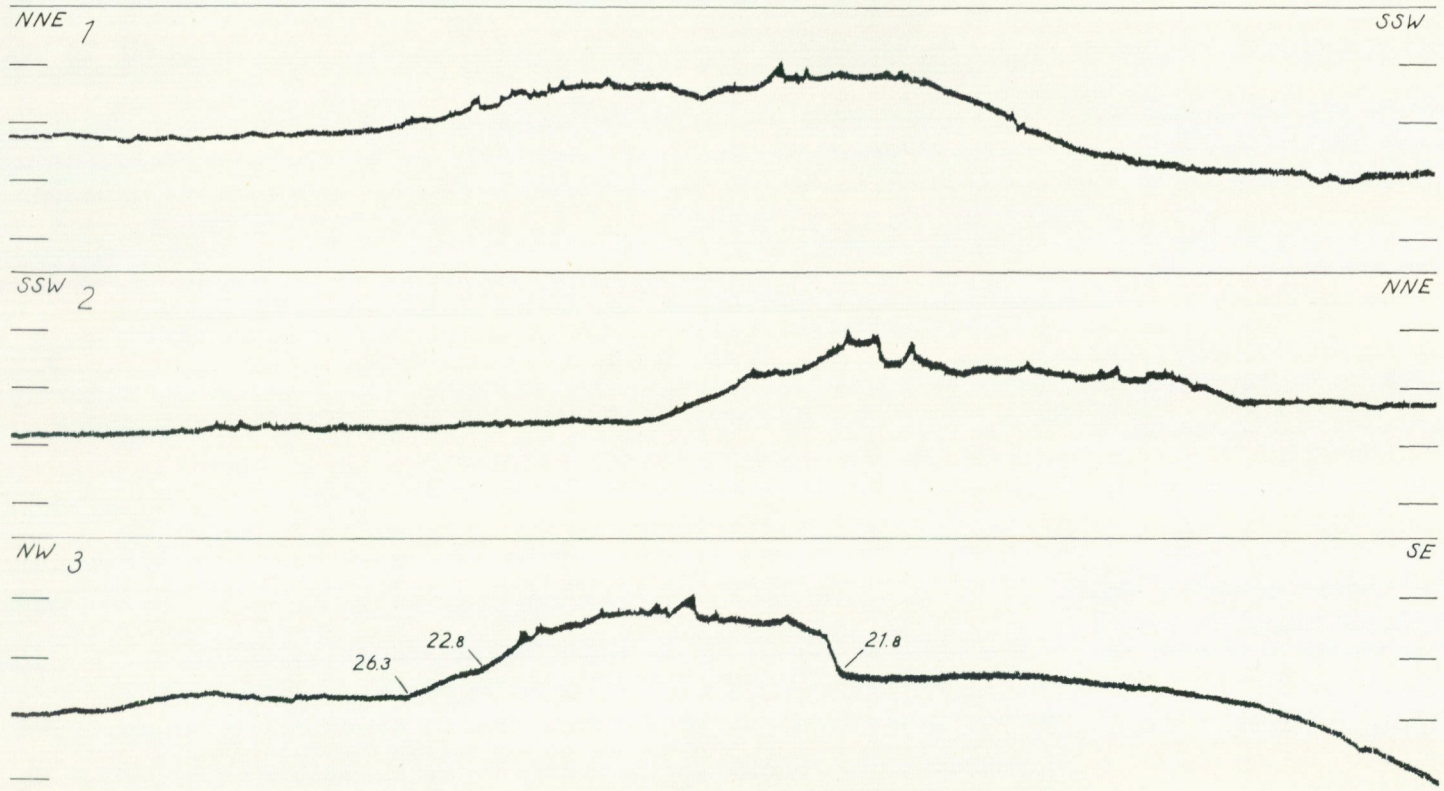


Fig. 6. *Echo diagrams across the shoal Store (St.) Middelgrund. The central part is rough (=rock and/or drift), while the surrounding area is flat and probably made up by sedimentary rocks. During ALV-1 the sea level was at about -26.3 m. Vertical scale gives depth in tens of meters. Horizontal scale: 1.7 cm = 1 km.*

St. Middelgrund. Fyrbanken and Rödebank have not yet been investigated. The information comes from the fishermen, whom there is no reason to disbelieve (they were checked on known localities). The shoal St. Middelgrund was crossed, echo sounding, four times (Fig. 6). The central part is steep and rough and gives the impression of Archaean rock. The surrounding area is a flat plateau at about –20 m, which according to the echo sounder may consist of sedimentary rock. Here an interesting sample (B 657) was taken with the pipe dredger. The following petrographical composition was found of the 177 classified pebbles and stones greater than 16 mm (cf. p. 274):

104 flints, without traces of transportation.
63 pieces of Archaean rocks from the Swedish West Coast, all more or less rounded.
3 pieces of chalk of the type from Saltholmen, without traces of transportation. One piece (now oxidized) was on board found to have a fresh fracture surface.
3 pieces of coal (probably belonging to the Triassic or Jurassic).
3 pieces of sandstone (probably Cambrian).

The pieces of Archaean rocks come to 100 % from the Swedish West Coast (cf. the map by W. Larsson in Caldenius *et al.* 1966) and are distributed to the following groups: 36 intermediate gneiss, 10 grey gneiss, 7 diorite, 5 diabase, 3 red gneiss rich in microcline, 3 basic coarse-crystalline gneiss. The only simple explanation is that we have here outcropping Cretaceous chalk — possibly with a horst of Archaean rock in the centre, as a continuation of the big horsts in Skåne. By mechanical erosion during the low shorelevel of ALV-1 and chemical solution of the chalk by the sea the flints were concentrated. The stones of Archaean rocks are good evidence of the ice streams from NE. Concerning the old explanations of the distribution of flints as having dropped from floating ice, it is here quite out of the question that three shoals had been peppered with flints while only a few flints were dropped in the other areas.

Between St. Middelgrund and Torekov there are some very flat shoals (in the 30 m contour), covered by fine gravel and sand (B 730). They were crossed thrice with the echo sounder and gave the impression of sedimentary rock (Fig. 96, no. 3—4) — possibly a continuation of the Cambrian sandstone in the Torekov area.

The answer to the question is: sedimentary rocks occur at least in St. Middelgrund and probably also in Fyrbanken and Rödebank and other areas east of Anholt.

The submarine cliff between Anholt and Laesö is described below. It is made up of drift and not of sedimentary rocks as has sometimes been proposed.

The formation of the deep channels in Kattegatt

The bottom of Kattegatt is traversed by a system of submarine channels (Fig. 7). These channels come together as branches in a tree and debouche via the deep channel, Djupa Rännan, outside Gothenburg into the Norwegian Channel,



Fig. 7. *Kattegatt is traversed by a system of submarine channels, forming the continuations of river valleys on the Swedish West Coast.*

which has a depth of 500—700 m. In the middle of Kattegatt the channels are seen, in the echo sounded profiles, to have been eroded down into Archaean rock. Furthermore, the channels seem to be connected with the river valleys on the Swedish West Coast. It has been shown that the floors of these valleys lie deep below the present sea level: at Gothenburg −100—80 m, in the Viskan Valley at least −60 m and in Halmstad −55 m. Evidently, several of the submarine channels are continuations of these valleys. Furthermore these channels or valleys are eroded down into the bedrock. With this information we may make an assumption about the formation: fluvial erosion following older tectonic lines during earlier geological periods with low water level. The first erosion may have occurred in Late Paleozoic, which was a land period in Scandinavia with low sea level. The final erosion may have occurred in the Pliocene, when the sea level in Kattegatt seems to have been low, and sediments were only deposited in the very SW end of Jylland. During this time the Mesozoic rocks, which ought to have been deposited in the channels, could be more or less eroded away.

This suggests that the Pliocene shoreline is tilted from SW to NE, i. e. in a quite opposite direction to the Late Quaternary ones. This indicates that the Pre-Quaternary equilibrium in the earth's crust is not yet restored.

The late Tertiary regression seen in Denmark is probably a result partly of the upheaval of the Danish-Polish Geosyncline and partly of the late Tertiary eustatic fall of sea level, recently discussed at the "Tertiary Sea Level Syposium" in 1967 (Tanner *et al.* 1968).

The channels in Öresund, Store Belt, Lille Belt and SW Kattegatt belong to the same system and are probably (at least originally) formed by the same processes. The bottoms of these channels lie too deep to have been formed by Late Glacial and/or Postglacial fluvial erosion (though such erosion has taken place in the more shallow parts).

Most of these channels are now kept clean by strong bottom currents (while a few are buried).

The Weichselian glaciation before 20,000 BP

With the coming of the radiocarbon method a new dimension has entered the study of the last glaciation. The Last glaciation — Würm, Weichsel or Wisconsin — is now split up into several larger and smaller stadials and interstadials. Now events not only can, but also must, be compared over large areas, e. g. between Europe and North America. In Fig. 8 some recent curves of the last glaciation have been compared.

The earliest part of the Weichselian glaciation is very well known thanks to thorough vegetational investigations by S. Th. Andersen (1961) in Denmark. In the Netherlands, Zagwijn (1961) found a quite similar development. With C^{14} datings this part has also been well dated. The climatic curves of Denmark and the Netherlands (Andersen, deVries and Zagwijn 1960) are given to the left in Fig. 8. Two distinct Early Weichselian interstadials were found, viz. the Amersfoort (Rodebaek) Interstadial at about 64,000 BP and the Brörup Interstadial at about 58,000 BP.

J. Lundqvist (1967) has shown that the county of Jämtland in western Central Sweden (and thus probably the whole of Sweden) was deglaciated during the Brörup Interstadial and that a subarctic climate, dominated by glacial sediments, occurred and that the sea level was low compared to the Late Glacial one.

Gross (1964) gives a climatic curve of Middle Europe (the third in Fig. 8) and a subdivision of the Würmian glaciation. The Mittelwürm he now terms the "Würmian interpleniglacial" (about 50,000—30,000 BP) instead of his older "Göttweiger Interstadial complex" (e. g. Gross 1960).

Out of the study of loess profiles Musil and Valloch (1966) introduce an interstadial, the Podhraden Interstadial, at about 33,000—38,000 BP.

In England NE of Birmingham (at the periphery of the maximum of the last glaciation) Coope and Sands (1966) found a long interstadial, the Upton Warren Interstadial complex, at about 50,000—23,000 BP (the fourth curve in Fig. 8). The insect faunas suggest a colder (mean annual temperatures about 11.5° C lower) and more continental climate than today.

The best determined and most up-to-date climatic curve of the last glaciation has been given by van der Hammen *et al.* (1967) from the Netherlands (the fifth curve in Fig. 8). It is based upon clear stratigraphical and vegetational evidence. Between the polar desert of the Lower and Upper Pleniglacial, they found in the Interpleniglacial two interstadials with a shrub tundra vegetation, viz. the Hengelo Interstadial at about 39,000—37,000 BP and the Denekamp Interstadial at about 32,000—29,000 BP. Vogel and van der Hammen (1967) have shown that the Paudorf Interstadial from the loess regions of Europe does not end at 25,000 BP as originally stated by de Vries (1958), but between 29,000 and 28,000 BP, i. e. exactly at the same time as the Denekamp Interstadial ends.

They also make it possible that the Paudorf soil may correspond to the whole Interpleniglacial, though this is not yet proved with C^{14} dates.

It is of great importance that the deep sea cores often show curves quite similar to the one from the Netherlands, e. g. the distribution of $CaCO_3$ in the North Atlantic core 280 described by Olausson (1960).

From North America the most detailed and up-to-date picture of the Wisconsin Glaciation (the sixth curve in Fig. 8) has been given by Dreimanis, Terasmae and McKenzie (1966, also Dreimanis and Vogel 1965). The similarity to the European curves is striking (cf. Gross 1967). The Wisconsin Glaciation is devided into Early Wisconsin, Mid-Wisconsin or the Port Talbot Interstadial complex at about 50,000—24,000 BP and Main (Classic) or Late Wisconsin. The Port Talbot Interstadial complex contains Port Talbot I and Port Talbot II Interstadials and the Plum Point Interval. In Early Wisconsin there is the distinct St. Pierre Interstadial at about 66,000 BP, which corresponds to a somewhat cooler climate than today (Gadd 1960) with a low sea level compared to the Late Glacial one. From Illinois and Wisconsin States a fairly similar glaciation curve is described (Frye, Willman and Black 1965). The Olympia Interglaciation in the Washington State area, which separates the Salmon Springs Glaciation from the Fraser Glaciation, has recently by a sequence of C^{14} dates of nonglacial deposits in British Columbia been determined to date from at least 43,800 ± 800 BP to after 25,840 ±320 BP and 20,230 ±270 BP (Fulton 1968). This means that this interstadial (not interglacial) fully corresponds to the Interpleniglacial in the Netherlands.

The last column in Fig. 8 gives the curve for Kattegatt and surrounding areas. It requires a closer examination.

The distribution of the Quaternary deposits in Kattegatt gives a very interesting picture. In the area Vendsyssel—Laesö—Anholt—Djursland there are very thick morainic sediments (cf. p. 31, Figs. 4 and 5), that must be older than the Late Weichselian (Upper Pleniglacial) glacial maximum. The surrounding areas of Kattegatt are much deeper and mainly contain Late Glacial deposits. This means that the Laesö—Anholt—Djursland line most propably marks the position of an old ice margin (Fig. 9). I think this position was reached during the Lower Pleniglacial in the Netherlands after the Brörup Interstadial by a Baltic ice stream, the Old Baltic ice stream, and an ice stream from the Swedish West Coast (the position of the Norwegian ice is not known). In Germany this position of the ice margin may be seen in the overridden Stettiner line (e. g. Woldstedt 1958) and in southern Jylland by the line mapped by Ödum (1927) outside the C line (cf. S. A. Andersen 1966).

The classical boring at Skaerumhede, west of Frederikshavn (A. Jessen *et al.* 1910), gives a very important stratigraphy. The surface is at +23.2 m.

A: To 57.4 m glacifluvial clay, sand and gravel (containing redeposited plants and shells) = the Upper Pleniglacial (of the Netherlands).

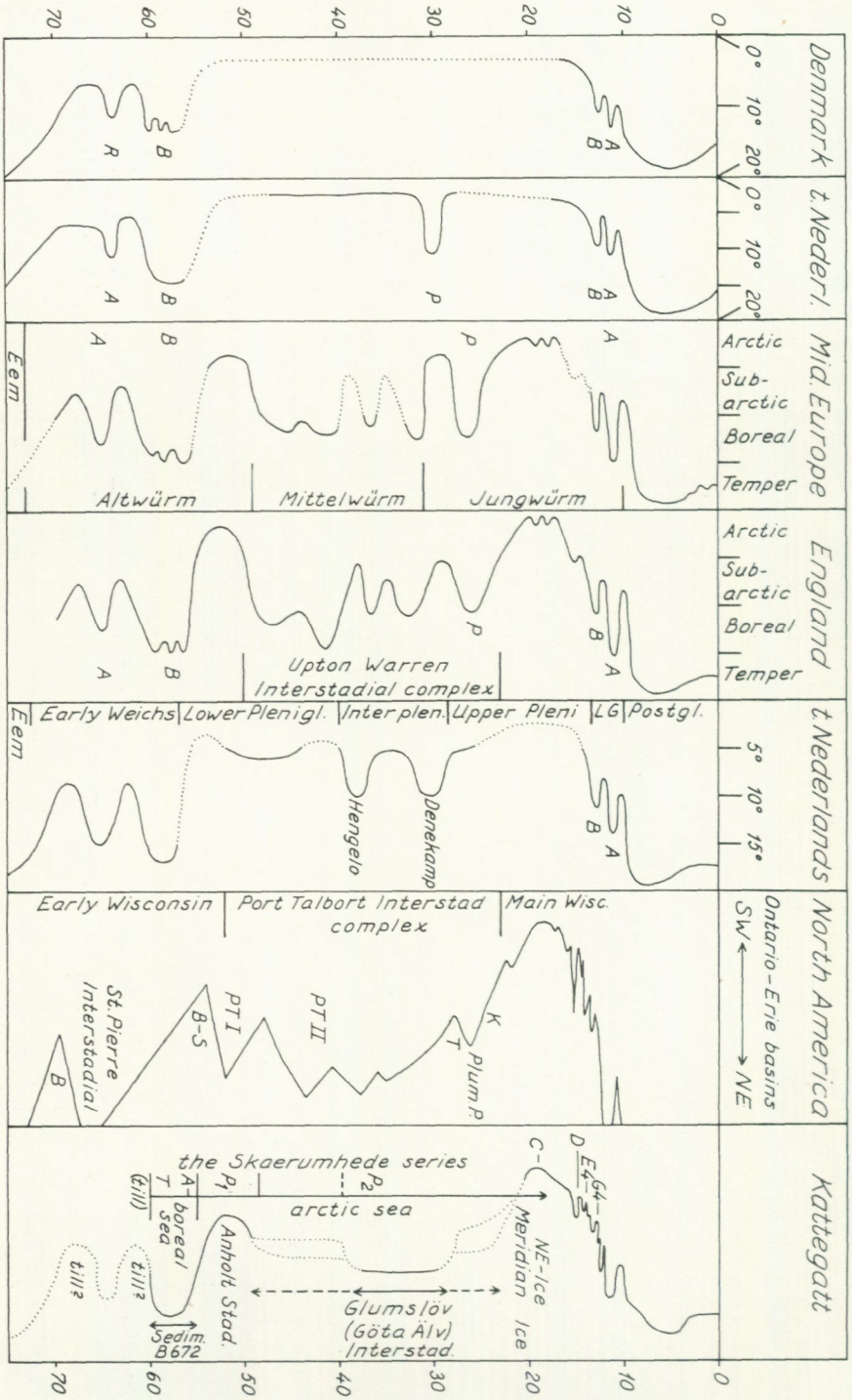


Fig. 8. *Different glaciation curves for the Würm Glacial Age. Time scale in thousands of years BP. The capital lettres refer to names of interstadials and stadials.*

B1: To 74.4 m glacio-marine clay (Older Yoldia clay) containing arctic shells and arctic-subarctic plants (*Betula nana, Salix polaris, Salix herbacea,* etc). = open sea during the Interpleniglacial (of the Netherlands).

B2: To 97.9 m glacio-marine clay with sand, gravel and pebbles, and containing arctic shells = sea (with icebergs) close to the ice margin during the Lower Pleniglacial (of the Netherlands).

C: To 106.4 m clay, the *Abra nitida* zones, containing a boreo-arctic shell fauna = the transition between the Brörup Interstadial and the Lower Pleniglacial (of the Netherlands).

D: To 180.3 m loose clay, the *Turritella tenebra* zone, containing a boreal shell fauna that Nordmann (in A.Jessen *et al.* 1910) compares with the present one outside West Norway and Lofoten = the Brörup Interstadial.

E: To 199.8 m Baltic till and glacifluvium = unknown glaciation, "Pre-Brörup till".

According to the minimum depth of the molluscs Nordmann (op. cit.) thought that the fauna of the *Turritella tenebra* zone showed a transgression, followed by a regression in the *Abra nitida* zone. According to his figures the sea level should have been about 30—50 m below the present one during the Brörup Interstadial.

The boring on Anholt (p. 31, Fig. 5) shows roughly the following stratigraphy:

A: To 72.7 m (= –70 m) an upper drift series = the Upper Pliniglacial (of the Netherlands).

B: To 77.2 m (i. e. 4.5 m thick) marine clay = layer B1 in the Skaerumhede series and the Interpleniglacial of the Netherlands.

C: To 228.8 m a lower drift series = the ice marginal deposits of the Lower Pleniglacial (of the Netherlands).

In Skåne, Southern Sweden, the existence has long been known of an old ice stream, the Old Baltic ice stream. Glacial striae and till from this are seen in many places in Skåne (e. g. Wennberg 1949). I think the Old Baltic ice stream belongs to the Lower Pleniglacial in the Netherlands, and reached to the distinct Djursland—Anholt line, where it joined an ice stream from the Swedish West Coast, that had its margin along the very distinct Anholt—Laesö line (Fig. 9). The position of the Norwegian ice is not known — it may have reached to Hirtshals—Frederikshavn—Laesö (but not to Skaerumhede). According to Wennberg (1949) the Old Baltic ice stream is separated from the younger ice streams by an interstadial, which I correlate with the Interpleniglacial in the Netherlands.

From borings in the Alnarp Valley in Skåne, K. Nilsson (1968) found three separate till beds at Tofthög. I find the following interpretation likely:

A: Till = the Upper Pleniglacial (of the Netherlands).

B: sediments = the Interpleniglacial of the Netherlands.

C: Till (characterized by Eocene diatoms) = the Old Baltic till of the Lower pleniglacial (of the Netherlands).

D: Sediments = the Brörup Interstadial.

E: Till (25 m thick, unique in Skåne) = Early Weichselian glaciation, "Pre-Brörup till".

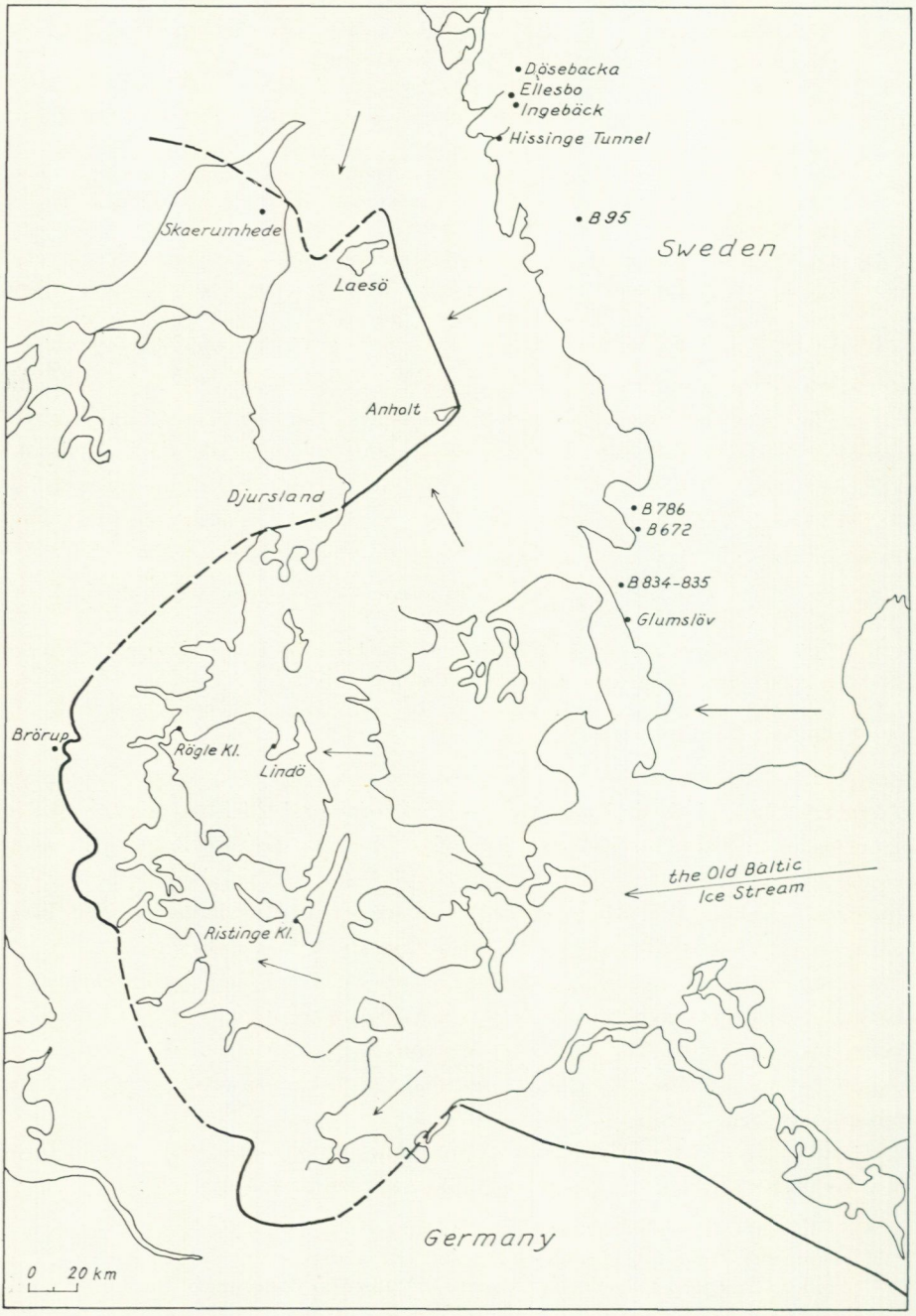


Fig. 9. *Supposed position of the ice margin during the Anholt Stadial at about 50,000—54,000 BP. It was preceded by the Brörup (Skaerumhede) Interstadial and followed by the Glumslöv Interstadial.*

From J. Lundqvist's (1967) investigation in Jämtland we know that probably the whole of Sweden was deglaciated during the Brörup Interstadial (p. 36). In Skåne this interstadial is represented by sediments below the Old Baltic till (and the dy in B 672, cf. below). In Kattegatt it is represented by the clay with a boreal mollusc fauna, the *Turritella tenebra* zone. This clay has a wide distribution according to Ödum (1933) and can be followed across Sjaelland and Mön to Rügen.

A new locality with redeposited shells of the Skaerumhede series can here be added. During an excursion from the Quaternary Department in Lund in 1967 we found lots of shell fragments in a till situated about +50 m at Åstorp (the NW point of Söderåsen). The field classifications gave: *Turritella tenebra, Portlandia arctica, Nucula, Saxicava, Mytilus?, Mya?* (the material is being kept at the Quaternary Department in Lund for further examination). In the same locality there is an interesting local breccia that seems to contain small traces of varved clay and organic material.

In the Viskan Valley it is apparent from several C^{14} dates that very old carbon (organic material) is here redeposited. This might not be so surprising in the samples with high clay content (e. g. BP 300:1 and BP 629:1, p. 206). However, B 95:4 (p. 232) was a coarse detritus mud with low clay content. The C^{14} dating gave about 12,000 BP instead of 9,000 BP, which means contamination by about 30 % of dead carbon. As it is a detritus mud, this suggests the presence of inactive or almost inactive mud and coarse detritus, i. e. of layers from the Brörup Interstadial or older.

NW of Ängelholm in the gravel pit named B 672 (Fig. 19), lumps of glacial clay, clay of Late Glacial type and black dy are found in the glacifluvial gravel, deposited from SW at the ice marginal fork of the F5 line (p. 72). The dy is clayey and has a 42.5 % loss on ignition. It was C^{14} dated at >40,000 BP. This means that the Interpleniglacial can be excluded.

The following pollen content was found (five slides): 115 *Pinus,* 5 *Picea* (?), 2 *Quercus,* 1 *Corylus*?, 1 *Filicinae,* 6 *Sphagnum,* 73 unclassified type A, 43 unclassified type B, 45 unclassified type C, and 41 unknown (= group D). The pollen grains were well preserved but often of types unfamiliar to Mrs Holm. Later some slides were gone through with Dr. J. Praglowski. The following was found: 1) some *Pinus* of *silvestris* type, 2) numerous *Pinus* of *haploxylon* type (the wall of the corpus is also thin at the proximale side), 3) one *Larix*?, earlier in group D, 4) two gymnosperms, earlier in group D (30—43 μ, the wall is 2—6 μ thick, the surface has characteristic gymnospermoid structures and fairly big punctae), 5) numerous Pteridophyts = type A (42 μ, the wall is about 1 μ thick), 6) some Pteridophyts, possibly of *Dryopteris* type, = type B (47—50 μ, the wall is covered with loose projections, 6—7 μ long and 8—12 μ thick at the base, no aperture was found), 7) some possible monocotyledons = type C (50—60 μ, no

structures on the surface, the wall is 1—0.5 μ thick; possibly not pollen at all), 8) dicotyledon, earlier in group D (with three colpi), and 9) a possible primitive monocotyledon, earlier in group D (25 μ, the wall is 2 μ thick with structures projecting inwards and punctae).

Taken as a whole 332 pollen and spores were found, belonging to the following main groups: 126 AP (= 38 %, 91 % of which is *Pinus,* probably mainly of *haploxylon* type), maximum 86 NAP (= 26 %) and 120 spores (= 36 %).

The pollen flora is clearly Quarternary according to Paglowski. This means that the dy most probably belongs to the Brörup Interstadial, Amersfoort Interstadial or Eem Interglacial. The state of preservation and the stratigraphical position makes a correlation with the Brörup Interstadial more probable than with the older stages. The pollen flora is too incomplete to give a clear picture of the climate and to allow a reliable correlation with other areas. *Pinus* of *habloxylon* type has today a boreo-montaneous distribution. This fact and the general dominance of *Pinus* and poorness of *Quercetum Mixtum, Alnus, Corylus,* etc. suggest a boreal climate, which would agree with the Brörup Interstadial. The dominance of *Pinus,* relatively poorness of NAP and abundance of spores may suggest a correlation with S. Th. Andersen's zone W5 (Andersen 1961), though a close comparison is as yet impossible.

Summing up, the dy most probably belongs to the Brörup Interstadial. The same probably applies to the lumps of clay, showing a change to colder climate and advance of the ice (or the reverse development).

From Lindö on NE Fyn (Fig. 9) six different till beds are described (S. Th. Andersen 1965). The direction of the ice streams depositing till I—III is determined by glacial striae in about 1000 boulders. From the microfossil content S. Th. Andersen found that the ice streams from the north probably eroded Pre-Quaternary deposits or tills rich in such material, while the ice streams from the east and southeast eroded deposits rich in Quaternary freshwater material. The whole sequence was supposed to belong to the Weichselian glaciation. I think the stratigraphy may be interpreted as follows:

Till I contains a high percentage of Quaternary pollen and *Pediastrum.* The glacial striae are from SE to NW. Till I probably corresponds to the later part of the last glaciation maximum.

Till II contains a high percentage of Pre-Quaternary pollen. It contains Wealden material transported from the north. The glacial striae are from north to south. It must correspond to the Meridian ice stream at the beginning of the last glaciation maximum.

Stratified drift, probably corresponding to the Glumslöv Interstadial.

Till III contains a very high percentage of Quaternary pollen and *Pediastrum.* It contains several peat lenses. The glacial striae are from east to west. The till must correspond to the Old Baltic ice stream during the Anholt Stadial after the Brörup Interstadial.

Till IV contains a high percentage of Pre-Quaternary pollen suggesting a transportation from north to south. It is probably a Pre-Brörup till.

Stratified drift, with uncertain position in the Early Weichselian (Pre-Brörup).
Till V contains a high percentage of Quaternary pollen and *Pediastrum* suggesting a transportation from the east or southeast. The position in the Early Weichselian is uncertain (Pre-Brörup to Pre-Amersfoort).
Stratified drift, with uncertain position in the Early Weichselian.
Till VI contains a high percentage of Pre-Quaternary pollen suggesting a transportation from north to south. The position in the Early Weichselian is not quite certain, probably a Pre-Amersfoort till.

The stratigraphies in Ristinge Klint and Rögle Klint are discussed on p. 52.

The interstadial between the Old Baltic till and the younger drift in Skåne, is seen in many places. The stratification in the cliffs and clay pits between Ålabodarna and Hildesborg near Glumslöv (between Hälsingborg and Landskrona) can be summarized in the following way (according to older descriptions and new observations):

A: Baltic till
B: sediment (according to Johnsson 1956)
C: NE-till
D: varved clay
E: deltaic stratified coarse silt — continuous transition to D
F: thick layers of pushed and folded fine sand — sharp limit to E
G1: homogeneous clay (or fine silt)
G2: homogeneous clay with stones and till lenses
G3: homogeneous clay

Layers F to G3 correspond according to my interpretation to the Interpleniglacial in the Netherlands. Layer G2 indicates that the ice margin was not far from this area, at least during the deposition of layer G2. Layers F to G3 indicate a higher sea level than today (above +20 m). Layers G to D show a decreasing depth, i. e. a regression. In layer E there are beautiful structures of load casts and turbidity corrents. These have been described as frost phenomena ("pocket soil") by Johnsson (1956), though they have nothing to do with frost activity, but have been formed below sea level (cf. p. 93). Layers E—D—C show the advance of the ice margin at the transition between the Interpleniglacial and the Upper Pleniglacial of the Netherlands.

According to Mohrén (1967) the hills of Glumslövs Backar is mainly made up of sediments covered by a thin layer of Baltic till (SW-till) and NE-moraine (the Baltic till was found right up to the top at +100 m). These submorainic sediments consequently belong to the Interpleniglacial (of the Netherlands), and suggest a high corresponding sea level.

In NW Skåne there are some gravel pits with submorainic sediments formed, according to my interpretation, during the Interpleniglacial (Fig. 10). Outside Hälsingborg two big gravel pits, at Björka (B 834) and at Brohusen (B 835), show till above stratified glacifluvial sand and gravel with its surface at about +45—50 m. The same stratigraphy has been found in many hills between Häl-

singborg and Åstorp in connection with geotechnical work. According to my interpretation the till belongs to the last glaciation maximum and the subsequent deglaciation, while the stratified layers belong to the time prior to the last glaciation maximum, i. e. the Interpleniglacial. It suggests an interstadial with high water level (tilted from NE to SW) and more or less close to the ice margin.

Probably several other hills in NW Skåne hide similar stratigraphies, e. g. Svedberga Kulle and the hills south of Kullen.

In the area of Förslövsholm and Grevie there are fairly big hills (at the foot of Hallandsåsen) that seem to consist almost entirely of drift. Today they have smooth drumlinoid surfaces. In a well drilling SE of Förslövsholm there was about 70 m of drift covering the bedrock. In the big gravel pit B 786 the following stratigraphy was found:

A: Silty till, max. 2 m thick.
A/B: Sometimes a sharp limit, sometimes a continuous transition.
B: Stratified sand and silt, deformed and folded. Up to about 4 m thick. Absent in SW.
B/C: Continuous transition.
C: Stony till (only Archaean rock) with lenses of stratified sand. Up to about 10 m thick (only in NE). The stones are fairly well rounded suggesting a long transportation.
C/D: Unconformity, though undramatic.
D: Stratified sand with gravelly-stony layers (only Archaean rock). Probably sloping towards NE. Up to about 10 m thick (in SW).

According to my interpretation the drumlinoid form and the uppermost till (A) belong to the last glaciation maximum, while the lower sequence (B—D) belongs to the Glumslöv Interstadial, i. e. the Interpleniglacial. In B 786 the interstadial beds reach about +65 m. In the Förslövholm—Grevie area as a whole they reach up to about +80—100 m, indicating a high corresponding water level. The types of sediment indicate proximity to the ice margin.

Hummel (1871 and 1877) found the following general stratigraphy in NW Skåne:

A: Postglacial sand, etc.
B: glacial clay
C: glacifluvial gravel
D1: till, yellow, without lime
D2: till, dark, rich in lime, gravelly-stony
E: glacifluvial sand ("hvitåsand"), rich in chalk (probably from the Båstad area)
F: glacial clay ("hvitåsand")

Layer E was found in several places in the Förslövsholm—Grevie area. Layer F was found at Fogdarp and Öllövs Kvarn within the same area. According to my interpretation layers E—F belong to the Glumslöv Interstadial (Interpleniglacial), though it cannot yet be settled whether they were formed during the middle of this interstadial or in connection with the advance of the Meridian

ice. As layer E contains material from the Båstad area and reaches up to about +80—100 m, it may suggest transportation with melt water from an ice margin north of Hallandsåsen out into water at a very high level south of Hallandsåsen. At Grevie Kyrka (B 848) layer E is fairly till-like, indicating proximity to the ice margin. The distribution of submorainic sediments in the Förslövsholm—Grevie area is marked on Fig. 24.

North of Hallandsåsen and in Halland there is not yet known any equivalent to the submorainic sediments in NW Skåne.

In the Götaälv Valley (north of Gothenburg) stratified silt, sand and gravel (containing remains of mammoth and muskox) between two different till beds are seen in Ellesbo (Hillefors 1955) and Dösebacka (Alin and Sandegren 1947). These sediments most probably correspond to an old interstadial more or less close to the ice margin. According to the present picture they were probably deposited during the Interpleniglacial in the Netherlands.

Brotzen (1961) has C^{14} dated two series of clays with only 1—3 % of organic material from the Götaälv Valley (Ingebäck and Hisinge Tunnel). The Postglacial and Late Glacial clays give too old ages, viz. about 10,000—15,000 BP. Below certain depths the ages change to about 27,000—29,000 BP (five datings in two borings). Brotzen regards this as evidence of an interstadial, the Göta Älv Interstadial. It is true that these datings are very bad, both geologically (redeposition) and technically (not pretreated in any way). But still the good agreement between the five dates, the intermorainic sediments in the surroundings (Ellesbo and Dösebacka) and the rough correspondence between these five dates and the end of the Denekamp Interstadial in the Netherlands, makes the presence of an interstadial of Interpleniglacial age highly probable. According to the foraminifera (Brotzen 1961) and the diatoms (Miller 1964) the environment was arctic during this interstadial, i. e. the ice margin was probably not far inland.

From the island Karmöy, SW Norway, shells of *Mya truncata* embedded in till have been C^{14} dated at 34,000 ±3000 BP (T-140, Trondheim II), which may show the presence of an interstadial of Interpleniglacial age on the SW Coast of Norway.

Summing up the data the following is seen:

Early Weichselian glaciations = ice margin not known. Till found at Tofthög, at Lindö and possibly in Skaerumhede. No local name is proposed.

The Brörup Interstadial = clay of the *Turritella tenebra* zone in Skaerumhede, found in many places (in primary or secondary position), sediments in the Alnarp Valley and probably the dy in B 672 that is C^{14} dated at >40,000 BP. The climate was boreal, at least in the sea. Probably the whole of Sweden was deglaciated. The following local names for the Kattegatt area are proposed: for the terrestrial deposits the Brörup Interstadial and for the marine sediments the Skaerumhede Interstadial.

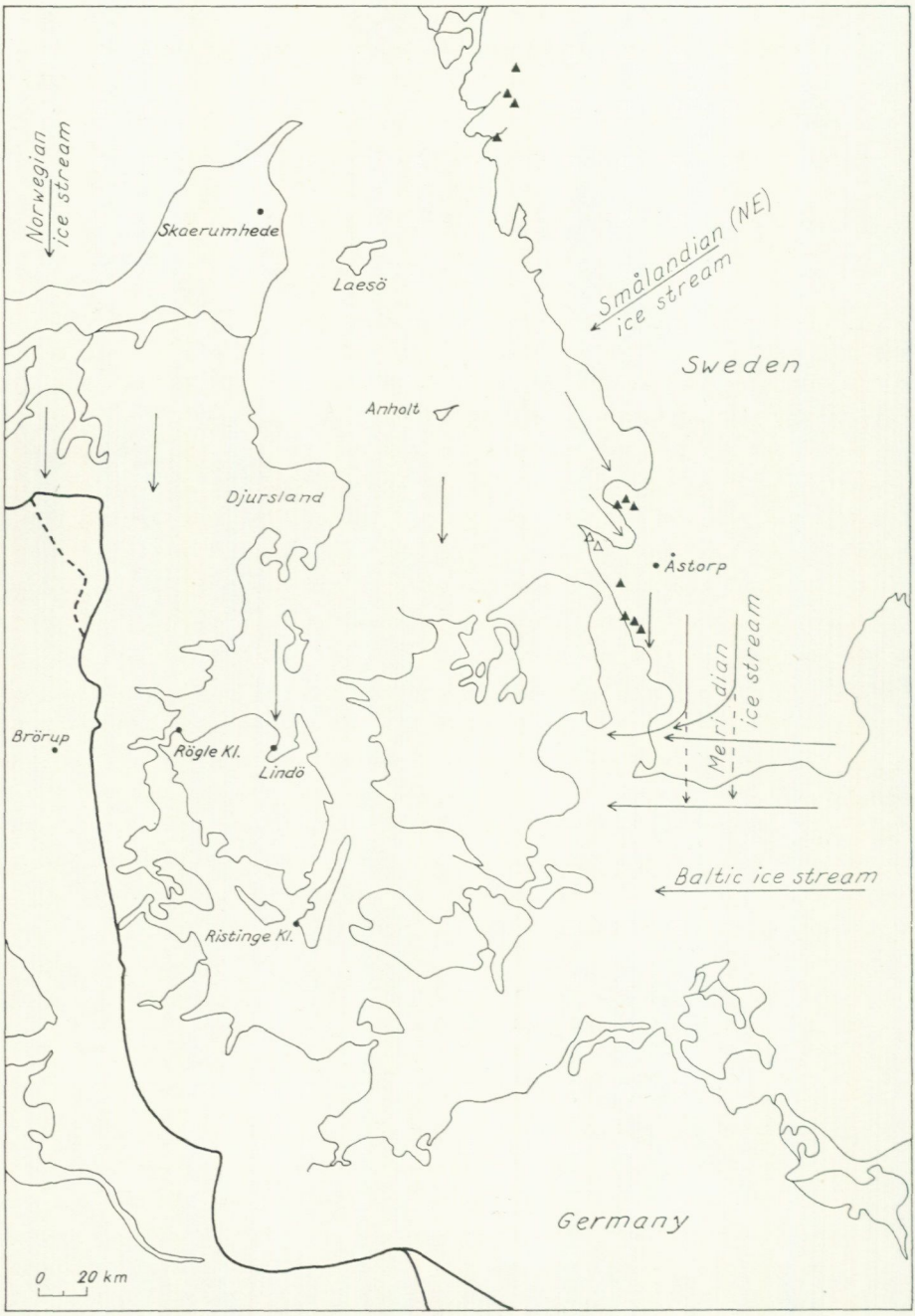


Fig. 10. *Glacial sediments from the Glumslöv Interstadial have been found in several places (= triangles), especially in NW Skåne. The ice margin was probably close to these localities. The corresponding sea level was high compared to the Late Glacial ones. The subsequent advance to the C line started with a strong Norwegian ice stream, the Meridian ice stream (in Skåne), which in SE Skåne met the Baltic ice stream and was forced to flow westwards. Later the ice flowed towards the periphery.*

The Lower Pleniglacial (totally or only the early part) = readvance of the Old Baltic ice from E—SE and of an ice stream from the Swedish West Coast (i. e. from NE) to the line Djursland—Anholt—Laesö (in Jylland probably roughly following the Late Glacial D line). Abundant drift was accumulated in front of the ice margin (Figs. 9, 4 and 5). The climate was arctic. As a suitable local name the Anholt Stadial is proposed.

The Interpleniglacial (no subdivision possible yet) = sediments in a lot of places in western Skåne, all showing more or less proximity to the ice margin, and intermorainic sediments and slightly muddy clays, dated at 27,000—29,000 BP, in the Götaälv Valley, all showing proximity to the ice margin. In Skaerumhede and Anholt, arctic marine clays without material dropped from icebergs were deposited. As a suitable local name the Glumslöv Interstadial is proposed.

The readvance of the ice at the beginning of the Upper Pleniglacial started with a strong Norwegian ice stream (Fig. 10). In Skåne this is known as the Meridian ice stream. It picked up older clays in Skälderviken and redeposited them in the till at Åstorp. From investigations at Lindö on northern Fyn (S. Th. Andersen 1965) it was shown that the Norwegian-Meridian ice stream reached at least to northern Fyn. In southern Skåne the Meridian ice stream met the Baltic ice stream (K. Nilsson 1959, Fig. 22 B) and was forced to flow westwards towards the C line in Jylland (Fig. 10). During the maximum of the Late Weichselian glaciation, i. e. when the ice margin was at the C line, the ice streams were directed towards the periphery. In the Kattegatt area this meant mainly an ice stream from NE. Later, during the deglaciation from the C line, there was again a separation into different ice streams. The Late Weichselian deglaciation of Kattegatt is characterized by a recession towards NE (of the NE-ice) and a separation from this ice of the Baltic ice stream, which became highly influenced by the topography.

The Late Weichselian deglaciation of the Kattegatt area

I correlate the Main Stationary Line or the C line in Jylland with the maximum extension of the Late Weichselian glaciation. This (and the next) chapter will deal with the deglaciation from that line over Denmark, Kattegatt, the Southwestern Baltic Sea and Southern Sweden (Pl. 2). In Jylland and the Danish islands, where I have very few field observations of my own, I am mainly following V. Milthers (1948), with a reinterpretation of NW Sjaelland. In Kattegatt everything is based upon new facts, giving rise to a geological map of the seabed of Kattegatt (Pl. 1). On the Swedish West Coast and in Skåne the picture of deglaciation is mainly based upon new material, but also upon older more or less reinterpreted material. The deglaciation of Southern and Eastern Skåne is almost entirely based upon older descriptions. The submarine ice marginal lines between the Danish islands are mainly based upon studies of the nautical charts. The ice marginal lines between Lolland—Falster and Mecklenburg roughly correspond to Kolp's lines (1965). In Mecklenburg I am following Kliewe (1966), Heerdt (1965), Reinhard and Richter (1961) and others. Very little is known about the submarine ice marginal deposits between Sweden and Germany. The picture, suggested, is based upon studies of nautical charts and upon obvious correlations of land deposits.

The methods of mapping the bottom of Kattegatt have already been dealt with (p. 21). It was surprisingly easy to follow and map the terminal moraines and till field of the bottom of Kattegatt. It is of course much harder to combine these into ice marginal lines. However, this is made easy by the presence of some distinct ice marginal lines, i. e. the E1, E4 and F2 lines. The weak area is the SW part of Kattegatt, where ice marginal deposits are not so common and easy to map. Minor changes of the connections within the ice marginal lines may of course be possible. The main picture, however, is well established, i. e. the NE-ice recedes towards NE and separates from the Baltic ice first from the lobes in the depressions of Store Belt and Lille Belt and later from the main Baltic ice stream in the depression of Öresund.

The ice receded at an obtuse angle between the Norwegian and Smålandian (NE-ice) ice streams, but at an acute angle between the Smålandian and Baltic ice streams. The existence and movement of this acute angle is very important for the total picture of deglaciation. As we will see further on in this paper the angle moved from the Viborg area (during the C line) to Djursland (during the D line) and in a curve across Kattegatt to the Ängelholm area, where deposition of drift from two different directions at the same time was found, towards SE across Skåne to the Kåseberga area, where it splits up into two angles, the main one of which turns to NE over Rörum and Ravlunda, across the Hanö bay, passing

the southern archipelago of Blekinge across SE Öland, and further up across Gotland. In connection with the movements of this angle, changes in the ice streams took place.

The C line

The C line or Main Stationary Line in Denmark was mapped by Ussing (1899). There are good reasons to correlate the C line with the Brandenburger—Frankfurter line in Germany. The C line corresponds to the maximum extension of the Late Weichselian glaciation. The continuation of the C line in the North Sea have been given very different extensions. However, it now seems probable that the Scandinavian ice continued out in the North Sea area and fused with the Scottish ice in the eastern Dogger Bank area (Valentin 1955, Veenstra 1965).

The recession to the D line (the CD lines)

Following the maps by K. Milthers (1942) and V. Milthers (1948) of the ice marginal lines in Jylland, it appears that no or very few lines are seen in Southern and Middle Jylland between the C and D lines, but several are found in Northern Jylland. These lines do not seem to correspond to any major stagnation, but only to small, more or less topographically caused retardations in the recession of ice.

In Southern Jylland the CD lines have apparently been overridden by a readvance to the D line.

In Middle Jylland on Djursland there are 2—3 lines orientated almost N—S. This indicates that the lines before the D line here had a more or less N—S direction.

In Northern Jylland the ice receded like a fan. According to A. Jessen (1918, 1936), K. Milthers (1942) and V. Milthers (1948) three distinct ice marginal lines are seen in Vendsyssel. However, S. A. Andersen (1961) has given a different picture of the ice recession in Vendsyssel.

I think the best way to follow the ice recession in Vendsyssel would have been to put it into relation to the Marine Limit (ML) and the direction of tilting. However, this is not easy, and has not been done. In the geological description of Vendsyssel A. Jessen (1918, 1936) deals with the Late Glacial shore marks. I have arranged his and S. A. Andersen's information about the shorelines in a distance diagram (Fig. 11) with the direction of tilting as the one found on the Swedish West Coast (p. 406), which cannot be too wrong as it fits well with the Postglacial shorelines. According to this diagram it looks as if the ML grows younger from SW towards NE. No irregularities in this fall of

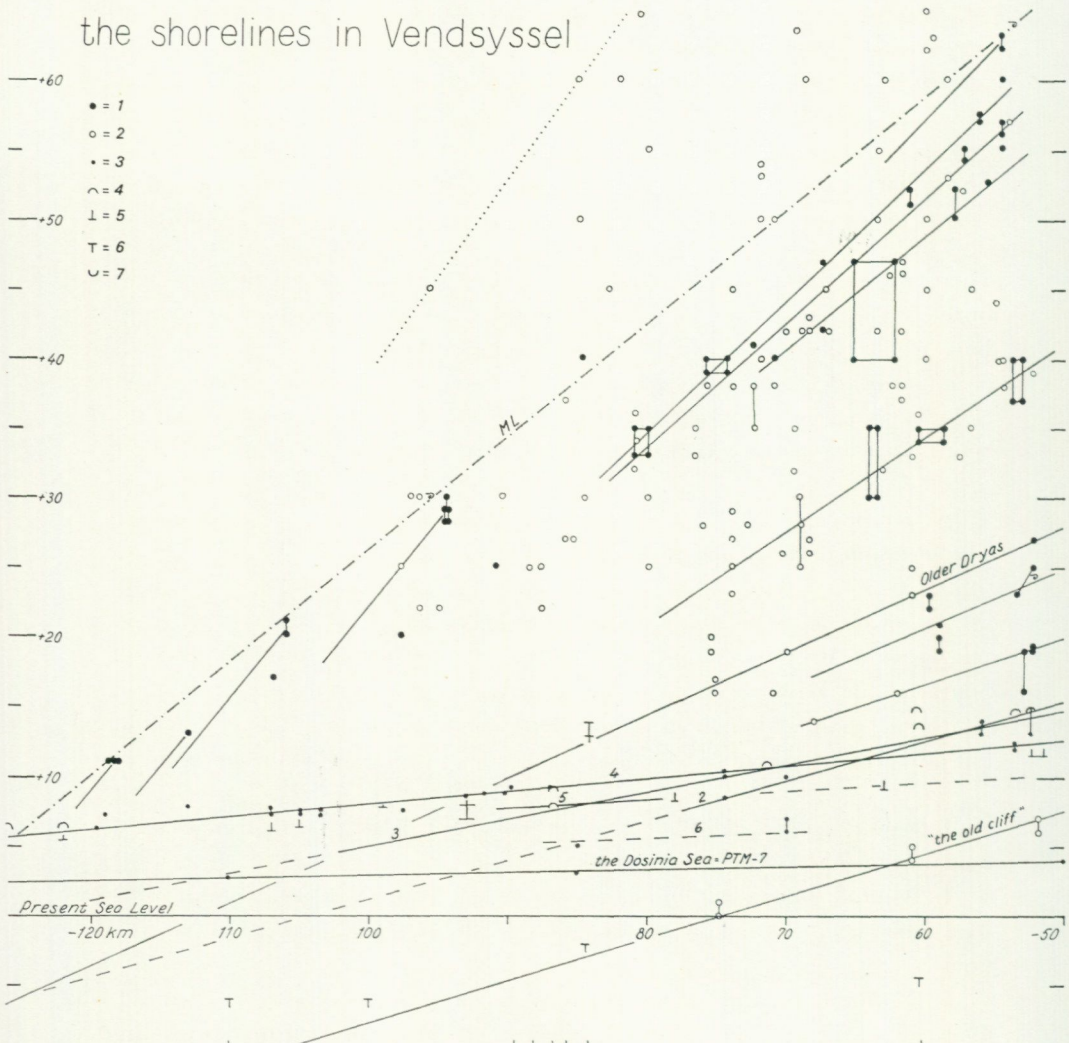


Fig. 11. *ML is either metachronous (full lines) or synchronous (dot-dashed line), i.e. formed by a transgression. Symbols: 1 and 2 = Late Glacial shore marks according to A. Jessen and S. A. Andersen respectively, 3 = Postglacial shore marks, 4 = beach ridges, 5 = transgression contact, 6 = isolation contact (e.g. submarine peat) and 7 = river channel.*

ML are seen, which suggests that there was no great readvance of and no long stagnation at the D line in Vendsyssel, but a more or less uniform recession of ice. However, ML could as well have been formed by a synchronous transgressive shoreline (dot-dashed line in Fig. 11), followed by a regression of 7—10 m during the stagnation of the ice along the D line (cf. p. 430, Fig. 151).

S. A. Andersen (1961) gives much higher figures for the marine shore marks. However, these figures seem too high — here we have also to consider the traces of ice lakes and washings along the slopes of the hills (e. g. + 100 m at Gerumhede and + 45 m at V. Harring). If Andersen's highest figures had been correct, shore marks at more or less unbelievable altitudes, 10th of meters above the generally accepted ML would have to be found in SW Vendsyssel.

The D line or East Jylland line

The D line or East Jylland line or Harder line was first mapped by Harder (1908). In Southern and Middle Jylland this line is very distinct, topographically as well as petrographically. In this part of Jylland it was caused by a distinct readvance. Petrographically this was a Baltic ice stream (K. Milthers 1942).

Wennberg (1949) thought that this line was reached after an interstadial separating the Old Baltic ice stream from the younger ice streams. Consequently a different opinion is here expressed.

The D line clearly belongs to the Late Weichselian deglaciation. But as the ice margin during the Lower Pleniglacial must partly have had the same extension, it may partly contain older overridden ice marginal deposits.

Evidence of a readvance to the D line is said to occur in Ristinge Klint and Rögle Klint. If this is true, there must have been a readvance of more than 80 km. However, the whole problem depends upon how one correlates the different moraines with the different ice marginal lines and this in its turn depends upon how one look upon the chronology and extension of the different ice streams. Hansen (1965) and most other Danish geologists correlate moraine C with the C line, moraine D with the D line, etc. S. A. Andersen (e.g. 1966) has pointed out that moraine C should be correlated with a Pre-C line, moraine D with the C line, moraine E with the D line, etc. Wennberg (1949) thought that moraine C was deposited by the Old Baltic ice and moraine D by the Meridian ice. The petrographical composition allows different explanations.

With the picture of the Weichselian glaciation here given, the whole problem is put in a new light. The following relations now seem obvious: Moraine C = the Anholt Stadial or Old Baltic ice stream, the intermorainic sediments in Rögle Klint and Ristinge Klint = the Glumslöv Interstadial, and moraine D = the Late Weichselian glaciation (the C line and the deglaciation from the C line).

The following Weichselian layers are seen in Rögle Klint on NW Fyn (Madsen and Nordmann 1940):

A: Moraine D = the Late Weichselian glaciation.
B: Glacifluvial sand and gravel (up to 18 m thick) containing redeposited shells = the Glumslöv Interstadial of Interpleniglacial time.
C: Moraine C = the Anholt Stadial (Old Baltic ice stream).

Layers B and C are pushed and folded from NE and with an unconformity overlaid by moraine D. Thus the deformation must be ascribed to the advancing Late Weichselian ice streams (and has nothing to do with any readvance to the D line).

The following Weichselian layers are seen in Ristinge Klint on SW Langeland (Madsen *et al.* 1908, Rosenkrantz 1944):

A: Moraine D = the Late Weichselian glaciation.
B: Glacifluvial sand and gravel containing plant remains = the Glumslöv Interstadial.
C: Moraine C = the Anholt Stadial (Old Baltic ice stream).
D: Glacifluvial sand = the advancing Old Baltic ice stream (or older).

The whole sequence is pushed and folded from SE. Consequently the deformation must be ascribed to a readvance or oscillation during the Late Weichselian deglaciation. As the surface form is drumlinoid, there seems to have been a real readvance. However, whether this readvance should be correlated to the D line (less probable) or any of the E or F lines (more probable) is a quite open question.

From the area between Wismar and Warnemünde in Germany Heerdt (1965) described thick layers of sand covered with an unconformity by a moraine from the Pommerian stage. This indicates a readvance. Woldstedt (1958) correlates the Pommerian stage with the D line in Denmark. However, the D line and E lines in Southern Denmark and Schleswig-Holstein lie so close together that I find it hard to settle which one should be correlated with the Pommerian stage. In the area investigated by Heerdt (1965) the first ice marginal line inside the Pommerian stage is the line of the Rosenthaler stage, which seems to be easily connectable with the so-called Langeland readvance or F2 line in Denmark. This means that there are no traces of the E lines. These things make me think that it is an open question whether the Pommerian stage should be correlated with the D line or the E lines. According to Woldstedt's map of the ice marginal lines (Woldstedt 1958, Fig. 46) the Pommerian stage is represented by 2—3 lines in the area between Oder and Memel. This may indicate that th line of the Pommerian stage in Germany corresponds both to the D line and the E lines in Denmark, and that an E line sometimes has overridden the D line and marks the line of the Pommerian stage.

According to the extention of the ice marginal lines in the map by Reinhard and Richter (1961) the E lines (especially the distinct E4 line) may correspond

to the Gerswalder Staffel or the outer part of the "Rosenthaler Staffel". Some geologists (e. g. Richter 1937, Hansen 1965) correlate the D line with the Frankfurter line and the E line with the Pommerian line.

Let us now turn to the continuation of the D line in Kattegatt and in Vendsyssel. I have drawn the line in a curve along the inner part of the Bay of Aalborg up to Asaa, where it turns up on land and joins the line mapped by Jessen (1918, 1936) along the "Jydske aas".

The line in Kattegatt is based upon the following: Just outside the NE corner of Djursland there is a till field according to the echo sounding — the fishermen say stones and sand. The shoal Tangen consists of till according to the echo sounding — the fishermen say stones, sand and clay. At the middle of the identation on the 10 m contour there is a ridge of till according to the echo sounder — the fishermen say stones, sand and clay. In an attempt to take a sample here (B 736), an ordinary dredger came up badly buckled — i. e. a hard bottom. A pipe dredger (B 737) gave a till of pebbles and fine sand (two fractions). The 6 m contour shows two ridges outside the Mariager fiord. The southern one consists of stones, sand and clay, and the northern one of pure sand according to the fishermen. These localities show a good line with a NW—SE direction. Its further continuation seems to follow the coast between Mariager fiord and Limfjorden with till accumulation at Als and Muldbjerg. At the mouth of Limfjorden there is a field of till according to the echo soundings — fine sand and stones according to the fishermen. The position of the D line is here given by the stony skerries Korsholm and Nordmands Hage. It continues upto Asaa, where it seems to turn up on land and join the "Judske Aas". This is a good ice marginal line. In Kattegatt and Vendsyssel there is no evidence of a readvance. In this part there seems to have been little or no readvance of the ice (the Norwegian and Smålandian ice streams). The shorelines in Vendsyssel may point to a more or less uniform recession (p. 51).

Summing up the information about the D line:

1. In Vendsyssel and Kattegatt there was little or no readvance.
2. In Middle and South Jylland the D line overrides the older CD lines (p. 49), which clearly indicates a readvance.
3. There is no sure evidence of any great readvance of the D line.
4. The deformation of Rögle Klint occurred during the advance to the C line.
5. The deformation of Ristinge Klint could as well be ascribed to an E line or F line as to the D line.
6. The readvance in Germany described by Heerdt belongs either to the D line of to an E line (the E4 line).
7. The line of the Pommerian stage could comprise both the D line and the E lines.
8. Some geologists correlates the D line with the Frankfurter line.

This means that we really do not know whether the D line or an E line marks the greatest readvance. And we do not know whether the D line was reached after a small oscillation of the ice (particulary in South and Middle Jylland) caused more by dynamic changes in the equilibrium between the different ice streams, or the D lines was reached after a somewhat greater readvance caused by a climatic deterioration.

At Smidstrup, just at the margin of the D line west of Vejle, V. Milthers (1925) found an intermorainic organic sequence (mud and peat) containing a subarctic fauna and flora (macrofossils). This indicates the presence of an interstadial prior to the advance to the D line — the Smidstrup Interstadial.

Then the question arises whether there occurred any known climatic change in the world during that time. As there seem to be good transatlantic correlations for the younger stadials and interstadials, I think a comparision is of interest.

In the Great Lakes area there is the Lake Erie Interstadial followed by a readvance (Dreimanis 1958). Dreimanis (personal communication 1967) thinks the age of the Lake Erie Interstadial is 13,000 BC, ±1,000 years. On the American East Coast the maximum extension of the Late Wisconsin glaciation was determined by C^{14} to be younger than 13,350 ± 800 BC and older than 12,290 ± 240 BC (Schafer and Hartshorn 1965). On the American West Coast in Washington State there is an interstadial separating the Evans Creek Stadial from the younger Vashon Stadial the maximum of which has been dated at about 13,000—12,000 BC (younger than 13,050 ±300 BC in Seattle). This means that there is a good possibility of a climatic oscillation about 13,000 BC, i. e. an interstadial followed by a distinct readvance of the ice. This interstadial is probably also registered — as the fluctuation 0.75 m down (which in age means about 13,000 BC) — in the curve of the distribution of $CaCO_3$ in the North Atlantic core 280 (cf. p. 37) described by Olausson (1960).

The DE lines

The period seems to be characterized by a relatively uniform and rapid recession of ice without any readvance, at least from climatic causes. Several ice marginal lines are found, at least 10 in Kattegatt, 5 on the Aebeltoft-Helgenaes peninsulas, 2—3 on Samsö, 5 on Fyn and 3 in Jylland west of Lille Belt. In Kattegatt the ice margin was more or less linear, whereas in the Belt Sea it and its surroundings were highly lobated.

The bottom of Kattegatt is traversed by several moraine ridges in a roughly NNW—SSE direction. There is no doubt about that. The map (Pl. 1) shows 10 lines. Line 1 is based upon a field with till topography south of Hals. Line 2 is based upon till topography just south of B 750 (separated from the till of

line 3 by a sand field), and on similar topography outside Hals (separated from line 3 by a depression) and NE of Djursland. Line 3 is a marked line, called Svitringen east of Hals. Dredging B 742 and 749 gave till gravelly pebbly sand containing Archaean rock, flint and sandstone (two fractions, Tab. 2). This line seems to pass up onto land at Lyngsaa, where Jessen (1936) has mapped an ice marginal line. The line passes down NE of Djursland via some small shoals containing stones. Line 4 seems to be connected with Jessen's line between Saeby and Frederikshavn. It is a marked line and contains the ridge Lange Revle and a string of stones and minor shoals NE Djursland. Line 5 is based upon: 1) stones and minor shoals NE Djursland, 2) the southern "leg" of the shoal Dameboxerne, consisting of till, and 3) the shoal Westre Knold, which according to the fishermen consists of sharp edged stones, sand and clay, i. e. till. It seems to be continued in some of the ridges just outside Frederikshavn. Line 6 is based upon: 1) the northern "leg" of the shoal Dameboxerne, which is covered by sand, but seems to consist in its interior of till, as all the other shoals in this area apperently do, 2) the shoal Östre Knold (of sharp edged stones, sand and clay according to the fishermen), 3) the shoal NE of Östre Knold (of the same material), 4) the area between the two channels west of Laesö, which according to the echo sounding consist of till and 5) some of the ridges between Frederikshavn and Hirsholmene (there seem to be about seven minor ridges in this area, the outermost of which belongs to the E1 line). Line 7 is based on: 1) a stone field NE of Djursland, 2) the shoal Fisken, which consists of till according to the echo sounding and the statements from the fishermen (B 518 gave fine sand, however), 3) a minor shoal, 4) the shoal Östre Flak, which consists of till according to the echo sounding, and contains stones according to the fishermen, 5) a till field at the bulge of the 10 m contour, 6) a shoal of till at Söndre Rönner Flak and 7) probably some of the ridges between Frederikshavn and Hirsholmene. Line 8 is based on a shoal of till at Söndre Rönner Flak probably connected with the inner part of the shoal Östre Flak and some ridges between Frederikshavn and Hirsholmene. Line 9 is based on: 1) the eastern part of Östre Flak, 2) a ridge of till (echo sounding) reaching from the 10 m contour line up the main part of Söndre Rönner Flak, 3) a part of Laesö NW-rev, and 4) some ridges SE of Hirsholmene. Line 10 is based on: 1) a till ridge east of Östre Flak (echo sounding in north and south), 2) stones and minor shoals east of Söndre Rönner Flak, 3) a part of Laesö NW-rev, and 4) the ridge containing Kolpen SW of Hirsholmene.

All the lines seem to pass just east of Djursland. This means that there was a very small or no recession of ice during this period in this area. The lines found in Kattegatt are a link between Vendsyssel and the Belt Sea area.

In the area in and around the Belt Sea several ice marginal lines have been described (e. g. K. Milthers 1942, V. Milthers 1948). However, I think the clear bottom topography allows a further development of the picture of ice recession.

On the Aebeltoft and Helgenaes peninsulas there are five ice marginal lines showing the existence of lobes in the Kalö Bay and the Aebeltoft Bay (V.Milthers 1948). One of these has its continuation in the marked line going SE of Aarhus — west of Horsen — the point at Rosenvold — probably to Rögle Klint — Middelfart — across Lille Belt — a lobe around the Koldinge Fiord — down to Christiansfeld. Between Vejle Fiord and Christiansfeld there is also an older DE line. In Northern Samsö there is an ice marginal fork, an acute angle, with the right line pointing towards NE just outside Djursland and the left line pointing towards NW—W over to Jylland. In the Middle of Samsö there is a second ice fork. The right line points towards NE, where it seems to make a new fork, and then turns east of Djursland in a curve pointing first NW and then NE. The submarine extension of the line is based upon the bottom topography and bottom conditions according to the nautical charts. The left line goes in a bulg over to Jylland, where it turns down to Fyn and continues in a lobe around Lille Belt. The next step in the recession of ice is a deepening of the forks NE of Samsö, on Samsö and on Fyn (see Pls. 1 and 2). V. Milthers' line at the SE coast of Samsö could have its continuation in: 1) Paludas Flak, where a fork was formed, 2) up along the west coast of Samsö, 3) over Svanegrund, 4) in a curve down over Middelflak, and 5) over to Aebelö, where it joins Milthers' line on Fyn. Two more lines could be seen SE of Samsö according to the nautical charts. On Fyn there are also two more DE lines, the last of which is well marked, according to V. Milthers' map.

On the whole the period of the DE lines is characterised by a more or less rapid and uniform recession, in Kattegatt as straight lines and in the Belt Sea area highly lobated

The E lines

On Jylland and in Kattegatt nothing was previously known about the ice margin during the time of the E lines, except for the submarine continuation of the peninsula Sjaellands Odde. In general, I have retained the ice marginal lines in Sjaelland and Fyn on Milthers' map, but I have made several important reinterpretations after a close study of the bottom topography and conditions on the nautical charts. The line along the peninsula Rösnaes is connected with Fyns Hoved via a well marked series of submarine shoals. Five different lines were found on and off the NW coast of Sjaelland, which makes me reinterpret Milthers' strange lobe SW of Isefiord.

THE E1 LINE is a very well marked line, which was followed without difficulty the whole way from Northern Jylland down to Lille Belt. This fact may point to a fairly well marked stagnation in the recession during this time. The line will be described below from north to south.

The shoal Skagbanke in Tannis Bay in Skagerak (of sand and stones) seems to belong to this line. The line goes between Aalbaek and Hirsholm, just inside the 10 m contour, where it is marked by the two small shoals, Krageskov Rev, and the well marked ridge containing the flat islands Graesholm and Hirsholm. SE of Hirsholm the echo soundings have shown the occurrence of an almost entirely buried ridge, which breaks through the Postglacial sediments, clayey silt. The inner part of Laesö SW-rev belongs to this line and seems to consist of till. The further extension of the E1 line towards south goes along the 4 m contour and is marked by some minor shoals and the occurrence of stones. In the SW corner of the 10 m contour there is a well marked ridge, which could consist of till (echo sounded at three different places). This ridge continues towards south as a very well marked ridge (not immediately apparent from the nautical chart as it lies between −10 and −20 m). Between this ridge and the shoal Fisken (line 7 in the DE system) there is a depression containing peat (p. 288). This ridge was echo sounded in several places. Often it seems to be covered by fine sand, but has always the form of a ridge. At the point where the line turns towards SW there is a field of till. It follows the 10 m contour east of Djursland and curves over to Sjaelland. This curve is very well marked by a series of shoals of sand, gravel and stones, the eastern part of Hjelm Banke, Moselgrund, Marthe Flak, Munke Grund, Middelflak and a line of minor shoals pointing to the peninsula Nörrehoved. It joins the NW coast of Sjaelland at Nörrehoved. In Sjaelland there is an ice marginal fork with the southern continuation turning out over Rösnäs peninsula. The fork in middle Sjaelland in this line and the following E lines is also marked by the melt water streams in the area between the two lobes, running towards the bay Saltbaek Vig and not via Lake Tissö Sö as the present drainage does (K. Milthers 1942). Between Rösnäs peninsula and the Hindsholm peninsula there is a series of well marked shoals, e. g. Bolsaks. I find it obvious that the line follows these, and does not go towards NW as the line in maps by K.Milthers (1942) and V.Milthers (1948). Furthermore it joins the NE part of the Hindsholm peninsula and does not pass down along the west coast.

It forms two lobes, one on each side of Kerteminde, and goes down across Fyn. Near the coast of Lille Belt it turns towards NW. It seems to cross the Lille Belt in the area of Baagö—Aasö, where big accumulations, presumably of drift, fill the Lille Belt valley. The lobe west of Sönderborg ought to belong to this line or some of the younger E lines.

The E2 line in Kattegatt was found as a ridge of till according to the echo soundings and is characterized by stones according to the fishermen. NW of Sjaelland the E2 line (which is not necessarily exactly the same as the one in Kattegatt) curves in over the shoals — one of which is Yder-flak — passes along the SW coast of Sejerö and the small island Nexelö and joins the coast at Havnsö. K. (1942) and V. (1943) Milthers thought that Sejerö is made up of two lines of

drumlins. I think it is two terminal moraines, the E2 and E3 lines. The E2 line has a deep fork in Sjaelland, where melt water was discharged towards NW (K. Milthers 1942). Then it turns out over the peninsula Asnaes. Via a well marked curve of shoals containing Asnaes Rev, Ryggen, Stubberup, Knold and Möllegrund, it crosses the Store Belt. It seems to join the third of the lines in Fyn mapped by V.Milthers (1948). Near the coast of Lille Belt it turns towards NW and seems to cross Lille Belt in the area Baagö—Aarö.

THE E3 LINE in Kattegatt is a ridge of till according to the echo soundings and contains stones according to the nautical charts and the fishermen. It seems to have a continuation along the east side of the submarine channel SW of Anholt. Outside the NW coast of Sjaelland it seems to go close inside the E2 line, i. e. in a curve from Yderflak to Sejerö, where it goes along the NE side and joins the peninsula Ordrup Naes via some minor shoals. After some lobes, it roughly follows the E2 line in the middle of Sjaelland. Concerning the direction of Shultz's Grund and the small shoal SW of it, it is possible that the E2 line from Yderflak passes over to Schultz's Grund, after which it takes a northerly direction and passes along Hastens Grund, to join some of the bulges in the 20 m contour east of Djursland.

THE E4 LINE is very distinct. It was formed during a marked stagnation in the recession, in parts maybe also by a short readvance. The line will be described below from north to south.

Between the small flat island Nordre-Rönner and the NW corner of Laesö there is a very well marked ridge rich in stones, the Rönnerev (–0.3 m depth). Along the shore at the NW corner of Laesö there is an abundance of stones and some boulders (usually there are beautiful sand beaches). Doubtless this is a terminal moraine. In the south corner of Laesö and around the island Hornfiskön there are also abundant stones and boulders (see also Jessen 1897). This must be the continuation of the terminal moraine. Without having any direct observations in the shallow area south of Laesö, I find it obvious that the line continues in the same direction, NNW—SSE, and passes the south point of the 6 m contour line and goes down to the bulge in the 10 m contour, (the occurrence of stones, coarse sand and ridges along this line support this). Between the 10 m contour and the small shoal NW of Anholt the echo sounding showed an uneven bottom string of till. From the perch NW of Anholt to the NW head of Anholt there is a very distinct terminal moraine, the outermost part of which is seen in Fig. 14, no. 5. The eastern two thirds of Anholt is a flat Postglacial desert (Fig. 136, p. 389). The western third is a hilly area of drift, reaching 48 m above sea level. According to A.Jessen's description (1897) the western part is made up by glacifluvial sand and gravel, which is covered by a thin layer of till (sandy, clayey) of stones and boulders. The stratification in the glacifluvial layers is sometimes deformed, indicating pressure from the ice. Shells and plant remains have been

found in the glacifluvial material, obviously redeposited. According to Jessen the petrographical composition in the glacifluvial material and the till is very complex and contains Norwegian, Smålandian and Baltic erratics together. Concerning the relationship between the till and the glacifluvial material Jessen (1897) concluded that both belong to the same ice stream ("... alle Forhold tyde paa, at disse Lag staa i naer Forbindelse med Hensyn til Dannelsetid, og at begge hidröre fra den samme Inlandsis."). In a till pit (B 779) on the top of Bybakken (+29.3 m) there is a lower clayey part and an upper silty part, containing pebbles of Archaean rock, flint and chalk. In the middle of the western hilly area there is a marked valley (Fig. 136), obviously a result of a long resting body of dead ice. My interpretation of the formation of the western hilly part of Anholt is the following. In the angle of the E4 line glacifluvial material was built up deltaically. An ice lobe projected into the central part. This was later left as a dead body of ice. Till (sandy and clayey) was deposited by the ice margin and the bodies of dead ice. The area as a whole consisted of a field of bodies of dead ice, with till accumulations and melt water streams depositing glacifluvial material. Smaller readvances seem to have occurred, as the till is often seen above the glacifluvial material and as the stratification sometimes shows deformations. As it is a question of ice marginal deposits, it seems reasonable that it was built up approximately to the Marine Limit. As the highest point lies at +48.3 m, this could roughly be a minimum figure for the Marine Limit (agreeing well with the circumstances in Vendsyssel and in SW Sweden). The shells and plants in the glacifluvial material ought to come from interstadial beds NNE, E or SE of Anholt. This ice marginal formation resembles in many respects the greater ones on the Swedish West Coast. The surprising thing is to find it here in the middle of Kattegatt. In my point of view it can only have been formed in an angle between two ice margins. The traces of readvance and the size of the ice marginal deposits speak for a formation during a fairly long stagnation in the ice recession, with small readvances.

The further extension of the E4 line follows a curve roughly along the 20 m contour. It is marked by the existence of till fields, stones and ridges (according to several echo soundings and some borings). The existence of this lobe could suggest a readvance.

In the area of the deep submarine channel the line turns at an ice marginal fork towards SW in a very well marked curve via the shoals Briseis Flak, Hastens Grund, Schultz's Grund and Sjaellands Rev to the peninsula Sjaellands Odde. It is a very distinct line. In contrary to the general view (e. g. V.Milthers 1943) I have found Sjaellands Odde to be made up during two stages in the recession, the outer main part being the E4 line and the innermost part the E5 line.

The E4 line seems to join the moraine curves Hönsinge—Lynghuse—Vejrhöj (Rördam and Milthers 1900) and continues in lobes around the already ice-free Aamosen area. As a continuation of V.Milthers' line between Slagelse and

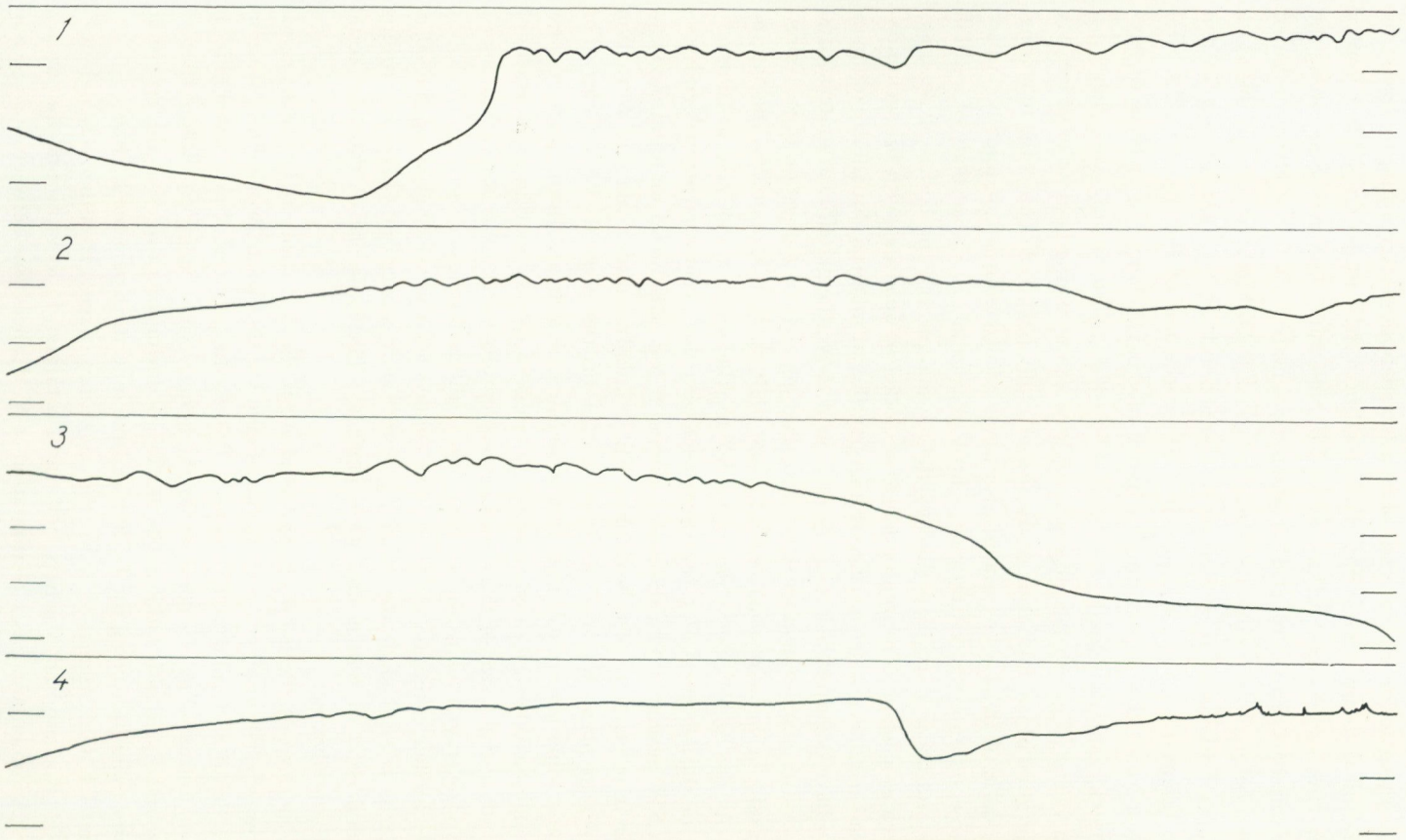


Fig. 12. *Echo diagrams across the shoals NW-N of Laesö. Vertical scale gives depth in tens of meters. Horizontal scale: 1.7 cm (1), 1.6 cm (2), 2.3 cm (3) and 1.9 cm (4) = 1 km.*

the peninsula Reersö it passes in a curve across Store Belt via Elefantgrund, Römsö, Römsö Puller, Rönnen and Möllegrund. It joins Milthers' line south of Risinge Hoved and crosses Fyn with a lobe in the SE highland and an acute angle at Kirkeby. In this angle Stenstrup glacial lake was dammed and a varved clay was deposited: 35—39 annual varves + an unknown number weathered = a little more than 50 years (Hansen 1940).

According to V.Milthers this line continues out on Helnaes. Illumö is a good link in this line. Via a well marked series of shoals, Langgrund, Alsten, etc., the line crosses Lille Belt in a curve to Taksensand. The E4 line may in Schleswig continue as the U line mapped by Gripp (1954). The continuation in Holstein and Mecklenburg is still uncertain (cf. p. 52).

THE E5 LINE is less well marked, and was probably formed during a short stagnation in the recession. NW of Laesö a field of till was found with the echo sounder (Fig. 12, no. 4). A boring B 604 gave pebbly gravelly sand, i. e. till. Via some minor shoals and occurrences of stones this line reaches Laesö at Horneksodde, where an abundance of stones and boulders are found along the shore arranged in one bigger or two minor ridges. The line continues towards SE across Laesö and a series of shoals and occurrences of stones, e. g. the till-like composition sand-clay-pebbles at the southern bulge of the 10 m contour. Just outside this bulge there is a field of big boulders according to the fishermen.

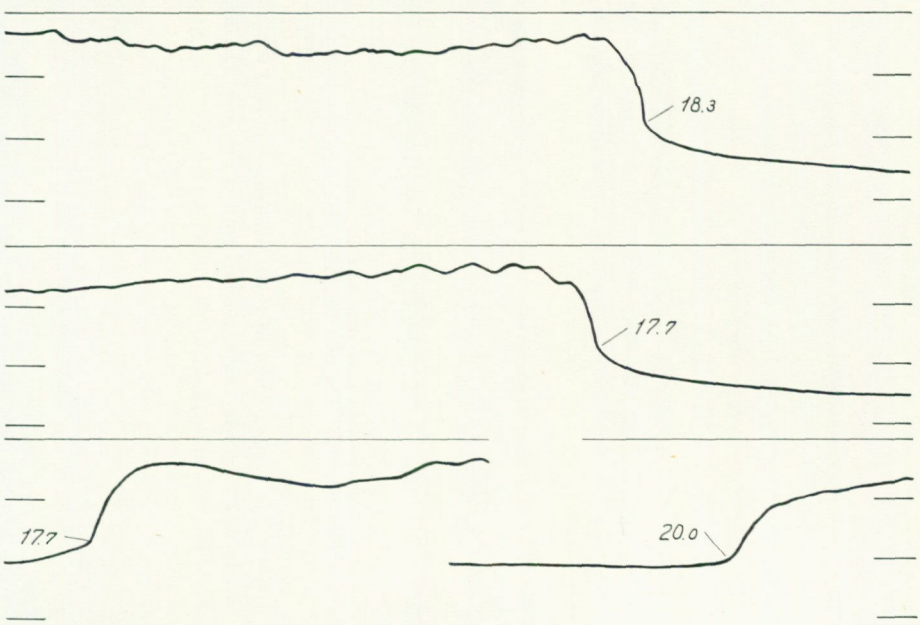


Fig. 13. *Echo diagrams across the cliff (drift, covered with eolian sand) south of Anholt. Vertical scale gives depth in tens of meters. Horizontal scale: 1.6 cm (1), 2.0 cm (2), 1.9 cm (3) and 2.1 cm (4) = 1 km. The cliff was partly formed by ice-contact, partly by shore erosion.*

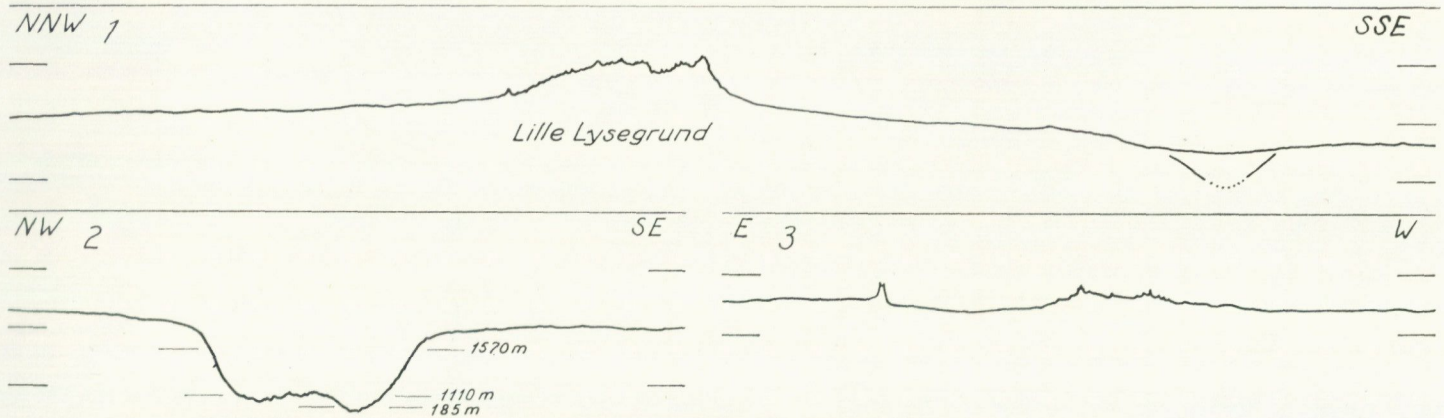


Fig. 14. *Echo diagrams from SW Kattegatt. Vertical scale gives tens of meters. Horizontal scale: 1.85 cm = 1 km. Lille Lysegrund is — tatally or partly — an accumulation of drift belonging to the E5 line. The buried channel belongs to the eastern arm of the channels from Store Belt. Diagram 2 shows the main channel from Store Belt. During ALV-1 this was a fiord rather than a river. The bottom of the channel is hard (rock or till). Diagram 3 shows some terminal moraines north of Sjaellands Odde belonging to the E5 line.*

All these indications of an ice margin are arranged in a line NW—SE. How this line is connected with Anholt is not yet known. Along the SE margin of the 10 m contour south of Anholt there is a marked till field with ridges (only partly seen in Fig. 13). From this field the E5 line seems to pass over to a marked ridge SSE of Anholt, which according to several echo soundings consists of till. In a curve it seems to be connected with the till field at the bulge of the 30 m contour. There it turns at a fork towards SW and makes a curve over Lille Lysegrund (Fig. 14, no. 1) and the two other shoals inside the E4 line. It joins the inner part of Sjaellands Odde at Ebbelökke, where a ridge projects towards NW. This was clear when with the echo sounder I found two minor ridges (Fig. 14, no. 3) just outside Ebbelökke pointing towards the shoals inside the E4 line. The E5 line goes along the hill to Nyköbing, where it joins V.Milthers' line across Sjaelland. It seems to follow close to the E4 line south of the Aamosen area, across Store Belt and down across Fyn. Possibly it follows the eastern side of the hills in SE Fyn instead of the lobe of the E4 line. At the old angle at Kirkeby it turns down towards SW according to V.Milthers' line. It seems reasonable to assume that the further extension goes over Skarö, with a fork at Hjortö, and continuing across Drejö, Avernakö, Lyö, Lyö W Flak and across Lille Belt.

THE E6 LINE was found with the echo sounder as a till field with some minor ridges just NW of Grönne-revle. According to the occurrences of stones this line seems to continue towards NW out over the 10 m contour. The southern continuation seems to change direction southwards at Grönne-revle and pass along the till area between Nörrevang and Rönnen-Nakke Hoved. Via a hypothetical continuation across the Isefjord it could join V.Milthers' line west of the bay Bramsnaes Bugt. The acute angle in the Aamosen area was probably now displaced to the Suså area SW of Sorö (S. A. Andersen 1931), from where the ice margin (of the Belt ice) turned and crossed Store Belt (probably close to the E4 line).

The F lines

The letters given to the different marginal lines do not mark any boundaries. They have been used for historical reasons, and to give every line an easy name. The possibility of giving a good picture of the recession of ice during the F lines is limited by the fact that the lines in SW Kattegatt are sometimes hypothetical and that the lines in Sjaelland (V.Milthers 1935) are incomplete, and have uncertain mutual connections and can thus be combined in different ways (K.Milthers 1942, Hansen and Nielsen 1960).

THE F1 LINE is V.Milthers' line at Hundested (the Droby—Lynaes line). Outside Hundested in Kattegatt there is a hard bottom of till and occurrences of stones. The line seems to continue towards NW via patches of stones and a till field. North of Laesö there is a till field and ridge, which lies between the E5

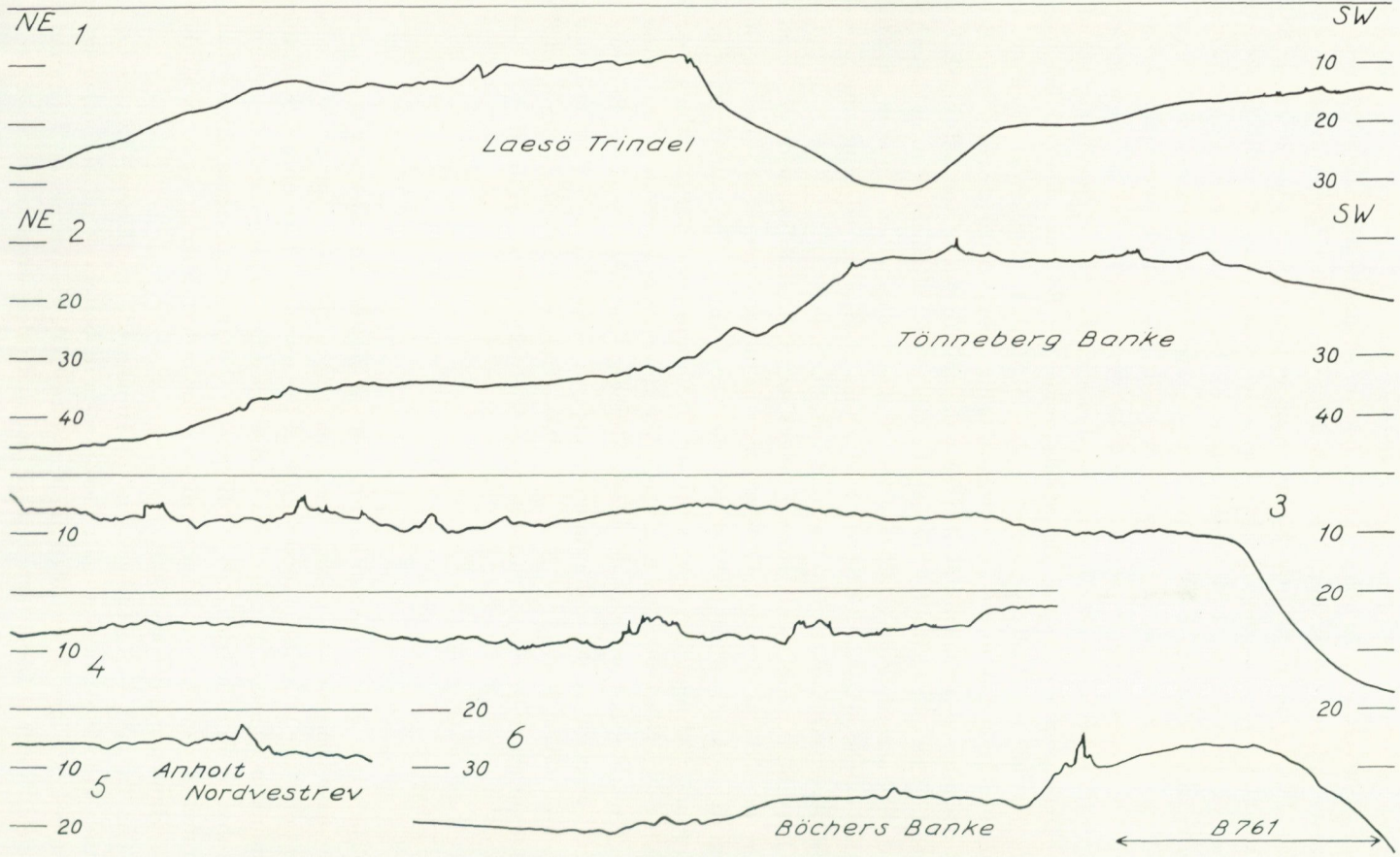


Fig. 15. *Six echo diagrams, all except no. 5) from the area N-NE of Laesö. Horizontal scale: 2.3—1.7 cm = 1 km.*

line and the F2 line. In the Suså area the acute angle was a deep cleft (S. A. Andersen 1931) and Store Belt was probably crossed somewhere in the Korsör—Nyborg area (possibly via Sprogö).

THE F2 LINE is a well marked line formed during a more marked stagnation. North of Österby Havn on Laesö there is a shoal containing stones. Two echo sounded lines clearly showed till, in the outer part as two separate ridges pointing to NE (Fig. 15, no. 3—4). Doubtless these are terminal moraines belonging to an ice marginal line (possibly two). The ridges reach Laesö at Jegens Odde and pass across Laesö towards SE (note the point SE of Österby). A gravel pit north of Österby shows stratified gravel, which could be glacifluvial material. The line continues towards SE via Flyndergrund and the shallow stone-rich Kobbergrund. It passes down to the point of the 10 m contour, where stones occur and where echo sounding has shown a moraine topography with ridges. The further extension is hypothetical, but it seems very likely that it joins the fields WNW and SSW of Store Middelgrund and here makes a fork with the left line pointing towards SW, i. e. Lysegrund. Due to technical mishaps I have hitherto had to miss Lysegrund. This is a pity, but I think the existence of a shoal covered with abundant stones and sand in this part of Kattegatt clearly speaks for an ice marginal deposit. Hesselö consists of clayey till (Rördam and Milthers 1900) with stony banks in NW and SE. I find it reasonable to explain it as an ice marginal deposit from the F2 line and connected with Lysegrund by a minor lobe. About 50 m of drift was found in a drilling on Hesselö (Danmarks Geologiske Undersögelse). Hesselö can be correlated with the hill of till at Mellby via a till field SE of Hesselö (echo sounding), the small shoal, occurrences of stones, a till ridge NW Torups Flak (echo sounding) and a till ridge on Torups Flak (echo sounding) just outside Mellby. From Hanehoved the line passes over to the eastern side of the Roskilde fiord (V.Milthers 1935). I find it likely that the further extension is marked by V.Milthers' Kyndbyline (V.Milthers 1935). Via V.Milthers' (1948) minor parts of an ice marginal line or S. A. Andersen's (1931) eighth line in the Suså area, the Kyndby line is connected with the classical F line in the Store Belt area, the so-called Langeland readvance, which via a series of shoals passes across Store Belt and passes down along Langeland as a very distinct line and turns over to Aerö. With several lobes, it follows just inside the German coast (see e. g. Kolp 1965) and as the Rosenthaler line across Northern Germany from Külungsborn to Stettin (Hesemann 1932, Heerdt 1965). The readvance at Grömitz (Schüttrumpf 1955) may also belong to the F2 line (or may be somewhat younger). In Schleswig, the F2 line may be represented by Gripp's (1954) V line.

THE F3 LINE is not a good synchronous line, but just parts of ice marginal lines between the F2 and F4 lines. East of Laesö there are two lines: a western line goes from the projection of the 10 m contour north of Eastern Laesö across the eastern point of Laesö and down to the shoal Stenknuder. An eastern line goes

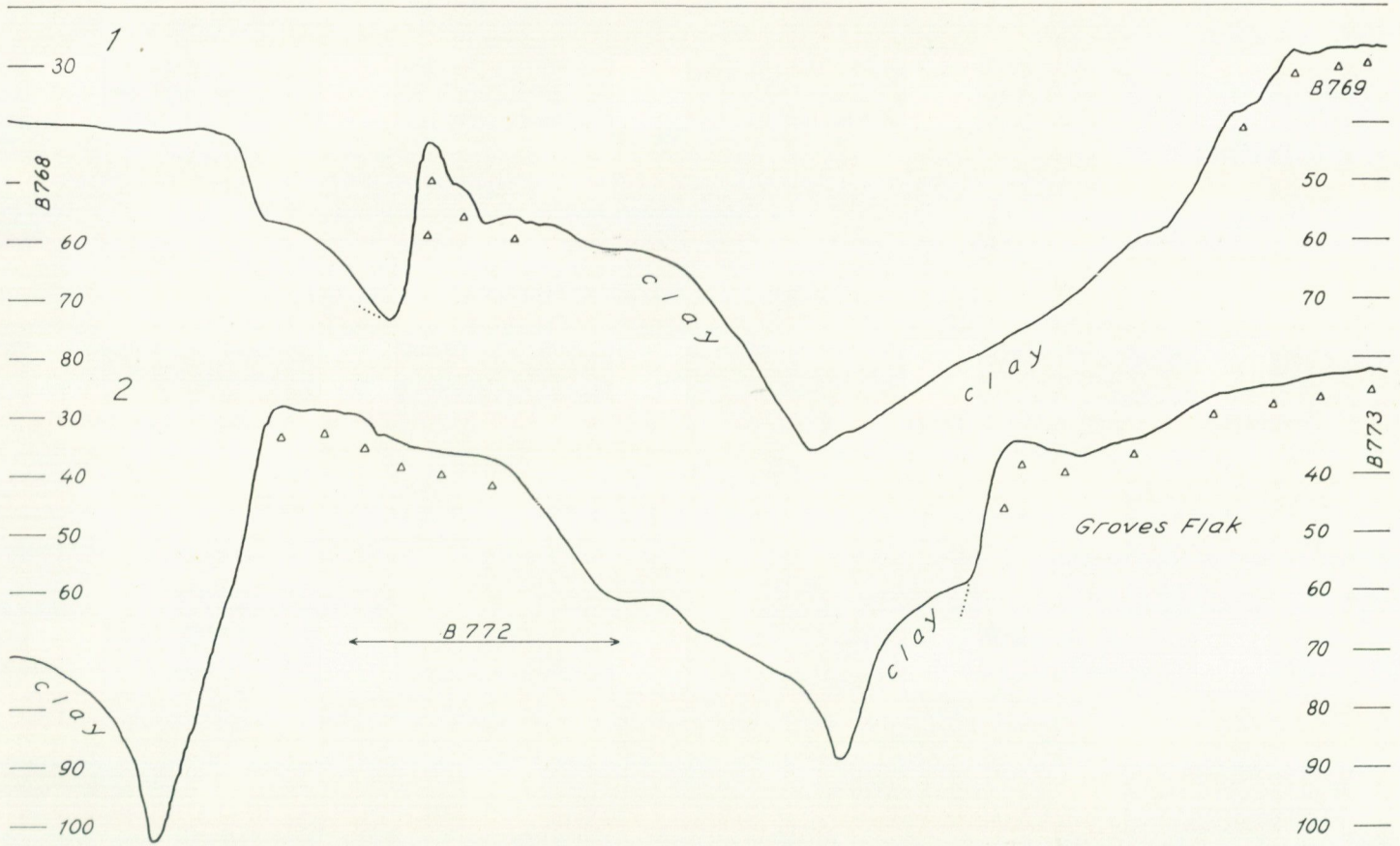


Fig. 16. *Echo diagrams from the shoals E-SE of Laesö. Horizontal scale: 1.7—2.2 cm = 1 km.*

just east of Laesö via the shoals Rasmusbanke, Taellemandsbanke, Knallen and Mellemgrund. In NE Sjaelland V.Milthers has the Skjaevinge line, which may continue in S. A. Andersen's (1931) ninth line in the Suså area and — via the coastal area of SW Sjaelland — cross Store Belt in the Skaelskör—Langeland area.

THE F4 LINE is a marked line, at least in Kattegatt. The northernmost part of this line comprises the shoals north of Eastern Laesö, which consist of till according to the echo sounder and contain stones according to the nautical charts. The line follows the cliff along the 20 and 30 m contours towards SE. Just after the bend of the deep channel it is marked by three shoals in a line. The first shoal is covered by Postglacial clay (dredging B 770), but of course there is something hard below the surface: moraine or rock. The second shoal has a very hard surface, but the dredging gave no material (B 771). The nautical chart says coarse sand with shells. The third shoal (B 772, Fig. 16, no. 2) has a surface of till, a chalk-rich silty pebbly gravelly sand (Tab. 2). The till also contains shells, partly recent Postglacial shells, partly subfossil arctic Late Glacial shells (*Balanus hammeri, Balanus* sp., *Saxicava arctica* and possibly old shells of *Mya truncata*). According to the echo soundings there are no traces whatsoever of rock in any of the three shoals, but a moraine-like bottom-line. The F4 line continues towards SE along the cliff. It passes the shoal Korallgrundet (B 775, Fig. 17), where a dredging gave caral-rich gravel and sand (the "corals" are the red alg *Lithothamnion calcareum*). However, it seems from the echo sounding as if the shoal is partly built up of Archaean rock, which in peaks breaks through the moraine material (for exemple the −13 m peak). The offset from this shoal towards NW (Fig. 17, no. 1) suggests an ice marginal line. It continues across the shoal SE of Korallgrundet. The nautical chart says here sand and stones. The echo sounder says morainic bottom. It passes over to the shoal Fyrbanken, which consists of stones according to the fishermen (mostly flint). An echo sounding at the SE offset of this shoal showed morainic bottom. The further extension is hypothetical. It seems probable that the line passes down along the east side of Store Middelgrund to the base of the 30 m shoal (where stones occur), where it turns at an acute angle and then curves towards Sjaelland, being marked by the limit between the occurrence of stones and gravel on the two long and narrow shoals and a till field just inside the 30 m contour. There is a marked ridge of till according to the echo sounding just outside the coast and V.Milthers' Slangerup line, which I correlate with the F4 line. The Slangerup line probably continues (via Rye) in the Giesegård line (S. A. Andersen 1931), which seems to follow the northern margin of Smaalandsfarvand and cross Store Belt from Helleholm—Agersö to the northeastern part of Langeland. In Kieler Bucht the Lille Belt lobe had diminished.

THE F5 LINE is a marked and very important line. The northernmost part of it is the shoal Herthas Flak, which breaks through the thick layers of silt and clay. It continues across the shoal Tönneberg Bank, which contains stones

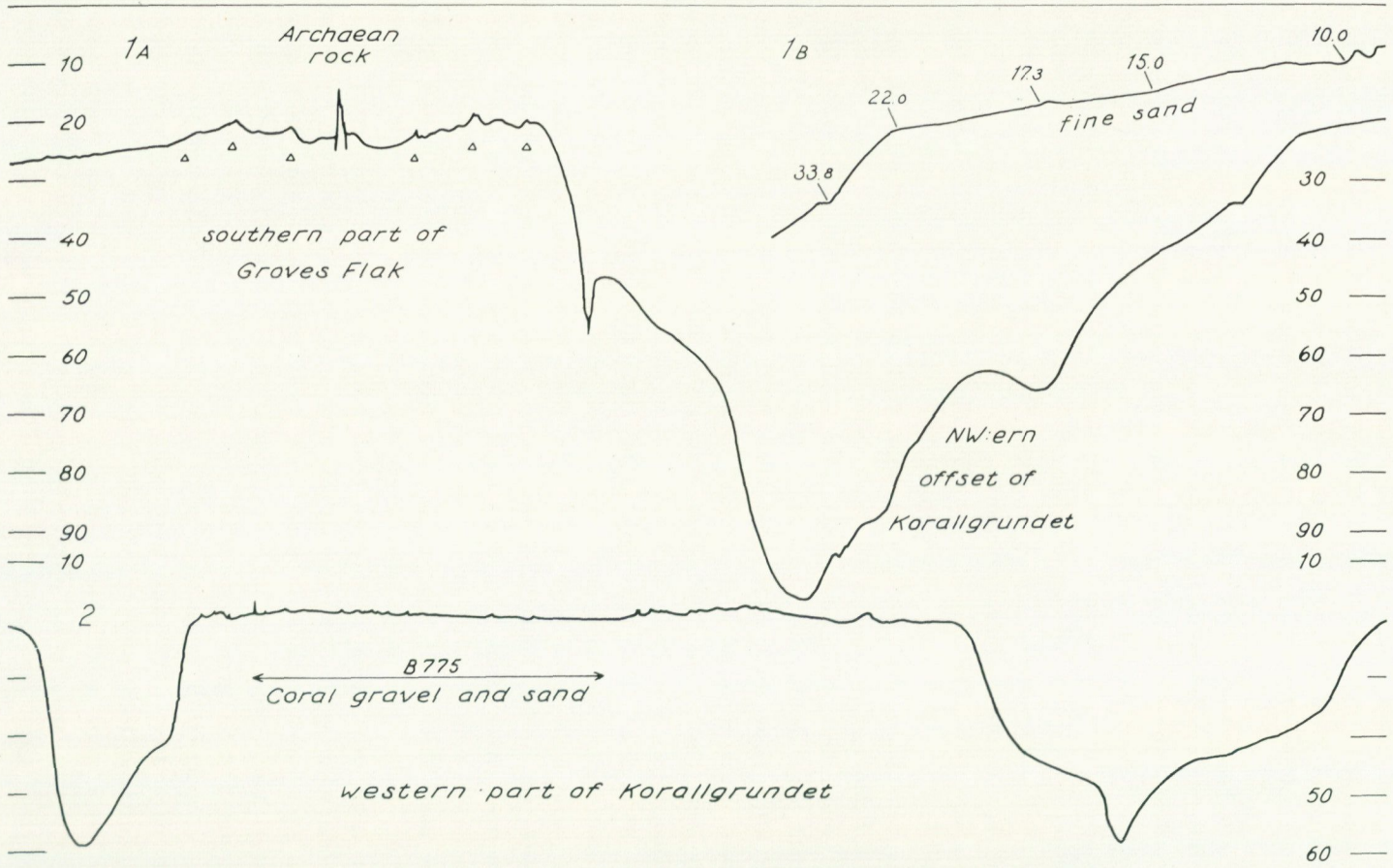


Fig. 17. *Echo diagrams from the shoals Groves Flak and Korallgrundet. Horizontal scale: 1.8—2.2 cm = 1 km.*

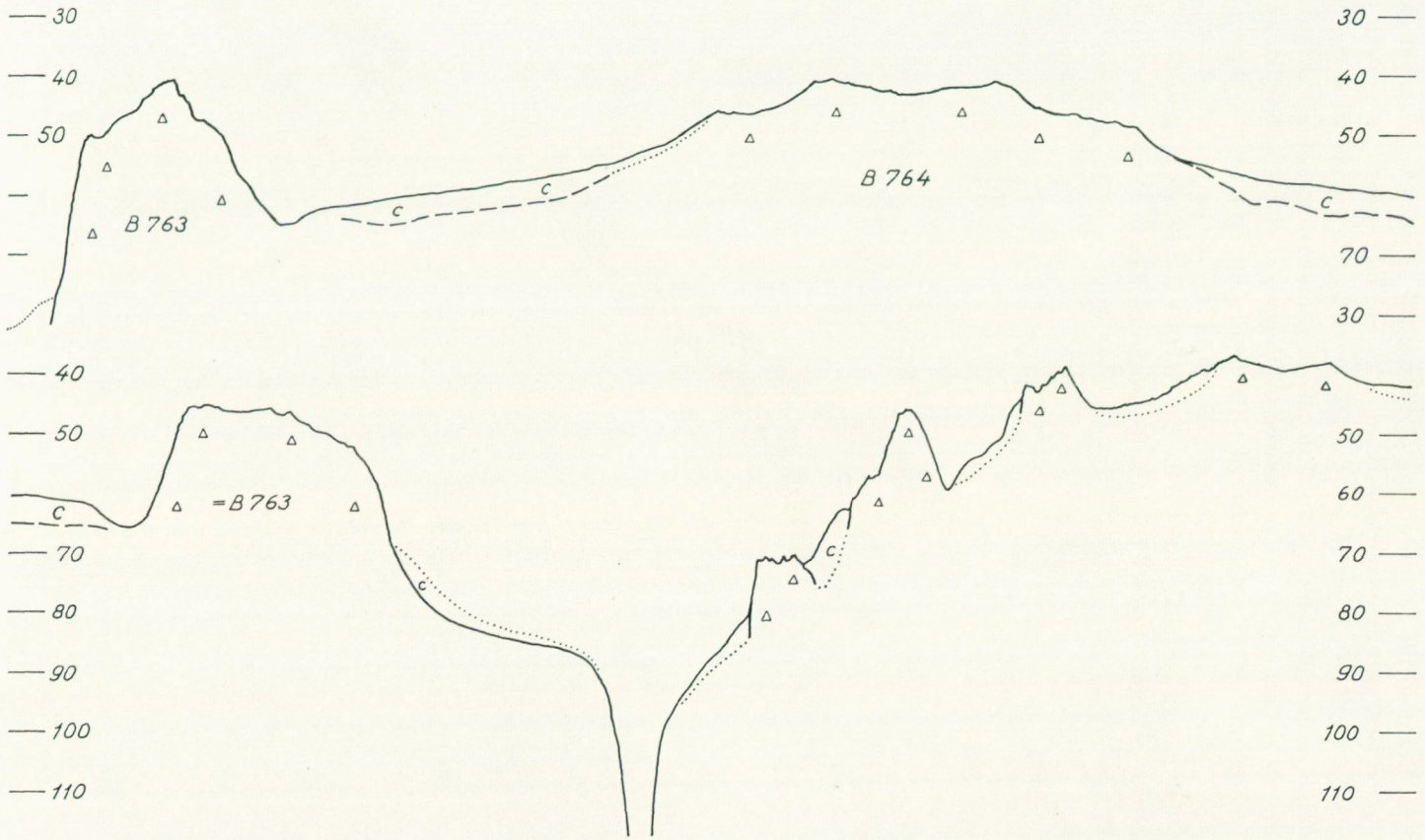


Fig. 18. *Echo diagrams from the small shoals N-NW of Groves Flak. Horizontal scale: 1.9 cm = 1 km.*

and according to the echo sounding consists of till (Fig. 15, no. 2), and passes along the western side of the projection of the 30 m contour (the eastern part consists of till, B 761, B 762; Figs. 15, no. 6, and 28). It continues across the more westerly of the two shoals just SE of the above-mentioned projection. The surface of this shoal (Fig. 16, no. 1) is covered by Postglacial clay (B 768). However, the echo sounding showed a series of till ridges in the offset of this shoal (Fig. 18, no. 2). It crosses the deep channel to the shoal NW of Groves Flak. A dredging (B 769) gave a clear till with a bimodal cumulative-frequency curve (Tab. 2). The echo sounding (Fig. 16, no. 1) agrees with this. The line crosses the big shoal

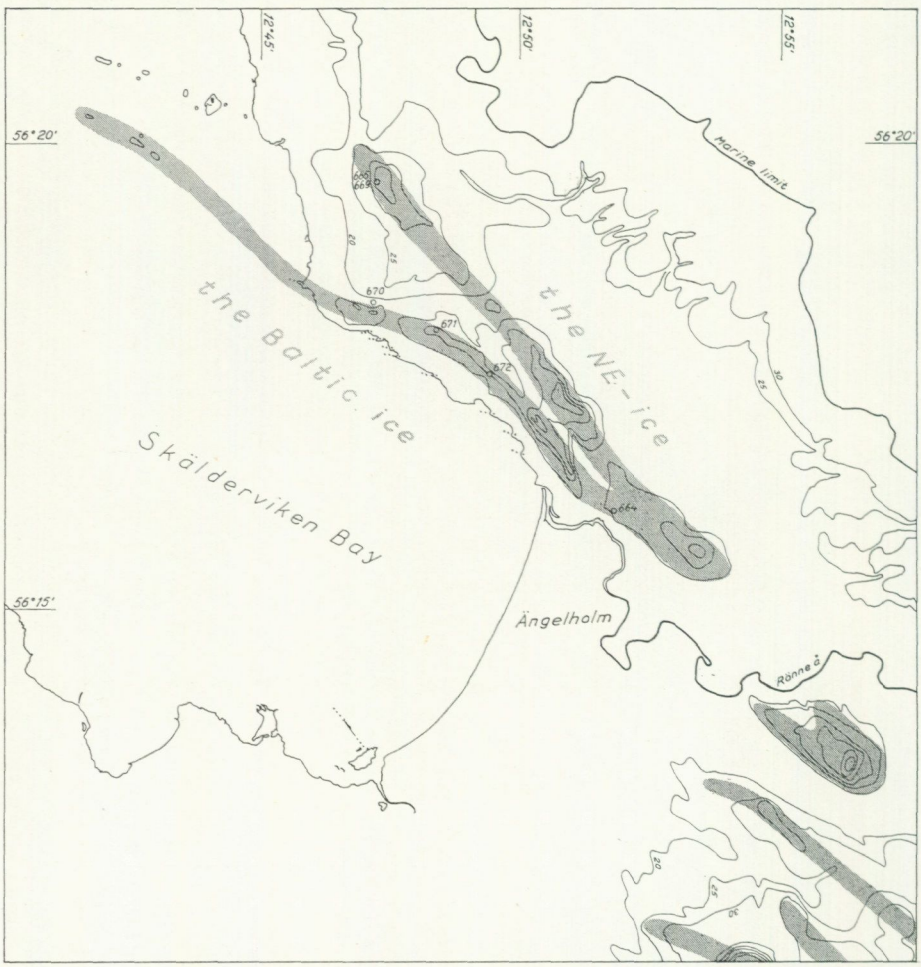


Fig. 19. *The ice marginal fork of the F5 line in the Skälderviken-Ängelholm area indicated by two distinct ridges of ice marginal deposits (the dark zones), showing transportation from two directions, ice pressure from SW and ice-contacts. This ice marginal fork illustrates the division between the Baltic ice (= the Öresund lobe) and the NE-ice (= the main Swedish ice cover). In SE, parts of the younger GF lines are seen (GFa-GF4).*

Groves Flak. The northern part consists of till according to the dredging (B 773) and the echo sounding (Fig 16, no. 2). The southern part seems to consist of Archaean rock (the peaks) and till (Fig. 17, no. 1A). It passes the two shoals SE of Groves Flak (with sandy surfaces) and follows along the western side of Lille Middelgrund. Then it crosses the flat 40 m shoal (sand and some stones according to the nautical chart) south of Lille Middelgrund and passes over to the shoal Rödebanke, which consists of stones (mostly flint) according to the fishermen. With a hypothetical line across the two projections of the 30 m contour it reaches a stone field south of Hallands Väderö (according to the primary maps for the Swedish nautical charts) and makes a very marked fork in the northern part of Skälderviken. This fork has been studied in detail on land and in Skälderviken and will be dealt with below. The left line of the fork goes in a curve (hypothetical) over to Sjaelland, where, via a well marked submarine ridge of till (according to the echo sounding), it joins V.Milthers' Kolleröd line, which most probably continues in the Lejre line (= S. A. Andersen's eleventh line in the Suså area). It forms a distinct lobe in Smaalandsfarvand (a series of submarine shoals) and joins V.Milthers' line in Lolland, which somewhere in the Rödby area seems to turn at an acute angle and continue in Kolp's (1965) lobes in Femarn Belt and Mechlenburger Bucht. In Nordmechlenburg this line seems to be represented by Kliewe's outermost line of "aufschüttungscharakter" (Kliewe 1966, Karte 2).

The ice marginal fork in Skälderviken is one of the most important things for the understanding of the deglaciation and the dividing of the ice into different ice streams. The first thing that drew my attention to this area was the existence of two topographically well marked ridges joining each other at Rebbelberga. The area is shown in Fig. 19. Tullström (1954) has studied the area and thinks it is an esker. I think it is two ice marginal lines from an ice fork (Fig. 19), when the receding ice along the Swedish West Coast, with an ice margin in NW—SE, was separated from the lobe in the valley of the sound Öresund.

B 664 is a gravel pit with very varied stratification. At point a the following stratification was noted (Fig. 20):

A: stratified sand
B: varved glacial clay, pinkish, about 2 m thick
C: sandy fine gravel
D: clay, grey, about 0.5 m thick
E: sandy gravel
F: till, clayey at the bottom
G: stratified sand and gravel

At point b (close to point a) the layers B, C and D are folded. At point c the layers slope towards NE:

A: glacial clay, varved, pinkish
B: clay, grey
C: sandy gravel

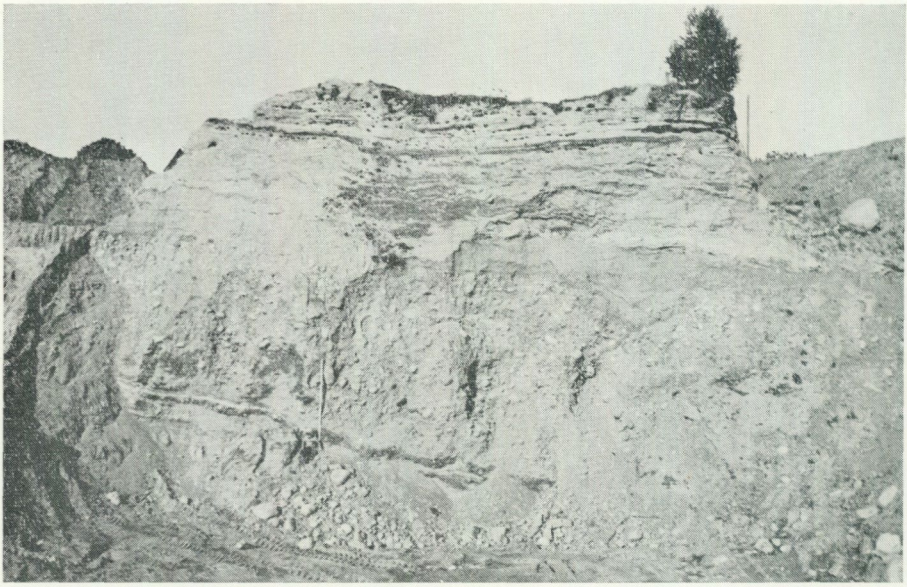


Fig. 20. *The gravel pit B 664 showing stratified drift, till and stratified sand and gravel. The measuring rod is 2 m long.*

At point d the picture is quite changed. The stratification is pushed and folded. The layers slope almost at 90 °. The pressure ought to have come from SW.

B 672 is a big gravel pit along the ridge where the following stratification has been noted:

A: Coarse, hardly sorted, till-like gravel. Sloping towards NW, i. e. along the ridge.
B: Stratified, better sorted gravel, sloping towards SW.

This was the NE wall. In the SW wall it is a quite different picture:

C (or B2.): Stratified gravel, very rich in pieces of black dy (see p. 41). Sloping towards NE.

B 671 and some unnumbered gravel pits are old and more or less overgrown and are of no interest.

B 665 and 669 are two sand pits in the Vejby hill (+39.5 m). The eastern parts of these pits show the distal part of a delta, consisting of sand. A beautiful cross-bedding occurs. The layers slope and the grain size is graded towards SW. In the western parts the delta slope is covered by till, which increases towards SW, i. e. it seems as if it has been deposited from SW. The limit between the till and the sand is more gradual than sharp (Fig. 21). The top of the till and sand is covered by a layer of washed gravel from the time when the sea level passed the surface during the Late Glacial regression. To summarize the stratification:

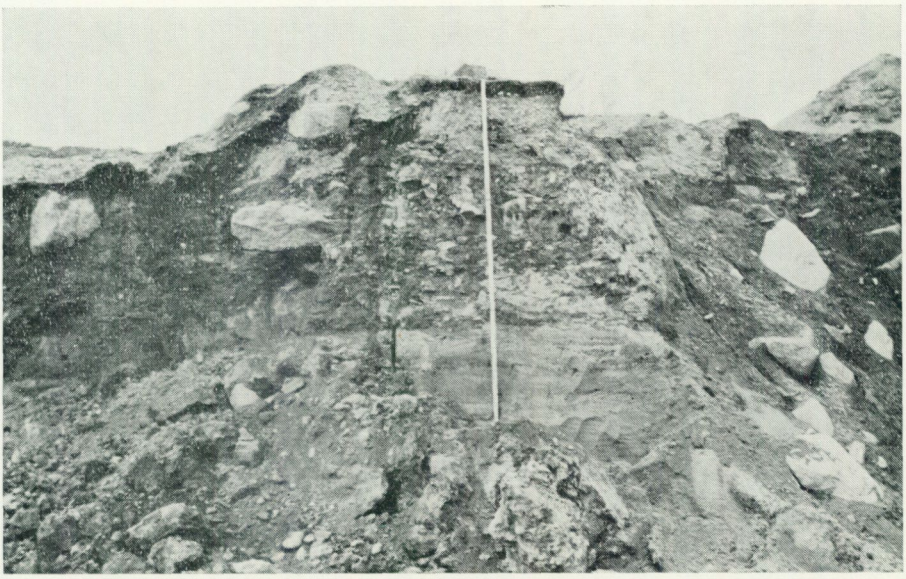


Fig 21. *Detail of the gravel pit B 669 showing the contact between the till and the stratified sand. The measuring rod is 3 m long.*

A: Washed gravel with an unconformity covering the sand (C) as well as the till (B).
B: Till (sandy-silty-clayey), containing boulders. At the bottom there is a thin layer of more pure sand and a thin layer of more pure clay.
C: Stratified sand, with cross-bedding, sloping towards SW.

Tullström (1954) described a locality, number 17 (Valhall), where stratified gravel sloped towards west.

Tullström (1954) also has two measurements of the orientation of the stone (his localities 16 and 15). These show transportation from west. They seem to derive from layers equivalent to layer A in B 772, i. e. a late stage in the sedimentation.

Seen as a whole, we can see an old transportation of material from both SW and NE—E, combined with ice pressure from SW (B 664). At a later stage the transportation was from SE—E in the inner part of the fork. The southern arm of the ice fork shows an ice-contact along the SW side of the ridge. Possibly there could also be an ice-contact along the outer part of the NE side. If this is correct, the southern arm is the initial phase of the fork and the northern arm is somewhat younger, i. e. the ice remained along the SW side of the southern arm, when it had receded from the NE side to the northern arm. The northern arm shows close proximity to the ice margin.

To me this is apparently an ice marginal fork (Fig. 19). This was the initial phase in the dividing of the ice into two masses which receded in different directions. The classical so-called Low Baltic ice begins somewhat later after a minor readvance.

The GF lines

After the dividing of the ice in Skälderviken, a new feature comes into the investigation of deglaciation. We can now put the recession of ice in relation to the Marine Limit (ML), which makes it possible to date the mutual relationship between the ice marginal lines and the shorelines forming the ML.

In Sjaelland V.Milthers (1935) has the complex of terminal moraines called the Gribskov line, which continues towards south in the Viby-Ballerup line. This complex shows traces of oscillations. In Smaalandsfarvand it is probably represented by a series of ice lobes (= the diminishing Store Belt lobe), seen as very distinct submarine ridges in the Fejö—Vejrö—Knudshoved area (Pl. 2). At Nöddebo Kro in the SW end of Lake Esarum there are shorelines at +12—14 m. These could have been formed in a bay of the sea (with fresh water). V.Milthers (1935) has two dotted lines on his map, corresponding to an old and a late part of the Gribskov complex. However, these lines have exact continuations towards NE in two distinct submarine ridges. The later one (GF7) just outside Gilleleje is a very well marked complex of several ridges (Fig. 22, no. 1 and 2). This points to a somewhat longer stagnation along this line.

A later ice marginal line, which belongs to this period is V.Milthers's Havreholm line.

Let us now turn back to the deglaciation in NE Skåne. As the terminal moraines can seldom be followed over large areas and as the ML is measured only at special places, it is hard to follow the deglaciation in all its detail.

The GFa stage is a possible ice marginal fork at the hill Höja (+47.8 m) 0.5 km SE of the main fork of the F5 line (Fig. 19).

The GFb stage is a wider fork with the southern arm along the ridge at Lunneborg to the hill Starby (+39.6 m).

The GFc stage has its southern arm along the hill at Tvängstorp (+40—45 m) east of Härninge Backe.

The GFb or GFc stage continues over the hills at Syllstorp and turns via the Bläsinge area up to the hill of gravel at Ellenberga (Tullström 1954). During these stages Kullen probably began to stick out of the ice. I have no measurements of the ML at Kullen, but occurrence of washed gravel +45—50 m between Mölle and Arild makes me accept older measurements: De Geer +51 m and Mohrén about +50 m (a till pit west of Arild B 788 at +60—65 m showed no signs of washing). If this shorelevel is marine, it is the oldest ML in Sweden (cf. p. 76). In the canyon Djupadal across Kullen I have tried to determine the direction of the melt water streams, but have not yet succeeded, as I have found traces which could speak for a melt water stream in either direction. SW of Kullen there is a big till area between Bräcke and Brunnby. A till pit at Brunnby (B 787) shows:

A: ½—1 m washed, hardly rounded, gravel
B: till, in the top clayey and in the botton gravelly

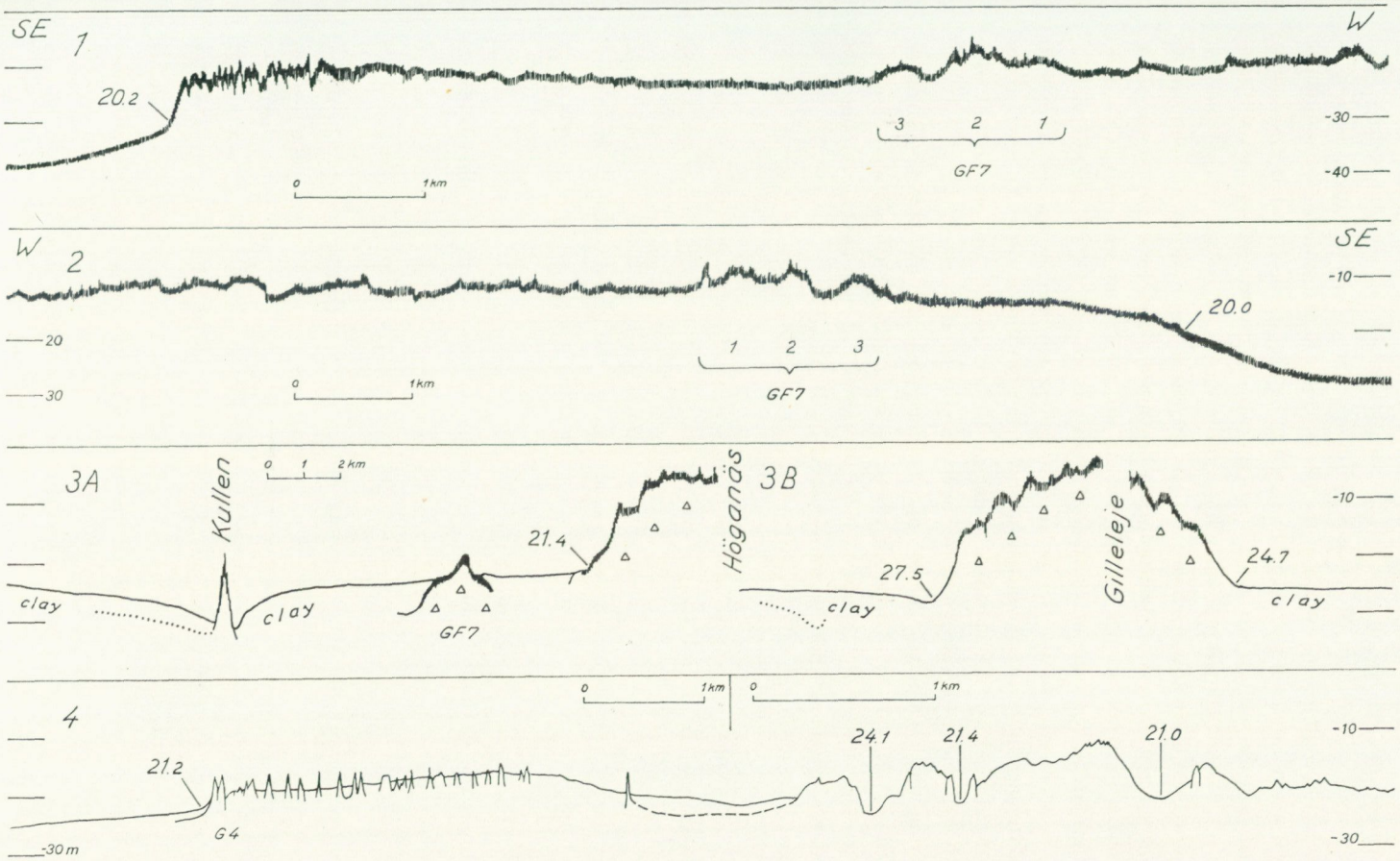


Fig. 22. *Echo diagrams from Gilleleje (1, 2 and 3B), Kullen-Höganäs (3A) and Landskrona (4). Diagram 3A illustates the differences in the bottom line obtained from clay, Archaean rock and drift.*

The surface was at +37 m (the ML consequently somewhere above this). The surface form is a ridge in N—S of drumlinoid character. This ridge, as well as the whole till area, lies just south of the point where Kullen finishes, consequently an area where we could expect changes in the ice streams and deposition of material. The genesis of this accumulation is not clear. According to Wennberg (1949, p. 18) the petrographical composition indicates deposition during the Old Baltic ice stream. In my opinion the petrographical composition does not allow any claer interpretation. As outcropping sedimantary rocks are most probably also present in SE Kattegatt (p. 33), it may just well — at least mainly — have been formed by the advancing Meridian ice stream (as a drumlinoid ridge), which the topographical position seems to indicate. However, it may also have been formed during the last deglaciation by the receding Öresund lobe. In my opinion the surface form and the position indicate an ice stream from north to south (the Meridian ice) or from south to north (the Öresund lobe).

During THE GF4 STAGE the ice margin was along the SW side of Härninge Backe. The ML +51 m (Tullström 1954) fits very well in with my own observations. A shore abrasion of about +50 m is obvious. A gravel pit at Möllebo (B 782), with a surface at about +50 m showed the following:

A: ½—1 m washed gravel (i. e. below ML)

B: 5—6 m silty till (mostly Archaean rocks, some flints, one Kinne diabase)

This ML at about +50—51 m is the second oldest ML in Sweden. Via some minor hills the GF4 line could more or less hypothetically be drawn to Tommarp, where it turns up towards NE (and possibly passes the gravel ridge at Ärrekärr). The continuation of the southern arm towards NE seems to go across Vegeholm—N. Häljaröd—Jonstorp and out into Kattegatt somewhere south of Kullen. Possibly it could go along the margin of the till area between Bräcke and Brunnby and reach the sea at Lerhamn. This line could be synchronous with the old Gribskov-line in Sjaelland.

THE GF5 STAGE contains six measurements of the ML by Tullström (1954), where the values lie very close to each other. I have no observations of my own in this area to check the ML measurements and settle the mean sea level (m.s.l.), which is what my shorelines are based upon. The top of a beach ridge or the limit between washed and unwashed till, for example, are limits for the wave action and not values of the mean sea level, the correct ML. Thus it is very hard to be sure of the exact relation between these figures for ML. Tullström's six ML figures fall into three lines:

1. Östra Ljungby +56.3 m (delta). Perhaps a little too high as a beach ridge reaches +56.0 m.
2. The second line 1 m below the first. Kärreberga +48.7 (shore cut) and Tåstarp +56.5 m (delta).

3. The third line 1.5 m below the second. V.Sönnarslöv +49.7 m (shore cut) — an escar reaches +55 m. Bjersgård +52.5 m (delta) — limit for washing of the till +54 m. Munka Ljungby +55.2 m (delta).

During this stage (two stages?) an ice marginal line stretched from Ausås over to the NW point of Söderåsen and (from the NE side further in of Söderåsen) on via Östra Ljungby up to Hillarp and Tåstarp. The northern arm of this fork is older than any ML figure on the Bjäre peninsula and the ice marginal line seems to have reached the sea just north of Dagshög, where a small terminal moraine could be seen (Fig. 24). The southern arm seems to have gone (more of less hypothetically) via Kärra and Tånga to the till area south of Kullen and Lerhamn (cf. GF4).

Mohrén and Tullström (Caldenius *et al.* 1960) described the inner part of the lowland north of Söderåsen as "Immense masses of glacio-fluvial drift seem to have been deposited in this bay of the Sea". A plain with its highest level at +50 to 52 m is said to have been built up to or fairly close to the ML. This could roughly be in concordance with the ML at V.Sönnarslöv +49.5 m (the same isobase latitude). However, further down they say that an outwash plain at about +55 m at Bonnarp corresponds to ML. This figure contradicts Tullström's measurements of 1954. However, the difference would only be that a narrow bay would have reached further in at an earlier time.

In the central part of Skåne Romeleåsen started to stick out of the ice as a nunatak at an early phase (Munthe *et al.* 1920). Nothing is known as to when this took place in relation to the deglaciation here described. Presumably it occurred during the later part of the GF stages.

The GF6 line is marked by a submarine terminal moraine ridge at Nyhamnsläge. The ridge contains the shoal Gaddebådabådan and points towards NW (note the different direction in comparison to the younger ones and probably also to the older ones). No further continuations of this line are yet known. If the line is extrapolated towards SE, it would pass Svedberga Kulle. However, Svedberga Kulle, at a guess, mainly consists of older drift from the Glumslöv Interstadial (as many other hills in this part of Skåne have turned out to do; cf. p. 44). According to Mohrén (Tullström 1954, p. 54) the till at Nyhamnsläge rests upon fossiliferous, till-like clay, which shows influences of the ice. This fact, as well as the direction of the terminal moraine ridge, could point to a small oscillation of the ice margin towards NW in this area.

The GF7 line is first of all characterized by the very well marked submarine terminal moraine (or rather terminal moraine complex) containing the shoal Skärsbådan and the Strandbaden peninsula, and maybe also the somewhat younger shoal Norrskärsbank. It points towards WNW. Echo soundings outside the part of the ridge, which is apparent from the nautical chart, have shown a very well marked ridge (ridge complex of till-character), which breaks through the clay sediments (Fig. 23, no. 1 and Fig. 22, no. 3A). The mere view

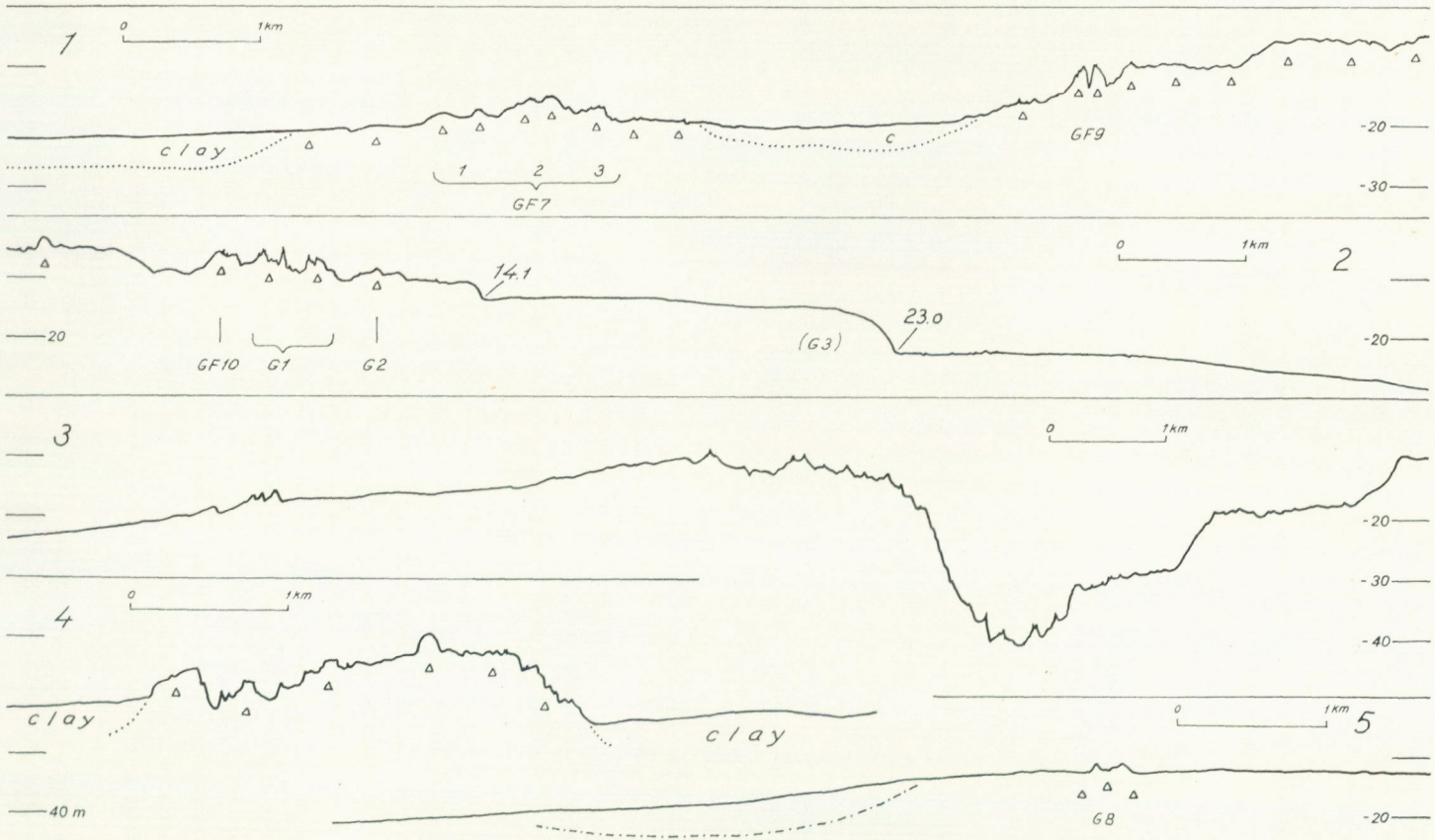


Fig. 23. *Echo diagrams from Öresund.*

of this ridge complex carries one's thoughts involuntarily to the submarine ridge complex outside Gilleleje (Fig. 22, no. 1 and 2), i. e. the later Gribskov line. The continuations of the GF7 line seem, with a curve across the lowland between Höganäs and Jonstorp, to reach Svedberga Kulle. If the GF6 line also reached Svedberga Kulle, there could thus have been an oscillation in the lowland towards NE. At Gärdslöv, Mohrén states the following sequence in a boring (Tullström 1954):

A: Late Glacial clay
B: Baltic till
C: NE-till

The two till beds could be ascribed to a big readvance of the so-called Low Baltic ice (older literature) or minor oscillation (my GF7 line). However, I think there is another explanation for these types of stratifications.

During the maximum of the last glaciation the transportation of material was towards the periphery and no special ice stream occurred along the Öresund depression. Later a special Baltic ice stream came about. This means that a subglacial deposited basal till of NE-material, from the time when the transportation was towards the periphery, may occur also in the area of the Baltic till. Furthermore, the transportation along the shear plains in the ice, from the picking up at the bottom to the deposition at the margin, takes time, i. e. NE-material may also have been deposited after the Baltic ice stream came about. This is why the real limit to the Low Baltic ice stream does not appear before the readvance of the G4 line, and a heterogenic material was deposited during earlier stages.

Thus I express the stratification at Gärdslöv in the following way:

The Baltic till = englacial to superglacial till deposited at the ice margin.
The NE-till = basal till deposited subglacially in connection with changes in the ice streams.

From Svedberga Kulle the GF7 line seems to continue to a ridge at Flenninge. If the GF7 line at Flenninge is extrapolated towards SE, it seems to reach the hill Pantabacken. In the area of Konga it probably turned towards NE. The melt water was discharged through the big canyon Skäralid (the watershed at Bakholmen—Lillö is at about +105—110 m). Towards NW the lowest point (between the hills Pantabacken and Söderåsen) is at +120—125 m (at Björkbacken). This means that an ice lake could have been dammed to about +120 m, discharging its water towards W—NW via the narrow canyon Skäralid. Later there must have been a drainage of this ice lake, either towards SW — possibly registered in the pit at Södra Vram (p. 80) — or towards SE—E (Odensjön, Nackarpsdalen).

Concerning the ML and shoreline of GF7 there are some important things to be noted. At the SW slope of Svedberga Kulle I have a measurement of ML.

The limit between a steep slope and a plain was measured to +37.8 m. I find it a good figure of ML. Above this shore mark I could find no traces of any higher ML and thus I do not trust Mohrén's statement of ML +50 m (Mohrén 1948). The shoreline of GF7 also contains a shore cut at Kärreberga +44 m (Tullström 1954). Every ML on the Bjäre peninsula is younger than this shoreline. This means that the ice margin stood further out.

With the study of ML it is also possible to make a synchronisation with the Danish ice marginal line. The shoreline of the GF7 line falls at Nöddebo Kro at +15.7 m. Shore marks have been described at +12—14 m. The shore marks are just inside the younger Gribskov line, but they are also a few meters too low to be compared with the GF7 shoreline. This, in connection with the very similar appearance of the submarine terminal moraines on both sides of Öresund, makes me regard this correlation as fully proved.

THE GF8 LINE is the well marked submarine ridge containing the shoal Långörsrevet and the point Långören (Höganäs). The direction is towards WNW. The continuation seems to go over Nygård and Ingelsträde (some minor elevations in the ground) and further after an interruption, over to the hills at Bräcke (B 834) and Kropp towards Mörarp. I have no measurements of the ML along this line. However, this must have been below +45—50 m, as no traces of washing are found in the big gravel pit at Bräcke (B 834). De Geer (1910a) has a figure of ML from this point at +38 m. This is about 4 m higher than I would have expected from the shoreline diagram, but the figure is not necessarily a figure of the mean sea level. This and/or the next GF line shall probably be conncted with the Havreholm line in Sjaelland.

THE GF9 LINE is the distinct submarine ridge west of Höganäs containing the shoals Möllegrund and Askegrund. This ridge points towards WNW—W. Outside the part of the ridge shown in the nautical charts, I found a very distinct continuation with the echo sounder (Fig. 23, no. 1). This is without doubt a terminal moraine. The line seems to be connectable with the Havreholm line in Sjaelland. The line continues towards SE via Äsperöd (till over clay) and the ridges at Hjälmhult, Allerum Kvarn and Väla, pointing towards the hill, point 71.63 m. No figure of ML is available. Mohrén has stated (Tullström 1954) that till occurs above clay at Äsperöd — this could indicate an oscillation. On the Bjäre peninsula the ice margin stood somewhere along the SW side. The oldest ML in this area, Glimminge +49 m (shore cut), lies 0.8 m above the next shore line and belongs consequently to the late part of the GF lines.

At S.Vram the following stratigraphy was observed:

A1: gravel
A2: fine sand, containing thin deformed layers of clay (= B) and signs that frozen blocks of fine sand also have been deposited
B: glacial clay, stratified but without definite varves
C: till (Archaean and Cambro-Silurian rocks)

My explanation of the layer A2 is that a strong and sudden stream has torn up frozen fine sand and clay and deposited them further out. This could have happened either during a drainage of the ice lake in the area south of Söderåsen (see GF7, p. 79) or during a readvance giving rise to melt water streams in the canyon from Skromberga to S.Vram (the A2 layer contradicts an explanation of a common silting up in gradually shallower water). Measurements of the altitude of the A layer at S.Vram could have settled the problem. The only figures now available are the ones from the map: +35—40 m. If the corresponding sea level was +36—40 m, it falls within the GF lines and layer A2 would have been formed by a drainage from SE during the time of GF8 or GF9. If, on the other hand, the corresponding sea level was +35—36 m, it falls within the G1 line and layer A2 would have been caused by new melt water streams from south due to an oscillation to the G1 line. Both the explanations are possible. However, I prefer the higher sea level and drainage from SE of the ice lake between Söderåsen and the hill Pantabacken. This could have happened about the time of the GF8 line. The GF9 line then passed across Röstånga, and melt water could have been discharged through Odensjön and Nackarpsdalen.

One or two younger GF lines could be seen in the submarine ridge (ridges) south of Höganäs. It (they) contains the shoals Långaredsreven and Sparbössan. The continuation was also found with the echo sounder (Fig. 23, no. 2) and points towards WNW (as the GF lines usually do).

The G lines

The letter G has for a long time been used to denote the well marked line/lines with traces of readvances, which from Gedser in the south crosses eastern Denmark and turns over to Sweden.

THE G1 LINE is a well marked line which shows traces of readvance at several places. West of Lerberget there are two well marked submarine ridges, one containing Skallören and Rosensgrund and one containing Jungnäsbådan and Sillören. An echo sounding shows that these form a complex of several ridges (Fig. 23, no. 2). This ridge complex points towards NW, i. e. a different direction to the GF lines. This shows a readvance of the lobe in Öresund towards NW.

A correlation with the Horneby line in Sjaelland seems very reliable. Evidence of a readvance has been found at several places along this line (V.Milthers 1935). In the terminal moraine "Horenby Aas" 2—3 m of gravelly till with boulders rests upon glacifluvial sand and gravel, partly undisturbed stratified sand, partly disturbed layers of gravel, clay and boulders. In the hill at Gurre 2 m of gravelly till rest upon a thin layer of clayey till, which in its turn with an unconformity rests upon vertical layers of gravel. East of Marianelund Kro gravelly till rests upon glacifluvial gravel deposited from east, which is partly thrusted and folded.

A readvance in this area is apparent. The further continuation towards south cannot be separated from the G4 line, as this has totally or partly overridden the G1 line in this area. In the strait between Gedser and the German coast Kolp (1965) has a line of an outer lobe of the G line. Possibly this could correspond to the G1 line.

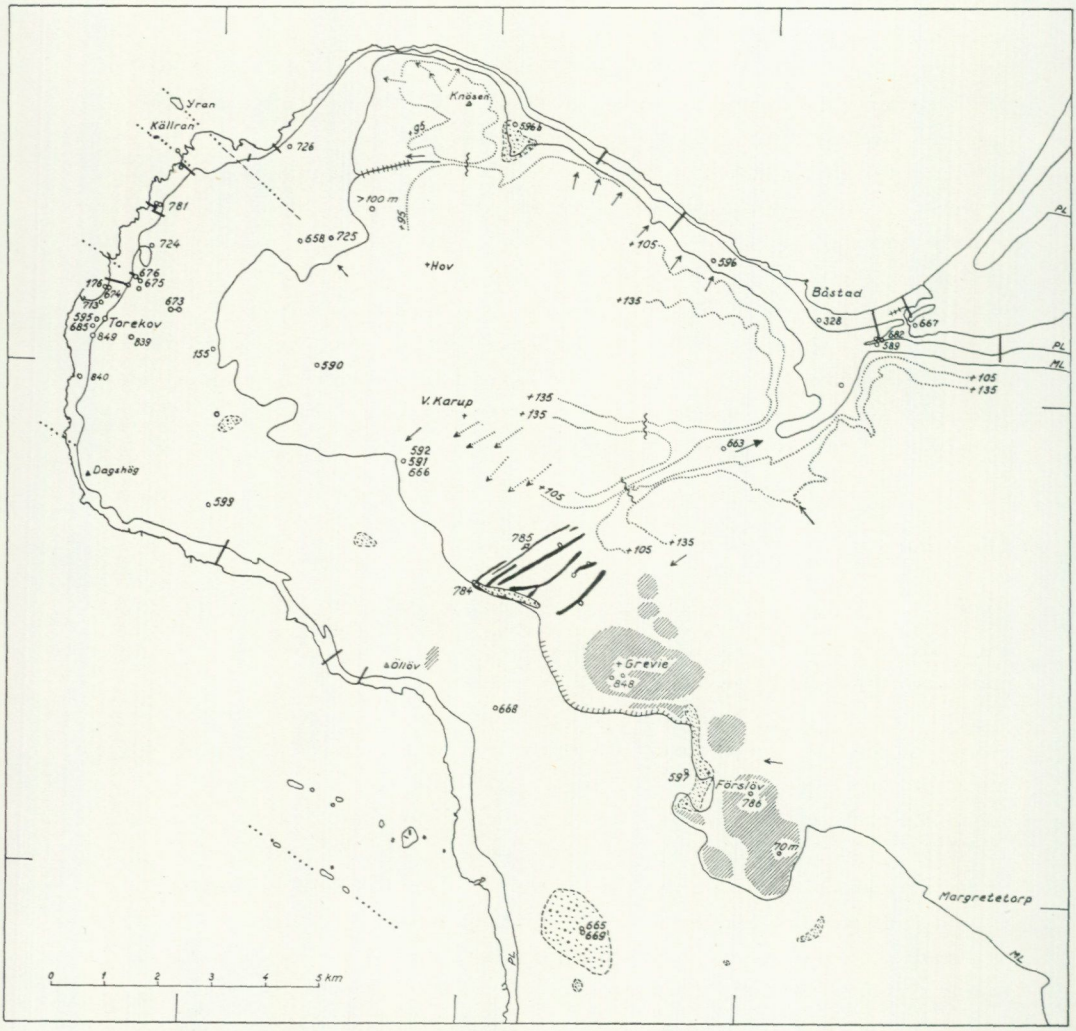


Fig. 24. *The Bjäre peninsula. Circles and numbers = borings. Hatched areas = known occurrences of sediments belonging to the Glumslöv Interstadial. Thick black lines = ridges between Grevie and Killebäckstorp. Thick dotted lines = terminal moraine lines. Short wavy lines = watersheds. Dotted arrows = melt water erosion. Full arrows = "canyons". Thick lines across PL = levelled sections.*

The continuation of the G1 line on the Swedish side is fairly well marked with a series of hills and ridges. The submarine ridges reach the coast at Svanebäck and go towards SE via Ry (small hill), Måsagården (small hill), Nällåkra (well marked ridge) and Allerum (well marked ridge) to the hills at Brohusen (B 835) and Filborna. The further extension is not yet known. In the big gravel pit at Brohusen (B 835) no trace of washing was found at +45—50 m. Along the NE side of the ridge at Nällåkra ML at its foot is about +30 m. A 1.5—2 m deep ditch (B 837) straight down the ridge showed a clayey till (containing flints) without any traces of washing in the surface. On the Bjäre peninsula the contemporary ice margin stood just north of Torekov, where a terminal moraine is seen as a stony point + a stony reef (Fig. 24). ML at Glimminge is 0.8 m higher and at Ängalag 0.5 m lower than the G1 shoreline. The submarine continuation of the G1 line seems (hypothetically) to pass three minor shoals (covered by clay) in the eastern margin of the area below the –40 m contour and to cross Lilla Middelgrund. The further continuation is well marked and goes from the shoal east of Groves Flak (dredging B 547 and 546 showed a pebbly fine sand to sand, i. e. a till-like mixture) to the NE part of Laesö Trindel (Fig. 15, no. 1) via a series of shoals that contain till, at least in the surface. The big shoal NE of Groves Flak with B 545 (dredging) contains shell-rich gravelly sand (two flints). The echo sounding did not give any clear information regarding the material of the shoal (presumably at least partly rock more or less covered by till). The next shoal north of Groves Flak with dredging B 764 showed a clear till (Tab. 2). The echo sounding also says till (Fig. 18, no. 1). The shoal NW of Groves Flak with dredging B 763 also showed a clear till, a pebbly clayey silty sandy till with shells (Tab. 2). The echo sounding also says till (Fig. 18, no. 1—2). The next shoal is east of Laesö and contains the dredging B 667, which showed a gravelly pebbly sandy till (Tab. 2). The echo sounding also says till. On the eastern side of the projection of the 40 m contour east of Laesö a dredging showed Postglacial clay. The echo sounding shows that there must be something harder below the clay layer. The line passes over to the eastern side of Laesö Trindel, which according to the echo sounding consists of till (Fig. 15, no. 1). The further extension is not settled but ought to go towards NW and pass close inside the F5 line.

In central Skåne a more and more broad area must have been melted free between the NE-ice and the Baltic ice and occupied by systems of ice lakes.

I think the readvance of the Middle Baltic ice in SE Skåne (the Svedala area) belongs to the G1 line. K.Nilsson (1959) thinks that the limit of the Middle Baltic ice was caused by a minor readvance and that this happened during an early phase of the Young Baltic ice stream. He also concludes that the Middle Baltic stage was not an independent ice stream, but rather a precursor of the Low Baltic ice stream. K.Nilsson's interpretation of the ice streams across SW Skåne is very important, but still I think he mixed older ice streams from the

advance to the C line with younger from the deglaciation (cf. p. 47). The Meridian ice stream and the conversion of this after the meeting with the Baltic ice stream belong to the advance to the C line while the younger belongs to the deglaciation. So the Middle Baltic ice stream flowed towards NW along the Öresund valley and also caused a readvance of the lobe in NW, i. e. the G1 line.

THE G2 LINE is a submarine ridge containing the shoal Svinbådan pointing towards NW just west of Viken. A continuation of this line was with the echo sounder found west of the shoal Jungnäsbådan (Fig. 23, no. 2).

THE G3 LINE is a marked submarine ridge from Grollegrund to Hittarpsrevet (note the abundance of stones outside Hittarp). It seems to reach the Danish coast somewhere about Hornbaek. From Hittarp it goes via a ridge to Gamla Kungshult and Gyhult and further, more or less hypothetically, towards SSE—SE. On the Bjäre peninsula the recession went on. The ML at Ängalag +49.5 (shore cut), Ingelstorp +49.0 (shore cut) and Hovs Hallar +52 (E.Nilsson 1953) all lie between the G1 and G4 shorelines.

THE G4 LINE is a very important line as it is equivalent to the Low Baltic readvance, which morphologically, stratigraphically and petrographically means a marked limit.

As the G4 line was formed by a readvance, there could have been older lines between the G3 and G4 lines, which were overridden and thus obliterated. No trace of any such lines has been found. The shoreline diagram gives 3.2 m between the G1 and the G4 shorelines. This means that there could not have been a long time between them, i. e. there was neither time enough for a marked interstadial nor for a greater readvance.

In Sjaelland the G4 line is V.Milthers' Hedehusene—Dyrehave—Helsingör line. This line continues down across the eastern part of Sjaelland and passes over to Falster, where a well marked terminal moraine is met, about which Hansen and Nielsen (1960) says: "The ice border must undoubtedly be considered as belonging to the G-stage." The G4 line passes via Gedser Odde and its submarine continuation in Gedser Rev over to the German coast (Kolp 1965) and joins the very distinct Velgaster line of "stauchcharakter" according to Kliewe (e. g. Hesemann 1931, Kliewe 1966, Karte 2).

At Niveröd, V.Milthers (1935) describes a glacial (varved) clay, that is folded from east. This shows oscillation of the ice margin. SE of Lungby in the bog Vintappermose, Rosenkrantz (Rosenkrantz and Henriksen 1921) described a very distinct Velgaster line of "stauchcharakter" according to Kliewe (e. g. following way:

1. Ice recession during late GF time or early G time. A Baltic clayey till was deposited.

2. Lake stage with water level at about +30 m. The lower varved series was deposited in this lake. The sediments contain fossils of plants, insects

and molluscs. The fauna of insects shows arctic environment. This is not contradicted by the plants and molluscs. The molluscs (*Pisidium* sp., *Limnaea auricularia, Limnaea ovata*) indicate that the lake was not ice-dammed.

3. Readvance of the Low Baltic ice to the G4 line. An ice lake was dammed to about +33 m (shore mark and occurrance of sediment). The upper varved sandy series was deposited in this ice lake with an unconformity to the older clay. Not a single fossil has been found in these sediments. Rosenkrantz thought that the ice margin probably had been stationary for quite a long time.

4. Ice receded some time after the G4 line (either immediately afterwards, or after the G5 line or the G6 line). The ice lake was drained and a new lake was formed with its water level just below +30 m. In this lake clay and sand were deposited, probably containing the fossils found by Steenstrup. Later a muddy phase started, containing a subarctic flora (Warming 1904) and finally it turned into a bog (Vaupel 1851).

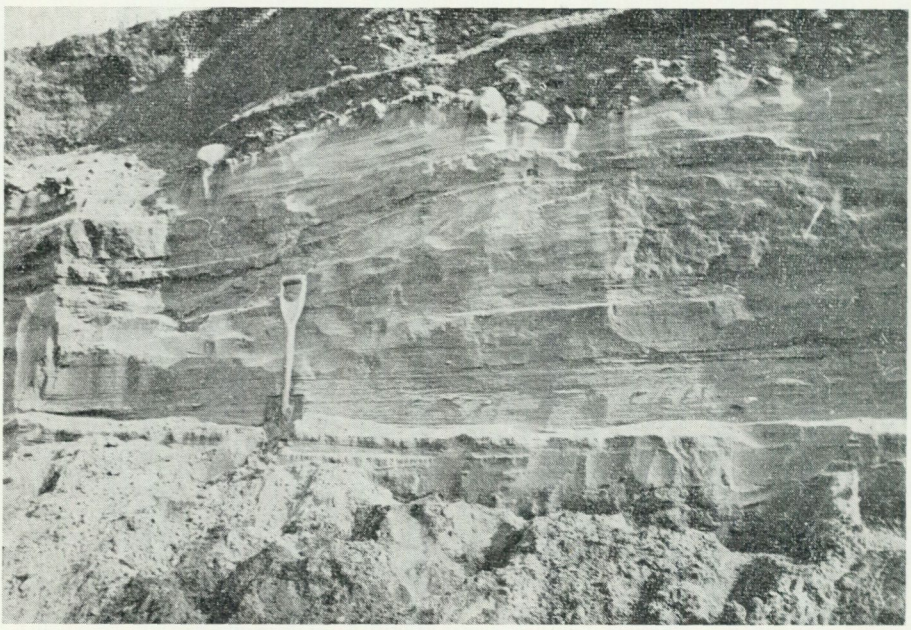
Consequently, we have here a fauna and flora that lived just before the Low Baltic ice readvanced to the G4 line. However, as the area could already have been deglaciated in late GF time, it does not contradict a short readvance without a distinct preceeding interstadial.

The readvance to the G4 line is clearly indicated by the large distribution of stratified drift between the NE-till and the Low Baltic till in SW Skåne (Möller 1959). The stratified drift does not contain any fossils and was deposited more or less close to the ice margin. However, ice wedges from below the Baltic till have been described (Johnsson 1958 and Gustafsson and Stjernkvist 1966).

From Helsingör I think the G4 line continues via the marked shoal Disken over to the Swedish coast, which is reached somewhere north of Ålabodarna. The advance of the ice margin seems to have stopped somewhere along the hills at Glumslöv, Algershög, Vadensjö and Rönneberga. The further continuation is mapped by Ekström (e. g. 1936, 1946) as the limit between NE-till and Baltic till. In SW Skåne H.Möller (1959) and K.Nilsson (1959) have developed the picture. In southern Skåne Ekström's limit goes down to the coast passing Skivarp. However, K.Nilsson (1959) has shown that the Low Baltic ice margin continued north of Skurup. This could be an indication that the G4 line is connected with the lobe in the lowland Våmbsänkan east of Romeleåsen (Munthe 1920, Ekström 1936, Wennberg 1949). Different opinions about the extension of this lobe have been expressed — I follow Ekström's soil limit (1936). From Våmbsänkan the line follows Ekström's limit between SE-till and NE-till to a point NE of Smedstorp, where the line turns towards NW — this is the margin of the NE-ice. Following Holst's till-limit (1892) it joins the terminal moraine zone, which Bergdahl (1953) described between Åkärrshus and Hörby. These terminal moraines are

important as they clearly show a deglaciation towards north (contrarily to E.Nilsson's picture of e. g. 1953 and 1968). The eskers in this area go straight across the watershed, which shows that they have been formed subglacially. To the area around Sjöbo, glacifluvial material was brought with melt water streams and deposited in large fields. In central Skåne there were systems of ice lakes. Linnermark (1942) found ice lakes both in front of the NE-ice (the Ringsjön ice lake) and in front of the Baltic ice. He found a gradient of about 5 m/10 km (in great contrast to E.Nilsson's 17 m/10 km). My gradient for the G4 shoreline is 7 m/10 km. From Hörby the G4 line continues towards NW, but before I deal with the ice margin on the Bjäre peninsula, let us consider the G4 shoreline.

From Tågarp—Sireköpinge melt water was drained along the Råå Valley (partly Pre-Quaternary, partly a melt water channel) to the sea. At the mouth of this valley (in the area around Raus) there is a big accumulation of sand



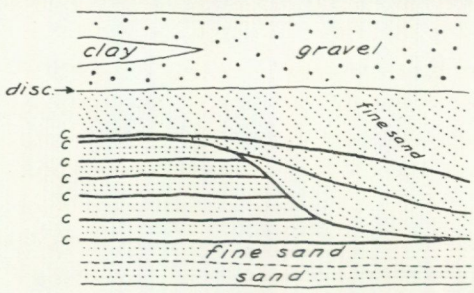


Fig. 25. *The gravel pit B 793, 1.7 km SSW of Raus, showing the distal part of a delta built up to ML at about +22 m. The gravel probably corresponds to a drainage in the Råå Valley from SE.*

and gravel reaching up to about +22 m. According to my interpretation this is a glacifluvial delta built up to ML.

1.7 km SSW of Raus a gravel pit (B 793), with the surface at about +22 m, showed the following stratification (Fig. 25):

A: About 2 m of glacifluvial gravel, petrographically consisting of flint, shale, Archaean rock and coal. In the southern wall there is a lens of glacial clay (1 m thick, 50 m long). The clay is pinkish-brown. In the bottom there are traces of varves (brackish water) and in the top there are varves.

B: 3—4 m of sediments from the distal part of a delta. Between layers A and B there is an unconformity. The most common sediment is a varved or stratified fine sand with sandy and clayey layers. Cross-bedding occurs frequently. The varved series consists of thick varves of sand to fine sand/clay to silt, but lower down the alternation is between sand/fine sand. The clay is pinkish-brownish. Several minor unconformities occur within the varved series (Fig. 25).

Layer B is a well developed distal part of a melt water delta, built up to ML, as there are traces of small tributaries which, with changing courses, crossed the delta. Layer A, with material from SE, is most probably a drainage varve corresponding to a drainage into the Råå Valley of the ice lakes along the eastern margin of the Baltic ice in the Eslöv area (cf. Wennberg 1949, p. 148).

1.7 km SE of Raus there is another gravel pit (B 794) with the surface at about +18—20 m. This shows the proximal part of the delta material: a bouldery stony gravel (Archaean rock is predominant, but flint and shale also occur frequently). Along the slope between Örby and Gantofta there is a marked shore cut just above the 20 m contour.

Out of these facts (a shore cut + a distal and proximal part of a delta) I fix ML at about +22 m.

The G4 shoreline includes a very distinct shore mark +31.0 m at Bräcke south of Kullen (a shore cliff). At the northern end of Härninge Backe Tullström (1954) measured a shore cut at +36.5 m. The shore cut is very distinct and I have followed it the whole way down to Möllebacken at Ausås. At the isobase latitude of Bonnarp the shoreline lies at +38.5 m, thus agreeing well with Tullström's and Mohrén's (Caldenius *et el.* 1960) statement that the sea level stood at +35—40 m at Bonnarp during the stage of the Low Baltic readvance, i. e. the G4 line. The abrasion at +44 m that Tullström (1954) described from Tåstarp falls into the G4 shoreline.

On the Bjäre peninsula several important details are to be considered before the extension of the ice during the G4 stage could be settled. At Segelstorp (SW of Grevie Kyrka) there is a very distinct cliff. The corresponding mean sea level was measured to +44.5 m. This figure falls exactly into the G4 shoreline. Between Grevie and Killebäckstorp there is a series of ridges (Tullström 1954), all ending at Killebäckstorp (Fig 24). The ML (mean sea level), which is here very well developed, was measured at four points, all giving the same result,

+44.5 m. This figure falls into the G4 shoreline (Fig. 26). This means that the ML here belongs to a younger shoreline than any other ML figure west and south of Hovs Hallar (cf., for example, Glimminge +49.0 m 2.2 km towards NE). At Kållinge east of Torekov there is a topographically small, but stratigraphically well marked shore (shore cut) at +44.5 m. This falls exactly into the G4 line. I have here studied a ditch, which went straight downhill across ML and the shoreline at +44.5 m. Above ML (about +50 m) there is an unwashed till, at and just below ML there is a field of washed gravel, and between this and the shore line at +44.5 m there is a hardly washed till of Archaean rock. At the shoreline at +44.5 m there is a marked limit to a littoral gravel, which contains flints. Further down there is again a badly washed till. Just outside the ML at Ängalag (+49.5 m) there is a gravel pit, B 725. The surface was measured to +46.0 m (the G4 shoreline here falls at +46.6 m). The cuttings show 3—4 m of washed gravel: a

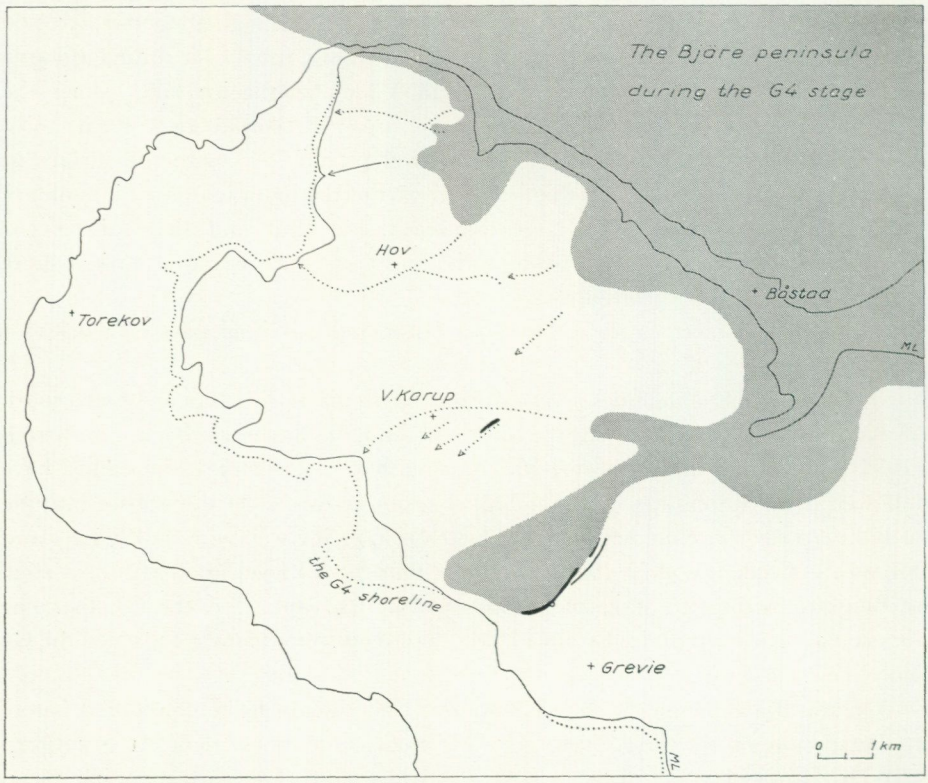


Fig. 26. *The dark area shows the extension of the ice on the Bjäre penensula during the G4 stage. The ice readvanced up on the slope of Hallandsåsen. From the Sinarp Valley a big lobe reached down to Killebäckstorp, where ML is unusually low and contemporary with the G4 line. At the eastern margin of this lobe there is a distinct ridge containing pushed and folded layers (Fig. 27). The arrows indicate melt water streams.*

loose stratified gravel interbedded with sand. The surface form is a flat ridge. The material is hardly rounded and seems only to have been transported a short distance. Archaean rock predominates, but flint and chalk also occur frequently. This is without doubt a shore accumulation. I think it has been formed as an offshore bar, i. e. it should belong to the G4 shoreline.

In the area of Kattvik, Tullström (1954) has studied the ML. I have made an independent study of the ML in this area. I found that the ML south of Kattvik followed the 50 m contour well (at or just below this) in the form of a bay. In a gravel pit (B 596b), at about +40—45 m, the following stratification was observed:

A: Several meters of glacifluvial gravel (Archaean rock predominating, chalk frequently).
B: In the bottom; a stony sandy clay, probably a boulder clay.

Tullström mentions some beach ridges. However, the one reaching +54,4 m is only a part of the drift-covered hill slope and has definitely nothing to do with shore processes. The ridge which reaches +48.2 m I have interpreted as an offshore bar built up to or just below ML. The ridge reaching +52.4 m cannot be called a beach ridge, as it is not built up by wave action, but a ridge of drift which may show some traces of washing in the surface. This makes me think that ML shall be fixed at between +48.2 and +49.0 m. If ML is at +50 m, it would belong to the G4 shoreline. If it is lower — as I think — it belongs to the period just after the G4 line.

If there had been a normal recession of ice towards NE, there would have been stages with ice lakes in the depressions along the northern side of the Bjäre peninsula (see the dotted lines in Fig. 24). I have searched for shore marks from ice lakes both in the Kattvik area and in Sinarpsdalen, but never found any such marks.

According to the above-mentioned facts, the limit of the G4 line on the Bjäre peninsula can be drawn (Fig. 26). From the Sinarp Valley a glacier lobe advanced down to Killebäckstorp. This is the explanation of the low ML here. Observations in four gravel pits in this area show cuttings in eskers, partly of the type of more or less open crevasses, partly more true eskers (B 795). A fifth gravel pit at Vysteborg showed thrusted layers, which had been set on their edges (Fig. 27). This ridge, which is separated from the other, looks like a terminal moraine of the glacier lobe from Sinarpsdalen, which it could very well be. The extent of the smaller lobe in the valley between Sinarp and V.Karup is not yet known, but anyhow melt water has been running in this valley and out into the sea at Glimminge. Two well marked (but small) melt water channels SE of V.Karup and a ridge ESE of V.Karup, that may be a terminal moraine, could perhaps indicate that the lobe reached as far as the hills just east of V.Karup. Minor melt water channels west of Boarp could indicate that this area was also occupied

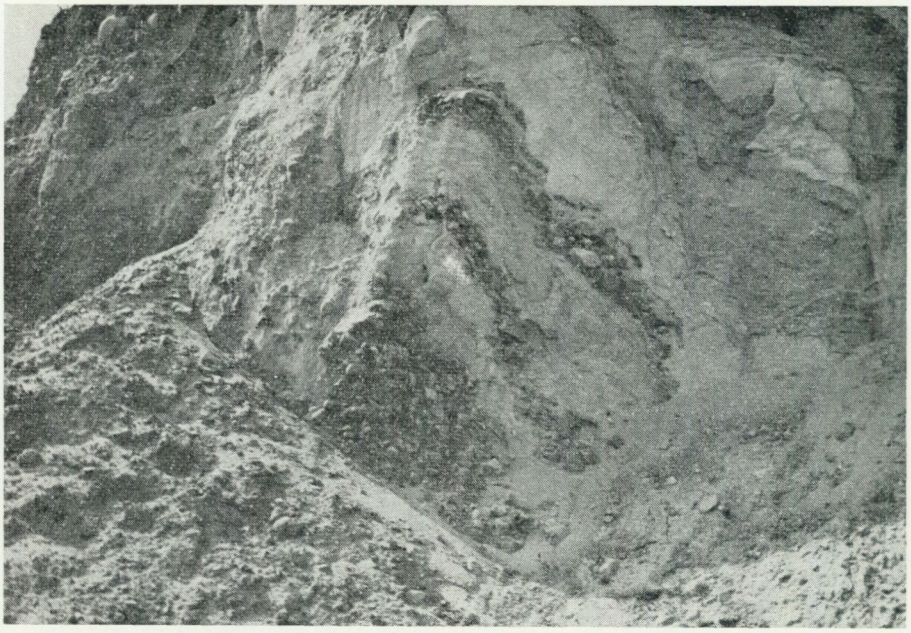


Fig. 27. *Gravel pit at Vysteborg in the ridge along the eastern margin of the glacier lobe of the G4 line. Thrusted layers, indicating ice pressure from NE. The section shown is about 4 m high.*

by a glacier lobe. South of Kattvik there must have been a lobe, which partly extended southwards discharging melt water to Ängalag via Hov (note the position of B 725), partly extended westwards discharging melt water through the canyon of the small brook, Ripaån (thus this canyon gets its explanation) and a melt water channel passing Hallavara. After following the steep slope of Hovs Hallar the ice margin continued into Kattegatt towards NE. Probably this line could be correlated with the line further out in Kattegatt, which via the two small shoals containing gravel, the eastern side of Lilla Middelgrund and Fladen Grund, passes over to the well marked terminal moraine of Böchers Banke. Two dredgings have been done here; B 761 gave gravel, B 762 gave till (Fig. 28; a gravelly pebbly sand; Tab. 2). The echo soundings also say till (Fig. 15, no. 6).

I have no information about the continuation of the glacier lobe in Sinarpsdalen towards E(—NE). The altitude of the lobe in Sinarpsdalen makes me think that the margin of the "living" ice went along the northern side of Hallandsåsen. This assumption is also supported by the rapid recession of ice from the northern slopes of Hallandsåsen after the G4 line (apparent from the ML-figure at Kärr). Of course, there remained a lot of dead ice on Hallandsåsen as well as along the SE slopes. This is evident from the occurrence of channels and canyons, which must be ascribed to melt water erosion (and not to the small recent brooks). The connection between Hallandsåsen and Hörup is

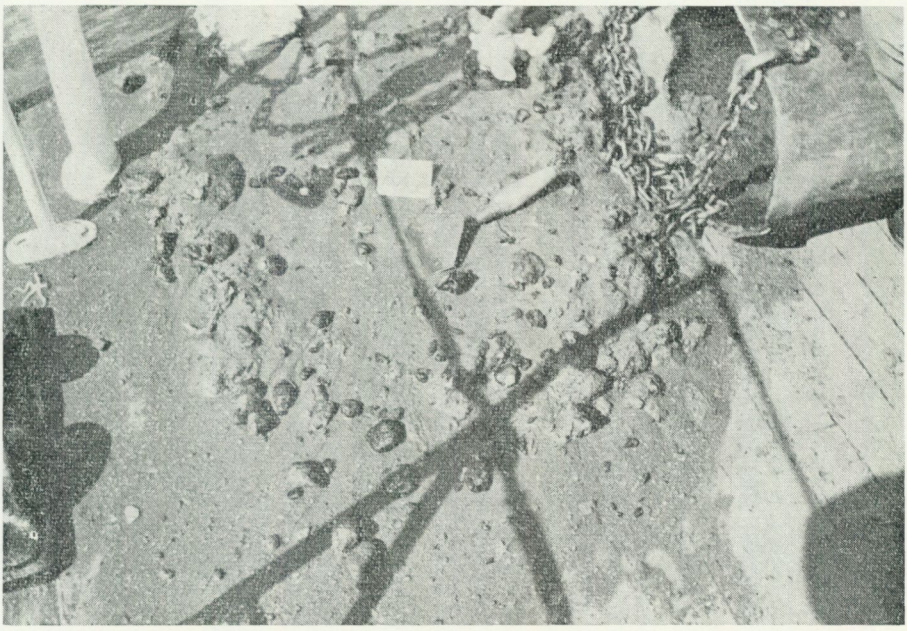


Fig. 28. *Dredging B 762 on the shoal Böchers Bank. Clearly a till material — a gravelly pebbly sand (cf. Table 2).*

hypothetical, maybe the very marked canyon at Trollehallar and the glacifluvial material in the Finkasjön area have something to do with this line. As Tullström (1954) stated, this area must to a great extent have been occupied by dead ice.

When the ice receded from the G4 line it left the ice in the Sinarp Valley as a separate glacier, which later receded from north to south. This is apparent from a series of terminal moraine lobes in the Sinarp Valley. A gravel pit, B 663, in one of these showed a till of englacial-superglacial type. The absence of ice lake stages also supports this interpretation. This glacier, the Sinarp glacier, seems to have persisted for a long time.

The given interpretation of the extension of the Baltic ice and the NE-ice means that no Baltic ice stream ever reached Hallandsåsen as Ekström (1936) and Wennberg (1943, 1949) thought (cf. Gry 1932). The occurrence of chalk and flint in the till on the Bjäre peninsula must be reinterpreted as coming from the Båstad area and its probably submarine continuation (e. g. St.Middelgrund, where outcropping chalk was found).

The stratigraphy of some cuttings on the Bjäre peninsula (Fig. 24), not discussed in the text, will here be listed:

B 726, digging in the botton of a gulley:

A: fine sand and mould
B: 3 varves of pure clay/till-like fine sand
C: clayey till rich in flint and chalk

B 658, digging:

A: 1.3 m of fine gravel
A/B: sharp limit
B: sandy silt, rich in chalk (presumably till)

B 724, house foundation:

A: 1 m of loose till
B: at least 3 m of till, clayey at the top, coarser at the bottom, only Archaean rock

B 155, part of the ditch mentioned on p. 88:

A: about 50 cm of till-like material
B: 2—5 cm of pitchy soil
C: about 20 cm of stratified sand
D: about 35 cm of peat (containing pollen of *Fagus* but not *Gramineae*)
E: a stone layer (black on one side)
F: till

B 590, foundation dug for a silo:

A: about 1.5 m of brown till, sandy, chalk-rich
B: about 0.7 m of grey till, a chalk-till
C: Archaean bedrock, highly weathered

The cumulative-frequency curves show a difference of 5—10 % between till A (finer) and till B (coarser).

B 599, house foundation:

A: 1/2—1 m of washed gravel
A/B: sharp limit
B: at least 1 m of grey till, chalk-rich

B 591, ditch:

A: about 0.4 m of unstratified sand-gravel
B: at least 1 m of stratified sand-gravel

B 666, ditch:

A: brown silty till
B: grey clayey silty till

B 668, ditch:

A: at least 1 m of sandy silty till, chalk-rich

In connection with the readvance to the G4 line there seems to be a general change in the clay sedimentation in the Ängelholm—Skälderviken area from a grey (B2) to a pinkish-brownish (B1) clay. On a whole the following clay types are found in NW Skåne (cf. Tullström 1954 and Hansen 1940):

B1: An upper pinkish-brownish, usually varved, glacial clay.
B2: A grey more or less stratified glacial clay without clear annual varves, but often with thin "varves" presumably corresponding to fluctuation within a year. This is Tullström's stratified clay, poor in $CaCO_3$, and Hansen's clay of type B.
A: A grey to bluish grey unstratified clay, rich in $CaCO_3$. This is Tullström's homogeneous clay, rich in $CaCO_3$, and Hansen's clay of type A.

The pinkish-brownish clay is seldom more than 1—2 m thick. At Ugglarp (B 783) north of Starby I found about 4 m of clay of the B1 type resting upon clay of the B2 type. According to Tullström (1954) the homogeneous clay has been deposited in freshwater and the stratified clay in marine water. The whole series seems to me to have been deposited in more or less brackish water. The whole time there was an open connection to the Atlantic Ocean, so it must have been the proportion of melt water that changed. The pinkish-brownish glacial clay was found in many cores taken in the seabed of Skälderviken at about −15—20 m. North of Hallandsåsen, i. e. inside the G4 line, the glacial clay is only of the pinkish-brownish type, varved or unvarved.

From Ven and the area between Landskrona and Hälsingborg Johnsson (1958) has described ice wedges and stones that have been brought up by the frost and sometimes showed traces of wind erosion. He regarded this as evidence that bare ground had existed before the readvance of the Low Baltic ice. However, structures very like ice wedges may also be formed in other ways than by frost activity, e. g. along ice tectonic fissures, along roots, fissures formed by subaquatic landslides, and structures formed by turbidity currents and different types of load cast. The so-called "pocket soil" (Swed.: "fickjord") that Johnsson (1956) described from sediments below the NE-till, seems to me to have nothing to do with frost activity, but to be the effect of load casts and turbidity currents (cf. p. 43). Such structures occur frequently in the distal sediments of deltas and in varved series. However, bare ground before the readvane of the low Baltic ice is just what one would expect from my interpretation of deglaciation and shore-level displacement.

Of the G4 stage as a whole, the following may be said: Traces of a simultaneous readvance have been found in several places and — this is important — both of the NE-ice and of the Low Baltic ice. This means that the readvance cannot be ascribed only to a dynamic change in equilibrium in the Low Baltic ice stream, but must be ascribed to a real climatic deterioration. I think this readvance was caused by a change to a colder climate. From the period just before the readvance there are arctic plants, insects and lake molluscs in Vintappermose and probably frost phenomena in the Öresund area. This readvance was a marked event, though the actual advance of the ice margin does not seem to have been as great as stated by Ekström (e. g. 1936).

From the determined rate of shorelevel displacement and the closely dated younger shorelines, the age of the G4 line was calculated at 11,150 BC (the margin of error is probably not more than ±50—100 years). Now the question arises whether there occurred any known climatic fluctuation about this time in the world.

Van der Hammen and Vogel (1966) introduced the Susacá Interstadial, which should have lasted from about 11,750 BC to about 11,150 BC. This interstadial was based upon more or less accurately C^{14} dated pollen diagrams from Colombia,

Kenya and Spain. The climatic amelioration is probably also seen in southern France (rise of AP pollen) and West Europe (rise of *Artemisia*). Dreimanis (1966) showed that the Susacá Interstadial is also found in the Great Lake area of North America (the Cary/Port Huron or Cary/Mankato Interstadial, or Bowmanville Interglacial, or Lake Arkona phase) ending about 11,050 BC. Dreimanis (1966) also pointed out the obvious correlation with the Raunis Interstadial, C^{14} dated at 11,440 ±500 BC (Savvaitov and Straume 1963, and Savvaitov *et al.* 1964) and the Plyasna Interstadial (Cherbotareva *et al.* 1965) in northwestern USSR.

This means that there was a world-wide climatic deterioration at about 11,150 BC. This is here seen as the readvance to the G4 line. As local name, Low Baltic Stadial is here proposed. The preceeding interstadial is represented by an arctic fauna and flora. As local name, Vintapper Interstadial is proposed. The beginning of the Susacá Interstadial corresponds in time with the recession from the F5 line. However, there are two distinct ice marginal lines, which at least locally show traces of readvances, viz. GF7 at about 11,400 BC and G1 at about 11,250 BC, between the F5 and G4 lines. This indicates that the Susacá Interstadial contains minor climatic fluctuations.

THE G5 LINE seems to go from Snaekkersten south of Helsingör to Ven (hypothetically) and via the shoal Staffans Bank (of drift according to the echo sounding) over to the big shoal Västerflaket—Valgrundet outside Landskrona (Fig. 102). Västerflaket—Valgrundet contains abundant stones and seems definitely to be an ice marginal deposit. From Valgrundet (Stensgrundet is the southern point) the G5 line passes over to the hill SW of Barsebäck (of till according to the geolocical map by Erdmann 1881) and further via the Löddeborg area down to the shoal Flädierev. Probably a continuation of the G5 line could be the northern part of the ice marginal line south of Arlöv, mapped by Munthe (1920), which then roughly joins the G4 line in SW Skåne and via Ekström's line (from Gärdslöv down to the coast) reaches the coast west of Ystad and then continues along the southern side of the Kåseberga esker. K.Nilsson (1959) concluded that the above-mentioned part of Ekström's line could be the limit between active and stagnant ice during a later stage or that it was formed during a minor oscillation. In SE Skåne there are series of parabola-shaped eskers (Kåsebergaåsen, Vallebergaåsen, Hörupåsen), which seem to me to have been formed in more or less open fissures in the ice. These fissures were caused by tensions in the ice when the Low Baltic ice margin turned around the SE corner of Skåne. The material in these eskers seems to be rather of delta type. At the village of Kåseberga there is a kettle. The slopes of these eskers are usually steep, suggesting ice contacts. The continuation of this fissured ice in the angle between Baltic ice and NE-ice seems roughly to follow the G4 line. North of Hallandsåsen the G5 line is very well marked. The area around Vindrarp has a marked dead

ice topography and was occupied by more or less stagnant ice during the G5 stage. The ice became active just south of Menlösa (Fig. 29), from where a very marked terminal moraine ridge can be followed the whole way to the coast at Skummeslövsstrand. The ridge must to a great extent consist of glacifluvial material, as a lot of freshwater is taken from the ridge at Skottorp. Outside Skummeslövsstrand there are two minor shoals, −7.8 m and −5.6 m Röset, which contain stones and where freshwater is said to flow up.

SE of Landskrona in the Saxå—Bråå area four gravel pits were studied in order to get an idea of the ML level. Johnsson (1956) has described a gravel pit south of Saxtorp, where details in the stratification were said to point to a corresponding low sea level, and the occurrence of ice wedges would show a subsequent land period with permafrost. The gravel pits studied will be described below in the order in which they occur in the shoreline diagram.

B 792, 1 km WSW of Asmundstorp. Surface at about + 10—15 m:

A: 1 m of washed gravel, till-like, hardly rounded
B: 1/2—1 m of stratified sand
C: 1/2—1 m of gravel (shore gravel?) of flint, shale and Archaean rock
D: 1—2 m of unstratified fine sand (marine type?)

B 789, 800 m SE of Saxtorp. Surface at about + 10—12 m:

A: 1/2—1 m of fine gravelly sand, hard, rich in flint
B: >1—2 m of stratified sand — fine sand, with "pockets" of brown unstratified sand and with lumps of fine sand that have been deposited in frosen condition and surrounded by silt, now brown

B 791, 1 km SE of Häljarp. Surface at about + 10—12 m:

A: 1/2 m of washed gravel, partly loose, partly very hard
B: sand

B 790, 2.2 km S of Ålstorp. Surface at about + 10—15 m (12—14 m?):

A: 1/2—1 m of sand, in the northern part containing a clayey lens at the bottom
B: >1—2 m beach ridge material of loose sand-gravel-stones, rich in flint

Judging from these stratifications, all four places seem to be situated in the distal parts of glacifluvial delta material. A close fixing of ML is not possible. However, everything points to a low ML level compared with the high figures given by Ekström (1947, 1953) and Mohrén (1941). The shoreline diagram says about + 17.5 to + 13.4 m, which is neither contradicted nor in detail supported.

During this stage the Lomma clay was deposited. According to the shoreline diagram there was shallow water in this area, with a connection to the sea. The Lomma clay is especially interesting as a fairly large number of specimens of the polar cod *Gadus saida* Lep. (= *G. polaris* Sab.) have been found in it (Torell 1887, De Geer 1887). The Lomma clay was often mentioned and discussed in the 19th century (e. g. Erdmann 1881, Torell 1887, De Geer 1887, Holst and Moberg 1895, Holmström 1899). An important contribution to the discussion about the genesis of the Lomma clay was given by Hansen (1940). The following

statements about the ecology of the polar cod were given by Hansen. The polar cod occurs nowadays only in quite arctic environments. It occurs abundantly close to the surface of the sea and may be particularly abundant in the proximity of the ice margin. On East Greenland it has several times been caught in the almost fresh pools on the surface of the fiord ice. However, it probably dislikes a dirty melt water. On a whole, there is nothing surprising in the occurrence of *Gadus saida* at Lomma considering the picture of deglaciation here given. The Lomma clay is varved. The varves are unusually thick — 20—50 cm according to Hansen (1940). The maximum number of varves has been counted to 13—14 by Hansen. This means that the conditions of the G5 line could only have existed for a short time or about 15 years. Hansen explains the genesis of the Lomma clay as being due to much meltwater (and consequently proximity to the living ice) containing a lot of suspended particles, which was deposited in a small and shallow body of water. All these conditions are fullfilled in the picture of deglaciation here given. Patches of a till-like material are in places found on top of the clay, probably floated moraine or derived from floating ice.

I think the ice marginal lines here described in most cases mark short stagnations in the ice recession. The number of varves in the Lomma clay confirms such a short duration. It also suggests a fairly slow regression of the sea, about 3 m/100 years (see also p. 104).

The altitude of the corresponding sea level at the ice margin on the north slope of Hallandsåsen can be fixed to within about 0.60 m by the following measurements. Von Post (1933) mentioned a beach at +53 m at Hasslöv (his ML at about +65 m is obviously wrong). It seems very likely to me that this is the true ML. This ML is slightly older than the G5 line. At Kärr the ML, a shore cut + accumulation terrace, was measured to +53.0 m. This ML falls in a line 0.6 m below the one of +53.0 at Hasslöv. This line also contains the ML about +9 m at the peninsula of Barsebäck (De Geer 1910), which is slightly younger than the G5 line. The exact G5 shoreline must lie between these lines. Accordingly the G5 shoreline should lie about 1.5 m below the G4 shoreline. This means that the G5 line is about 50 years younger than the G4 line. At Kärr a gravel pit, B 796, in an esker-like ridge along the slope of Hallandsåsen showed stratified sand and gravel covered by till, which at least down to +60.0 m is totally unwashed. This ridge has apparently been formed in a (more or less open) crevass between the mountain and the ice. The till on top comes from the roof and the wall of this crevass. This indicates that ML lies at least below +60.0 m (in contrast to the opinion of De Geer 1910a and von Post 1933).

In the area between the G5 and G8 lines there is a big accumulation of drift in the shoal WNW of the light buoy Västerflak (Fig. 23, no. 4). This accumulation, or at least its surface, seems to have been formed at a series of ice marginal positions, among which two lines may be distinguished (Pl. 1).

THE G8 LINE goes from Nivaa to Nivaa Flak and down via the Lous Flak, which is a series of shoals lying in a line, to the 6—10 m deep area north of Saltholmens Flak. In the flat area between the southern shoal in the above mentioned line and Saltholmens Flak, the echo sounding showed that a till-like ridge breaks through the sediments precisely in the continuation of the G8 line (Fig. 23, no. 5). This ridge shows that we have here a line which can be followed the whole way down from Nivaa to the area north of Saltholmens Flak. The G8 line continues outside the NE margin of Saltholmens Flak and passes via the shoals Gustav av Klint, Kroken, Sjollen and, maybe also, Kalkgrundet (or via the shoals Brodden, Björnen and Nordre Flint) over to the coast between Limhamn and Lernabacken (occurrence of stones at Sibbarp). The line continues towards SSE just inside the coast, between Sjötorp and St.Hammar probably as a part of the line mapped by Munthe (1920). In SE Skåne the turn around the SE corner and the division between the Baltic ice and NE-ice continued. Nothing is known about the extension of this line between the Hörby area on Lindrödsåsen and the northern slope of Hallandsåsen. Just north of Hallandsåsen the deltas at Yllevad, Hylta and Källtorp were deposited at least mainly during the younger H1 stage (p. 100), burying and destroying the older beds from the G8 line (Fig. 29). At Källtorp an older part of a delta seems to remain. The top of this has been measured to +51.5 m, which exactly falls within the G8 shoreline. North of Våxtorp there is a very marked terminal moraine (apparent in the 50 m contour) which I think belongs to this line. East of Vallen there is a gravel pit, B 798a, which shows the proximal material of a subglacial melt water river, a coarse gravel. The top is at +55.0 m and shows no traces of washing. North (B 798b) and south (B 797) and probably also west of this place a finer, more distal material was deposited. From this area the G8 line seems to continue to the terminal moraine at Mammarp (a till ridge). SE of Mammarp it passes just west of Lake Tjärbysjön, which is a kettle from a big body of ice left here during the recession from the G8 line. The SW part of the esker Eldsbergaåsen has a NW—SE direction, in contrast to the real esker, which has a NE—SW direction. I think this outer part is a terminal moraine belonging to the G8 line. The line continues to the point Skäret at Påarp. Between Skäret and Örnäsudden west of Halmstad there is a well marked submarine ridge, which is a terminal moraine. It continues as a very distinct terminal moraine from Örnäsudden to Söndrums Kyrka and Mjällby. Parts of a terminal moraine can be followed to the eastern slope of Villshärad and over to the southern slope of Nyårsåsen. On the eastern slope of Villshärad ML lies at 61.3 m (De Geer 1893). This ML is probably slightly older than G8 line, but still gives a good idea of the G8 shoreline. Between the shoal Påarps Reven and the southern slope of Nyårsåsen there is another terminal line just outside the above one. Probably this is just a slightly older position of this part of the G8 line. Its extension is: Påarpsreven — Långenäs



Fig. 29. *The plain Laholmsslätten. Dark lines = the ice marginal lines G5, G8, H1 and H2. Dark circles = bodies of dead ice. Arrows = mealt water streams. Dotted areas =glacifluvial delta material.*

udde — Björkegård — the eastern slope of Villshärad — the southern slope of Nyårsåsen. From the SW slope of Nyårsåsen the line seems to continue to Haverdal and then pass along the eastern side of the road towards Steninge Strand. It is not known whether the G8 line should be connected with one, two or several of the terminal moraines in the Falkenberg—Varberg area. A marked terminal moraine line that totally or partly seems to correspond to the G8 line has the following extension: Knölagrund — Stutarna — terminal moraine on land — Ugga Revet — Södra Bergs Revet — Norra Bergs Revet — Yttre Björsgårdsgrunden — Rödskärsgrundet — a series of minor shoals W and NW of Varberg (Fig. 30). The further continuation seems to go via the big shoals NW of Fladen over to the shoal Kummelbanken and the NE part of the 40 m contour. A boring on Kummelbanken, B 529, showed a gravelly sandy till (Tab. 2). The NE part of the 40 m contour consists of till according to the echo sounding (Fig. 15, no. 2).

If the established G8 shoreline is extended down to the ice margin at the shoal Sjollen in Öresund, it falls at –2.6 m (and a bit further out at –1.8 m). This means that the shoals in this area could very well be terminal moraines of deltaic type. However, the Quaternary deposits further towards SW between Saltholmen and Limhamn have turned out to be fairly thin (Larsen 1966).

The H lines

The letter H has been given these lines after the classic H line along the Danish eastern coasts.

The H1 line has been mapped in the Copenhagen area by V.Milthers (1935) as the Avedöre—Drogden line. It seems to continue along the coast of the Köge Bay, probably including Köge Flak, turn around the Stevens Klint and from the Rödinge area pass over to Mön. Gripp (1947) thinks that Mön was formed by glacio-tectonic compression between a northern and a southern ice lobe. He found that the eastern part, Höje Mön, should have been a nunatak and that thrust moraines existed west of the nunatak. The correctness of this interpretation is not known. However, it seems likely that the H1 line has followed the coast of Mön. The line continues close outside the eastern coast of Falster and turns via Darsser Schwelle over to the German coast. This submarine continuation has been mapped by Kolp (1965). From Darss the line crosses Nordmecklenburg as a distinct line of "stauchcharakter" according to Kliewe (1966, Karte 2).

From the shoal Knolden, where Milthers ends his line, the H1 line continues to southern Saltholmen and via the shoal Söndre Flint, a lot of very small shoals, and the shoal Trindelen it passes over to Lernacken and Skålären outside the Swedish coast. The line follows the coast down to Klagshamn, where it turns out

to sea and via Dynan, Knudarna and Näsörar reaches the peninsula Näset. Somewhere in the Fredshög—Skåre Läge area the line passes out to sea and is indicated to about 5 km towards SE by the abundance of stones. No further submarine continuation is apparent from the nautical charts. Probably the line roughly follows the coast. (The terminal moraine fork on Bornholm is probably younger). The ice marginal lines in SE Skåne and their synchronization with lines in SW Skåne and in Halland are here delt with, not in order to give a complete picture (detailed studies are necessary for that), but in order to give a rough picture and to show that older observations in this area anyhow do not contradict the picture of deglaciation, which I have found to apply to the Kattegatt—Öresund area.

In SE Skåne the H1 line could have roughly the following extension. The line follows the southern margin of Kåsebergaåsen and then turns to the Rörum area, where an ice lake was dammed and more or less filled with sediments (according to a drilling more than 40 m coarse silt to fine sand). This line may be supported by three varve measurements by De Geer: Borrby –4,346, Jerrestad –4,350 and Rörum –4,350 (De Geer, unpublished map). The following extension probably goes along the slopes at Stenshuvud to the Ravlunda field and Maglehem, where the line turns westwards, passing Fjällmossen and Vissmosse according to some terminal moraines (Bergdahl 1953). In the Ravlunda area T.Nilsson (1961) has mapped Baltic till at Killehus and west of Blåherremölla. In the depressions between Linderödsåsen and the ice margin glacifluvial material was accumulated. In such areas there usually also occurred a lot of dead ice (the Degeberga and Brösarp area). The esker Hörrödåsen (Bergdahl 1953) continues as a true esker almost down to the H1 line, which means that there was a deglaciation of an active ice. In the Trollalior area, however, there was no longer active ice but a mixture of dead ice and sediments. The so-called esker Andrarumsåsen is a true esker only SW of the G4 line, while the NE part, which usually consists of sand and coarse silt, probably was built up in an area with a lot of dead ice between Linderödsåsen and the ice margin.

The H1 line is the second mapped line along the eastern margin of the plain Laholmsslätten (Fig. 29). Several measurements of ML were made. In the Jonstorp area just north of Hallandsåsen the H1 line cannot be distinguished from the G8 line. During the marked stagnation of the H1 line a big delta was built up to ML. Today it is divided by Stensån into three minor parts, with the following ML figures: the Yllevad delta +47.0 m, the Hylte delta +49.0 m to 48 —47 m and the Källstorp delta +50.0—49.0 m (an older part from the G8 line lies at +51.5 m). In the Skrårnered area a delta was built out towards Växtorp. The top of this has been measured to +51.9 m and a cutting, B 832, showed:

A: 1/2—1 m of washed gravel or till loose, badly sorted

B: stratified sand

From Skråmered a lobe extended to the inner margin at Vallen of the terminal moraine of the G8 line. A sand pit NE of Våxtorp, B 797, shows stratified sand containing lumps of fine sand that must have been deposited in the frozen condition. NW of Vallen there is a new gravel pit, B 798b, with the following stratification in the southern wall: about 5 m of stratified gravel, sand and varved clay, which show several changes in the stream directions. The surface has been measured to +54.0 to 52.9 m. The sediments seem to have been deposited close to the sea level (just below to just above).
The northern wall showed:

A: about 1/2 m of till-like gravel
B: 1/2—1 m of gravel
C: stratified sand with two structures that look like ice wedges

From Vallen the H1 line turns over to the horseshoe-shaped hill west of Ålstrop. The hill consists entirely of drift, coarser in east and finer in west, usually fairly badly sorted. It seems to be an ice contact deposit. Kettles occur in the middle of the "horseshoe". The altitude in west is +52.5 m. This is a minimum figure of the sea level, not a sure ML. From this hill the line passes over the plain around River Lagan to the Veinge—Tjärby area, where a glacifluvial delta was deposited. On the northern side of the hills two shore cuts, which seem to be the ML, were measured to +58.7 m (between Ramshall and Tre Högarna and on the NE slope of Tre Högarna). The continuation of the H1 line is seen in the Fladje—Eldsberga area, where the Eldsberga esker becomes much broader, indicating the position of an ice margin. As recently shown by Mohrén (Mohrén and Larsson 1968), the stratigraphies in the gravel pits in this area also indicate a readvance. Thus the correlation with the H1 line is obvious. The further extension probably passes inside the PL cliff — possibly via two accumulations of till at Kistinge (Mohrén and Larsson 1968) — to Snöstorp (thick layers of till), where it turns and joins the big glacifluvial marginal delta at Galgberget (Nelson 1910). By different geologists the ML has here been fixed at +63.0 m. At Harpling there is a distinct terminal moraine, which continues over to Tittut on the slope of the Steningeberget. ML lies at +63.0 m at Tittut (e. g. De Geer 1893). In the depression of Undarsmossen an ice lobe (later left as a big body of dead ice) extended towards SW and had its margin at Hulabäck, where a terminal moraine is seen (gravel pit B 690). West of Undarsmossen the line continues towards NW via a ridge at Kvarntorpet. The further submarine extension was mapped and is clearly apparent in Pl. 2. However, there are two lines that lie so close together that it is impossible to say whether both or just one of these belong to the H1 line. From the small islands Norra and Södra Ören the line passes close outside Grimsholmen (two ridges) and continues via a series of shoals (e. g. Lybeckarevet) to the western pier of Falkenberg, forming a marked terminal moraine line. Out of geotechnical borings (Orrje &

Co, no. 57.1141) this line seems to be joined by a buried esker or radial moraine following the River Ätran Valley. The line continues along the main road to Bölse. From Listerudde and its southern point, the lines cross the bay in two series of shoals to the area at Galtabäcksskär, from where one line via Träslöv passes over to Subbeberget south of Varberg and the other to Rödskär. The lines continue in two distinct ridges via the western part of Getterön to the island Sandeln and the shoal Isak Lars Grund (Fig. 30). The lines point towards NW (note the different direction to the younger ones) and an extrapolation would connect them with the island Nidingen, which consists of till. I think such a correlation is very likely. (Pl. 3).

During the H1 stage special distinct shore marks were also often formed in areas below the ML. The shore marks +40.0 m at Hovs Hallar, +36.0 m west of Torekov and +21.0 m at Svedberga Kulle all fall within the H1 shoreline. The 21 m beach at Svedberga Kulle is a very distinct shore cliff. Such formations of distinct shore marks have in my material been shown usually to occur in connection with the more marked ice marginal lines.

If the established H1 shoreline is extended to the ice margin in the Öresund area some important contributions can be given to the development here. In the outer part of the submarine channels Hollaenderdybet (today about −15 m) and Kongedybet (today about −15 m) the H1 shoreline should fall at −7.3 m and −8.2 m respectively. In the area where these two channels join each other the sea level should have been at −10.0 m (today −14 m). At the ice margin in the Drogden area between Amager and Saltholmen the sea level was at −17.7 m (today −8.4 to −13.0 m). This means that a melt water erosion then took place in this area. At the ice margin in the area of Flintrännan and the shoals Oscarsgrundet the H1 shoreline falls at −9.1 m (today about −7.2 m), which means that this part could have been formed by an ice marginal delta towards NE. However, the Quaternary deposits between Saltholmen and Limhamn have turned out to be fairly thin (Larsen 1966). In Foteviken, where T.Nilsson (1935) found no traces of any Late Glacial marine stage (the clay between −2.70 and 5.85 m), the shoreline falls at −15.0 m. This means that the sea never reached beyond the thresholds in Öresund.

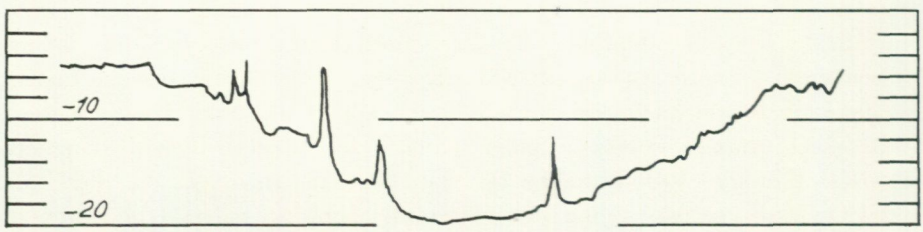


Fig. 30. *Echo diagram perpendicular to the submarine terminal moraine ridges in the Getterön-Balgö area. Horizontal scale: 1.5 cm = 1 km.*

As a whole the H1 line indicates a fairly well marked stagnation in the recession of ice. During this stage the sea level seems to have fallen about 1 m, i. e. the stagnation would have been roughly 30—35 years long. Such a duration seems very likely.

In Nordmecklenburg THE H2 LINE probably corresponds to Kliewe's line of "aufschütterungscharakter" in the Usedom—Rügen area (Kliewe 1966, Karte 2). The submarine continuation has been mapped by Kolp (1965). The H2 line passes over to Denmark in a series of lobes (more or less hypothetical), one passing the shoal Plantagenetgrund. Along the southern coast of Mön it seems to have the same extension as the H1 line. From northern Mön (the bulge in the 10 m contour that contains a lot of stones) the line crosses the Köge Bay in a curve passing the shoal Juelsgrund and reaching up to Amager. From Amager the line turns towards SE and passes via the shoals Kirkesten, Aeblesten, Söndre Röse, Quartusgrund, Norra Lillgrund, Södra Lillgrund, Knaggen, Sporren, Bredgrund, Kogrund, and V.Haken over to the peninsula Knösen. The absence of stones in the area of Knösen may indicate that the H2 line instead follows a line Bredgrund—Ö.Haken—Höllrevet. It crosses the Skanör—Falsterbo peninsula and passes again out into the sea at Stensudde. The line continues in a submarine ridge between Segelskären (Själhunaskäret) and Klapperåsen. I think the H2 line passes over to Bornholm. However, this part of the line is only marked by some minor shoals and occurrences of stones and gravel (according to the nautical charts). On Bornholm there is an ice marginal fork, the first line of which, the Smilegaard line (Grönwall and Milthers 1916), seems to belong to this stage. From NW Bornholm the H2 line passes over to Skåne, where it follows the coast between Simrishamn and Stenshuvud. The further continuation could go along the slope from Olseröd to the Degeberga area and then turn up on Linderödsåsen or follow its NE slope. However, I prefer another hypothesis. From Stenshuvud the H2 line could pass over to the big shoal that in a curve extends from Kiviks Bredan to Södra Karet and the Revhaken area south of Åhus (occurrence of stones just here). This submarine ridge is very well marked, but as very little is known about the material, the problem cannot be solved until samples have been taken and analysed. From the Revhaken area the line probably extends to the Debegerga—Borrestad area and then continues up on, or more or less along, the NE slopes of Linderödsåsen. This extension of the H2 line is not contradicted by the varve measurements made by Antevs (1915). The line would be older than his oldest varve, i. e. –423 at Skogsma (the connections between his localities 7 and 12, and 12 and 15 are not quite certain). The varve series at Borrestad and Vittskövle were not connected with the ones at Ö.Sönnerslöv. The extension to Laholmsslätten through the hilly woodland is not known. Just north of Hallandsåsen I have no direct indication of the exact position of the H2 line. A delta sedimentation continued in the Yllevad delta and the

Hylte delta. The Yllevad delta has a lower delta plain at +45.5 m with a beach ridge on its eastern margin and the Hylte delta has a lower delta plain at +43.0 m. Both could roughly correspond to this line. On the western side of the terminal moraine north of Våxtorp there is a distinct shore cut, measured at Tormarp to +48.0 m, which falls exactly within the H2 shoreline. The H2 line is the third ice marginal line mapped on the plain Laholmsslätten (Fig. 29). The ice margin seems to have been situated about 1 km east of Stäme, discharging meltwater and sediments towards west. From the Stenabygget valley a lot of material was transported towards W and SW, giving rise to a big flat delta, with ML at about +53.0—54.0 m. In the Storsjö area there must have been a lot of dead ice and the material was transported and deposited between ice blocks. No good ML could be found. ML must be below +54.5 m according to a gravel pit at Källstorp (B 831), where the material seems to have been deposited supra-aquatically. The ice margin turned around the hill Höggoster and projected a lobe along its northern slope to the area of Karseforsen and the eastern part of the hill at Forsagården. In this area we have the first evidence that the H2 line at several places was reached by a readvance. Von Post (1933) described a glacial varved clay (layer F) that with an unconformity is overlaid by gravel (layer E). Von Post interpreted the stratification as a shore deposit after a transgression to a 36 m beach. However, a gravel pit (B 686) in von Post's 36 m cliff (von Post 1933, Fig. 15) clearly shows that this "cliff" is nothing but the distal slope of a glacifluvial delta with top-set and fore-set beds. My interpretation of the events in this area is thus the following:

1. The area was covered by ice during the H1 line.
2. A glacial varved clay was deposited during the time between the recession from the H1 line and the readvance of the H2 line.
3. The ice reached the H2 line after a readvance from an unknown position further inland. Glacifluvial material was transported from the ice margin. The unconformity arose between the clay and the gravel. In the area of B 686 a delta was built out with a top level at +41.5 m, i. e. about 12 m below the corresponding sea level. A marked distal slope with fore-set beds was formed (fine gravel). The gravel in von Post's "inlet-channel" and my B 686 must also be equivalent to the sand and gravel (layer D and C) in the "outflow-channel" (note however the occurrence of pollen in layer D).
4. The ice receded from the H2 line and a normal marine clay (layer B) was deposited in the "outflow-channel".
5. During the regression the gravel (layer A) was deposited on top of the clay in the "outflow-channel".

According to the shoreline diagram there is 3.3 m between the H1 and H2 shorelines, corresponding in time to about 110 years. The varved clay at Lejeby contains 90 varves. This means that there is a surprisingly good agreement

between the calculated shore level displacement and this varve series. De Geer (von Post 1933) and E.Nilsson (1960, 1968) have tried to connect the varve series from Lejeby with the Swedish time scale. However, this varve series can, according to my interpretation, not yet be connected either with the Swedish time scale, which in my opinion is not established further south than southern Bolmen (p. 178), or with the other varve series in the Laholm—Halmstad area (E.Nilsson 1968). Along the southern slope of the hill at Forsagården there is a notch, which possibly could be interpreted as a shore cut. The altitude was measured in east to +55.0 m and in west to +53.7 m. The fact that this possible shore cut is not quite horisontal, makes me unsure whether it really marks ML. However, the altitude fits very well with the H2 shoreline, which here lies at +54.0 m. Anyhow, ML does not lie above this possible shoreline. The hill contains a core of Archaean bedrock that is often covered only by a thin layer of till that shows no traces of washing.

From the hill at Forsagården the line continues to the western side of the kettle lake at Ånnaberga. A gravel pit, B 829, showed the following stratification:

A1: (on the top of the hill) at least 1 m of gravelly till, without any sign of washing and containing all fine fractions
A2: (only in the western wall) 1/2 m of washed gravel
B: at least 3—4 m of stratified sand and fine gravel, sloping from NE—ENE

This means that we have here further evidence of a readvance. The top of this hill lies at +54.0 m. A marked shore cut on the western side lies at +48.0 m, but this belongs to a younger stage (p. 118). According to the shoreline diagram the H2 shoreline should lie at +56.4 m. The hill must have been influenced by the big body of dead ice left in the Lake Ånnabergasjön area. This body of dead ice has never been floating; it was left by the receding ice margin — like the dead ice of all the other big kettles on the Laholmsslätten. From Ånnaberga the H2 line continues to the eastern part of the Veinge delta from the H1 stage. This area could be studied in detail thanks to several gravel pits and good shore marks. A gravel pit, B 826, at the eastern part of the 50 m contour showed the following stratification. The surface was measured to +54.8 m and the corresponding ML was (in the field) determined to lie 1 m higher.

A: 3—4 m of till; in the upper part 1 m of sandy till, in the lower part 2—3—4 m of coarse gravelly till. The till also contains small lenses of sand.
B: Stratified sand, probably with an unconformity between A and B (no real good cutting shows this limit).

Consequently a readvance is registered also in this gravel pit. In Veinge a shore cut was measured to +55.8 m. At the southern slope of the hill at Nebo a marked shore cut was measured to +55.8 m at two places. A levelled map of the area of the gravel pits mentioned below (B 825) shows that this shore cut lies between the contours of +55.0 and +56.0 m. All these figures show such a surprisingly good agreement that the corresponding sea level can without doubt be fixed at

+55.8 m. This figure is the main point for the fixing of the H2 shoreline. A series of gravel pits just outside the shore cut south of Nebo showed roughly the same stratification. The biggest gravel pit, B 825, showed the following stratification:

A: About 4—5 m of horisontally stratified sand and gravel. The material is fairly unsorted and the grains are badly rounded compared with the ones in the layer below. This points to a short transportation.
A/B: A sharp unconformity.
B: More than 10 m of stratified sand with gravel with very well rounded grains and sloping from west to east. This layer ought to have been deposited during the H1 stage and the subsequent recession, possibly from an esker just west of these pits.

Consequently, we have also here evidence of a readvance, though the ice did not covered this area.

Between Perstorp and Älvaberga the Eldsberga esker becomes much broader, clearly indicating the position of an ice margin. At Haga there is a typical ice marginal delta with an ice-contact and a feeding esker. The delta reaches +56 m, which means 2.7 m below the corresponding shoreline of the H2 line.

From Haga the line seems to continue to the glacifluvial accumulation at Hult. However, the interjacent area has at present not given any clear information about the extension of the H2 line. The synchronization with Hult is based upon the following. ML at Hult has been measured to +63.0 m (Caldenius *et al.* 1966), which falls exactly within the H2 shoreline A cutting NE of Karlstorp in the SW side of the southern delta lobe deposits in the Murbäck area showed the following (Caldenius *et al.* 1966):

A: 1.5 m of washed gravel
B: 0.5 m of fine gravel
C: 0.9 m of sandy gravelly till, hard packed and containing a large patch of silty clay
D: at least 1.5 m stratified gravel

This stratigraphy is an indication of a readvance. The position of this cutting indicates that the corresponding ice margin must have been situated further westwards, probably building up the delta at Hult.

The further continuation of the H2 line is not so easy to determine because the description of the geological map (Caldenius *et al.* 1966) has very little information about the details of the deglaciation and because I have only a few observations of my own concerning the deglaciation within this area.

The continuation of the H2 line seems, however, to have had roughly the following extension:

1. The glacifluvium at Tippakull.
2. The big terminal moraine delta at Karlstorpa Fure.
3. The northern slope of Nyårsåsen.
4. The glacifluvium at Skogby (or some of the lines with minor patches of glacifluvium further south between Nyårsåsen and Rydsberg).

5. A lobe in the valley between Rydsberg and Bårarpåsen down to Lilla Brännarp. A shore cut at Hagastugan at +63.5 m (Caldenius *et al.* 1960) fits exactly with the H2 shoreline.
6. Around the northern slope of Stenstorpaberget. A shore mark at +65 m on the geological map fits with the H2 shoreline.
7. A lobe in the valley between Stenstorpaberget and Klockberget down to Vastad. ML at +64.0 (Caldenius *et al.* 1960) fits with the H2 shoreline.
8. Unknown connection with one of the terminal moraine lines in the Falkenberg—Varberg area (Pl. 3).

It seems likely that the H2 line joins the system of terminal moraines NW of Getterön (Fig. 30), which has a different direction than the older ones belonging to the H1 stage. If so, the line (or rather the line complex between Falkenberg and Balgö) seems to join the island Malö, which is made up of till and contains at least one distinct terminal moraine. The direction of this terminal moraine on Malö (as well as the older one forming Nidingen) seems to be a local change probably due to changes in the ice streams caused by the influence of the peninsula Onsalahalvön. The interpretation that the orientation of Malö, Nidinge and the shoals north of Fladen only represent a local deviation of the ice streams during the G8, H1 and H2 stages respectively, is supported by the direction of the older terminal moraine lines in Kattegatt (Pl. 1) and the direction of the younger ones in the Gothenburg area. The curious traces of a young ice stream from NNW found on the skerries Hallands Svartskär and Rön (Hillefors 1967) may be explained as being due to this lokal change of the ice streams.

If the established H2 shoreline is extended to the Öresund area, the following depth would be reached: at the outer part of Hollaendardybet −10.0 m (today about −15 m), at the outer part of Kongedybet −11.7 m (today about −15 m), in the area where these two channels join −13.5 m (today −14 m), in the middle part of Drogden −15.3 m (today −8.4 to −13.0 m), in southern Drogden just outside the H2 line −18.0 m (today about −7.0 m) and at the threshold at Flinträннan −12.6 m (today about −7.2 m). This means that the sea never reached beyond the thresholds in Öresund and that melt water erosion of the above mentioned submarine channels took place.

Final remarks on the ice marginal lines in the Kattegatt area

A lot of ice marginal lines have been found and described in this chapter. They give a detailed picture of the Late Weichselian ice recession (Pl. 2 and Fig. 42). Summing up, the following can be said:

1. The C line or Main Stationary Line: The very distinct line of the maximum extension of the Late Weichselian glaciation. This position was reached at about 18,000 BC (Cepek 1965). The time of recession from the C line is not fixed (however, probably not before 16,000 BC).

2. The CD lines: Only scattered parts known here and there.
3. The D line or East Jylland line: Very distinct and reached by a readvance at least of the Baltic ice stream. Probably equivalent to the readvances in Eastern, Central and Western North America, which have been C^{14} dated at about 13,000 BC. It may have been preceeded by an interstadial equivalent to the Lake Erie Interstadial in North America (Dreimanis 1958). The age of the D line is calculated at 13,000—12,800 BC.
4. The 10 DE lines: They all seem to correspond to minor stagnations in the recession, probably not climatic. The greatest distance for the recession from D to E is 44 km. With a recession of 100—200 m per year, this would have taken 440—220 years. During this recession the Lille Belt lobe and the lobe north of Fyn were formed; also the formation of the Store Belt lobe had started.
5. The E1 line: A very distinct line that marks a distinct stagnation or even readvance. The Store Belt lobe is now separated from the main ice at an acute angle in the Aamosen area. The age is calculated at about 12,600 BC.
6. The E2 and E3 lines: Fairly indistinct.
7. The E4 line: A very distinct line that was probably reached after a general readvance. It seems to correspond to a climatic deterioration. The age is calculated at about 12,400 BC.
8. The E5 line: Distinct line, often closely following the E4 line.
9. The E6 and F1 lines: Indistinct.
10. The F2 line: A very distinct line that at least partly includes readvances, e. g. the Langeland readvance of the Belt lobes. The age is calculated at about 12,100 BC.
11. The F3 and F4 lines: The F3 line is very indistinct or absent in Kattegatt, while the F4 line is fairly distinct.
12. The F5 line: A very important line that clearly shows the dividing of the NE-ice (Smålandian ice) and the Baltic ice in the Skälderviken—Ängelholm area (Fig. 19). The age is calculated at about 11,800 BC.
13. The GFa to GF6 lines: Stages of the deepening of the ice marginal fork in NW Skåne. The GF4 lines contains the oldest sure ML locality in Sweden, viz. Herninge Backar +51 m. The age of this ML is calculated at 11,750 BC.
14. The GF7 line: A distinct line that contains the oscillations at Gribskov and distinct submarine till ridges at Gilleleje—Strandbaden. It also corresponds to the first shoreline followed over a greater area. The age is calculated at 11,400 BC.
15. The GF8 and GF9 lines: Fairly well marked lines of the Öresund lobe.

16. The G1 line: A distinct line, with traces of readvances in several places. It probably corresponds to the Middle Baltic readvance (oscillation) in SE Skåne. The age is calculated at 11,250 BC.
17. The G2 and G3 lines: Usually indistinct stages in the continued recession.
18. The G4 line: Equivalent to the Low Baltic readvance in Skåne. A Corresponding readvance of the NE-ice was found on the Bjäre peninsula. The age is calculated at 11,150 BC. It apparently corresponds to the cold period or readvance that has been found in different parts of the world after a preceeding interstadial ending about 11,150 BC, viz. the Susacà Interstadial in Colombia, Kenya and Spain, the Lake Arkona Interstadial (also other names) in North America and the Raunis (and Plyusa) Interstadial in the East Baltic area. This preceeding interstadial may also be seen in the Vintappermose.
19. The G5 line: A fairly distinct line. The Lomma clay was deposited during this time. The age is calculated at 11,080 BC.
20. The G6 to G7 lines: Indistinct.
21. The G8 line: A distinct line. The age is calculated at 10,950 BC.
22. The H1 line: A distinct line (corresponding to a stagnation of about 30—35 years). The age is calculated at 10,850 BC.
23. The H2 line: A distinct line with a clear readvance at least in Southern Halland. The age is calculated at 10,750 BC.

Among all these lines there are five very distinct lines indicating readvances, viz. C, D, E4, F2 and G4, and eight distinct lines corresponding to marked stagnations, oscillations or minor readvances, viz. E1, E5, F5, GF7, G1, G8, H1, and H2. The mean value for the recession from the D line to the H2 line straight across Kattegatt is 36 m per year. This low mean is probably due to the stagnations and readvances of the ice, and to the generally cold climate at that time.

The deglaciation in the southern part of the Baltic

After the H2 stage there seems to have been a period with a fairly rapid and unbroken recession, at least in northeastern Skåne. The recession of ice across the plain Kristianstadslätten has been followed by Antevs (1915) by counting the annual varves in the glacial clay. He found that the recession took about 400 years with a mean value for the recession of about 75 m per year.

During an early part of this recession (or maybe even earlier at the time about the H2 stage) there must have been a big ice-dammed lake in the Lowland between Nävlingeåsen and Linderödsåsen. In this ice lake the deltas at Sandåkra (+98 m) and at Ljungarum were built up. Later, this ice lake was drained either towards SE, eroding the canyon of Vramån (according to the contour map this canyon seems to go down to just below +50 m) or towards west via Tyringen.

According to E.Nilsson (e. g. 1953, 1968) there was a drainage of the Baltic Sea via Tyringen. He also thinks that Antevs' varve –100 is a "secondary drainage varve" from this drainage, which by several long distance correlations he dated at 10,214 BC (E.Nilsson 1964, 1968). However, the Baltic Sea never reached such altitudes. Consequentely, there cannot have been any drainage of the Baltic Sea either via Tyringen or via Vanåsfors and through the Lagan Valley, but only of local ice-lakes. This is evident from the HK (= highest shoreline, equivalent to ML) and the damming of Öresund. At Ryssberget and Listershuvud I have visited HK localities mapped by B.Ulf (1948, unpubl.) and K.Hellberg (unpubl.), respectively. I find it apparent that the HK is at about +54—55 m at Ryssberget (Jokkarp) and at about +54—55 m at Listershuvud. At Ivö Klack De Geer (1910a) has a measurement of HK at +53.8 m. From the field study it seems to me to be good HK locality. Berglund's shorelevel displacement curve from Eastern Blekinge proves that these HK figures belong to the time of deglaciation and has nothing to do with any limit of the Yoldia Sea as E.Nilsson (1953) and G.Lundqvist (1961) have stated. If E.Nilsson's Baltic lake level at Tyringen +112 m is compared (perpendicularly to the direction of tilting) with my shoreline diagram, it falls about 67—70 m above the corresponding sea level. A shore level 67—70 m below the threshold in Öresund is definitely out of the question. At the mouth of the canyon of Vramån a rough HK figure could be about +48 m according to the contour map and De Geer's HK figures (1910a), +48 m at Nävlingeåsen and +42 at Linderödsåsen. The figure +48 m falls about 13 m above the corresponding marine shoreline, which is exactly the same difference as between the threshold and the level of the marine shoreline in Öresund.

Outside Listershuvud there is a series of submarine ridges lying SW—NE. The question is whether these ridges are drumlins or eskers formed by the NE-ice or terminal moraine formed by the Baltic ice. The problem cannot be solved until the area has been investigated. However, one thing is clear: somewhere we must have traces of the Baltic ice. On the Lister peninsula the hills (= monadnocks) are drumlinoid and the glacifluvial material seems to be connectable with the eskers to the NNE. The main glacial striae have the same direction. However, there also occur crescentic cracks from a more eastern direction (Johnsson 1956). These can be traces of the turning point between the NE-ice and the Baltic ice. The submarine ridges are very like terminal moraines. They seem to lie too close together to be eskers and to be too long and narrow to be drumlins. I therefore look upon them as terminal moraines of the Baltic ice — well aware that an examination with echo sounder and sampling is necessary to settle this. There are 12—13 ridges in 16—17 km, i. e. if they are annual moraines, they show a recession of about 130 m per year, which is a normal rate of recession.

By studying the annual varves in submarine cores Arpi (personal communication 1967) has found an ice recession from NW towards SE in the bay of Hanöbukten, i. e. a recession of the Baltic ice just as one would have expected.

In the area of Karlskrona, Utlängan and Utklippan there are glacial striae from east indicating a Baltic ice stream.

In SE Öland the glacial striae and petrographical composition of the drift (J.Andersson 1893, Munthe 1902a and 1902b) indicate the presence of the Baltic ice. In the southern part of Kalmarsund, Dannstedt (1947) mapped a submarine field of 44 till ridges in 8.8 km (i. e. one ridge per 200 m). These ridges show that the ice margin crossed the outer part of Kalmarsund as a straight line. Bergdahl (1947) stated that the Degerhamn esker, with material from NE, shows that the ice margin was already "oblique", i. e. showed influences of the transition to the Baltic ice, in southern Öland.

On Bornholm three stages of an ice marginal fork are seen (Grönwall and Milthers 1916). The general stratigraphy in the bogs (all situated outside the third ice marginal fork) are (op. cit.):

A: peat
B: "Birch mud"
C: Gastropod mud
D: upper Dryas clay
E: Alleröd mud
F: lower Dryas clay

A pollen diagram (Iversen 1954) from Vallensgaard Mose shows that the clay at the bottom corresponds to Older Dryas. The clay seems to have been deposited when the ice margin formed the third fork, which means that this position corresponds to Older Dryas (= the Moslätt/Berghem complex, cf. p. 143). Thus the second ice marginal fork must correspond to the end of Oldest Dryas (= the Fjärås line, cf. p. 127).

In Nordmecklenburg, the Nordrügener line is reported to correspond to Older Dryas, the sediments of which are directly overlaid by Alleröd sediments (Kliewe 1968). Consequently the third ice marginal fork on Bornholm must be correlated with an ice margin in the Rügen—Usedom area (e. g. Kliewe 1966, Reinhard and Richter 1961). As the corresponding ice marginal line (the Moslätt/Berghem complex) on the Swedish West Coast can most probably be extended to Kalmar (p. 143), there was a distinct ice lobe in the Bay of Hanöbukten.

The Baltic lobe of the ice marginal line corresponding to the end of the classical Oldest Dryas, the Fjärås line (p. 127), follows close outside the one of Older Dryas (p. 143).

In early Alleröd the ice marginal fork on Bornholm was probably deepened to the shoal Stolpe Bank, leaving the southern lobe as a separate stagnant body of ice. This body of ice was probably divided by the shoals Rönner Bank and

Adlergrund into two main parts. The deltaic shoal Oder Bank was probably built up between these bodies of stagnant ice.

The ice marginal fork between the main Swedish ice and the Baltic ice was, during Alleröd, displaced from Öland towards NE (probably crossing Gotland).

The deglaciation on the Swedish West Coast and the Late Glacial shorelevel displacement

The same irregular recession with repeated stagnations which has been found in Kattegatt continues on land. Three different types of terminal moraines occur:

1. Smaller ridges which, however, are very well marked topographically and can be followed over long stretches of the lowlands. These ridges mostly consist of till. I mapped the area between Falkenberg and Klosterfjorden, where these ridges occur on land as well as off the coast. The areas at Grimeton and Värö Backa were mapped by Caldenius (1942). These ridges seem to correspond to a stagnation of one or only a few years.
2. Greater accumulations of till and glacifluvium in the valleys. These accumulations lie one after the other along the valleys. In the Viskan Valley they were mapped by von Post (Caldenius 1942, von Post † 1955). These accumulations seem to have been formed during stagnations of more than one year. Morphologically they cannot be followed laterally.
3. Ice marginal deposits from marked stagnational lines, which can be followed along the whole coast. These seem to have been formed during periods with colder climate, i. e. to be climatically caused. Two such lines were found in the area investigated: the Fjärås line and the complex Berghem line.

In Pl. 3 the known ice marginal deposits have been put together.[1] As the mapping was not a major purpose of this investigation, there must of course be still more ice marginal deposits. In the coastal parts the map is more complete. In those areas of the woodland, where no special mapping was done, the map is incomplete. The continuation of the two big ice marginal lines — the Fjärås line and the complex of the Berghem line — was mapped carefully. The terminal moraines along these lines are usually very distinct and strikingly different to the small and irregular ones in the areas around and between these lines.

In the slopes along the Swedish West Coast there are aboundant Late Glacial shore marks. However, I do not think these shore marks represent synchronous Late Glacial raised beaches nor do I belive in the existence of any Late Glacial transgressions at these isobase latitudes. I think these shore marks were formed during the Late Glacial regression at various places depending upon the material in the slope, the gradient of the slope, the transportation of material, the degree of exposure, etc. Consequently, no shoreline diagram can be constructed upon such marks. One has to use other methods to determine the shorelines and their gradients. In NW Skåne and along the plain of Laholmsslätten the circumstances are different. In this area the shore marks are few and usually distinct. In

[1]) The names mentioned in the text (and not given in Pl. 3) can be found in the ordnance map in the scale 1 :100000, which was originally intended to form the base of Pl. 3.

most cases these shore marks can be connected with synchronous shorelines, usually corresponding to the more distinct ice marginal lines. Consequently, it seems as if the processes forming the shore marks were accelerated during the time of the stagnations along these ice marginal lines. At this position in the direction of tilting (i. e. NW Skåne, the Bjäre peninsula and the plain Laholmsslätten) stagnations in the regression and also a transgression occured.

Several Late Glacial transgressions have earlier been described from the Swedish West Coast. However, I think the evidence quoted for every one of these can be interpreted other ways.

From Bohuslän De Geer (1910c) and Antevs (1917, 1921 and 1928) described Late Glacial transgressions based upon the succession of faunas in the shell banks and the occurrences of sand and shell beds between two layers of clay. However, these transgressions are not at all proved and we have to consider other explanations: the mechanical mixing together, the variations of the reaction currents causing changes in fauna and the wave actions bringing sand and shell beds out between clay layers (Halden 1921, T.Nilsson 1927, Odhner 1918 and 1927, Sandegren 1923, Hessland 1943). As a whole, we have no reason today to consider the possibility of any Late Glacial transgressions in Bohuslän.

Sand and shell beds within Late Glacial clay layers have also been found in several places in the southern part of the Swedish West Coast. However, all these beds seem to be derived from the tops and slopes of the surrounding hills. The development is illustrated by the changes of sediment when a shoal covered by drift is raised above sea level. At a certain depth the wave action starts to redeposit the drift and mix it with shells (the shoal Fladen Grund is in this stage). When the sea level falls the redeposition may cease and a new clay sedimentation start — either due to the lack of material on the slopes (e. g. a

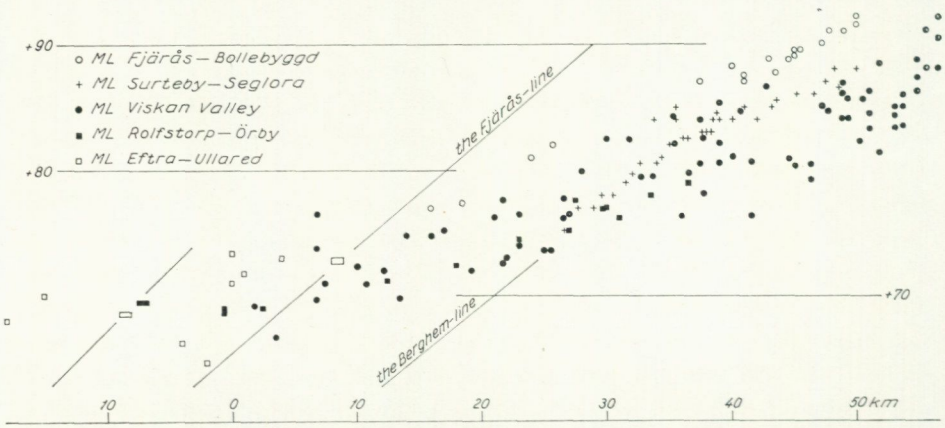


Fig. 31. *Measurements of ML in different valleys on the Swedish West Coast (mainly from von Post † 1968 and Gillberg 1952).*

steep rock slope) or due to the new land causing a more calm bay, fiord or lake, where the wave action is not strong enough to redeposit the material on the slopes.

Niklasson (1932) described artefacts covered by sediments at Råö and Varberg as evidence of an earlier transgression. However, it is still quite unknown whether these flints really are artefacts (C.-A. Moberg, personal communication).

Asklund (1936) in his description of the malacological development assumed several transgressions, the ML having been formed by one of them. However, this is definitely wrong. As is shown in this paper, the ML is highly metachronous, becoming continuously younger with the recession of the ice (Fig. 31).

Von Post (1933, 1938, 1947, 1952, 1968 †) has described a complicated development with several Late Glacial transgressions. The so-called Gotiglacial transgression at Lejeby (von Post 1933) has earlier (p. 104) been shown to have another explanation. From his work in Halland and the Viskan Valley von Post claimed that he had proved several very great so-called "shock-transgressions" (caused by rapid isostatic land subsidences). No such transgressions were found by me. Von Post based his hypothesis upon shore marks (cf. above), stratifications (misinterpreted according to the description below) and a Late Glacial pollen zonation based only upon variations of *Pinus* and *Betula* (NAP is necessary for establishing a Late Glacial pollen zonation, cf. below). Von Post interpreted layers of stratified sand at low altitude between two layers of Late Glacial clay in the Veddige area (Section 105 and 84B) as shore deposits. He saw in the younger clay evidence of a transgression that he connected with layers of clay above muddy sediments further inland at higher altitudes. However, the occurrence of stratified sand in the Veddige area is reinterpreted as a certain Late Glacial redeposition of sand and gravel (further dealt with on p. 148) that has nothing to do with any changes in sea level. In several localities more or less pure clay rests upon muddy sediments. However, these layers are reinterpreted as belonging to the colder Younger Dryas period, i. e. to be climatically caused.

I have spent a lot of work on this possible Late Glacial transgression. Bogs and other areas, where such a transgression had to be registered, were investigated: e. g. Barnamossen (B 566), Strätedal (B 553), Stuv (B 555), Bollestorp Mossen (B 563—565), between the ridges at Värö Backa, Valinge (B 554). No evidence or even the slightest trace of any such transgression was found. Pollen diagrams and C^{14} datings have proved that the layers of clay upon muddy sediments belong to the Younger Dryas. In Section 50 (von Post † 1955, Fig. 15) there is a buried mould in which von Post saw an indication of a Late Glacial transgression (von Post † 1968, p. 88). A new boring B 552 was made there. The mould was found 1.30 m down, beneath sand. It is a 20 m thick mould in fine sand that downwards changes over into a rusty sand and further down into a till-like sand, i. e. a good soil profile. However, a C^{14} dating

gave 150 ±75 BC. Consequently, it represents a Postglacial event, probably sliding, that has nothing to do with any changes in sea level.

To sum up the results of my work on possible Late Glacial transgressions: there is no evidence or even traces of any Late Glacial transgression on these isobase latitudes.

Gillberg (1952, 1956) stated in his study of ML and the ice lakes that there were stages of land sinking, so-called "phases of reversion". In my studies of ML with a well fixed isobase system I have not found any of Gillberg's "ML-anticlines". Gillberg's diagrams (1952) are not based upon an isobase system; they are more of the type of relation diagrams, where localities sometimes may change their geographical positions. In the study of the ice lake development, Gillberg (1956) also claimed to have found stages of land sinking. As these "phases of reverssion" in the diagrams are all seen as funnels pointing towards the coast, this would mean that the land sank further inland (towards the centre of the glaciation) and that either the drainage took place in the northern end of all the lakes or there was a continuous lowering of the thresholds in the ice lakes not draining northwords I find this hard to believe. The "funnels" in Gillberg's diagrams are never wider than 8 m in the outermost part. It must be very hard to fix the lake level and distinguish different Late Glacial shore lines within only a few meters. Gillberg's picture requires a big body of dead ice in the Viskan Valley. According to the picture given here the receding ice was highly active throughout the whole Viskan Valley. My shoreline diagram shows a continuous lowering of the gradients with no place for any land subsidences.

By mapping the continuations of the Fjärås line and the Berghem line and gathering information about ML along these lines, I hoped to be able to determine the corresponding shorelines. However, this turned out to be fairly difficult as the ice marginal lines pass up above ML towards SE, the Berghem line was found to be complex and the isobases change their direction towards Gothenburg. In spite of this it was possible to fix the shorelines corresponding to these lines.

Caldenius (1951) described the occurrence of shells of *Portlandia arctica* in the glacial varved clay at Berghem and Berg. As a C^{14} dating of these shells would have given a very good date of the deglaciation in this area, I spent a lot of time in these localities, digging and boring, but always in vain. I never found any shells in the glacial clay.

Thanks to the kindness of Professor B.Asklund I was allowed to use his excellent collection of shells from Halland for C^{14} datings. These and some other dates are dealt with below (p. 167).

Another way to fix the shorelines is to date the isolation levels in bogs and lakes. Several such isolation contacts were dated by the C^{14} method and/or pollen analyses. Many of the pollen diagrams that von Post had made in connection with the Viskan investigation, were made just in order to date the Late Gla-

cial isolation levels. However, the pollen zonation of the Late Glacial portion is very difficult as the diagrams only contain arboreous pollen (AP). In the old analysis notes I found that nonarboreous pollen (NAP) had in fact also been identified. So I recalculated and redrew all the pollen diagrams containing a Late Glacial isolation level. The result was surprising. Thanks to the NAP curves a good pollen zonation could now in many cases be introduced. The results are dealt with below. Four of these diagrams are published here. And I think I am justified in doing so, as neither von Post himself, nor G.Linnman, who in 1965 presented von Post's chapter about the vegetational development in the Viskan Valley for posthumous publication, paid any attention to the identified NAP. If I had not returned to the analysis notes, these diagrams would never have been published in this way. In the localities of some of the more important and not so deep lying isolation contacts, I took new samples for C^{14} datings with a piston corer.

The older shorelines

In the rough topography of the Swedish West Coast it is less easy to follow synchronous ice marginal lines.

By the comparison of the ML in the different valleys, some of the ice marginal deposits could roughly be correlated with each other. The gradients of the earlier described shorelines are all about 9.8 m/10 km.

THE FIRST SHORELINE is approximative. Its gradient is 9.4 m/10 km. It gives a rough synchronization between the following places: 1) The great ice marginal lobes SW of the lakes Skärsjön and Ottersjön, at Dagsås (Caldenius 1942). By several levelled sections von Post has fixed the ML at +69.5 m. 2) The area around Vessige, where ML by von Post has been levelled to 68.5 m. 3) The marked ice marginal lobe at Oskarström, with a corresponding ML at +67 m (Caldenius *et al.* 1966). 4) The innermost marine delta of the Stjärnarp esker at Jonstorp, which seems to lie at about +56—57 m, falls on this line. 5) The innermost marine delta of the Eldsberga esker at Dalabygget at about +54—55 m. 6) The distinct shore cliff at +55 m in the outermost part of the delta at Perstorp. 7) The delta at Kårarp, north of Skogaby, which I have found to have an ML at +53—54 m. It is important that the deltas at Kårarp, Dalabygget and Jonstorp belong to this time, as it shows that the ice margin from its position in the Nissan Valley turned down towards SSE. The direction of the glacial striae also indicates this bend of the ice margin (e. g. G.Lundqvist 1961). It is not surprising, as the time gap to the H1 line is not big and this line according to the picture given here ought to be synchronal with some of Antevs' lines in the middle of the plain Kristianstadslätten: the altitude and position of these deltas provide welcome evidence of this bend.

THE SECOND SHORELINE contains several distinct shore marks in the SW area. This shoreline represents a transgression outside the isobase 65 km outside the zero point on the profile line of the diagrams. The gradient is 8.4 m/10 km. In Öresund this shoreline falls at −6 m. As the threshold today is at −7 m, this means that there could have been a small ingression of saltwater into the Baltic Ice Lake around the time of this shoreline. It is very possible that this ingression caused the marked change of Antevs' varve −100 in the varve series on the plain Kristianstadslätten. The position of the ice margin of varve −100 also makes such a correlation probable.

This shoreline gives an approximate correlation between the following ML localities: 1) +79 m at Hylteråsen on the Onsala peninsula, 2) about +69 m at Valinge, 3) somewhere outside Rolfstorp, 4) +71.8 m at Svartrå, and 5) a marked shore cut terrace at +71.0 m at Okome just below the ML (von Post 1947). In southern Halland and NW Skåne this shoreline contains several very distinct shore marks: a distinct shore cut at +48.0 m in the western side of the hill at Ånnaberga, a very distinct cliff +46.5 m at Tjärby, a distinct shore cut +46.2 m between Lejeby and Forsagården, a shore cut terrace +33.5 m at Eskilstorp (von Post), the very distinct shore cut terrace along the slope of Hallandsåsen, for example the well marked shore at Norrviken levelled to +31.0 m (Fig. 117) and a fairly distinct shore cut at about +26—28 m in the Öllöv area. Between Torekov and Hovs Hallar, B.Junker (unpubl.) has measured a series of shore marks at about +27 m, wich at least partly belongs to this second shoreline.

THE THIRD SHORELINE gives a rough correlation between: Änggården +93 m, S.Sandsjön +83 m, Section 6 in the outer Viskan Valley +69.2 m, Skällinge +69 m and some place between Svartrå and Ullared in the valley of Högevadsån.

The Fjärås line

This is a very marked and synchronal ice marginal line. By morphological mapping and comparisons of ML it was followed along the whole Swedish West Coast. The name is given after the classical ice marginal deposits at Fjärås. Earlier, parts of this line have been called the Gothenburg moraine. I think the Fjärås line was formed during a climatically caused stagnation, as the line is very distinct and as corresponding lines seem to be found on the East Coast and probably also in Southern Norway (cf. below). The age is estimated at about 10,300—10,350 BC (cf. p. 170). This period marks the end of the classical Oldest Dryas (Ia, DR—1). It was preceded by the Ågård Insterstadial (cf. p. 169), and followed by the classical Bölling Interstadial (Ib, BÖ). The shoreline of the Fjärås line has a gradient of 8.4 m/10 km.

The Fjärås line has the following extension (from south to north) along the Swedish West Coast (Pl. 3):

1. The Nissan Valley: Caldenius (Caldenius *et al.* 1960 and 1966) showed that a distinct ice lobe existed in the Spenshult—Boås area. In my opinion this lobe can now be correlated with the Fjärås line. The western margin of the ice lobe probably turns SE somewhere SE of Mosilt.

In the Sennan Valley a distinct ice lobe probably extended down to about the rapid at Hallsbo, later left as a dead ice (cf. Johnsson 1956, p. 309).

2. The Fröslida-Drängsered area: As the hills on the western side of the Nissan Valley are high, the ice margin cannot have crossed them, but must have continued northwards. In the Fröslida area a lot of till is accumulated on the valley slopes (west of Öllsjö a clear basal till was observed). Melt water was probably discharged towards SW via the valley of River Lillån. At Hästift there are some distinct terminal moraine ridges running N–S. Apparently these form a link of the Fjärås line between Drängsered and the lobe in the Nissan Valley. At B 844, just outside the main part of this line, the following stratigraphy was found:

A: 2.5 m of hard basal till. The stones and boulders are not rounded. The till contains redeposited material from layer B.
B: Stratified silt (Swed: "mjäla/mo") and till.

Consequently there is an indication of a readvance — apparently in connection with the Fjärås line.

3. The Drängsered area: In the area Älmö—Drängsered—Gångarebo there is an ice marginal indentation, shown by a line of distinct ice marginal deposits. The pit B 845 shows a basal till partly with very big boulders. The big hill NE of Ramsered consists of rock. SE of this hill there is a canyon indicating melt water erosion. From Gångarebo the ice margin must have turned up to Greppered.

4. The Greppered area: Two very well marked and some less well marked terminal moraines pass Lake Hagasjön in a SE—NW direction. At Yered they turn towards NNW. The outermost one follows the road to Bökhult, where it turns towards Gällared. This extension is obvious and the other terminal moraines seem to follow just inside, e. g. the two ridges SE of the church of Gällared. Between Gällared and Ullared only a few ridges have been mapped. However, their direction makes a correlation highly possible.

5. The delta at Ullared: It is a fairly big delta. It contains several depressions and two small lakes, which presumably are all kettle holes. The altitude of the delta was measured at six different points: +74.5 m on the inner part of the western plain, +70.0 m on the plain at the church, +73.0 m on a plain with a small gravel pit, +75.5 m a plain above a small shore cut at about +73 m, +73.0 m good delta plain. Von Post has levelled the ML to +72.4 and +72.5 m (unpubl.). The shoreline falls at +72.5—73.0 m at the isobase of this delta.

6. The Ullared-Källsjö area: A series of very well marked terminal moraines passes from Ullared via Hjärtaredssjön to Källsjö, where it turns towards Nösslinge.

7. The Nösslinge area: A marked terminal moraine passes with an E—W direction to the church and with a lobe around the northern part of the lake St. Nedan. West of the church there is a delta plain (or an outwash plain) with a somewhat rough surface. The plain was measured to +82.7 m (81.7). If this is a delta, it was not formed in the sea but in a local ice-lake, which had its outlet towards south.

8. The delta at Mäshult: The valley south of lake Mäsen is filled with a big accumulation of drift. At Mäshult just south of the lake there is a big terminal moraine lobe — obviously an ice-contact formation. Outside this there is a big delta, which has partly been built up above ML like an outwash plain. The exact position of the ML was not possible to fix. Four measurements were made: +84.2 m at the foot of the terminal moraine, +78.0 m at a plainer area just outside the latter, +72.8 m at the middle of the plain and +68.3 m at the main road (clearly below ML). According to the field notes I placed ML in the area about +72.8 m or just below this. The shoreline falls at +71.4 m.

9. The delta at Grimmared: SE of the church and 2 km SW of Lake Valasjön there is a very impressive delta. In the southern side there is a big gravel pit (B 801) with the following stratification:

A: ½ m of washed gravel (soil surface at +64.5 m)
B: about 15 m of delta material of distal type with strongly sloping layers (sometimes about 40° slope)

The whole delta ends with a very steep slope towards NE — an ice-contact. On the top of the delta there is a terminal moraine with a cutting (B 802) that shows pure till without any traces of washing. From the NE margin of the delta a small stream bed crosses the delta, passing just east of the rock that breaks through the delta. The following measurements were made: different altitudes of the plain in the area of B 801, +64.5, +65.0 and +67.1 m and at the foot of the terminal moraine (B 802) +69.1 m. According to Nelson (1910) the surface fo the delta is at +69 m. The shoreline falls at +72.0 m.

10. The delta at Vägryd: I have not visited this locality. It was described as early as 1893 by Svedmark. Nelson (1910) stated that the altitude was +67 m. The shoreline falls at + 72.0 m.

11. The Järlöv area: NE of Veddige there are in the valley sides two big deltas, Högaslätt and Barkhult. The corresponding ML is about +71.0 m. Von Post hade these deltas mapped in detail (Caldenius 1942, von Post † 1955). Between these two deltas there is a small "delta" (surface +44—45 m) at Kalvhult. Von Post and Caldenius looked upon this as an ice marginal deposit. However, the whole delta at Kalvhult rests upon Late Glacial clay containing shells that were C^{14} dated at 9.615 ±160 BC, i. e. the "delta" is not an ice marginal deposit

but a result of later redeposition (cf. p. 145). The occurrence of flint in the gravel supports this statement. The round form of lake Dran and the fact that it has not been filled by glacial and Late Glacial sediments makes me consider it to be a kettle hole. The shoreline falls at +71.1 m.

12. THE DELTA AT BJÖRKHULT: Here I have no observations of my own. Blomberg (1883) described this delta and pointed out its connection with a marked line Lindome—Fjärås—Gällinge—Björkhult—Veddige. The consulting firm Hagconsult AB has investigated the area. A contour map shows: a steep proximal slope — probably an ice-contact —, a fairly steep distal slope and a delta plain between +72 and +66 m. The material is sand and gravel. According to older local borings the delta was thought to rest upon "clay". However, this is not at all certain. Some seismic profiles made by Hagconsult show two different layers. However, the lower one, the "clay", is now interpreted as the ground water surface in sand-silt. The shoreline falls at +73.1 m.

13. THE IDALA-GÄLLINGE AREA: An impressive, slightly curved, terminal moraine extends from Idala to Gällinge. The surface of this ridge is covered with stones and boulders and it looks as if it consists of till. As no cutting is available, nothing is known about the material in the interior of this ridge (it may contain stratified drift). Behind this ridge there is a glacifluvial plain at Gällinge church with its surface at about +73—74 m (according to the map). The shoreline falls at +76.5 m.

14. FJÄRÅS BRÄCKA: Fjärås bräcka is a classical ice marginal deposit. It has been investigated by Nelson (1910) and Wenner (1951). De Geer (1893) measured the ML to +77.4 m at a point 2.5 km inside the terminal moraine ridge. The highest point in the southern end is at +76.4 m. The top of the till ridge in the middle of the field is at +66 m. The plain south of Fjärås church is at +50 m. According to Wenner (1951) Fjärås bräcka is not an unusually big delta, but an impressive terminal moraine with portions of glacifluvial material. The mouth of the meltwater streams should have moved from SE (Dalboviken) to NW (Bräckaviken). Traces of minor oscillations occur. There was a great Late Glacial redeposition and very thick layers of sand and gravel were transported by littoral streams southwards and deposited in the bay between Stena and Limmanäs. These layers reach +50 m and partly rest upon glacial clay. Towards NW, between Fjärås church and the outlet of Lygnern via Stensjön, the ice marginal deposits consist of a big till ridge. The shoreline falls at +77.4 m in the southern end and at +78.2 m at the plain south of the church.

15. THE HJÄLMERED AREA: The valley of Lillån is here crossed by a marked terminal moraine, a till ridge with glacifluvial material outside. In this area Wedel (1967) has measured ML at two places: at Stora Iglakärr to +87 m (= the limit washed/unwashed till) and at the hill east of Svartetjärn at +89 m (= the limit washed/unwashed till around the hill). However, Wedel also stated

that there are distinct shore marks at lower altitudes at the same points: at +82.6 m (a ridge of shingle) and at +83—84 m (a shore cut), respectively. The shoreline of the Fjärås line falls at +82 m at Stora Iglakärr and at +84.0 m at the hill east of Svartetjärn, which means that this shoreline exactly corresponds to the distinct shore marks here, but not to the stated ML. The limit washed/unwashed till falls 5 m above my shoreline and seems either to correspond to washing above the real ML or to an older shorelevel before the Fjärås line (which does not seem likely considering the ML at Skärsjön, Vessige, etc.). As a principle, washing limits should be avoided for the fixing of ML.

16. The Lindome-L.Vämmedal area: Between Lindome and L.Vämmedal there is a distinct continuous terminal moraine, which seems to consist mainly of till. At Lindome church there is glacifluvial material on the SW side. The altitude of the ridge has been measured at the church to +72.0 m and just SE of this place to 76.5 m, which seems to be the highest point. The shoreline falls at the church at +84.8 m, i. e. the ridge was formed several meters below sea level.

17. The deltas at Stensjön and Delsjön: West of the lakes Stensjön and St.Delsjön there are big glacifluvial deltas. The delta W—SW of Stensjön has according to Sandegren (Lundegård and Sandegren 1953) been built up to the ML at +91 m. The proximal slope towards Stensjön is steep and presumably an ice-contact. A gravel pit in the distal slope shows that layers of till also occur. The delta west of St.Delsjön is built up to +95 m. The corresponding ML is according to Munthe (Munthe *et al.* 1923) at +97 m and according to De Geer at +92 m. Munthe (op. cit.) described a gravel pit in the distal part which showed strongly folded and pushed sand layers resting upon undisturbed stratified drift. Consequently, there is evidence of an oscillation of the ice margin at a late time of the stagnation along the Fjärås line. The shoreline falls at +91 m at the Stensjö delta and at +93.0—93.5 m at the St.Delsjö delta.

18. The terminal moraine of Kyrkåsen: Several cuttings in this ridge have been described by Munthe (Munthe *et al.* 1923). The ridge consists of alternating beds of sediment and till. Apparently it was formed during several minor oscillations.

19. The Lärje-Lärjeholm area: At Lärje there is a ridge of till running in N—S direction. At Lärjeholm there is an accumulation of glacifluvial material.

20. The terminal moraine at Bäckebol: NW of Bäckebol there is a marked terminal moraine pointing from SE towards NW. It shows that the ice margin crosses the Götaälv Valley between Lärjeholm and Bäckebol, probably with a small bay caused by calving (Sandgren and Johansson 1931). The continuation of this line is seen north of Lerbäck in a glacifluvial accumulation and a till ridge.

21. The continuation towards NW: The further extension of the Fjärås line towards NW cannot be fixed exactly, as the traces are too incomplete.

However, it seems roughly to follow the A_3 line of Björsjö (1949). At Hålta, which is included in Björsjö's A_3 line, Sandegren (1943) put the ML at +113 m. My shoreline falls here at +112 m.

The delta at Rösered, which has its continuation west of Götaälv in the two terminal moraines at Kärra, is built up to +103.8 m. According to Alin the corresponding ML is at +108 m and according to Gillberg (1952) at Linnarhult, 1 km SE of the delta, at +93 m. Compared with older and younger shorelines the figure 108 seems to be too high and 93 to be too low. The shoreline of the Fjärås line falls at Rösered at +103.0 m, i. e. it is possible that the Rösered—Kärra line belongs to a late stage of the Fjärås line; at least it cannot be much younger.

Out of this comparison between given shorelines and ML figures, I think it can be established that the Fjärås—Gothenburg line does cross the Götaälv Valley towards NW (as Munthe, Sandegren, Caldenius, Gillberg and Johnsson think) and does not follow the eastern side of the Götaälv Valley, and later to join the Backamo—Tanum Line as Björsjö thinks.

It is striking that the Fjärås line is very distinct along the margin of the highland of Småland, but in Bohuslän, which was almost entirely covered by the Late Glacial sea, not at all more marked than the other lines. This may indicate that the longer stagnation along the Fjärås line, clearly indicated by the big ice marginal deposits along this line, was topographically rather than climatologically caused. However, the lack of distinct ice marginal deposits in the costal area of Bohuslän is a general feature, which may have a topographical explanation (e. g. the position outside the big depression of Lake Vänern and inside the southeastern continuation of the Norwegian Deep Channel). Furthermore the development of molluscs and barnacles in the sea and the vegetational development on land show that the climate during the time of the Fjärås line was slightly colder than the preceding Ågård Interstadial and definitely colder than the subsequent Bölling Interstadial (closer dealt with below, p. 167).

Further out along the direction of tilting the shoreline of the Fjärås line falls at the following levels: 1) +50.4 m at Danstorpsmossen, where a peat bog with its surface at +51 m is pollen analysed (see below); 2) +28.3 m at Eskilstorp, where I have levelled a distinct shore cut terrace to +27—30 m with a more or less undetermined mean sea level (Fig. 117); 3) +27.4 m in the eastern part of Hovs Hallar, where Junker (1961, unpublished) has a shore cut at +28.7 m; 4) +26.8 m at the western part of Hovs Hallar, where Junker (op. cit.) has a shore cut at +27.3 m; 5) +23.5 m at Trollarehall, NE of Torekov, where Junker (op. cit.) has a distinct shore cut at +23.3 m; 6) +22.2 m at Öllöv, where I have measured a very distinct shore cut to +22.2 m; 7) +12.5 m at Lerhamn, where I have measured a very distinct shore cut (cliff) to +14.5 m, and 8) about −10 m at the threshold in Öresund. Consequently it looks as if the Baltic Ice Lake was

dammed about 3 m above Kattegatt. As the isolation of the peat bog Danstorpmossen occurred about the time of this shoreline, this bog is worth a closer examination.

The peat bog Danstorpmossen has been pollen analysed by Linnman. However, I find the description incomplete and the pollen zonation of the older part unconvincing (Linnman in Caldenius *et al.* 1966, Fig. 33). According to Linnman (1965a) the isolation took place about the zone boundary III/IV at the limit between clayey mud and detritus mud. However, such a late isolation is according to the shorelevel displacement curve out of question and the stratification and pollen diagram also speak clearly for a much earlier isolation. On the Swedish West Coast isolation levels older than Younger Dryas are almost always marked by the increase of mud — usually from clay to muddy clay or clayey mud. As the clay content in the sediments above an isolation level is derived from marine clay, it is not at all surprising to find some marine diatoms in the sediments above the isolation level. The isolation contact in Danstorpmossen lies at least 6.07 m down in the pollen diagram at the limit "clay"/clayey mud. According to an earlier version of the diagram (Linnman 1965b), the top of the "clay" is a sandy muddy clay. This means that the isolation level may be still further down. The content of *Hippophaë* between 6.07 and 6.33 m indicates proximity to the shore. The lower part of the pollen analysed stratigraphy is as follows:

D: to 4.72 m *Phragmites* peat
E: to 5.29 m coarse detritus mud
F: to 5.535 m sandy clayey coarse detritus mud
G: to 5.85 m grey sandy clayey mud
H: to 6.07 m algal clayey mud
H/I: probable isolation level
I: to ? sandy muddy clay
I/K: possible isolation level
K: to ? clay

I would give the following zonation of the pollen diagram (the figure marks the lower limit of each zone):

BO—2 (VI) to 5.07 m: Onset of the *Alnus* curve, A°.

BO—1 (V) to 5.31 m: Onset of the *Corylus* curve, C°. Rise of *Pinus*. Fall of NAP, *Ericales, Salix (Myriophyllum alterniflorum)*.

PB (IV) to 5.535 m: Limit F/G. Rise of *Ericales*. Small rise of *Betula* (arboreous?). Fall of *Salix*. Rise of *Myriophyllum alterniflorum*.

DR—3 (III) to 5.79 m: Rise of *Artemisia*. Rise of *Chenopodiaceae*. NAP, *Betula (nana?)* and *Salix* are high within this zone. Layer G seems to be a typical sediment from Younger Dryas. Similar layers have been found at several localities along the West Coast. The zone limit could also be at 5.85 (G/H).

AL (II) to 6.025 m: Rise of *Ericales*. Fall of *Gramineae* and *Artemisia*. *Artemisia* is fairly low and *Ericales* high within this zone. *Empetrum* forms the peak of *Ericales*. *Pinus* makes a marked top in the middle of the zone.

DR—2 (Ic) and BÖ (Ib) to 6.17 m: Fall of *Artemisia, Cyperaceae* and *Salix*. *Ericales* is low within this zone. Probable isolation in this zone at 6.07 m, the limit H/I (also rise of pollen of limnic plants).

DR—1 (Ia) *Artemisia, Cyperaceae* and *Salix* are high.

According to this interpretation the isolation took place some time in zone I, but it is not possible to settle in which part of it. Consequently, the stratigraphy and pollen analyses in Danstorpsmossen do not contradict but support my chronology and shoreline diagram.

According to the shoreline diagram the clay surface at –1.75 m in Nivaa (K.Jessen 1920) was passed by the falling shorelevel just before the shoreline of the Fjärås line. The following stratigraphy is seen (surface at +1.4 m):

A: 75 cm of beach sand with stones.
B: 12 cm of brown mud = zone VII.
C: 18 cm of dyey peat = zone VI.
D: 32 cm of grey-brown mud = zone V.
E: 4 cm of brown clayey mud = zone IV (61 % *Betula*, 30 % *Pinus*, 9 % *Salix*).
F: 38 cm grey limy clayey mud = zone (?), with subarctic plant remains. Pollen: 68 % *Betula*, 28 % *Pinus* and 4 % *Salix*.
G: 13 cm of grey-brown limy clayey mud = zone (?), with arctic plant remains.
H: 13 cm of dark, grey limy claye mud = zone (?), with arctic plant remains. Pollen: 75 % *Betula*, 15 % *Salix* and 10 % *Pinus*.
I: 20 cm of grey-blue shore gravel = shore deposit from the "isolation".
J: >75 cm of clay = marine (not proved) Late Glacial clay.

I find it obvious that the clay is a marine Late Glacial clay and not a lacustrine "Dryas clay". This is also shown by the superimposen shore gravel. Layer H (and G) contains an arctic flora (e. g. *Betula nana, Dryas octopetala, Salix polaris, Salix reticulata* and the shore plant *Triglochin maritima*), which may correspond to Older Dryas.

In Rungsted Havn the clay surface at –4.7 m K.Jessen 1923) would have been passed by the sea just after the shoreline of the Fjärås line. The following stratigraphy is seen (surface at –2.2 m):

A: 80 cm of shore sand and gravel
B: 50 cm of grey-green sandy shore dy
C: 50 cm of peat (forest peat)
D: 70 cm of brown sandy mud and lime mud
E: 70 cm of grey-blue clay

I think the clay is a marine Late Glacial clay, though no evidence for this assumption is available. The flora of the clay is arctic, containing *Betula nana, Dryas octopetala, Salix polaris,* etc. The proximity to the sea shore is indicated by the presence of *Callitriche autumnalis, Triglochin maritima, Statice armeria* and *Salda littoralis*.

The continuation of the Fjärås line SE of the ice lobe in the Nissan Valley has not yet been investigated. However, the Fjärås line seems to continue towards SE to the northern part of the plain Kristianstadslätten, where is turns eastwards

to the big delta at Bredåkra (O.Andersson 1927, De Geer 1910a). This correlation, though as yet more or less unproved morphologically, is supported by Antevs' varve chronology (Antevs 1915). If Antevs' varve –100 is identical with the ingression of saltwater (p. 118), the delta at Bredåkra and the Fjärås line are of the same age, as there are 100 or slightly more years between the varve –100 and the delta at Bredåkra and according to the shoreline diagram there are 100—130 years between the shoreline of the ingression and the one of the Fjärås line.

The correlation between the Fjärås line and the area of the Bredåkra delta is strongly supported by the fact that the shorelevel displacement curve given by Berglund (1966, Fig. 14) would be much more reliable if the ML is given the age of the Fjärås line. Then there is a smooth land upheaval (Fig. 32) without Berglund's strong change in intensity in early Alleröd. Berglund uncritically assumes that Erik Nilsson's varve chronology is correct (cf. p. 105) and that the Bredåkra delta belongs to Older Dryas. But this gives an abnormal land upheaval, which is not the case if the age of ML is changed to correspond to that of the Fjärås line.

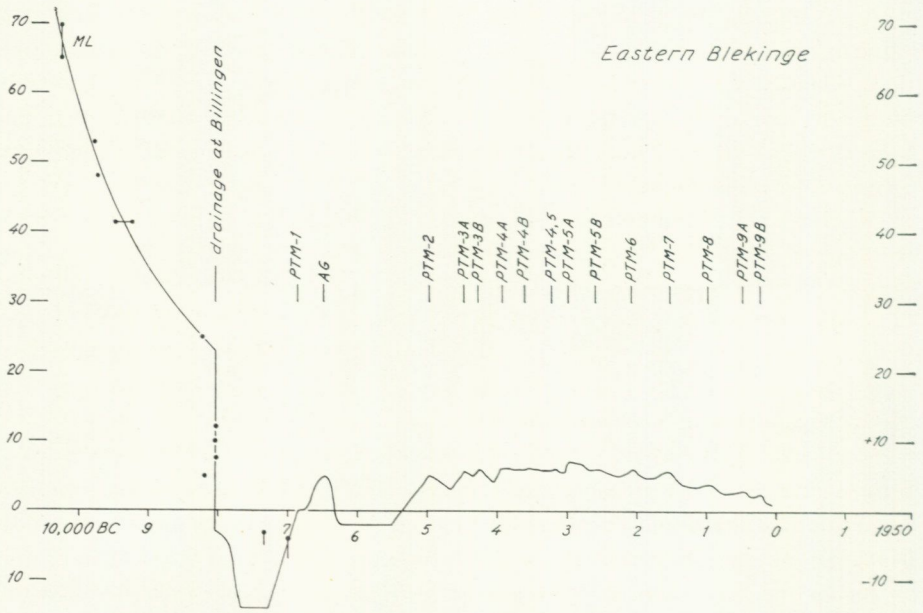


Fig. 32. *Berglund's (1964, 1966) shorelevel displacement curve from Eastern Blekinge, altered. ML is here given the age of the Fjärås line, which gives a much more likely curve. The Postglacial part is changed in concordance with the new results from the Swedish West Coast.*

According to some terminal moraine ridges (De Geer 1910a) and numerous varve measurements (unpublished map) De Geer found that the ice margin corresponding to the Bredåkra delta turned up along Kalmarsund to Kalmar, where it crossed Kalmarsund and turned southwards across Öland. However, Bergdahl (1947) found a terminal moraine zone, the Karlslunda line, running SW—NE from Vissefjärda to Kalmar, which via the ridge "Övetorpsmoränen" on Öland was supposed to change over into a Baltic ice along SE Öland. Consequently there are two quite different opinions about the position of the ice margin in the Kalmar area. However, it seems likely that two different ice marginal lines come together in the Kalmar area, viz. the older Fjärås line (from S—SSW) and the younger Moslätt/Berghem complex (from SW). In connection with a projected bridge, borings were made in Kalmarsund right in the area of the terminal moraine zone (Königsson 1967b). The borings show alternations of till and glacifluvium. Consequently we have here indications of oscillations in connection with the terminal moraine zone.

The Fjärås line (the Baltic lobes) curves from southern Öland, in a big lobe (more or less hypothetically drawn on Pl. 2), over to the second ice marginal fork on Bornholm, the Splitgaard—Robedale line (cf. p. 111; Grönwall and Milthers 1916). From southern Bornholm the line continues in a very distinct lobe between Skåne and Rügen (more or less hypothetically drawn in Pl. 2) over to one of the ice marginal lines on Rügen (cf. p. 111; Kliewe 1966; Reinhard and Richter 1961).

In southern Norway the terminal moraine "Kristiansand-trinnet" (B. Andersen 1960) is roughly of the same age as the boreo-arctic shell fauna (at about +35 m in stony glacial clay) at Tingsager near Lillesand (just outside "Kristiansand-trinnet"), which has been C^{14} dated at 10,600 ±200 BC = 10,295* ±225 BC (Trondheim II). This date points to an age of the "Kristiansand-trinnet" that is euivalent to the age of the Fjärås line. However, it is also possible that the "Kristiansand-trinnet" is younger and corresponds to the Moslätt/Berghem line of Older Dryas. It is really a pity that the correlation cannot yet be settled, as the total view of the importance of the Fjärås line and Moslätt/Berghem line would then have been much more clear. The fauna (cf. p. 175) suggests a correlation with the Bölling Interstadial. "Kristiansand-trinnet" is a complex of terminal moraines and is thus formed in a similar way as the Moslätt/Berghem terminal moraine complex. This may indicate a correlation, also suggested by the geographical position of the terminal moraines in Norway and Sweden. If this is correct the "Spangereid-trinnet" would be equivalent to the Fjärås line.

A big problem with the fixing of the Late Glacial shorelines is that the isobases bend towards Gothenburg, where the land upheaval has been somewhat stronger and the direction of tilting is from about N 16° E. I have tried over and over again with varying isobase directions and different connections between the two systems. However, the picture here given has always turned out to be the

superior one. According to this picture the isobases turn along a line 35 km NW of and parallel to the direction of tilting in the Viskan Valley. With this model the shore marks within these two isobase systems have been put together with good results for the Late Glacial shorelines as well as for the Postglacial ones. Also it was possible to settle the continuation of the two big ice marginal lines, the Fjärås line and the Moslätt/Berghem line.

The Moslätt line

This is a marked line which, however, in great areas cannot be separated from the younger Berghem line. The name is given after the impressive delta at Moslätt. At some places there are indications of a readvance. This line corresponds to the beginning of Older Dryas, and can thus be dated at about 9,950—9,925 BC. It marks a colder climate after the warmer Böllinge Interstadial. In the clay pit at Agnesberg (p. 171) it would be equivalent to the varves 30—46 that contain a more arctic *Portlandia* fauna. Between the Moslätt line and the Berghem line there are about 70—79 varves containing a more thermophilic *Mytilus* fauna. The shoreline of the Moslätt line has a gradient of 8.0—8.2 m/10 km.

The Moslätt line has the following extension from north to south (Pl. 3):

1. The area south of Hindås: The extension of the Moslätt line south of the Hindås area is not sufficiently known as the mapping and measuring of ML are incomplete (due to the fact that at the time of the mapping I concentrated the work in this area to the Berghem line, not knowing the existence of a separate Moslätt line).

From the available figures of ML it seems obvious that the Moslätt line lies outside the Berghem line in the area north of Torestorp. Only a preliminary picture of the extension can be given.

At Lejonslätt in the southern end of lake Tolken there is a marked terminal moraine that could belong to the Moslätt line. If this is correct it means that the ice margin did not reach the higher parts of the hills and probably joined the Berghem line in the Torestorp—Kroksjö area. The Öxnevalla delta could according to the shoreline belong to the Moslätt line. The hanging delta at Kattunga could also belong to this line. The further extension probably goes east of the hills at Surteby to the delta at Nödinge (according to Gillberg's figures of ML this delta is younger). The delta at Almered could belong to the Moslätt line (Gillberg's figure of ML +84.0 m fits with the shoreline). SE of Bosgården there is a gravel pit (B 809) with a stratification that indicates an oscillation:

A: 1—2 m of till
B: 2—3 m of coarse gravel and pebbles
C: stratified sand and fine gravel, sloping out from E—ENE

The Moslätt line probably continues along the NW side of the River Storån valley and joins the ridges from Hindås in the Björkboås—Rydal area (Gillberg's figures of ML in this area fall below the shoreline).

2. The Hindås area: The area around the railway station has been interpreted by Ekström (1955) as an ablation moraine area. I think the area shows a marked terminal moraine zone belonging to the Moslätt line. Two very marked terminal moraine ridges from the hills south of Hindås can be followed to Hindås and out into the lake as the marked peninsula in the S side of lake V. Nösjön. From Hindås church a ridge towards Älmhult in SW runs perpendicularly to the terminal moraines. The genesis of this ridge is not clear. The smooth and rounded surface is striking. The NE part consists of at least 1 m of till. According to Ekström it is a drumlin.

3. The Uspen-Lensjön area: A very distinct terminal moraine zone passes between the two lakes in SSE—NNW with glacifluvial material outside and beneath till. At Högsboholm a till ridge runs along the eastern side of lake Uspen. An upper, uneven and probably supra-aquatic plain lies at +116.7 m. A lower plain at the northern end of lake Uspen lies at +98.5 m. South of lake Lensjön there are two big gravel pits (B 812—813) with the following stratification.

B 812 at Sågbron:

A: 1—2 m of hardly sorted till-like coarse gravel and pebbles. In the northern wall it is a typical till with very big boulders (up to 3—4 m diameter).
B: Stratified sand-gravel.

The surface of the till is in NE at +106.4 m and in SW at +105.4 m. The surface of the sediments is in SW at +104.4 m, which seems to be a minimum value of the corresponding water level (probably an ice-lake).

B 813 at the cottage 250 m NW of B 812:

A: 3—4 m of basal till, hard and containing large boulders
B: 0.3 m of gravel
C: 0.1 m of grey fine silt
D: 0.1 m of sand
E: 0.25 m of varved silt
F: 0.4—0.5 m of gravel
G: at least 1—2 m of stratified sand-gravel, sometimes with stones and boulders at the surface, which may have dropped from icebergs.

Layers A and G extend throughout the whole gravel pit, while layers B—F only occur in the western part. The sediments are unevenly cut off by the till. The stratification shows a definite readvance. The question is whether the sediments were formed before the readvance to the Moslätt line or are much older. The circumstances in B 812, where the till changes over to coarse gravel, show that the till belongs to the Moslätt line and that, consequently, the sediment probably had been deposited just before the readvance to the Moslätt line.

4. The Skallsjö area: No large till ridges or glacifluvial accumulations have been found here. Small till ridges occur and all run SSE—NNW, which may support the synchronization of the terminal moraine at Sågbron and the delta at Moslätt. Just beneath the hill 1 km SW of the church there is a gravel pit (B 814) with the following stratification:

A: 1—2 m of basal till with boulders
B: at least 2—3 m of stratified sand-gravel

The limit between layer A and B is very uneven and shows a clear unconformity. Consequently, the stratification shows a readvance, which must be equivalent to the one in the Uspen—Lensjön area. Two measurements of the possible ML were made SW of the church: +96.5 m (too low) and +99.5 m (better). However, these are not certain ML marks. Gillberg (1952) gives the following values of ML: Skallsjö +101.5 m, Fridhem +103.0 m and Floda +102.0 m. The shoreline falls at +100.0 m.

5. The Moslätt delta: At the southern end of lake Mjörn there is a very impressive glacifluvial delta around Moslätt. This delta has given the name to the corresponding ice marginal line. Sand and gravel have been quarried in several big pits. The stratification in some of these (B 815—818) is given below: B 815 in the SW corner of the delta. Surface +90.0 m.

A: 1 m of coarse gravel and pebbles
B: ½ m of stratified gravel with steeply sloping layers
C: >1—2 m of stratified sand-gravel

B 816, a very big gravel pit in the SW part of the delta between Moslätt and the main road. Surface +100.5 m (below ML).

A: 1—2 m of gravel
B: 1 m of horizontally stratified sand
C: >15 m of sand-gravel, sloping from about NNE

B 817, a big gravel pit in the steep NE slope. The surface of the top level is +103.0 m.

A: Fairly coarse and unsorted till-like material.
B: Sandy layers that usually slope out towards NE. Layer B shows that the NE slope is not an ice-contact but a proximal upstream slope, where meltwater, debouching at a low level, has forced the material up over the delta crest, which ought roughly to correspond to the ML. This type of marginal delta has been fully described by Nelson (1910, fig. 3) and is similar to the well known delta at Dal's Ed (De Geer 1910b).

B 818, two big sand pits just SSW of B 817 and also in the NE slope. The surface of the top level is at +102.5 m.

A: ½—2 m of gravel, often till-like. Just between the two pits it is till.
B: >15 m of stratified sand, horizontal or sloping out towards SW—SSW.

Today the delta does not reach across to the SE side of the valley. The explanation seems to be that the material was eroded away during the drainage of the big ice lake that must have occupied the Mjörn area east of the Moslätt delta. In the northern end of the delta three measurements were made in order to fix ML: +105.5 m at the limit between till and hill slope, +104.5 m at a till plain, and +103.0 m at the sediment plain just outside a small shore cut in the till. For good reasons ML seems to be fixed at +103.0 m. Gillberg (1952) gave the same figure. The shoreline of the Moslätt line has been based upon the ML +103.0 m at Moslätt. However, the other localities belonging to the Moslätt line suggest a 2 m lower shoreline. Whether this lower shoreline is the real shoreline of the Moslätt line or corresponds to a later stage of the Moslätt line cannot yet be settled, and it is not of great importance as these lines are parallel.

6. The area NNW of Moslätt: NNW of Moslätt there is a stretch of 8 km, where I have no direct indication of the position of the ice margin. However, it is striking how well a series of lakes range themselves into a SSE—NNW zone (Pl. 3): Kroksjön—Trehöringen—Långesjön—Gärdsjön—Holmesjön—Sundasjön—Sverkesjön. These lakes might be the result of a series of ice lobes belonging to the Moslätt—Kollanda line, which were left as dead ice when they were cut off by the higher hills to the east. (The position of the slightly younger Berghem line is east of these hills.)

7. The Floga area: Around Floga there is a plain, which consists of glacifluvium covered by a thin till layer. The stratification in the available cuttings is described below:

B 821, several small gravel pits 400 m east of Floga. The surface of the plain here lies at +107.0 m.

A: 1—½ m of till, totally unstratified gravelly fine sand
A/B: distinct unconformity
B: >2 m of stratified sand and gravel

The stratification indicates an oscillation of the ice margin.

B 822, a large but not deep gravel pit just south of Floga. The surface of the plain here lies at +106.0—105.0 m.

A: till
A/B: unconformity
B: stratified sand

In the NE part of the pit there occur varved sediments as follows:

A: ½—1 m of till, fine sand and gravel
B: 1—1½ m of varved silt, several thin varves
C: 0.3 m of varved fine sand/coarse silt, 3 thicker varves
D: coarse gravel

The surface of the sediments is at +104.0 m and of the till at +105.0 m. Consequently we have also here an indication of an oscillation of the ice margin.

8. The Kollanda area: Around Kollanda there is a glacifluvial delta. Gillberg (1952) also connected this with the Moslätt delta and stated the ML level to be +108.0 m. A big sand pit (B 823) shows:

A: 1 m of till-like gravel (might be washed gravel)
B: stratified sloping sand with cross-bedding

The surface of the plain here lies at +106.5 m, but the sediments reach up to +107.0 m, where bare washed rock occurs. ML is probably at +107—108 m. The shoreline falls at +110.0 m, but as stated above, it could also be 2 m lower.

As the area north of the delta is now occupied by a big peat bog it is possible that an ice lobe extended into this depression during the time of the Moslätt line, and was later left as a big body of dead ice. At the western end of the bog there is a till ridge. As a whole the ice margin of the Moslätt line seems to be very much influenced by the topography of the area between Moslätt and Uddetorp (NW of Kollanda).

9. The area of the Götaälv Valley: It is still an unsolved problem how the Moslätt line crosses the Götaälv Valley between Kollanda and Björsjö's delta (1949), Håltfältet. There are two possibilities:

1. The valley was crossed by a more or less straight ice margin (probably via Skepplanda).
2. The readvance to the Moslätt line caused the extension of an ice lobe towards SW. Such an ice lobe could explain the curious so-called Högstorp terrace, which runs along the SE valley slope.

10. The continuation towards NW: Thanks to the shoreline diagram the Moslätt line can be connected with Björsjö's (1949) E_3 line (E line). The altitude of the deltas and the corresponding ML (Björsjö 1949) fit extremely well with the shoreline of the Moslätt line. At Backamo the Moslätt line is joined by the younger Berghem line and towards NW they continue together as the distinct Backamo—Tanum line or E line according to Björsjö.

In the SW slope of the delta at Huveröd, +124 m according to Björsjö (1949), a part of a rib of a whale (probably *Balaena mysticetus)* was found at + 101 m below downwashed sand and gravel (Björsjö 1953). The bone must have come into this position in Older Dryas or earliest Alleröd according to my shoreline diagram. By Professor B.Hubendick at the Museum of Natural History in Gothenburg I was kindly permitted to C^{14} date this bone. Unfortunately the bone had earlier been treated with sodium silicate. Almost the whole bone had to be used to get enough collagen. The C^{14} dating gave, 5,740 ±180 BC. However, this apparently does not correspond to the age of the bone itself, but must be ascribed to contamination. This contamination may have taken place when the bone lay in the sand or later when the bone lay in the museum (the sodium silicate may have taken up modern CO_2).

HÖGHULTS MOSSE, +7—8 M: This bog (in NW Skåne) was described by G.Andersson (1892, 1893). Andersson found the following stratigraphy:

A: 48 cm of peat.
B: 23 cm of muddy clay containing lacustrine diatoms.
C: 12—15 cm of grey sand with a sharp limit to layer B.
D: 85 cm of alternating sand and mud (at the bottom resembling varved clay). Besides abundant leaves and other parts of mosses, the mud contains remains of the following plants: *Betula nana, Salix polaris, Salix reticulata* and furthermore *Batrachium* sp., *Empetrum nigrum, Hippuris vulgaris, Menyanthes triofliata, Myriophyllum* sp., *Polygonum viviparum* and *Potamogeton* sp., i. e. an arctic-subarctic flora, which may correspond to Older Dryas.

Höghults Mosse is today swampy and can thus only be investigated during winter. In 1968 I went back there in order to take a sample of the possible isolation contact described by Andersson at about 1.70 m below surface. However, the isolation contact was found 7.34 m below surface. Due to lack of time only a few samples were taken. The following stratigraphy was found:

A: 143 cm of peat, muddy in the lower part
B: (to 1.88 m) 45 cm of green-yellow mud
C: (to 2.69 m) 81 cm of grey-yellow clayey mud
D: (to 3.83 m) 114 cm of peaty coarse detritus (brown moss peat) with thin layers of coarse silt to fine sand (at the top)
E: (to 4.32 m) 64 cm of somewhat clayey coarse detritus mud (brown moss peat)
F: (to 6.63 m) 216 cm of coarse detritus mud — brown moss peat
G: (to 7.00 m) 37 cm of clayey mud with coarse detritus (of brown mosses)
H: (to 7.34 m) 34 cm of hard, black, silty clayey mud with lumps of humus (dy) and coarse detritus of brown mosses
I: >38 cm of alternating grey clay and silt to fine sand

A sample of layer E at 4.10—4.20 m below surface was pollen analysed. The spectrum clearly belongs to the Early Boreal time, i. e. zone V or BO-1: 47.2 % *Pinus,* 45.1 % *Betula,* 20.9 % *Corylus,* 3.3 % *Quercus,* 2.2 % *Carpinus,* 101.1 % of NAP (10.8 % *Artemisia,* 19.8 % *Gramineae,* 67.0 % *Cyperaceae*) and 66.0 % *Pediastrum.* A sample from 6.95—6.97 m below surface (layer G) was C^{14} dasted at 9.120 ±135 BC, i. e. the end of Alleröd. A sample of the lowermost organic sequence (layer H) from 7.15—7.34 m below surface (exclusive the part 7.21—7.26, which was forgotten at the dating laboratory) was C^{14} dated at 9,785 ±110 BC, i. e. at the zone boundary I/II. The transition from layer I to layer H corresponds to the isolation of Höghults Mosse.

According to the shoreline diagram (Pl. 4) Höghults Mosse falls immediately below the shoreline of the Moslätt line, i. e. it would have been isolated in Older Dryas. This is fully proved by the C^{14} date of the lowermost 19 cm organic material that gave 9,785 ±110 BC.

B 838 was one of the last borings made and with its position in the diagram it gives an extremely good confirmation of the correctness of my shore-lines including the bend at –43.4 km.

If a body of dead ice did not remain here, the lagoon in central Anholt (cf. p. 59) should have been isolated during Older Dryas (between the Moslätt and Berghem lines).

The Berghem line

This is a distinct ice marginal line, or rather ice marginal zone, as it usually contains several well marked till ridges close together. It derives its name from the five terminal moraine ridges at Berghem. This name has earlier been used for parts of this line. By morphological mapping and comparisons of ML this line was followed along the whole Swedish West Coast. It was formed during the later part of the Older Dryas (Ic, DR-2). In the clay pit at Agnesberg (p. 171) it should be equivalent to the varves 125—175 that contain a more arctic *Portlandia* fauna, i. e. it should have lasted about 50 years or about 9,850—9,800 BC. The shoreline of the Berghem line has a gradient of 8.0 m/10 km.

The Berghem line has the following extension from south to north (Pl. 3):

1. The Torup area: At Torup church there is a delta or outwash plain with a distinct ice contact towards NE. The ice contact changes towards NW over into a terminal moraine ridge pointing towards the Ätran area. However, the interjacent area (15 km) has not yet been investigated. Towards SE the Berghem line continues (cf. p. 143) as the terminal moraine complex, "Torupsmoränen", mapped by Johnsson (1956).

At Gohult (NW of Torup) there are some terminal moraines, showing the following stratigraphy, B 846:

A: 4—6 m of till, containing fairly well rounded stones and boulders, and lenses of more or less stratified drift
B: 0.5 m of folded stratified drift of alternating (varved) layers of sand and clayey fine silt
C: >1 m of fine gravel, unstratified

Consequently there is an indication of a readvance. The ridges at Gohult probably belong to the Moslätt line, as they seem to lie somewhat outside the main Berghem line.

2. The Ätran area: Just south of Eserydsjön (which at least in SW seems to be a dead ice hallow) there is a terminal moraine zone with a NW—SE direction. Just south of the village there are some ridges running in N—S. These could indicate a turning of the ice margin towards Krogsered. However, this area is not sufficiently studied to settle the extension of the Berghem line. West of the village the till ridges point SE—NW, i. e. towards Tjärnesjön.

3. The Tjärnesjön area: I went to this area in order to find out whether the islands and peninsulas on the eastern side of the lake were formed by

terminal moraines or not. The outer parts of the peninsulas turned out to consist of rock. The inner parts are covered by till, but it is not known if this corresponds to any greater accumulation. The abundance of boulders and beach sand suggests an earlier existence of much moraine material in this area. SE and NW of the lake there are distinct till ridges with a direction that makes it very possible that they belong to the Berghem line.

4. The Lia area: The Högevadsån is here crossed by several terminal moraines. The ones at the village are especially well marked. Their directions mark a link between the ridges in NNW and SSE, which I think belongs to the Berghem line. Between Lia and Högsjön there is an 8 km stretch, where I have no information except for two places in the outer part of this ice marginal zone, where a till ridge can be followed in SSE—NNW.

5. The Högsjö area: At Prästhult there are two fairly distinct till ridges. Otherwise the area is strikingly poor in till and great parts consist of bare washed rock. Great ice-lake systems seem to have occupied the area. There are only thin ridges and small hills of till. However, these ridges always run in SSE—NNW, which makes their position in the Berghem line possible.

6. The Alsjö area: Here also, it was hard to follow the terminal moraines, as the area is poor in till and bare washed rock occurs frequently. However, several till ridges cross the area in NNW—SSE completely in line with the fully established position of the Berghem line at Älekulla. Between Kinnasjön (+156.2 m) and Alsjön (+144.5 m) there is a drainage canyon. From the eastern end of lake Alsjön there is a very distinct drainage canyon. This canyon can be followed down along the Lundaboån to the area Backabo—Sandryd—Sandsjön. Between Backabo and Sandryd there is a field of sand and gravel, and an esker has been cut off. As the drainage reached down to a point inside the Berghem line in the Kroksjö area, the drainage must have occurred after the time of the Berghem line. This proves that the Berghem line in the Alsjö area had a position west of the drainage point in the eastern end of the lake. This fact supports the synchronization between the ridges in the Alsjö area and the terminal moraines in the Älekulla—Kroksjö area.

7. The Älekulla area: On each side of the main cross roads two big terminal moraine ridges run in N—S, with one smaller ridge outside and three smaller ridges inside these. This is without doubt a part of the Berghem line.

8. The Kroksjö area: Here the Berghem line consisting of four beautiful terminal moraine ridges (and one diffuse on the hill slope) turns around the hilly area between Torestorp and Älekulla. The formation is impressive and forms an excellent example of a terminal moraine zone. The above-mentioned remains of an esker run perpendicularly to the till ridges (from about N 42° E). A part of this line was already mentioned by Caldenius (1942). As has been mentioned above (p. 128), it is very possible that the continuation of the Moslätt

line from the position at Lejonslätt (in the southern end of lake Tolken) turns and joins the Berghem line in the Torestorp—Kroksjö area. However, this has not been investigated, as at the time of mapping I thought the Moslätt line was a continuation of the Berghem line.

9. The Torestorp area: The area between Sandsjön and Torestorp is crossed by 4—5 terminal moraines running NW—SE. These were partly mentioned by Caldenius (1942). Concerning the ML, Gillberg (1952) has +77.5 m for Torestorp, which according to the shoreline diagram seems to be a little too high, and +75.2 m for Vik. I have the following measurements: +81.4 m at a plain in the SW end of Sandsjön (apparently above ML), +80.0 m at the limit between a plain and a bouldery slope in Torestorp (probably above ML), and a series along the road to Björnholmen: +71.5 m at the plain below a shore cut, +72.5 m in the shore cut and +75.0 above the shore cut and at the highest possible sea level according to the topography. According to the shoreline diagram ML would be at about +75—76 m.

10. The areas around Lake Öresjön: The peat bog Vareviksmossen is crossed by four till ridges, all easily connectable with the ones in the Torestorp—Kroksjö area. Caldenius (1942) described three lines that cross the lake Öresjön. Gillberg (1952) measured ML at Backen to +77.0 m and at Hulta to +77.0 m. Both localities lie in the outermost part of the Berghem line and also exactly correspond with the level of the shoreline.

11. The Berghem area: During the Viskan investigation von Post had the ice marginal deposits mapped (Caldenius 1942, Fig. 3; von Post † 1955). At Berghem von Post found five marked ridges of glacifluvial material, which on the NW side were covered by till. Later Caldenius (1942) found varved clay folded into the till. Consequently, we have here evidence of a readvance. This marked terminal moraine zone made me choose the name "the Berghem line", for its whole continuation along the Swedish West Coast. Three of the ridges at Berghem are more distinct and Caldenius (1942) found their continuation SE of Berghem. NE of Berghem I have found three till ridges pointing towards Hajom and doubtless belonging to the Berghem line. Von Post († 1968) measured ML to +82.4 m in the outermost part of the Berghem line (section 50) and to +79.5 m inside the terminal moraine zone (section 51). The shoreline falls at +80.0 m.

12. The Hajom delta: Glacifluvial deltas have been built out just north of the church and just north of the cross road 1.5 km NW of the church. The surface of the southern delta was measured to +78.5 m, but with ML some meters higher, i. e. about +80.0—80.5 m. In the delta north of the cross road there is a big gravel pit (B 806) with the following stratification:

A: 2—3 m of till-like coarse gravel and pebbles
B: more than 15 m of stratified delta material sloping from NE, sand to fine gravel at the top, and sand to fine sand at the bottom

The altitude of the delta plain was measured to +81.0 m, with a higher crest at +82.0 m. A stream bed with NE—SW direction was found in the delta surface with a bottom level at about +79—80 m. ML must be at about +80.0—81.0 m. The same value of ML was given by Gillberg (1952). The shoreline falls at +80.3 m at the southern end and at +80.6 m at the northern end of this area.

13. The Hyssna delta: The valley of River Surtan is here filled by a big delta. A gravel pit (B 807) in SW with a plain surface at +74.0 m shows stratified sand and gravel, varved silt and a big lens of till (dropped by an iceberg), i. e. a clear distal subaquatic deposit. At Klateberg it was possible to fix ML very exactly. A shore cut on the eastern side of the valley with an unwashed till above lies at +83.0 m. On the western side of the valley the limit between a plain and a steeper slope, just above a cutting with 0.5 m of washed gravel at +79 m, lies at +83.0 m. This means that exactly the same ML height was found on each side of the valley at two very good and independently determined ML-localities. Gillberg (1952) has also determined ML at Hyssna to +83.0 m. At the church the delta plain is at +81.0 m and further out at +77.0 m. The corresponding ice margin probably was at the western end of lake L.Hålsjön. The shoreline falls at +83.0—83.5 m.

14. The delta at Olofsred: From the Ustjärn—Kroksjö area a delta has been built out towards Härsjön. ML probably is at about +84—85 m according to the following measurements: +84.0 m at the limit between delta plain and rock slope, +83.0 m at the outer part of the delta, +86.5 m at the inner part of the delta in the narrow valley (probably above ML), and +85.0 m at the upper delta plain in the NE part. The shoreline falls at +83.8 m.

15. The Rävlanda area: As the ice marginal deposits in this area usually only remain on the valley slopes, it is not so easy to determine the position of the Berghem line. However, there is a distinct delta at Värred with a probable ice-contact on the NE slope, where till occurs. On the eastern part of the plain there are abundant stones and boulders. A curious bouldery ridge of unknown genesis, but definitely situated above ML, runs parallel to the valley slope in the eastern part of the delta. The limit between the till area and the sedimentary plain was measured to +89.6 m. A shore cut in the NE side of the delta was measured to +85.5 m, but this is probably younger than ML. Gillberg (1952) put ML at Värred at +88.7 m. The shoreline falls at +88.6 m. At the NE end of the Värred delta the valley is more narrow than elsewhere, which means that there is also a topographical reason to expect a stagnation here. I think the Värred delta belongs to the Berghem line.

16. The lakes Nösjöarna area: Ekström (1955) mapped an accumulation of glacifluvium at Lunkebäcken. At Tullebo—Äskegärde there is an impressive terminal moraine. The NE proximal side is steep and covered by till — probably representing an ice-contact. According to Ekström's map (1955) of

the bottom of lake Ö.Nösjön it seems as if the steep proximal slope can be followed down about 60 m below water level. The SW distal side is plain and probably consists of stratified drift. These deposits can be followed as a marked ridge towards NNW between the two lakes, from where it continues with more or less long interruptions to lake Sävelången. At the northern end of lake Viebosjön there is a gravel pit (B 811) with the following stratification:

A: 1 m of gravelly till
A/B: unconformity
B: at least 1—2 m of stratified sand-gravel, which shows deformations

Consequently there is evidence of an oscillation. The whole area is situated above ML.

17. The Näs area: The marked terminal moraine at Tullebo seems to have its continuation in the ridge that run SSE—NNW along the road at Näs. However, it was not easy to estimate the size of this accumulation, as outcropping rock was found at least at one point. Gillberg (1952) determined ML at Näs to +100.5 m and at Öjared to +99.0 m. The shoreline falls at +97.0 m at Näs and +98.1 m at Öjared.

18. The Gethult area: Along the eastern side of the hill there is a big accumulation of till, probably in the form of two till ridges. On the eastern slope of the hill there is a gravel pit (B 819), which shows 3–4 m of stones–gravel, partly well rounded stones, partly less well sorted gravel, and stratified sand in the easternmost part. The more or less plain surface is at +122.5 m (above ML). This glacifluvial layer was probably deposited in front of the ice against the hillside. This fact supports the assumption of a marked ice marginal line at Gethult. I think this ice marginal line is the continuation of the Berghem line. According to Gillberg (1952) ML at Gethult is at +105.0 m. The shoreline falls at +105.0 m. Between Lövås and Kåretorp (1 km west of Gethult) there is a glacifluvial plain, which was measured to +105.0 m. A gravel pit (B 820) shows:

A: ½ m of fairly unsorted fine gravel
B: 1—1½ m of well rounded coarse gravel and pebbles
C: stratified sand

This material was probably deposited by melt water from the ice margin at Gethult.

No further mapping of the continuation of the Berghem line NW of Gethult was done. However, Gillberg (1952) has several measurements of ML in this area. According to these, the ice margin would roughly pass Ryksdamm with ML at +110 m and Skår with ML at +112 m, as these figures fall within the shoreline of the Berghem line.

19. The continuation towards NW: By means of the shoreline diagram the Berghem line can be connected with Björsjö's (1949) E_1 line, which contains the deltas at Man (+123 m) and Måröd (+124 m). At Backamo the

Moslätt line and the Berghem line join each other and continue together towards NW as the Backamo—Tanum line, or the E line according to Björsjö.

In connection with the shoreline of the Berghem line four peat bogs, pollen analysed by von Post, were isolated:

BP 1409, BERGSJÖN, +68 M: The shoreline falls at +68.5 m. The isolation level is 4.44 m below the surface at the limit between clay and clayey mud. The pollen zonation older than zone IV (BP) is difficult to construct. This diagram cannot be used as evidence of an isolation in Older Dryas, nor does it contradict such a statement. However, we must also consider the possibility of dead ice in this area.

BP 1531, BASJÖN, ABOUT +65 M: The shoreline falls at +65.4 m. The isolation level seems to be 4.55 m below surface (clay/fine sandy mud). Neither the sediments nor the pollen analysis give any clear idea of the time of isolation. In order to get a sample for C^{14} dating of the isolation level I made a new boring (B 718) in this locality. My interpretation was that this basin had been occupied by a body of dead ice. This is indicated by the stratigraphy, the form of the basin and the surrounding topography.

BP 1410, BARNAMOSSEN, +59—60.5 M: The shoreline falls at +59.2 m. The isolation level seems to be 4.50 (4.55) m below surface at the limit clay/clayey mud. As von Post's original analysis notes were not available, it has not been possible to use NAP, which makes the Late Glacial pollen zonation unsure. However, the AP curves, which allow a good zonation from the transition III/IV, seem to date the isolation to Alleröd.

BP 1747, KLINEHÖGKÄRRET, 53,9 M (FIG. 33): The shoreline falls at 54.4 m. The threshold seems to be at or just above the bog level. The isolation level is 1.86 m below surface at the limit between clay (slightly muddy in the uppermost 6 cm) and clayey mud. This isolation level is proved by diatom analysis. Thanks to the new diagram (Fig. 33) it was possible to introduce a very good pollen zonation. I place the zone boundary DR-2/AL (I/II) at 1.81 m, i. e. 5 cm above the isolation level. Consequently, this bog was isolated in the latest part of Older Dryas, which fits extraordinarily well with my chronology and shoreline diagram. In order to confirm this with a C^{14} datings I made a new boring, B 715, in Klinehögkärret. I think this boring was made at exactly the same place as BP 1747 for the following reasons: the place fits exactly with von Post's field notes, the place is the only one hard enough to stand on and the isolation level is 1.85 m below surface at the limit blue-clay/clayey mud. Six cores of the isolation level were taken within an area of about 30 x 50 cm with a modification of the standard piston corer in order to reduce the thickness of the C^{14} sample as much as possible. The sediments can be divided into three layers:

A: Clayey silty mud. A freshwater deposit. The lowermost 4.5 cm are lighter and probably correspond to the upper part of Older Dryas.

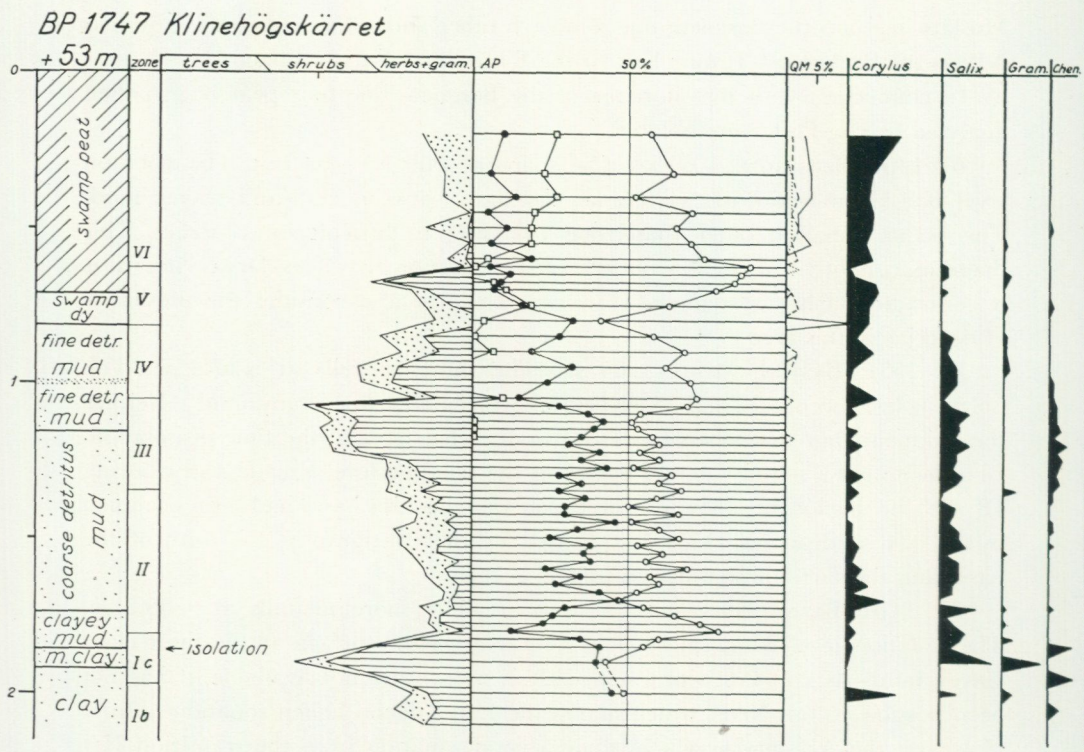
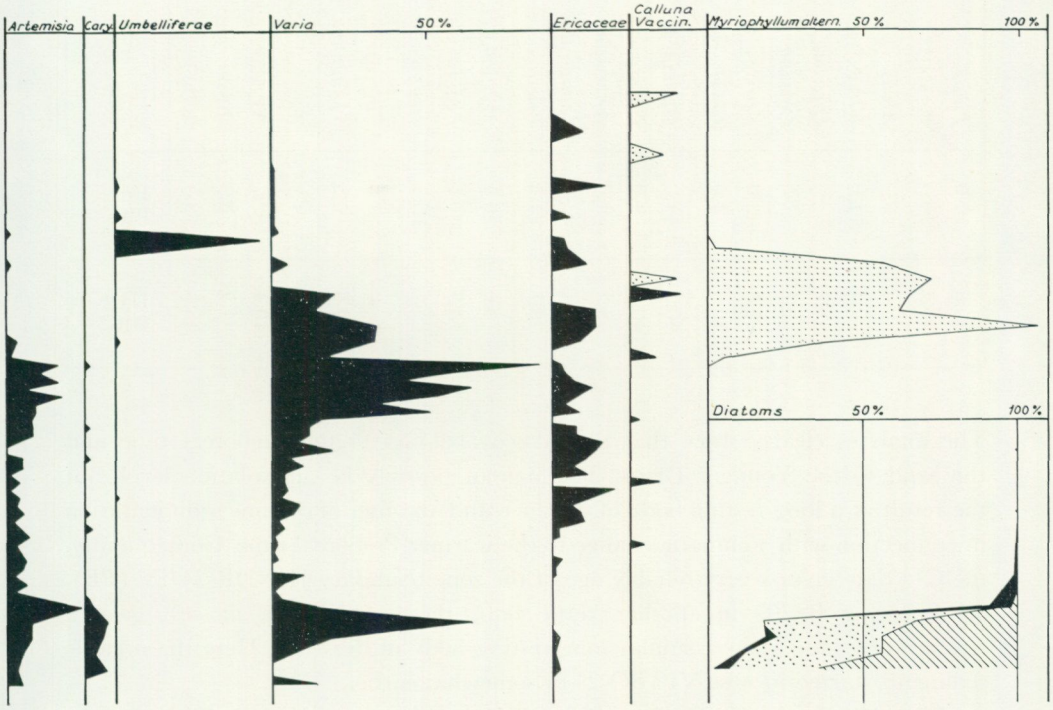


Fig. 33. *An old pollen diagram by von Post (AP), here recalculated and with a Late Glacial zonation based upon herbs and shrubs added. The isolation level falls in the later part of Older Dryas (Ic). According to the shoreline diagram (Pl. 4) the lake was isolated*

B: Silty clay, blue-clay, about 10 cm thick. Probably a lagoon deposit.
C: Varved clay (thin varves). The diatoms indicate marine depostion.

The lowermost 1.9 cm of layer A was C^{14} dated at 9,820 ±215 BC. This age is in excellent agreement with the expected age as deduced from the pollen diagram and the position of the shoreline of the Berghem line.

On the plain "Laholmsslätten" widely distributed tundra polygons have been found (Svensson 1963, 1964). Cuttings have shown that they are true ice wedge polygons. It is of great significance that the polygons only occur between ML and about +27—28 m, with some single occurrences down at +25—26 m. This means that a colder climate with formation of ice wedges predominated (in time) down to a certain shorelevel and that a warmer climate with no formation of ice wedges predominated after the time of this shorelevel. The morphologically determined shoreline of the Berghem line falls at +27.2—26.0 m at Munkamjäl, where polygons occur down to about +27 m. I think this is adequate evidence that



at the time of the shoreline of the Berghem line. The isolation level was in a new boring, B 715, C^{14} dated at 9,820 ±215 BC.

the ice wedges were formed up to the limit Older Dryas/Alleröd, i. e. till about 9,800 BC. (Svensson's opinion that the ice wedges were formed during Younger Dryas is thus definitely wrong). The agreement in altitude between the extrapolated shoreline and this climatic and morphologic limit also supports the correctness of my shoreline diagram and chronology.

At Munkamjäl there is a kettle hole (threshold about +27 m), now occupied by a peat bog. A boring B 711 was made here. The contact between organic and inorganic material was found 8.20 m down at the limit fine sand/lake dy. The lowermost 2.0 m of lake dy was C^{14} dated at 8,050 ±120 BC. Three samples, one above and two below the limit sand/lake dy, were diatom analysed at the Swedish Geological Survey. No salt water diatoms occur, only lake types: some single diatoms in the sand and a rich lake flora in the lake dy, showing a probably oligotrophic fresh water lake. Pollen analyses were made 0.6 cm above and 0.5 cm below the limit sand/lake dy. The result is given below:

Pinus	17.0	35.6
Betula	79.0	57.8
Alnus	—	0.6
Ulmus	1.0	—
Quercus	—	1.7
Carpinus	—	1.7
Salix	3.0	2.8
Corylus	1.0	10.6
Gramineae	11.0	40.5
Cyperaceae	4.0	40.5
Artemisia	1.0	3.3
Compositae	—	1.1
Ericaceae	1.5	26.7
Myrioph. alt.	0.5	10.0
Pediastrum	0.5	13.3
diatoms	lake	—
Filicinae	1.0	—
Sphagnum	0.5	0.6
dwarf shrubs	1.3	12.0
AP	82.7	48.4
shrubs	2.5	1.2
herbs	13.5	38.4
zone	IV PB	III DR-3

The analyses clearly show that the lake dy belongs to the Preboreal time and the sand to the Younger Dryas. This cannot possibly be an isolation level, but the result of a long-resting body of dead ice and an onset of organic sedimentation in connection with a climatic change to the warmer Preboreal time. Consequently, the C^{14} date gives a very reliably age of the zone boundary III (DR-3)/IV (PB).

A boring B 707 in another kettle hole, the bog "Furala mosse", gave a stratigraphy indicating a similar long-resting body of dead ice. Here the organic sediments started in zone VI (BO-2) or somewhat earlier.

From the area of Våxtorp a very marked melt water channel (Fig. 29) can be followed down to about +20—30 m at Menlösa (today occupied by a small brook). The shoreline of the Berghem line falls at +23.9—25.1 m at Menlösa, which means that meltwater streams occurred in the area at least up to the limit Older Dryas/Alleröd.

In a house foundation, B 839, near Torekov at about +15—20 m the following stratigraphy was found:

A: 0.2 m of mould

B: about 1 m of yellowish brown sand and fine gravel. The upper part (B1) is unstratified and almost till-like. The lower part (B2) is stratified. Layer B1 often projects down into layer B2, deforming the stratification as 1 m wide and 0.5 m deep depressions. These projections are most probably periglacial frost structures (type; involutions).

C: at least 1 m of grey stratified gravel and pebbles containing a lot of flints, one piece of chalk and two Cretaceous Belemnites. The material seems only to have been transported a short distance.

As the shoreline of the Berghem line here falls at +12.6 m, these frost structures are probably formed during Older Dryas as a parallel to the ice wedges in the Laholm area (p. 140).

At the threshold in Öresund the shoreline falls at about −18.0 m, which means that the Baltic Ice Lake was probably dammed about 11 m above sea level.

As already stated (p. 134) the Moslätt/Berghem line continues in the big terminal moraine zone "Torupsmoränen" between Torup and Annerstad (Johnsson 1956). According to Johnsson's description of this terminal moraine zone, it seems very similar to the one of the Moslätt/Berghem line, i. e. it is a complex of several ridges. Some of the distinct terminal moraines outside the main line — e. g. the ones at Lidhult and Boberg — probably correspond to the Moslätt line, while the main line corresponds to the Berghem line. In the Nissan Valley outside the drainage channel at Skattegård there is a delta or outwash plain of badly sorted material reaching +83—84 m. Johnsson stated that the water level in the Nissan Valley "cannot have been higher than, and can hardly have been as high as +83—84 m". As the shoreline of the Berghem line falls at +58—59 m, the Nissan Valley must have been occupied by an ice dammed lake. The damming ice most probably was a rest of the big ice lobe in the Nissan Valley of the Fjärås line.

The correlation between the Moslätt/Berghem line (= Older Dryas) and the "Torupsmoränen" has recently been supported by varve series inside the "Torupsmoränen" (E.Nilsson 1968). The varve series indicate a more or less even recession northward. Furthermore, the bottom varve in Kullsbacken, 1—1.5 km inside the "Torupsmoränen", was by E.Nilsson dated at 9.984 BC (± undetermined margin of error). This is in my opinion the oldest bottom varve that has been correlated in a reliable way to the Swedish Time Scale. The age of the bottom varve in Kullsbacken is 184 years older than the end of Older Dryas according to the C^{14} dates (p. 178), which fits exactly with the difference of about 170 years between the varve chronology and the C^{14} chronology concerning the age of Younger Dryas (cf. p. 178).

From Annerstad the Moslätt/Berghem line most probably (though not yet settled by morphological mapping) continues towards SE to Lake Möckeln, where it turns eastwards and, via the southern margin of Lake Åsnen, joins Bergdahl's (1947) terminal moraine zone from Vissefjärda to Kalmarsund (cf. p. 127).

From Öland the Moslätt/Berghem line curves, via a big ice lobe in the bay Hanöbukten (more or less hypothetically drawn on Pl. 2), over to the third ice marginal fork on Bornholm, the Rö—Arnager line (cf. p. 111; Grönwall and Milthers 1916). From southern Bornholm the line continues in a distinct lobe between Skåne and Rügen (more or less hypothetically drawn on Pl. 2) over to northern Rügen, where it joins one of the terminal moraine lines in northern Rügen (cf. p. 111; e. g. Kliewe 1966; Reinhard and Richter 1961). The age of this position of the ice margin on Bornholm and Rügen is indicated by the fact that the Older Dryas is here represented by glacial deposits, directly overlaid by Alleröd deposits (cf. p. 111).

In southern Norway the Moslätt/Berghem line probably corresponds to the terminal moraine zone "Kristiansand-trimmet" (B.Andersen 1960).

The development during Alleröd and Younger Dryas

After the stagnation along the Berghem line the ice recession continued towards NE. On the West Coast this recession took place with repeated intervals (as it also did during earlier time) caused by other reasons than climatic ones. In the river valleys, series of terminal moraines (of type 2 according to the description on p. 113) from such intervals are seen. In the extremities of the Late Glacial sea fiords large glacifluvial deltas were often formed; e. g. at Örby, Seglora and Kinnarumma. The succession of ML levels shows a continuous fall inland (Fig. 31). From the continuous series of terminal moraines and the continuous fall of ML I find it obvious that it was an active ice that receded, and not a downwards melting ice that left a big separate dead ice in the Viskan Valley as Gillberg (1948, 1956) and von Post (1938) thought. A comparison of the altitude of the shoreline of the Berghem line with that of ML at the younger more distinct terminal moraines and deltas in the area around the Viskan Valley gives the following ice recession and shorelevel displacement:

1. The delta at Örby (ML +79.0—80.5 m) and the terminal moraine at Kinna (ML +81.0—82.0 m): shorelevel displacement about 3.1 m. This position of the ice margin might perhaps be correlated with the terminal moraine damming Lake Anten (Caldenius *et al.* 1960) as ML +110.5 m at Ålanda (Gillberg 1952) means a shorelevel displacement of 3.1 m.
2. The delta at Seglora (ML +86.0—87.0): shorelevel displacement about 4.7 m.
3. The terminal moraine at Fritsla (ML +84.5—85.0 m): shorelevel displacement about 6.4 m.
4. The terminal moraine at Ramslätt (ML +84.4—85.6 m): shorelevel displacement about 8.7 m.
5. The delta at Kinnarumma (ML distally +83.3—85.0 m, ML proximally +83.5—85.9 m): shorelevel displacement about 11.2 m.

As I do not trust (at least in this area) the synchronism of the Late Glacial shore marks and the possibility of using these as a base for shoreline diagrams (p. 113), I have to construct my diagrams on other methods. I use pollen and radiocarbon dated isolation levels. This means that the gradients of the shorelines cannot be fixed as exactly as the gradients of the older and younger shorelines. However, the gradient variation is limited within 8.0 m/10 km for the shoreline of the Berghem line and 5.0 m/10 km for the shoreline of the "regression maximum" between the Late Glacial regression and Postglacial transgression. The big area in the direction of tilting, which was investigated, is of great importance for the determination of gradients. I tried to get some isolation levels on "Laholmsslätten", the Bjäre peninsula and NW Skåne, but did only succeed in Höghults Mosse (p. 133) as the other depressions investigated had been

occupied by bodies of dead ice. The available data, which have been used for the determination of the shorelevel displacement during Alleröd and Younger Dryas, are chronologically dealt with below.

1. BP 1248, LÅNGAREDSMOSSEN, +59.5 M (THE THRESHOLD): The isolation level is 5.75—5.77 m below surface at the limit clay/clayey mud (also proved by diatoms). The pollen zonation is very good and it is obvious that the isolation took place early in Alleröd, probably shortly after the zone boundary I/II (DR—2/AL). This fits extremely well with the position in the shoreline diagram, 9.3 m below the shoreline of the Berghem line. The corresponding ice margin stood between Ramslätt and Kinnarumma. The gradient of the corresponding shoreline is about 7.7 m/10 km and the age about 9,650 BC, which means that the ice receded at a rate of about 112 m/year from the Berghem line.

2. B 504, SW KATTEGATT, –21.0 M: See p. 282.

3. BP 1251, BASTERÅSMOSSEN, ABOUT +77 M: The stratigraphy and pollen zonation are not clear. However, the isolation seems to have occurred in Alleröd. The corresponding ice margin was just inside the delta at Kinnarumma.

4. BP 1562, VAREVIKSMOSSEN, +63 M: The isolation level seems to be 6.15 m below surface at the limit sand/mud. Between 4.48 and 5.69 m down there is drift clay and sand, which probably corresponds to Younger Dryas. Consequently, the isolation probably took place in Alleröd. However, the isolation level is not quite certain, as the occurrence of sand and not marine clay at the bottom means that we cannot preclude the possibility of an early body of dead ice.

5. A POSSIBLE ICE WEDGE: At the distal part of the delta at Kinnarumma I have found a structure very similar to an ice wedge. It is not a quite certain ice wedge, however, as there also occur flow structures and structures of minor foldings. Cumulative-frequency curves from material inside and outside the possible ice wedge gave a clear difference, viz. medium sandy fine sand and coarse silty fine sand, respectively. However, the problem is that this "ice wedge" is covered by 1—2 m of stony sand. The altitude is +78—80 m. Only 6 km up the valley there is a marked canyon from the drainage of the big Frisjö ice lake (Gillberg 1956). The development (in full agreement with the shoreline diagram) could thus be: an ice wedge was formed, 5—6 km in front of the ice margin, in the distal sand of the delta at Kinnarumma, when the shoreline stood at +77 m, but was shortly afterwards buried under a stony sand layer from the drainage of the Frisjö ice lake.

6. THE "DELTA" AT KALVHULT, +44—45 M: Outside the two big glacifluvial deltas at Högaslätt and Barkhult in the Viskan Valley (formed by the Fjärås line) there is a smaller "delta" at Kalvhult in the middle of the valley. Von Post and Caldenius thought this was a remnant of a big ice marginal delta once crossing the valley in a lobe Högaslätt—Kalvhult—Barkhult. However, the

deepening of the gravel pit in the "delta" at Kalvhult has shown that it is not a glacifluvial delta, but a much younger deltaic accumulation of rebedded sand and gravel (Fig. 34).

The following stratigraphy was found (called B 583):

A: About 25 m of deltaic sand-gravel containing flints.

B: A thin layer of green-blue clay. A lump of this clay was found mixed with a pitchy soil like silty mud (Swed.: beckjordsartad mogyttja). The clay contains shells of *Balanus hammeri* (and possibly also *Mytilus edulis*). The clay is very poor in pollen. However, the flora is clearly Late Glacial, with predominance of *Pinus* (about 40—50 %). The silty mud contains a quite similar Late Glacial flora predominated by *Pinus* (about 85 %). The pitchy soil like silty mud was C^{14} dated at 35 ±150 BC (B 583: III), which means that it is a young infiltration of humus and mud. Big shells of *Balanus hammeri* (probably from one individual) were C^{14} dated (B 583:II) at 9,615 ±150 BC (= 9.310*±175 BC). This is a reliable date.

B2: A thin layer of blue-clay containing small pieces of *Balanus* sp. (probably *B. creneatus*).

C1: A brown-grey glacial clay containing thin shell fragments of *Macoma calcaria*. These fragments were C^{14} dated (583:I) at 5,250 ±130 BC, which is apparently too young an age — the thin shell fragments were not very suitable for a C^{14} dating (the agreement in age with the Postglacial transgression PTM-2 must be a coincidence).

C2: Lighter, more pinkish glacial clay with leached white shells (probably *Portlandia arctica*).

C3: Lighter, more pinkish glacial clay without shells.

C4: Lighter, more pinkish, varved glacial clay without shells.

The whole clay series studied is not more than about 1.5 m. It was found throughout the bottom of the gravel pit. The occurrence of *Balanus hammeri* means a strong outflow of water giving rise to a strong inflow of salt water as reaction current. In such an environment the Copepods, which are the food of *Balanus hammeri*, proliferate allowing *Balanus hammeri* to live in unusually shallow water (Hessland 1949). The C^{14} date of *Balanus hammeri* gives the age of the open sea fiord just before the 25 m deltaic sand and gravel were accumulated. The occurrence of flint in the sand and gravel is a good criterium of redeposition, as flint never occurs in ice marginal deposits in this area, but must have been brought here by icebergs from Kattegatt in Late Glacial time.

Now the question arises how such a deltaic accumulation can be formed in the middle of the valley in Late Glacial time. Some sort of obstacle on the northern side of the "delta" seems necessary. The most easy explanation seems to be that a body of dead ice occupied the area north of the "delta". When the sea level stood at about +50—45 m this plug of dead ice in the narrow valley caused a heavy redeposition of older glacifluvial material. Either these streams went over a bigger body of ice or round a smaller one. As Lake Dran has no Late Glacial sediments (Postglacial sediments right over a sandy-gravelly material) it is probable that the lake was occupied by a long lasting body of dead ice,

which need not have any connection at all with the dead ice at Kalvhult. As the sand-gravel contains flints (several were collected) the body of dead ice north of the "delta" could have been a standed iceberg from Kattegatt. A plug here in the narrow part of the valley would, when the sea level was lowered, cause a strong erosion in the slope of the big glacifluvial deltas at Högaslätt and Barkhult. The interesting thing about this description is that the sea level and the age have been fixed.

However, the redeposition of sand and gravel is also met with in several places further downstream (Fig. 34). It seems very likely that these layers of sand and gravel resting upon clay are derived from the same event.

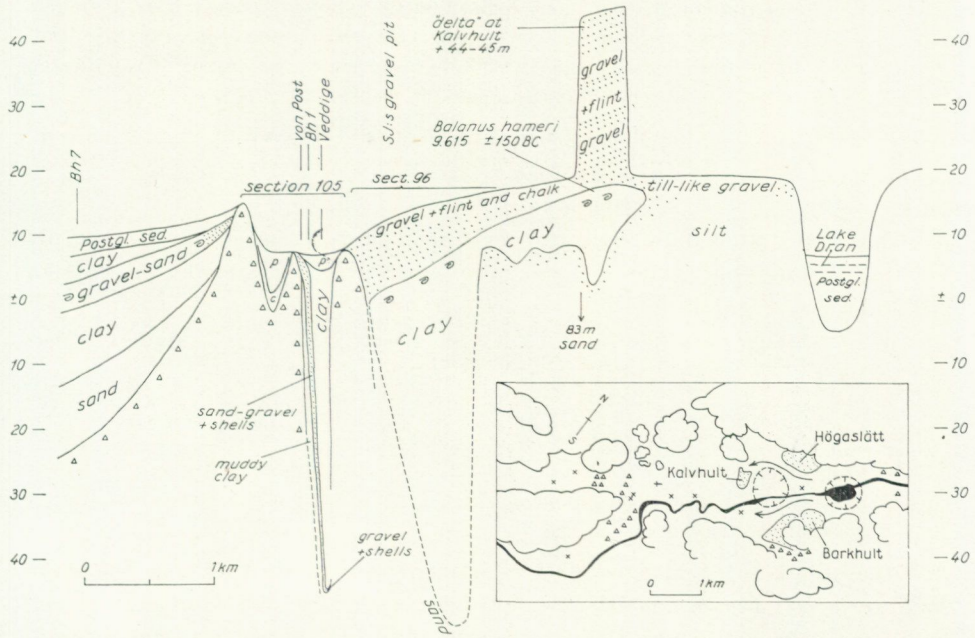


Fig. 34. *At about 9,550 BC there was a huge redeposition of gravel and sand in the Veddige-Kalvhult area. The delta at Kalvhult is supposed to have been built up against a stranded body of dead ice (marked as a dotted circle on the map). The crosses on the map are boring points.*

Von Post's Section 96, SJ's gravel pit in Veddige and some older drillings for water have shown:

A: An up to 10 m thick deltaic layer of sand and gravel that contains flint and chalk, i. e. rebedded.

B: A layer of clay of varying thickness that contains "shells of *Mytilus edulis* etc." (von Post † 1968, Fig. 12). In the bottom of SJ's gravel pit von Post found at least 10 m of clay. According to an older boring, however, this clay layer should be 60 m thick and rest upon sand (marked on Fig. 34). In Section 96 the clay can be followed some 100 m north of the "delta" at Kalvhult ,where it disappaers in

sand and gravel. According to my interpretation it consists of a thin layer of Late Glacial clay and a thick layer of glacial clay.

In Section 105 von Post († 1968, Fig. 9) found a layer of stratified sand below Late Glacial clay. Von Post thought it was a shore deposit and regarded this as evidence of one of his "shock-transgressions". However, some new deep borings for water have changed the picture. The boring point, Bh. 1, in Veddige by the firm Kjessler & Mannerstråle AB showed (soil identification by me):

A: To 2.50 m clay
B: To 16.8 m sand and gravel, rich in shells of *Mytilus edulis, Balanus* sp. (*B. creneatus?*), *Saxicava arctica*. Water.
C: To 21.0 m dark to grey muddy clay containing small fragments of white shells. The mud content is surprisingly high; 4.96 %. The clay is very poor in pollen. The pollen flora is Late Glacial (with some redeposited pollen grains) with predominance of *Pinus* (about 40—50 %). The marine environment is indicated by the high percentage of *Hystrix* (about 40—50 %).

A boring for water at the cement works in Veddige (just NE of Bh. 1) showed:

A: To 52 m alternating sand and clay.
B: Gravel, rich in shells. Artesian water.

Water analyses from the gravel with shells in these two borings gave practically identical results (but differing from most other wells in this area by its high pH and high content of Cl).

In the western part of Section 84 B (von Post † 1968, Fig. 7) there is a deltaic layer of sand. The stratification is:

A: Postglacial sediments
B: Late Glacial blue-clay, fairly thick
C: sand, deltaic
D: thin layer of Late Glacial blue-clay
E: thick layer of varved glacial clay

I do not think this deltaic sand layer has anything to do with any low shore level; it is a continuation of the above described layers of sand and gravel.

In the valley outside the SW till threshold at Veddige Kjessler & Mannerstråle AB made a boring, the samples of which I recived and have identified:

A: to 3.0 m clayey sand
B: to 7.0 m clay (probably Late Glacial)
C: to 11.0 m gravelly sand containing small shell fragments of *Mytilus edulis, Balanus* sp. (most probably *B. creneatus*) and one undetermined (possibly *Macoma calcaria*)
D: to 22.0 m clay (no samples)
E: to 33.0 m silty fine sand
F: to 35.0 m till

At the bridge over the brook Syllån (Geotekniska Institutet, No. K 2565) the following stratigraphy have been found (in several borings):

A: 7.5 m of Late Glacial clay
B: 1.2 m of sand

C: 6.0 m of clay
D: till

I think all these layers of sand and gravel resting on clay result from the same event: the redeposition of glacifluvial material at Kalvhult. To sum up:

1. The sand and gravel generally grow finer downstream.
2. These sediments rest upon clay: a glacial series + a thin Late Glacial part containing a boreo-arctic (Ab—aB) fauna that has been C^{14} dated at the middle of Alleröd. In Bh.1 the mud content is high.
3. The sediments are covered by a thick layer of Late Glacial clay (not in the Veddige—Kalvhult area). Consequently, they must have been formed in a more or less deep sea fiord without any other changes in sea level than the continuous regression.
4. The sediments were followed at least 4 km downstream.
5. The lower clay layer disappears just north of Kalvhult.
6. The occurrence of *Balanus hammeri* means a strong reaction current, which in its turn means that there was no earlier plug in the valley north of Kalvhult. i. e. the plug is younger, which supports the statement that it must be a stranded iceberg from Kattegatt.

All these facts and aspects make me believe that it really is a stranded iceberg that blocked the valley and caused a huge redeposition of glacifluvial material, which was found at least 4 km downstream. This occurred in Alleröd or, more exactly, about 9,550 BC according to the shoreline diagram. This event is just older than the C^{14} dated shells B 583:II, 9,310* ±175 BC, and slightly younger than the below mentioned C^{14} dated isolation level in B 710 (=BP 1530) or 9,700 ±250 BC. The mean value of these dates is about 9,500—9,450 BC, i. e. in good agreement with the estimated age, though the correction of B 583:II is only approximate.

If the cause of this redeposition may be more or less unproved, the distribution, age and altitude of corresponding sea level are clearly determined — and that is the important thing for this investigation.

7. BP 1530, PEAT BOG, +49 M: The isolation level is 1.85 m below surface at the limit marine clay/muddy clay. The clay contains shells of *Mytilus edulis* below 2.13 m down which is evidence that the area was not occupied by dead ice and the isolation level consequently must be a real one. The pollen zonation is not sure, but it may date the isolation to the middle-lower part of Alleröd. In order to get a C^{14} dating of the isolation I made some new borings here. As the borer was heavy and the bog swampy, I could only reach a point where the isolation level was 0.80 m below surface. Three cores, B 719, were taken of the isolation level with a piston corer. The isolation level was at the limit silty clay/clayey mud. The lowermost 3.0 cm of clayey mud were C^{14} dated at 9,700 ±250 BC. Within one sigma this fits with the estimated age 9,500—9,450 BC.

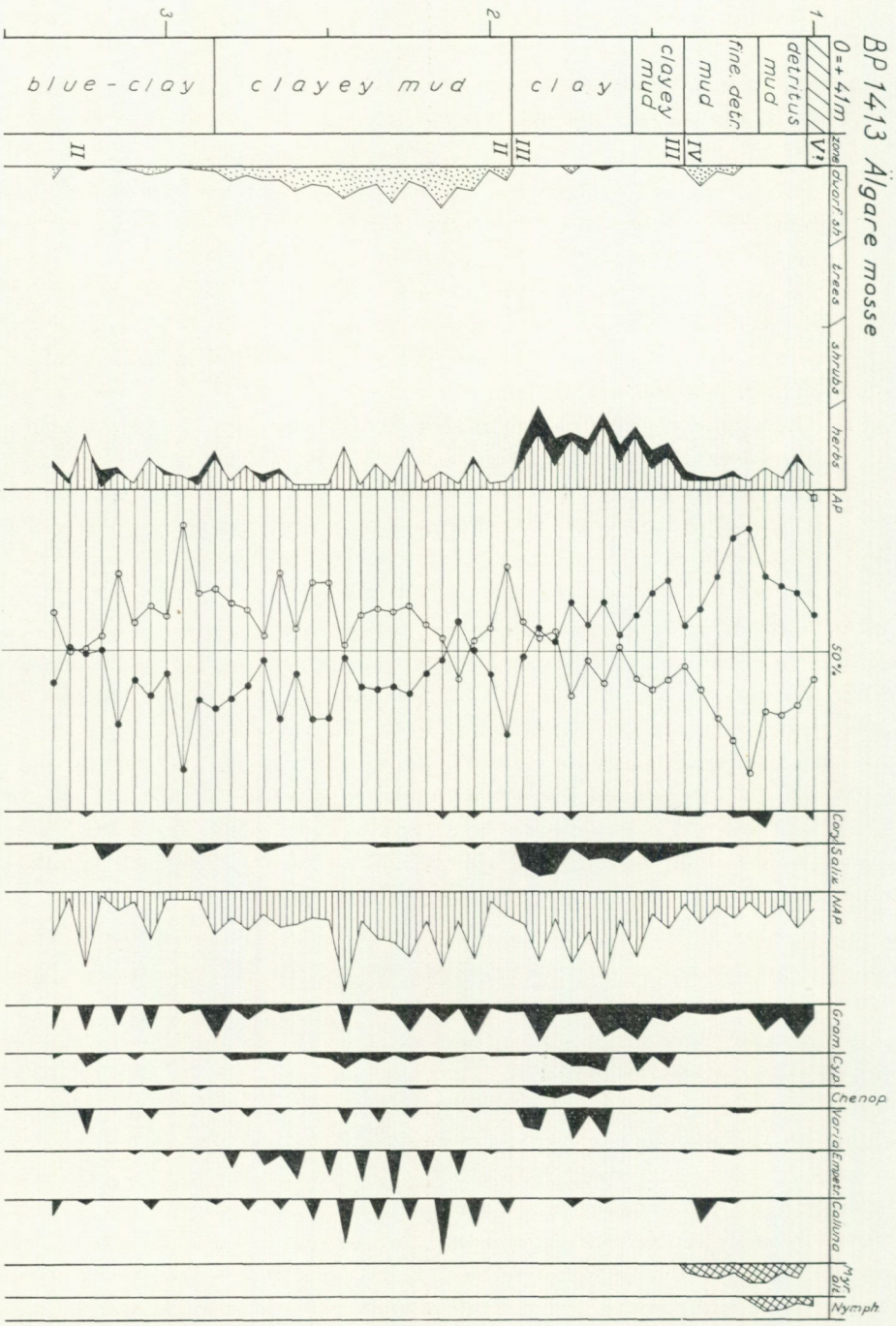


Fig. 35. *An old pollen diagram by von Post (AP), here recalculated and with a zonation based upon herbs and shrubs added. In a new boring, B 717, the zone boundaries II/III and III/IV were C¹⁴ dated at 8,965 ±230 BC and 7,965 ±180 BC, respectively. The C¹⁴ date of the isolation level was too old.*

8. BP 1413, ÄLGARE MOSSE, ABOUT +41 M: Completed with NAP, this pollen diagram (Fig. 35) turned out to be one of the best diagrams from the whole Swedish West Coast. The pollen zonation is obvious:

Alleröd (II, AL): dominance of *Pinus*, dwarf shrubs high, herbs fairly low, shrubs very low. Isolation 1.85 m below surface at the limit clay/clayey mud, probably in the middle of this zone.

Younger Dryas (III, DR—3): Change from clayey mud (=AL) to clay (= DR—3) and in the upper part back to clayey mud. Dominance of *Betula* (probably *B. nana*), shrubs high, herbs high, dwarf shrubs absent (or very low).

Preboreal time (IV, PB): Change to more organic sediments. Dominance of *Betula* (probably arboreous), dwarf shrubs high in the lower part, shrubs low, herbs lower than in zone III.

In order to get C^{14} dates of the isolation level and the zone boundaries a new boring, B 717, was made at the same place. The stratigraphy was determined with a helical auger. Eight 65 cm cores were taken around the C^{14} dated levels with a modification of the standard piston corer. The following stratigraphy was found below 1.15 m:

A: To 1.292 m yellow mud, at the bottom somewhat clayey-silty (= zone IV, PB). The lowermost 1.4 cm was C^{14} dated at 7,965 ±180 BC.

B: To 1.304 m muddy "mo" = transition zone III (DR—3)/IV (PB).

C: To 1.370 m grey to yellowish brown clayey mud (= later part zone III).

D: To 1.637 m grey to blue clay (slightly muddy towards the upper and lower limit) = zone III (DR—3).

E: To 2.515 m grey to yellowish brown clayey mud, the lowermost 10 cm is a muddy clay = zone II (AL). The uppermost 2.4 cm of clayey mud was C^{14} dated at 8,965 ±230 BC. The lowermost 6.0 cm of muddy clay was C^{14} dated at 10,360 ±370 BC.

F: To 2.785 m grey to blue somewhat silty blue-clay = zone II (AL).

The agreement with von Post's pollen analysed BP 1413 cannot be better. The correlations are obvious and no new pollen analyses are needed. The following can be said about the C^{14} dates:

7,965 ±180 BC dates the lowermost 1.4 cm of zone IV (PB). It is a very good date of the zone boundary III (DR—3)/IV (PB).

8,965 ±230 BC dates the uppermost 2.4 cm of zone II (AL). It is a very good date of the zone boundary II (AL)/III (DR—3), though the sigma value is big.

10,360 ±370 BC dates the isolation. However, this age is too high, probably due to older carbon in connection with the high clay content (muddy clay) and the proximity to numerous older shells.

The layers slope from the threshold (a till ridge) in the south. The marine clay covered by a thin sand layer breaks surface some 100 m nearer the threshold. The sand and clay contain numerous shells, collected as B 716. The shell fauna is boreo-arctic (aB). It was C^{14} dated at 10,205* ±165 BC, which is a minimum age of the Fjärås line. B 716 is closely dealt with on p. 170.

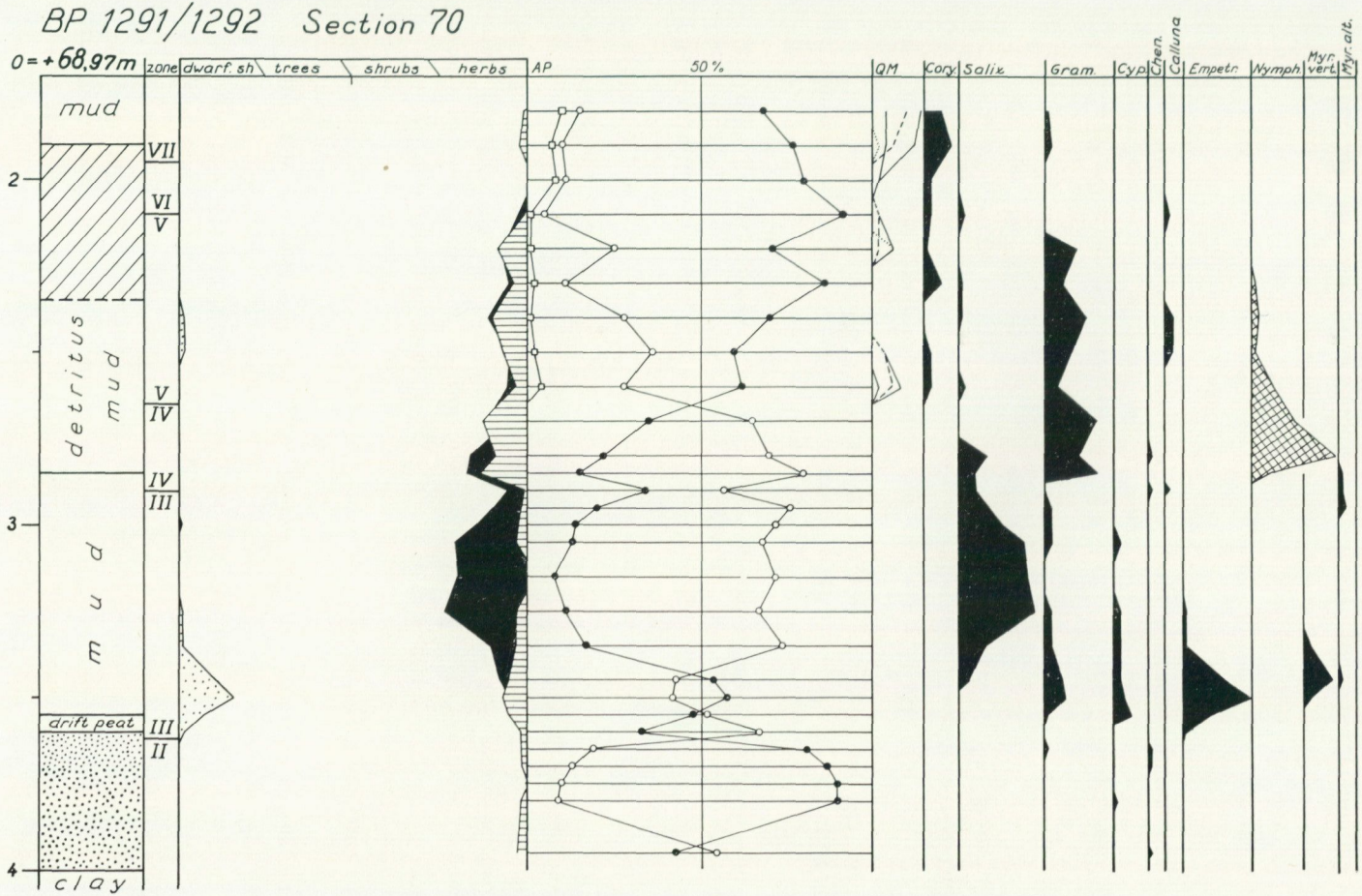


Fig. 36. *The "drift peat" was in a new boring, B 432, C¹⁴ dated at 8,450 ±220 BC.*

9. HÅLE MOSSE (= KRO MOSSE), +52—49 M: According to the shoreline diagram this bog should have been isolated at the same time as BP 1413 and slightly after the isolation of B 710 (C^{14} dated at 9,700 ±250 BC). G.Andersson (1893) and R.Sernander (1902) found the following stratigraphy and flora:

A: The peat bog proper.
B: 0.20 m of peat of *Carex* and *Phragmites* roots.
C: 0.20—0.35 m of mud with a *Populus-Betula* flora containing: *Betula odorata, Carex* sp., *Menyanthes trifoliata, Nymphaea alba, Populus tremula, Potamogeton natans, Potamogeton* sp. (probably *P. praelongus*) *Salix cinerea, Salix* sp. and *Scirpus lacustris.*
D: 0.4 m of lacustrine clay, slightly muddy according to Andersson but glacial according to Sernander. It contains an arctic-subarctic flora, viz. *Batrachium* cfr. *confervoides, Betula nana, Bryum obstusifolium, Ceratodon purpureus, Dryas octopetala, Empetrum nigrum, Menyanthes trifoliata, Polytrichum* cfr. *alpina, Potamogeton cfr. praelongus* and *Scirpus lacustris.*
E: Gravelly sand clay with shells of *Mytilus edulis* and *Saxicava rugosa.*

10. BP 1292/1291, SECTION 70, +69 M: The isolation level seems to be 4.00 m below surface at the limit clay/sand. The pollen zonation is good and worth a closer description (Fig. 36).

A: To 1.95 m zone VII (AT—1): onset of the *Tilia* curve, T°. The change from peat to mud corresponds to the marine transgression up to PTM-2 (cf. below).
B: To 2.10 m zone VI (BO-2): onset of the *Alnus* curve, A°.
C: To 2.65 m zone V (BO-1): onset of *Corylus* curve, C°, (not so well developed so far inland), rise of *Pinus* curve and fall of *Betula* curve.
D: To 2.88 m zone IV (PB): *Betula* maximum (arboreous), rise of *Gramineae* and rise of *Nympheae.*
E: To 3.60 m zone III (DR-3): *Salix* high. *Betula* (*nana* ?) high. NAP surprisingly low. The drift peat of the lower limit was C^{14} dated at 8,450 ±220 BC in a new boring B 432.
F: To 4.05 m zone II (AL): *Pinus* high. NAP low. Sedimentation of sand.

Consequently, the isolation ought to have taken place in Alleröd at the transition between a *Betula* and *Pinus* phase (the significance of which is not yet known). In order to date the lowermost part of the organic sequence (II/III) I made a new boring, B 432, at the old boring point. The sand was found 3.50 m below surface. Three cores were taken with a piston corer 3.30—3.70 m down. The stratification was:

A: clayey fine detritus mud
B: 1.5 cm dark somewhat clayey coarse detritus mud (obviously equivalent to von Post's "drift peat")
C: pure sand

The 1.5 cm thick layer of dark mud was C^{14} dated at 8,450 ±220 BC.

11. BP 1254, RINGE MOSSE, +52 M: As neither the isolation level nor the pollen zonation is clear, this pollen diagram has very little to tell.

12. EDARED, +48.20 M: This locality has been described by Lönnberg (1909) in conncetion with the find of a horn of a reindeer in Late Glacial sediments. Contributions to the stratigraphy were given by von Post and to the shell fauna by Hägg (Lönnberg 1909). The horn (other bones were also found, but thrown away) was according to the workers found 0.6 m down in the clay in a small clay pit. Von Post found the following stratification at a point close to the waterfilled clay pit:

A: 20 cm of peat mould
B: 10 cm of sand
C: 20 cm of grey sandy clay without fossils
D: > 120 cm of blue to grey clay fairly rich in shells

The following shells were determined by R.Hägg (cf. p. 173): *Litorina rudis, Litorina palita, Litorina litorea,* var. *intermedia, Mytilus edulis* (in masses), *Macoma baltica, Macoma calcaria* and *Saxicava arctica* (some). Hägg stated that the fauna shows a climate equivalent to the climate of the coast water of Murmansk and that the maximum depth was about 1 m according to the occurrence of *Litorina.* The bones of the reindeer belong to layer D and consequently are roughly contemporary with the shell fauna. According to Asklund (1936) the altitude is +48.20 m.

In order to collect shells for a C^{14} dating I returned to the locality. The old clay pit was found and a boring B 556 was made 10 m from this. The stratification was:

A: to 1.73 m peat and lake dy
B: to 1.85 m mud, loose
C: to 2.20 m blue-clay, very hard
D: to 3.20 m glacial clay, hard at the top

The hardness of the clay indicates that the clay surface was exposed and weathered before the ground water was raised and the lake/bog was formed which shows that the till ridge in SW did not cause any damming. Other borings and diggings showed a very varying stratification within a small area and 27 m from B 556 the clay is at the surface. No shells were found.

From the Museum of Natural History in Stockholm I was kindly given the horn described by Lönnberg in order to make a C^{14} dating. An about 40 cm long part of the horn (which consists of bone) was C^{14} dated by the collagen method (Sellstedt *et al.* 1966) at 9,315 ±100 BC, i. e. about the middle of Alleröd.

This date shows that the reindeer (not yet exactly classified) lived here at least as early as the middle of Alleröd (which is also important for archeological reasons, as we can then also expect the presence of hunters). The corresponding shell fauna was boreo-arctic (aB, cf. p. 173). The corresponding sea level probably was at +49—50 m.

This shorelevel at Edared ought to be roughly contemporaneous with the isolation of BP 1254 and BP 1292/1291. The gradient of the shoreline

seems to be 6.7—6.4 m/10 km, which means that it falls around the organic layers in B 504 in SW Kattegatt and either could mean a small transgression up to −21.0 m or a regression down to −25.0 m. The pollen analyses of B 504 do not give any solution of this problem (cf. below).

13. The sand covered bog at Slätter, about +19 m: Two pollen diagrams are available (Caldenius *et al.* 1966). The limit stoney sand/sandy dyey peat is 1.80 m down. The lowermost part of the organic layer was according to the pollen diagram formed during the Preboreal time (zone IV, or PB). This is not a date of the isolation but only a minimal age of the land stage. New borings in this area did not show any clear isolation contact worth C^{14} dating.

14. Undarsmossen, +16—17 m (threshold in NW at +15 m): Undarsmossen is a big peat bog between the hills. At its southern end there is a big terminal moraine at Hulabäck (p. 101). At the northern end the treshold is at +15 m, while the bog level is +16—19 m.

The stratigraphy has been pollen analysed and described by Linnman (in Caldenius *et al.* 1966, Fig. 38). The pollen diagram does not contain NAP. No pollen zonation is introduced. Linnman (1965a) stated that the isolation took place at the transition zone IV/V at the limit clayey mud/mud. The shorelevel displacement clearly shows that such a young isolation is definitely out of the question.

I think the real isolation level is 4.65 m below surface at the limit clay/muddy clay. However, a closer dating is not possible, as the Late Glacial pollen zonation is not clear, due to the lack of NAP analysis. Below the zone boundary IV/V *Betula* doinates (cf. Danstorpsmossen p. 124 and Klinehögkärret p. 140). However, this *Betula* dominance may hide variations between arboreous birch and dwarf birch. The isolation seems to be older than the zone boundary III/IV and a rough dating would be somewhere around the boundary II/III or middle III to late II. An attempt to get material from the isolation level for a C^{14} dating had to be given up.

According to my shoreline diagram Undarsmossen would have been isolated during a late part of Alleröd. This can not be proved by the pollen diagram. However, an important thing is that it is not contradicted either.

15. "Törvegraven" (B 703), NW of Anholt, −14—17 m: See p. 288.

16. B 574 Hålsjön, +41 m: A boring was made just north of Lake Hålsjön in order to date the isolation level. With a helical auger the isolation level was found about 3.35 m down, but it was also found that a more grey and clayey layer occured 43 m above this level. This layer was assumed to correspond to Younger Dryas (it could also correspond to one of von Post's transgressions). In order to get enough material for C^{14} datings of the different levels eight cores were taken with a piston corer at various depths between 2.80 and 3.55 m depth. The following stratification was found (Fig. 37):

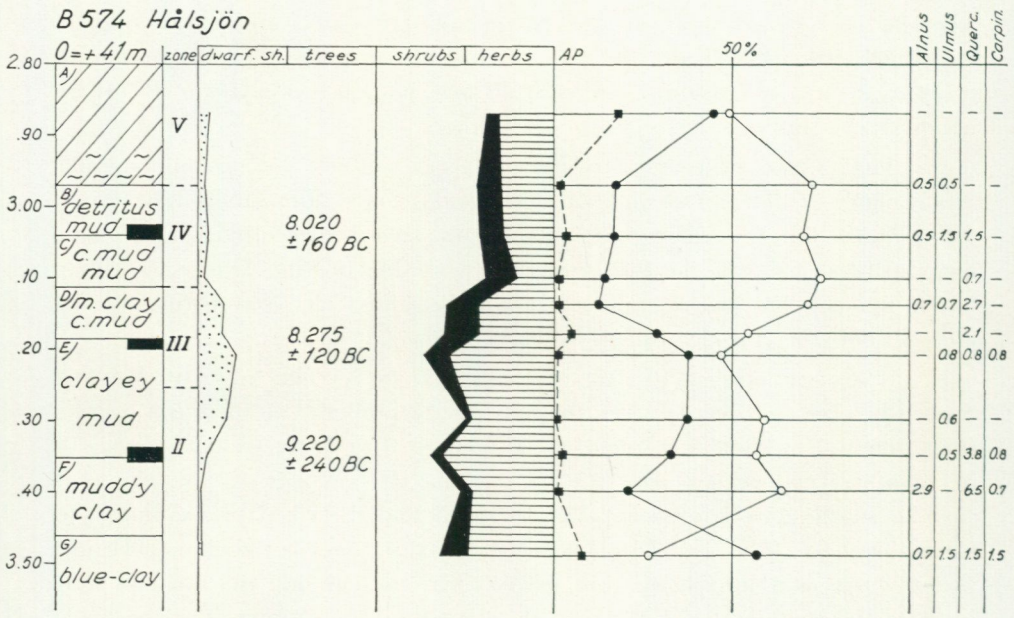


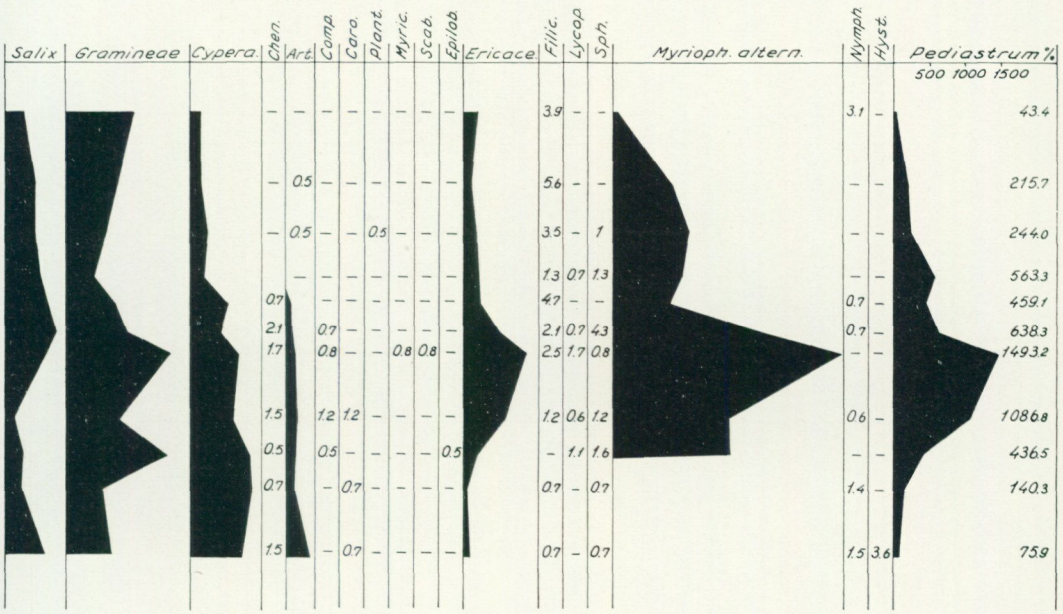
Fig. 37. *This basin was isolated in the latest Alleröd (II). Layer D is more clayey and obviously corresponds to Younger Dryas (the later part).*

A: to 2.97 m black peat and (at the bottom) coarse detritus mud
B: to 3.03 m yellowish dark coarse detritus mud
C: to 3.112 m yellow clayey mud to mud
D: to 3.185 m yellowish grey muddy clay to clayey mud
E: to 3.352 m yellow clayey mud
F: to 3.46 m mottled somewhat muddy clay
G: to at least 11.00 m blue-clay

The pollen diagram and the three C^{14} dates have given the following (not quite obvious) pollen zonation:

BO-1 (V) to 2.95 m: Rise of *Corylus* curve, C°, and rise of *Pinus* curve.
PB (IV) to 3.112 m: Fall of *Gramineae, Cyperaceae, Chenopodiaceae* and *Artemisia. Betula* high. The lowermost 1.5 cm of layer B and the uppermost 0.5 cm of layer C were C^{14} dated at 8,020 ±160 BC.
DR-2 (III) to 3.25 (3.185) m: Rise of herbs, *Salix* and *Betula* (*nana* ?). *Ericaceae* high. The uppermost 1.5 cm of layer E mas C^{14} dated at 8,275 ±120 BC.
AL (II) below 3.25 (3.185) m: The lowermost 1.5 cm of layer E + the uppermost 0.5 cm of layer F, i. e. the isolation contact, were C^{14} dated at 9,220 ±240 BC.

The isolation seems to have taken place in the latest part of Alleröd shortly before the zone boundary II/III (AL/DR—3), which fits in well with the shoreline diagram. The gradient of the corresponding shoreline seems to have been 6.2 m/10 km. In SW Kattegatt this gradient would mean shallow water in B 502 and land in B 504.



17. B 551, Björketorpsmossen, +46.7 m: A possible isolation level was found 1.92 m below surface at the limit sand/mud. The lowermost 2.0 cm of the mud was C^{14} dated at 5,575 ±180 BC. Consequently, it is not an isolation level, but a rise of groundwater in connection with the marine transgression up to PTM—2. Such a groundwater rise was found at several places far above the limit of the marine transgression (e. g. BP 1292/1291). However, a pollen analysis 1.0 cm up in the mud points to the lower part of zone VI (BO—2) according to the following fairly interesting composition: 35 % *Pinus*, 25.5 % *Betula*, 3 % *Alnus*, 2 % *Quercus*, 34.5 % *Salix*, 23 % *Corylus*, 0.5 % *Hippophaë*, 28 % *Gramineae*, 69.5 % *Cyperaceae*, 11 % *Ericaceae*, 7.5 % *Filicinae*, 45.5 % *Sphagnum*, 47.6 % AP and 52.4 % *NAP*.

18. BP 1246, Lilla Hornsjön, +29.7 m: This diagram was used by von Post as evidence of a transgression (his F2e-line). However, I find another explanation of the stratigraphy. The redrawn diagram (Fig. 38) shows that the clay 1.95—2.22 m down belongs to zone III (DR—3) and consequently corresponds to the colder climate during Younger Dryas and not to any marine transgression. The isolation contact is 2.36—2.39 m down and probably derives from the latest part of Alleröd.

Several attempts were made to find this locality, but a similar stratigraphy was never found. In B 437 a possible isolation level was found 1.17 m down at the limit silty clay/coarse detritus mud. The lowermost 1.5 cm of the detritus

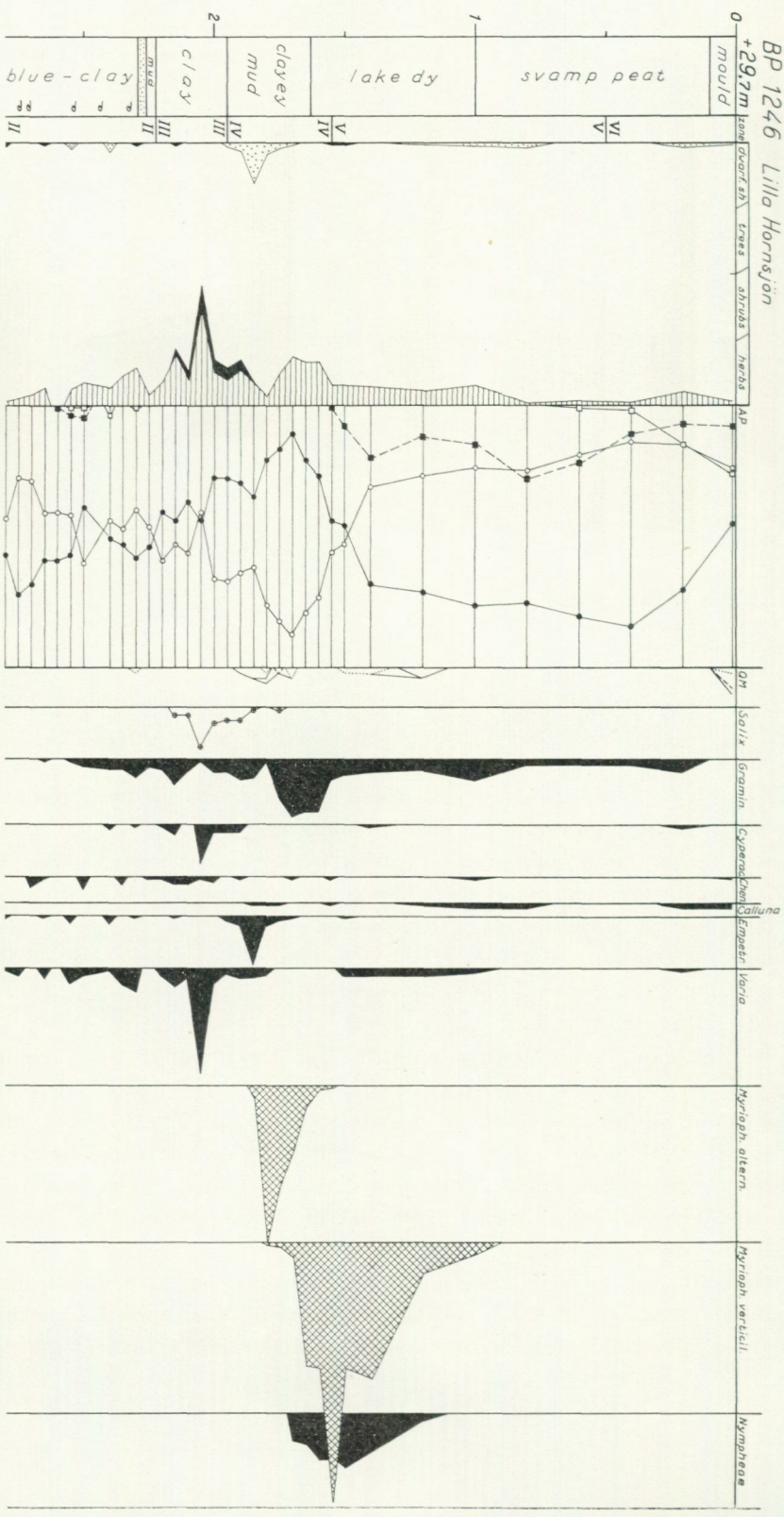


Fig. 38. *This basin was isolated in latest Alleröd (II) and the clay above the isolation contact is a "Dryas clay".*

mud was C^{14} dated at 6,170 ±210 BC. A pollen analysis of the same sample showed a clear Preboreal flora (equal to the one 1.80 m down in BP 1246). Apparently the C^{14} dating gave too young an age, probably due to rootlets (all macroscopical roots were excluded).

19. BP 1306, Section 75, +45.75 m: The pollen diagram shows contamination at several levels. The portion below 1.20 m is better and shows:

A: 17 cm of peaty dy = zone IV (PB).
B: 23 cm of a sequence with increasing mud content: somewhat muddy clay — muddy clay — clayey mud. Belongs to zone III (DR—3).
C: 48 cm of sand probably belonging to early III (DR—3) + late II (AL). A possible isolation level is 2.13 m below surface at the limit clay/sand.

Consequently, the isolation probably took place in the latest part of Alleröd.

A new boring B 557 was made and samples were taken with a piston corer. The following stratigraphy was found:

A: to 1.03 m silt (at least at the bottom)
B: to 1.065 m somewhat muddy alluvial clay
C: to 1.09 m black clayey mud
D: to 1.115 m muddy silty clay
E: clayey silt

The muddy sediments 1.07—1.10 m down was C^{14} dated at 7,775 ±115 BC. A pollen analysis from the mud 1.08 m down included: 37.5 % *Pinus,* 46 % *Betula,* 12.5 % *Salix,* 8 % *Corylus,* 55 % *Gramineae,* 34,5 % *Cyperaceae,* 0.5 % *Ericaceae,* which means the earliest part of zone V (BO—1). Consequently, the C^{14} date gives a good age of the zone boudary IV/V (PB/BO—1). The isolation is older.

20. Vallda Mosse +25 m (Lundegårdh and Sandegren 1953, Fig. 43): The lowermost part of the lacustrine mud contains a pollen flora of zone IV (PB). The alluvial clay 3.70—3.80 below surface is apparently a Dryas clay, which the pollen content may suggest. Below 3.80 m there is a marine Late Glacial clay. The isolation level lies 3.80 m down at the limit between the alluvial clay and the marine clay. Consequently, the isolation took place in or just before zone III (DR—3). The diagram suggests an isolation at the same time as in BP 1246 and BP 1306.

21. B 502, SW Kattegatt, −25 m: See p. 280.

The localilies BP 1306, BP 1246, Vallda Mosse, and B 502 were probably isolated roughly at the same time. This is supported by the pollen diagrams. The gradient of the corresponding shoreline is about 6.0 m/10 km. Such a shoreline falls 1 m above the organic layer in B 502 that was C^{14} dated at 8,870 ±200 BC (p. 280).

22. The delta at Berghem: The western part of von Post's Section 51 is interesting as it shows a "double delta". To clarify the picture this part of the

section was redrawn exactly according to the old field notes. The stratification and development can be expressed in the following way:

A: Sand = the delta from the time when the sea passed this area. The top of the delta is at +37.0 m.
B: Clay, 1—2 m thick. Probably this is a drift (alluvial) clay that corresponds to the beginning of younger Dryas.
C: Sand = distal delta sediments from the time just before Younger Dryas.
D: Clay = the marine sea fiord.

Von Post has six pollen diagrams from this area, but the poorness of pollen and infiltration of younger pollen in the upper part do not allow any zonation. The pollen content is very uniform, which points to a rapid sedimentation. BP 1431 and BP 1462 are better and show: absence of boreal pollen types and no marked dominance of *Betula,* but at least in the clay (B) a dominance of *Pinus.* This means that the pollen diagram suggests an age older than the Preboreal time. This fits in with the assumption that the upper clay is a drift clay from the beginning of Younger Dryas. The level +37.0 m falls exactly in the above mentioned shoreline at which BP 1306, BP 1246, Vallda Mosse and B 504 were isolated and which was estimated to date from the latest part of Alleröd. This may indicate a small disagreement. However, the exact level of the thresholds at the time of isolation of BP 1306 and BP 1246 is not known. Furthermore, the delta may have been built up some meters above the sea level.

23. B 438, Tvåker Kanal, about +12 m: The occurrence of intermarine peat was mentioned by Asklund (1936). In order to C^{14} date the Late Glacial isolation and Postgalcial transgression a boring was made here. The isolation level was found 3.42 m below surface at the limit clayey sand/dyey coarse detritus mud. The samples were taken with a piston corer. The stratification around the isolation level is:

A: 6.5 cm of *Sphagnum* peat = zone IV (PB) according to the pollen content: rise of *Betula,* fall of *Pinus,* rise of *Salix,* fall of NAP except *Cyperaceae* that rises to 108.6 %, *Myriophyllum alterniflorum* and *Pediastrum* disappear while *Sphagnum* rises to 65.5 %.
B: 3.5 cm of dark dyey coarse detritus mud = zone III (DR—3) according to the pollen content: 34.7 % *Pinus,* 49.6 % *Betula,* redeposited pollen, and NAP = 58.0 % of total pollen content. 45.4 % *Pediastrum* and 12.8 % *Myriophyllum alterniflorum* indicate a lake stage. The lowermost 1.5 cm was C^{14} dated at 8,355 ±120 BC.
C: 6 cm of grey clayey sand, at the bottom fine gravel. The pollen content indicates zone III (DR—3): 30.5 % *Pinus,* 61 % *Betula,* redeposited pollen, NAP high = 37.8 % of total pollen content, 7.8 % *Artemisia,* 52.6 % *Pediastrum* and 0.6 % *Hystrix.*

The sand layer was probably deposited in the shore zone during the Late Glacial regression. As we cannot preclude the possibility of a hiatus between layer C and B, the date of layer B only gives the minimum age of the land stage. The limit sand/mud is at about +8—9 m. According to the shoreline diagram the sea would have passed this level in early to middle zone III (DR—3).

24. B 566, BARNAMOSSEN, ABOUT +27 M: A boring was made in order to date the isolation. The following stratification was found:

A: To 0.55 m peat.
B: To 0.90 m a clayey sequence with increasing mud content from somewhat muddy to muddy clay. The sediment from 0.82—0.87 m down was C ^{14} dated at 2,260 ±130 BC. A pollen analysis was made at 0.88 m.
C: A very hard blue-clay.

The pollen analysis is in good agreement with the C^{14} dating and points to the earlier part of zone VIII (SB—1). It contains: 21 % *Pinus,* 1 % *Betula,* 66 % *Alnus,* 0.5 % *Ulmus,* 10.5 % *Tilia,* 0.5 % *Quercus,* 0.5 % *Salix,* 10.5 % *Corylus,* 5 % *Gramineae, 68 % Filicinae, 3 % Sphagnum.* Consequenly it is not an isolation level, but a ground water rise, over the earlier weathered clay, in early Sub-Boreal time.

25. KROKENS MOSSE +21 M (LUNDEGÅRDH AND SANDEGREN 1953, FIG. 44): The isolation level lies 3.78 m below surface at the limit between lacustrine mud and Late Glacial clay. The pollen diagram shows a flora in the lowermost part of the mud (no analysis in the clay), that belongs to early zone IV (PB) or the zone boundary III/IV (DR—3/PB). The diagram suggests an isolation in the middle of zone III (DR—3).

26. THE ANCIENT SETTLEMENT AT TOSSKÄRR, +47.5 M: This is one of the most important archeological localities on the Swedish West Coast. The most up-to-date description has been given by Fredsjö (1953). He found it obvious that the settlement is connected with a shorelevel at +47.5 m. Such a level would in my diagram belong to the later part of Younger Dryas. Fredsjö described solifluction in connection with the settlement and solifluction is known frequently to occur during Younger Dryas.

27. B 579, LÖKEBERGA MOSSE, +30.3 M (TRESHOLD +41.0 M): A pollen diagram from the same peat bog has been made by Erdtman (1921). According to this the isolation level is 2.95 m below surface at the limit clay/lime mud. Erdtman's pollen diagram seems to date the isolation level at the zone boundary III/IV (DR—3/PB).

The bog occupies a depression between the hills. The bog level is at +30.3 m, while the threshold is at +41.0 m. Shell banks with a Late Glacial fauna occur at several places. The new boring was made in the NW part of the bog. Five cores of the isolation level were taken with a piston corer. The stratification around the isolation level is:

A: black peat, with a sharp lower limit
B: yellowish white lime-mud containing Gastropods
C: brownish yellow lime-rich mud containing small Gastropods
D: yellowish brown muddy clay, containing a brackish-marine diatom flora (predominated by *Rhopalodia gibberula, Achnanthes brevipes* and *Surirella striatula*)
E: yellowish grey muddy clay
F: loose blue-clay (slightly muddy), *Mytilus edulis* 3—4 cm down

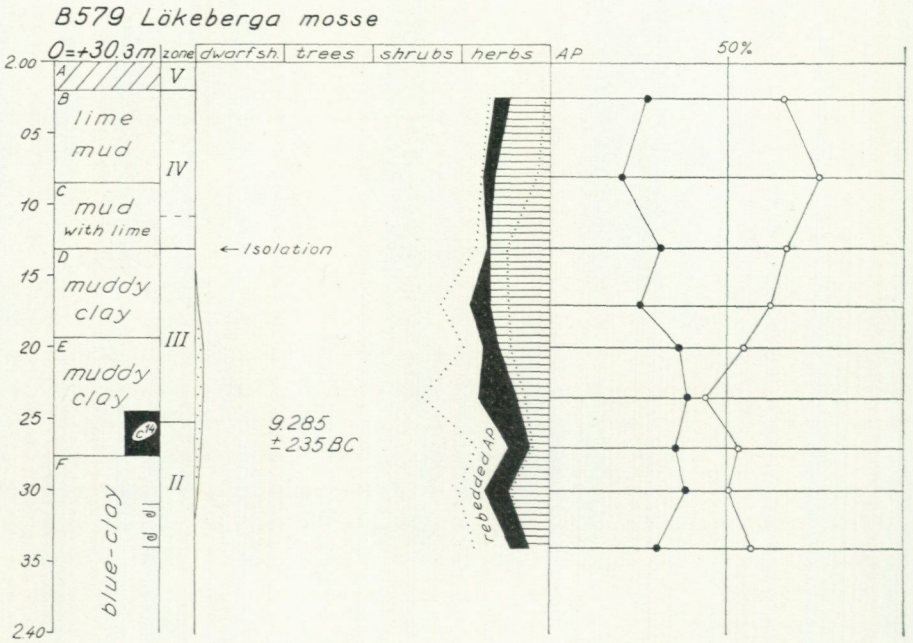
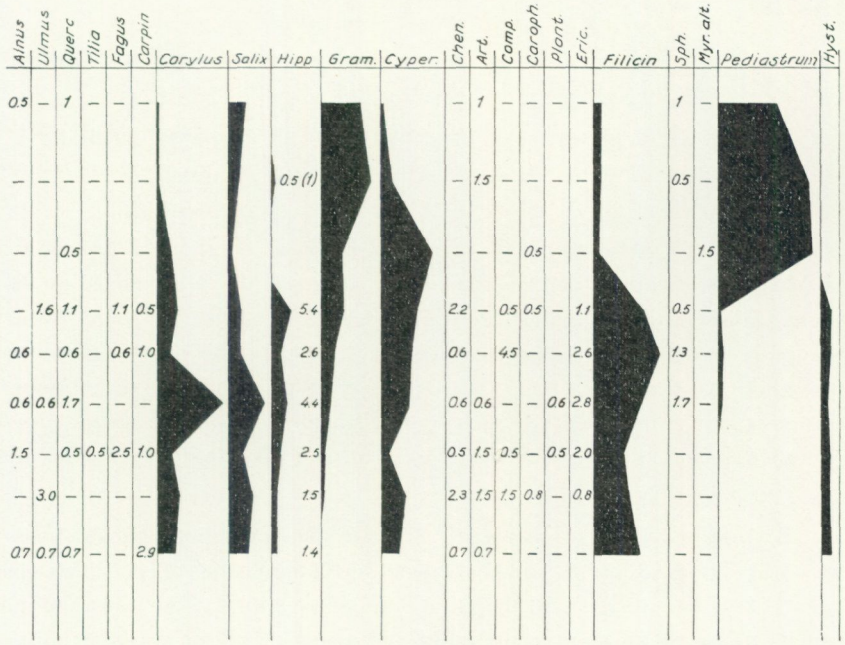


Fig. 39. *This basin was restricted to a lagoon in latest Alleröd (= the limit E/F), isolated at the zone boundary III/IV (= the limit C/D) and overgrown in connection with the regression down to ALV-1 at about the zone boundary IV/V (= the limit A/B). Rebedded*

The zonation of the pollen diagram (Fig. 39) is not quite obvious. However, the variations in the total diagram are significant, though not of special big amplitude. The AP diagram is uniform. Though no analysis was made in the peat, this seems, after a comparison with Erdtman's diagram, to belong to zone V (BO—1). Layers B and C (possibly exclusive the lower part of layer C) belong to zone IV (BP). Layer D and the main part of layer E belong to zone III (DR—3): occurrence of dwarf shrubs, low frequency of tree pollen, high frequency of rebedded AP pollen, high frequency of *Salix* (and shrubs) and culmination of herbs (exclusive *Gramineae* which seems to represent the local flora) especially of *Cyperaceae*. Layer F and the lower part of layer E belong to zone II (AL). The lowermost 3.0 cm of layer E were C^{14} dated at 9,285 ±235 BC, i. e. the end of Alleröd (just as the pollen diagram suggests).

The high percentage of *Hippophaë* in layers E and D indicate a woodless shore vegetation, which lasted up to the limit between layers D and C (see also the content of *Chenopodiaceae*). The content of *Hystrix* in layers D to F, like the diatoms in layer D, indicatesa a marine-brackish environment lasting up to the limit between layers D and C. The Gastropods and the sudden rise of *Pediastrum* in layer C indicate lacustrine environment. The limit between



AP are separated from the others (Pinus and Betula) by a dotted line. Gramineae (to the left) are separated from the other herbs by a dotted line.

layers D and C thus corresponds to the isolation, which consequently is dated at about the zone boundary III/IV (DR—3/PB) or the latest part of zone III (DR—3).

Layer F is a marine clay of common Late Glacial type. Layers E and D are shallow sea deposits. The mud content is surprisingly high. Lökeberga Mosse occupies a deep depression between steep hills of bedrock. Between th hills there are two thresholds at +41 m in east and NW. At the southern end there is a threshold at about +49 m. The topography shows that the basin of Lökeberga Mosse was restricted to a lagoonal depression connected with the sea via two narrow straits, when the southern threshold was lifted above the sea level. The change from the more or less open sea stage (with a connection to the sea also at the southern end) and the lagoonal stage apparently corresponds to the change from layer F to E or the rapid increase of mud, which is dated at the end of Alleröd. This is in full agreement with the shoreline diagram, as the corresponding shoreline (p. 166) here falls at +51 m.

When this basin was isolated the lake level was about 13 m above the sediment surface in B 579. However, the ground water level of the lake must have sunk more or less in time with the marine regression outside the thresholds, as the

lake at +28 m in B 579 was overgrown at about the zone boundary IV/V (PB/BO—1; no rise of *Pinus* and/or *Corylus* in Fig 39), i. e. at the beginning of ALV —1. ALV—0 here falls at +31.4 m and ALV—1 at +26.9 m.

This locality consequently gives information about the position of the shore not only at the isolation but also at the end of Alleröd and at the zone boundary IV/V (PB/BO—1).

The occurrence of Gastropods is a special problem. As the hills around Lökeberga Mosse were surrounded by the sea, an immigration via land is out of the question. The Gastropods must definitely have been brought here by birds. (Gastropods are found today on the feet of birds). In the new virgin environment without competition, the Gastropods could proliferate in great numbers (a common rule for pioneers). Such a suprisingly old immigration is found in many other localities: e. g. Bräcke Mosse (Sandegren and Johansson 1931) and B 427 (below).

28. Blinkens Mosse, treshold +27.5 m: This peat bog was analysed and described by Thomasson (in Alin, Niklasson and Thomasson 1934). The isolation level is 3.88 below surface at the limit clay/clayey mud. The pollen diagram (only AP) dates the isolation to the middle of zone IV (PB) or the zone boundary III (DR—3)/IV (BP). The absence of NAP analysis prevents a closer dating.

29. B 427, Lunnaled, about +12 m: The occurrence of intermarine peat and lacustrine mud in this area have been described several times. Sandegren (Sandegren and Lundegårdh 1952) described a pollen diagram from Lunnaled, where the isolation level is at 2.55 m at the limit marine clay/lime-mud. According to the pollen diagram (only AP) the isolation seems to have occurred in the middle of zone IV (PB) or at the zone boundary III (DR—3)/IV (PB). This is in full agreement with the pollen diagram from Lunnamosse (+12.5 m) described by Thomasson (in Alin, Niklasson and Thomasson 1934). Here the isolation level is 3.45 m below surface at the limit marine clay/lacustrine mud. The pollen diagram (only AP) dates the isolation to the middle of zone IV (PB) or the transition (DR—3)/IV (PB).

A new boring was made at Lunnaled (Fig. 86). Three cores containing the isolation level were taken with a piston corer (two cores of the transgression contact were also taken). The stratification below 2.65 m down was:

A: To 1.685 m coarse detritus mud with Gastropods.

B: To 1.800 m Gastropod mud (coarse detritus). A pollen analysis from the level 1.80 m down gave the following Preboreal fauna: 67.7 % *Betula*, 27.4 % *Pinus*, 2.4 % *Salix*, 121.0 % NAP (112.9 % *Gramineae*) and 79.0 % *Pediastrum*.

C: To 1.870 m somewhat clayey mud rich in Gastropods. A pollen analysis from the level 1.862 m down gave the follwing Preboreal fauna (poor in pollen): about 74.2 % *Betula*, 24.2 % *Pinus*, 1.6 % *Salix*, 116.1 % NAP (104.8 % *Gramineae*), 35.5 % *Pediastrum* and 1.6 % *Hystrix*.

D: To 1.940 m somewhat muddy clay with single shell fragments and statoblasts of *Plumatella* sp.

E: To 2.000 m blue-clay.

The isolation level seems to be 1.87 m down with a lagoon stage 1.87—1.94 m down. The lowermost 3.0 cm of mud (1.84—1.87 m down) was C^{14} dated at 8,050 ±330 BC, i. e. somewhere around the zone boundary III (DR—3)/IV (PB). The pollen analysis of the same level shows a Preboreal flora. So the isolation seems to have taken place in early Preboreal time.

The occurrence of statoblasts of *Plumatella* sp. is worth a closer description. This Bryozo is an entirely freshwater animal that today is found in eutrofic lakes. A great number of statoblasts lying close together were found. 1.90 m down in one of the three cores. Not a single statoblast was found in the other cores. I think these statoblasts must have been brought here by birds coming from more southern areas, probably by some web-footed bird resting in this lagoon on the way north, bringing the statoblasts from a eutrofic lake in Jylland or further south. The same explanation seems to apply to the occurrence of Gastropods.

30. B 118—119 (BP 1540), SECTION 105, +8.71 M (TRESHOLD ABOUT +15—9 M): With a foil piston corer two continuous cores were taken down to 9.90 m at von Post's old boring point BP 1540. The isolation level is 8.80 below surface at the limit clay/mud. A C^{14} dating of the lowermost 2.0 cm of mud gave 8,450 ±170 BC, i. e. the isolation would have taken place in Younger Dryas. However, the isolation would, according to von Post's pollen diagram from BP 1540 (only AP), have taken place in early Preboreal time. The problem cannot be solved as th level of the thresholds cannot be more closely fixed. The altitude of the most important threshold towards SW is at about +15.0 m. The less important threshold towards east is today at about +9.0 m, but it may earlier have been higher. An isolation at +15 m would have taken place in Younger Dryas, while an isolation at +9.0 m would have taken place in Preboreal time. A pollen analysis of the C^{14} dated sample gave: 7 % *Pinus,* 88 % *Betula,* 0.5 % *Ulmus,* 0.5 % *Quercus, 4 % Salix, 2 % Hippophaë, 34 % Gramineae, 2 % Cyperaceae, 0.5 % Ericaceae,* 4 % *Filicinae,* 0.5 % *Nymphea* and 14 % *Pediastrum* (the diatom flora was lacustrine), i. e. probably a Preboreal flora.

31. LAHOLMSBUKTEN, SUBMARINE PEAT −16 M: Several cores, proving the existence of an early Postglacial land stage, were taken here, but will be dealt with further on. When dredging for algae M.Waern got pieces of peat from about −16 m. These pieces have been described by Fries (1964). Some smaller pieces of peat consist of *Sphagnum* peat *(Sphagnum teres)* containing some leaves of *Betula nana.* The rest of the peat is fen peat, probably birch-sedge fen peat. The fen peat has been C^{14} dated at 8,110 ±140 BC. The four pollen analyses point to a Preboreal age (according to Fries the upper part of zone IV). According to my shoreline diagram a Preboreal age can be expected, probably about 7,900 BC.

Final remarks on the Late Glacial shorelines

In this chapter the following 13 Late Glacial shorelines were described (Pl. 4):

1. The shoreline of the ML at Skärsjön, Vessige and Oskarström. The age is calculated at 10,600 BC.
2. The shoreline of ML at Hylteråsen, Valinge, Svartrå, etc. The age is calculated at 10,450 BC.
3. The shoreline of the Fjärås line. The Fjärås line was dated at 10,300—10,350 BC. It marks the end of Oldest Dryas.
4. The shoreline of the Moslätt line and the isolation in Höghults Mosse. The Moslätt line was dated at 9,950—9,925 BC. It marks the beginning of Older Dryas.
5. The shoreline of the Berghem line and the isolaion in BP 1747 (B 715) and limit of ice wedges on the plain "Laholmsslätten". The Berghem line was dated at 9,850—9,800 BC. It marks the end of Older Dryas.
6. The shoreline of the isolation in BP 1248. The age is determined at early Alleröd or about 9,650 BC. On the Bäre peninsula the shore marks are very distinct possibly indicating a transgression.
7. The shoreline of the isolation in BP 1562 and the delta at Kalvhult. The age is determined at about 9,550 BC.
8. The shoreline of the isolation in BP 1530 (B 719), just before the isolations in Håle Mosse and BP 1413 (B 717). The age is determined at about 9,500 BC.
9. The shoreline of the isolation in BP 1292, BP 1254 and Edared Mosse. The age is determined at about 9,300 BC or middle Alleröd.
10. The shoreline of the isolation in B 574. The age is determined at 9,200—9,100 BC or late Alleröd.
11. The shoreline of the isolation in BP 1306, BP 1246, Valda Mosse, and B 502 (also fixed in B 579). The age is determined at latest Alleröd or about 9,000—9,100 BC.
12. The shoreline of the isolation of B 438 and Krokens Mosse. The age is determined at the middle of Yonger Dryas.
13. The shoreline of the isolation in B 579, Blinkens Mosse and B 427. The age is determined at 8,050 BC or the zone boundary III/IV (DR—3/PB).

The Late Glacial chronology

The Late Glacial marine shell bearing faunas and the chronology

The immigration and development of the shell bearing faunas offer important supplements to the knowledge of the climatic fluctuations in the Late Glacial time. With C^{14} datings of shells exact dates can also be obtained for the oldest Late Glacial parts in which the sediments were very poor in organic material that could be dated.

By Professor B.Asklund I was kindly permitted to use his excellent collection of shells from clay pits (now more or less destroyed) in the Falkenberg—Varberg area (Asklund 1936) for C^{14} datings.

Concerning the environment of the shell bearing organisms (Hägg 1952) I use the following abbreviations: A stands for arctic, B for boreal and L for lusitanic. In the fauans consisting of a mixture of boreal and arctic types, i. e. boreo-arctic faunas, I distinguish between three groups, viz. from colder to warmer Ab, AB and aB, where the capital letter marks the dominating environment.

1. Torsgården, clay pit 5 km SE of Varberg at about +16 m

In 1936 Asklund collected a very interesting series of samples in this locality (earlier described under the name "Sven Tors Märgelgrav", Asklund 1936). The shells belonging to six zones (I—VI), were carefully classified, but the results have not yet been published. In 1967 the material was put at my disposal. The following succession is seen in the six zones:[1]

I: 2.75—3.00 m down. Arctic fauna (A—Ab) with 13 different species. *Portlandia arctica* is 13—19 mm long. The ratio between *Portlandia arctica* and *P. lenticula* is 28:5.

II: 2.50—2.75 m. Arctic fauna (A—Ab) with 20 different species. The length of *Portlandia arctica* varies between 12 and 21 mm, with a distinct maximum at 17—19 mm. The ratio between *Portlandia artica* and *P. lenticula* is 217:24. Shells of *Balanus hammeri* were C^{14} dated at 11,100 ±140 BC = 10,795* ±165 BC. This date gives the end of the arctic sea.

III: 2.25—2.50 m. Boreo-arctic fauna (Ab) with 19 different species. *Portlandia arctica* is now clearly reduced in length, being only 3—13 mm long. Also *Saxicava arctica* seems to have become smaller. The ratio between *Portlandia arctica* and *P. lenticula* is 44:311, i. e. *Portlandia lenticula* is now predominating. The faunistical change between zone II and III corresponds to the climatic amelioration after about 10,700 BC.

[1]) NB The Roman numbers used in this chapter to denote the malacological zones must not be confused with those of the pollen zones.

IV—VI: 1.00—2.25 m. Boreo-arctic faunas (AB). *Portlandia lenticula* occurs abundantly, while *Portlandia arctica* has disappeard. This fauna corresponds to a distinct rise of the temperature, which apparently corresponds to the Bölling Interstadial. This is Asklund's *Portlandia lenticula* zone (Asklund 1936).

2. Fajan, clay pit 1 km east of Falkenberg at about +3—4 m

This locality is described by Asklund (1936). It contains the following four zones:

I: 0—1 m from the bottom, clay with thick varves. The fauna is arctic (A—Ab). *Portlandia arctica* is about 15 mm long. *Portlandia lenticula* does not occur. Shells of *Neptunea despecta* were C^{14} dated at 10,980 ±280 BC = 10,675* ±305 BC.

II: 1—2 m from the bottom, clay with thick varves. Boreo-arctic fauna (Ab—AB). *Portlandia arctica* is reduced in length. Also *Saxicava arctica* seems to be smaller (maximum at 16—18 mm). Shells of *Balanus* sp., *Natica clausa* and *Lunatia pallida* were C^{14} dated at 11,020 ±280 BC = 10,715* ±305 BC. This date gives the age of the onset of the rise of the sea temperature.

II/III: Unconformity with accumulation of pebbles.

III: The lowermost part of the clay with thin varves (pebbles at the bottom). Boreo-arctic fauna (AB). *Portlandia arctica* is further reduced in length, with a distinct maximum at 5—7 mm, no shell being more than 13 mm long. The ratio between *Portlandia arctica* and *P. lenticula* is 135:31. *Mytilus edulis* is the characteristic shell, at least in the upper part. There was unfortunately too little material for a C^{14} dating.

IV: The uppermost part of the clay with thin varves. At the bottom small shells of *Portlandia lenticula* still occur, further up they disappear.

3. Ågård, clay pit 4 km east of Falkenberg at about +15—20 m

This locality is described by Asklund (1936). It contains the following three zones:

I: 0–0.5 m from the bottom, sandy clay with thick varves. Boreo-arctic fauna (Ab—AB). *Portlandia arctica* is not present. *Saxicava arctica* varies between 18 and 30 mm with maximum at 25 mm. Shells of *Neptunea despecta* were C^{14} dated at 10,625 ±235 BC = 10,320* ±260 BC. The date gives the age of the rise of the temperature of the sea.

II: 0.5–2.25 m from the bottom, clay with thick varves. Boreo-arctic fauna (Ab—AB). *Portlandia arctica* is not present. *Saxicava arctica* varies between 19 and 30 mm with maximum at 25 mm. Shells of *Balanus* sp. (pro-

bably *B. hammeri*) were C^{14} dated at 10,980 ±270 BC = 10,675* ±295 BC. If this date is compared to the one in zone I, the age (with one sigma) of zones I—II should be 10,580—10,380* BC; which seems very likely.

II/III: Unconformity, gravel with stones.

IIIa: The lower part of the upper clay with thin varves. The fauna is arctic (A—Ab). It mainly contains shells of *Portlandia arctica,* which are up to 20 mm long. The fauna gives evidence of a lowering of the temperature in the sea.

IIIb: The upper part of the upper clay with thin varves. *Mytilus edulis* has now immigrated, which may indicate a slight rise of the temperature.

Together these three localities show the following development:

1. An arctic sea stage before about 10,700 BC: Fajans I and Torsgården I—II.
2. At about 10,700 BC there is a distinct change in the fauna. *Portlandia arctica* and usually also *Saxicava arctica* get smaller. At the same time *Portlandia lenticula* immigrates. This indicates a rise of the temperature of the sea, starting about 10,700 BC (Fajans II, Torsgården III) and ending about 10,380 BC (Ågård I—II). The onset of this amelioration exactly corresponds to the onset of a rapid isostatic land upheaval after the recession from the H2 line, estimated at 10,750 BC. The stage here described is older than the classic Bölling Interstadial of land deposits (p. 177), and as will be shown below (p. 170), separated from the Bölling Interstadial by the Fjärås Stadial. The name Ågård Interstadial is here proposed, at least as local name.
3. Between Fajans II and III and Ågård II and III there are distinct unconformities. These seem to correspond to a general change in Kattegatt (p. 174). In Ågård the unconformity clearly belongs to the transition from the Ågård Interstadial to the Fjärås Stadial.
4. In Ågård III the fauna indicates a lowering of the sea temperature. This apparently corresponds to the Fjärås Stadial. In Fajans this stage is represented by the gap.
5. During the Bölling Interstadial there is a distinct rise of the sea temperature. In the beginning the fauna is characterized by *Portlandia lenticula* and later by *Mytilus edulis.*

4. Falkenberg Brickyard, clay pit at about +3—4 m

This locality is described by Asklund (1936). It contains the following two zones:

I: The lowermost 1.0 m, a pebbly clay with thick varves.
The fauna is arctic (A—Ab).

I/II: Limit (corresponding to the unconformities in Fajans and Ågård).

II: 1.0—2.5 m from the bottom, a clay with thin varves. Boreo-arctic fauna (AB). *Portlandia lenticula* occurs frequently. Further up *Portlandia arctica* disappears.

5. The brickyard at Getinge, clay pit at about +10—15 m

The fauna was described by Asklund (1936). It is an arctic fauna (A—Ab). *Portlandia arctica* is 5—17 mm long with maximum at 10—13 mm. Apparently the fauna corresponds to the time before about 10,700 BC, i. e. the arctic sea stage.

6. The brickyard at Slottsmöllan, clay pit at about +10—15 m

This locality is described by Asklund (1936). In the lower part the fauna is arctic (A—Ab). In the part 5—8 m from the bottom there is a change, which probably corresponds to the change at about 10,700 BC. *Portlandia arctica* is reduced in length from 10—12 mm to 5—7 mm, and *Portlandia lenticula* immigrates (some shells). Also the clay changes from thick to thin varves.

7. The brickyard at Trönninge, clay pit at about +10—11 m

This locality is described by Asklund (1936). Here also a change can be seen. In the lowermost part there are shells of *Portlandia arctica* with a maximum length of 12—14 mm. Higher up *Portlandia arctica* decreases in length and *Portlandia lenticula* immigrates.

8. B 716 Älgare Mosse at about +41 m

The locality is described on page 151. It lies 2 km outside the Fjärås line (the delta at Björkhult). In a Late Glacial sandy clay the following shells were collected: *Saxicava arctica* (abundant) of 17—38 mm length with maximum at 27 mm, *Balanus creneatus* (many), *Mytilus edulis* (many), *Macoma calcaria* (5), *Mya truncata* (2) and *Litorina litorea* (5). This means a boreo-arctic fauna (aB). Shells of *Mytilus, Balanus* and *Litorina* were C^{14} dated at 10,510 ±140 BC = 10,205* ±165 BC. This fauna can definitely not have lived 2 km from the ice margin of the Fjärås line; it must be younger and belong to the Bölling Interstadial. Thus the C^{14} date gives a minimum age of the Fjärås line. From the dates in Ågård we know that the Fjärås line must be younger than about 10,380 BC and from the C^{14} datings of pollen analysed stratifications of non-marine deposits we know that the Bölling Interstadial started at about 10,300 BC (cf. p. 177). This means that the Fjärås line can be dated at about 10,300—10,350 BC and that this line marks the end of the classic Oldest Dryas. As it is preceded by a warmer interstadial, the Ågård Interstadial, the cold period of the Fjärås line must be given a special name. The Fjärås Stadial is here proposed, at least as a local name.

The association of shells in B 716 gives the fauna during the Bölling Interstadial.

9. BP 1411, at about +47 m

This locality was investigated by von Post. It lies 500 m outside the delta at Björkhult. The following shells were found by von Post: *Mytilus edulis, Saxicava arctica, Macoma calcaria, Mya truncata, Cyprina* sp., *Litorina* sp. and *Balanus* sp., i. e. a boreo-arctic fauna (aB). It belongs to Bölling or the very oldest part of Alleröd (0—12 m depth).

10. B 715 Klinehögkärret, at +53 m

The clay below the C^{14} dated isolation level (p. 139) contains shells of *Mytilus edulis* (abundant), *Saxicava arctica* and several unclassified fragments. This fauna must belong to the Bölling Interstadial.

11. The Viskan Valley

Caldenius (1951) found shells of *Portlandia arctica* in varves 28—45 at Berg (= latest Bölling) and in varves 60—100 at Hulta (= earliest Alleröd). These shells represent the fauna that lived close to the receding ice margin. After the disappearance of *Portlandia arctica* in Hulta there is a sequence of clay without any shells, until the final boreo-arctic (aB) fauna has immigrated (von Post † 1955), i. e. *Astarte borealis, Balanus hammeri, Litorina rudis, Mytilus edulis* and *Saxicava arctica.* Several attempts were made to find shells of *Portlandia arctica* in glacial varved clay, as a C^{14} dating would have given a very good date of the ML and the ice recession.

12. Agnesberg in the Götaälv Valley

In 1924 N.Odhner collected a series of samples in the clay pit (Steken) at Agnesberg (Sandegren and Johansson 1931). The clay pit was 10.6 m deep and contained shells that showed very interesting faunal changes. The lower part is varved. The following stratigraphy was found:

A: 0.9 m of unvarved clay
B: 1.0 m of glacial clay without clear varves, probably containing at least 50 varves
C: 0.5 m of glacial clay with indistinct varves, containing about 25 varves
D: glacial varved clay containing 105 measured varves
E: sand, the surface of which lies at +19.25 m

The following faunal changes are seen:

1. Nine varves without shells.
2. Boreo-arctic shells (AB) in varve 10—23: *Modiolaria laevigata* (10), *Mytilus edulis* (11, 23), *Macoma calcaria* (15) and *Balanus creneatus* (15, 17).
3. No shells in varve 24—30, but thick varves containing redeposited glacial clay (Odhner's field notes) suggesting a readvance of the ice margin.

4. *Portlandia arctica* and *Portlandia lenticula* in varve 30—46, indicating a lowering of the temperature in the sea or at least an increased outflow of cold and loaded meltwater.
5. From varve 55 to 97 is again a boreo-arctic fauna (Ab—AB). "*Mytilus* fauna", containing: *Mytilus edulis, Balanus creneatus, Macoma baltica, Modiolaria laevigata, Saxicava arctica, Buccinum groenlandicum* and furthermore *Portlandia arctica* (only in varve 66) and *Portlandia lenticula* (only in varve 90). Layer C contains the same fauna. This fauna corresponds to an amelioration of the climate.
6. Layer B contains again an arctic fauna (A—Ab), "*Portlandia fauna*", containing: *Portlandia arctica* (abundant, big shells), *Portlandia lenticula, Nucula tenuis, Leda pernula,* some barnacles and a very few shells of *Mytilus edulis.* This fauna indicates a deterioration of the climate.
7. Layer A contains a third boreo-arctic (AB) fauna, "*Mytilus* fauna", indicating the final amelioration of the climate.

The annual varves of the clay give the following duration of the different faunal zones:

I: 10 years without shells
II: 15 years with AB fauna
III: 20—30 years with A—Ab fauna
IV: 75—85 years with Ab—AB fauna
V: 50 years with A—Ab fauna
VI: (later) AB fauna

This means that we have two colder periods within about 150 years, which are separated by a warmer period of about 75 years.

Sandegren (Sandegren and Johansson 1931) suggested a possible correlation between the lower *Portlandia* fauna (= zone III) and the big delta at Rösered (= 1.5 km towards NE) and between the upper *Portlandia* fauna (= zone V) and Munthe's ice marginal line Hjärtum—Hyssna, containing the delta at Moslätt (= 19 km NE of Agnesberg). However, I think this is wrong for the following reasons:

1. The AB fauna of zone II can hardly have lived 1.5 km or less from the ice margin.
2. The distance between Rösered and Moslätt is 17.5 km, which would mean a recession of 233 m per year. Such a rapid recession does not agree with any geological observation (e. g. Caldenius 1951) in this area.

Instead I find the following correlation:

Zone I—II = the recession during late Bölling up to the Moslätt line.
Zone III = the readvance to the Moslätt line (e. g. in the Uspen—Lensjö area, p. 129) and the deposition of the impressive delta at Moslätt (p. 130) lying 19 km NE of Agnesberg. This marks the beginning of the Older Dryas (pollen zone Ic or DR-2).

Zone IV = the recession — at a rate of 53 m per year — between the Moslätt and Berghem lines, corresponding to a warmer period within the Older Dryas.

Zone V = the Berghem line about 23 km NE of Agnesberg. This marks the younger part of Older Dryas. The Berghem line is usually made up by 3—5 terminal moraine ridges.

Zone VI = the onset of Alleröd.

Consequently, Older Dryas lasted for 150 years. This fits extremely well with the C^{14} datings of pollen analysed stratifications (p. 178), which give an age of about 9,950—9,800 BC. The warmer period of 75 years in the middle may be seen in some pollen diagrams, e. g. the one of Bölling Sö (Iversen 1942, Fig. 3, and 1954, Pl. 10). The name Agnesberg Subinterval is proposed.

13. BP 1401 Ringemosse, at +52 m

This locality was investigated by von Post. The following fauna was found: *Mytilus edulis* (abundant), *Astarte* sp. (many), *Litorina litorea* (many), *Litorina conferoides* (many), *Balanus* sp. (some), *Macoma calcaria* (a few) and *Saxicava arctica* (2), i. e. a boreo-arctic fauna (aB). According to the position this fauna must be younger than the Berghem line but older than 9,300 BC. This means that we here have a fauna of early Alleröd.

14. Edared, at about +48 m

This locality was described by Lönnberg (1905). The shell fauna is boreo-arctic (aB). It is roughly of the same age as the C^{14} dated horn of a reindeer (p. 154), i. e. 9,315 ±100 BC.

15. Brobacken, shell bank at +65 m

This locality was described by Mohrén (Caldenius *et al.* 1960). The fauna is boreo-arctic (aB), containing: *Saxicava arctica, Mya truncata, Buccinum groenlandicum, Litorina litorea, Litorina rudis, Zirphaea crispata* and *Balanus hammeri*. According to the altitude and position this fauna must belong to the earlier part of Alleröd.

The faunas of the above-mentioned localities on the Swedish West Coast are all closely dated and give the faunal changes all the way from the arctic sea stage before about 10,700 BC up to the middle of Alleröd. The climatic deterioration of Younger Dryas is not reflected in the marine shell faunas in this area.

16. Vendsyssel and Laesö

A. Jessen (e. g. 1936) made the following division of the marine Late Glacial deposits in Vendsyssel:

1. the Lower *Saxicava* sand
2. the *Yoldia* clay
3. the Upper *Saxicava* sand

4. the *Zirphaea* layer, corresponding to a marine transgression

However, recent C^{14} datings (Copenhagen VII) of shells in relation to the results from the Swedish West Coast, suggest a reinterpretation. The following C^{14} datings have been made:

1. The Lower *Saxicava* sand			
K-858 Lönstrup Klint	11,950 ±220 BC	=	11,645* ±245 BC
2. The *Yoldia* clay			
K-887 Dybvad	11,230 ±200 BC	=	10,925* ±225 BC
K-903 Dybvad	11,060 ±190 BC	=	10,755* ±215 BC
K-894 Laesö	10,960 ±180 BC	=	10,655* ±205 BC
K-891 Bindslev	10,700 ±170 BC	=	10,395* ±205 BC
3. The transition from *Yoldia* clay to *Zirphaea* layer			
K-898 Skeenmöllebaek	10,820 ±160 BC	=	10,515* ±185 BC
K-897 Skeenmöllebaek	10,570 ±180 BC	=	10,265* ±205 BC
K-860 Skeenmöllebaek	10,280 ±170 BC	=	9,975* ±195 BC
4. The *Zirphaea* layer			
K-899 Skeenmöllebaek	10,290 ±180 BC	=	9,985* ±205 BC
K-862 Skeenmöllebaek	10,410 ±150 BC	=	10,105* ±175 BC
K-861 Skeenmöllebaek	10,240 ±170 BC	=	9,935* ±195 BC
5. The Upper *Saxicava* sand			
K-859 Borgbakke	10,080 ±130 BC	=	9,775* ±155 BC

Out of these C^{14} dates the following conclusions can be drawn:

1. The *Yoldia* clay corresponds to the arctic sea stage in the Varberg—Falkenberg area on the Swedish West Coast.
2. The change in sedimentation from clay to gravel-sand took place during the Ågård Interstadial.
3. The *Zirphaea* layer clearly belongs to the Bölling Interstadial.
4. The Upper *Saxicava* sand at Borgbakke (in a shore accumulation at +25 —27 m) is younger — and not older — than the *Zirphaea* layer and belongs to Older Dryas (Fig. 11).

The change from clay to sand-gravel is seen not only at higher altitudes as at about +15 m in Skeenmöllbeaek, but also at −2.5 m (O.Mickesen 1967) on Laesö. The sand and gravel are not covered by younger clay. As already stated (p. 29) this lack of clay is also seen on several shoals in Kattegatt. This indicates that the change from clay to sand-gravel was not caused by a change in sea level but by a general change in sedimentation in Kattegatt. This change took place during the Ågård Interstadial and may perhaps be due to the following:

1. The warmer period meant a longer ice-free sea stage each year (earlier the sea may have been more or less covered by ice the whole year).
2. A lot of floating ice dropped stones and gravel, sometimes with living barnacles on their surfaces.
3. The margin of the Baltic ice was now inside the Swedish—Danish thresholds and the body of water in front of the ice may have served as a sedimentation basin.

4. The circulation in Kattegatt must have changed radically.

This means that the gravel with worn shells and barnacles attached to pebbles etc. does not give evidence of a transgression.

Iversen (1947) has shown that the *Zirphaea* layer at Skeenmöllebaek pollen statistically corresponds to a warmer period, which he thought was Alleröd. However, the C^{14} dates clearly show that it is the Bölling Interstadial.

The shells at Borgbakke lie in a shore accumulation at +25—27 m (e. g. A.Jessen 1936). Shells of *Litorina rudis* and *Mytilus edulis* and bones of *Balaena mysticetus* and *Pagonetta glacialis* have been found here. The C^{14} dating shows that this shore accumulation belongs to the later part of Older Dryas, i. e. to the time of the Berghem line. The corresponding shoreline (Fig. 11) falls at +12.5 m at Nörre Lyngby, which means that the freshwater basin at +13—14 m would have been isolated from the sea at about the transition Bölling/Older Dryas. This fits well with Iversen's pollen diagram (1942) and C^{14} datings of the peat layer at 9,730 ±140 BC and 9,830 ±180 BC (Copenhagen V), i. e. the transition Older Dryas/Alleröd.

17. Tingsager near Lillesand in Southern Norway, at +35 m

In a clay pit at Tingsager B.G.Andersen (1960) found a glacial clay containing shells of *Mytilus edulis* (abundant), *Saxicava arctica, Macoma calcaria, Mya truncata, Chlamys groenlandica* (?), *Balanus creneatus* and *Balanus balanoides,* i. e. a boreo-arctic (AB) shell fauna. Shells from this layer have been C^{14} dated at 10,600 ±200 BC = 10,295* ±225 BC. Most probably this fauna belongs to the Bölling Interstadial (though the date also allows correlation with the Ågård Interstadial). If this is correct the terminal moraine zone, "Kristiansand-trinnet", further inland should belong to Older Dryas (p. 127).

The C^{14} dates and the Late Glacial chronology

Several C^{14} dates concerning the Late Glacial events are now available from different parts of North Europe. In order to fix the age of the boundaries between the main Late Glacial periods, the most important C^{14} dates have been put together in the following list (all corrected to the NBS standard).

1. Datings of Oldest Dryas (zone Ia or DR-1): ending 10,300—10,350 BC
   - 10,670 ±130 BC GrN-935 (Groningen II) Usselo Ba VI. The same level (moss peat) as GrN-928 and K-546.
   - 10,490 ±110 BC GrN-928 (Groningen II) Usselo Ba VI.
   - 10,580 ±140 BC K-546 (Copenhagen IV) Usselo Ba VI.
   - 10,590 ±110 BC GrN-1104 (Goningen II) Usselo Ba V. The same level (4 cm of moss peat) as K-545.
   - 10,490 ±140 BC K-545 (Copenhagen IV) Usselo Ba V.
   - 10,460 ±140 BC K-544 (Copenhagen IV) Usselo Ba IV.
   - 10,290 ±230 BC K-709 (Copenhagen V) Witow, Poland. 4.5 cm of peat = zone Ia.

2. Datings of Bölling (zone Ib or BÖ): 10,300 to 9,950 BC

10,310 ±140 BC K-707 (Copenhagen V) Witow. The oldest part of zone Ib.
10,150 ±140 BC K-708 (Copenhagen V) Witow. Upper part of 11 cm of sandy coarse detritus mud = zone Ib (the lower part was dated as K-707).
10,250 ±140 BC K-543 (Copenhagen IV) Usselo Ba III. The same level (4 cm of moss peat) as GrN-927.
10,645 ±180 BC GrN-927 (Groningen II) Usselo Ba III. Apparently too old.
10,350 ±100 BC GrN-4782 (Groningen VI) Zelzate 2, Belgium. Peat in coversand.
10,070 ±120 BC GrN-2024 (Groningen VI) Konin 5, Poland. Base of Late Glacial mud.
10,050 ±110 BC GrN-2993 (Groningen VI) Clinge II, Datch—Belgium border. Peat = a late part of Bölling (7.5—9.5 cm from the top).
9,970 ±110 BC GrN-2891 (Groningen VI) Clinge I. Seeds from peat below 4 m of coversand.
9,950 ±180 BC K-706 (Copenhagen V) Witow, Poland. Sandy coarse detritus mud 2.40—2.60 m below surface = the transition Bölling/Older Dryas (zone Ib/Ic).

3. Datings of Older Dryas (zone Ic or DR-2): 9,950 to 9,800 BC

9,820 ±140 BC K-541 (Copenhagen IV) Usselo Ba I. The same level as GrN-926. 3 cm of peat = the top of Older Dryas.
10,115 ±130 BC GrN-926 (Groningen II) Usselo Ba I. Apparently too old.
9,830 ±150 BC GrN-811 (Groningen VI) Amersfoort X. 2 cm of peat = the top of Older Dryas.
9,820 ±200 BC St-2508 (p. 140, Fig. 33) Klinehögkärret. 1.9 cm of clayey mud = the uppermost part of Older Dryas.
9,830 ±120 BC K-963 (Copenhagen V) Nörre Lyngby. The lower 2.5 cm of peat = Older Dryas.
9,730 ±140 BC K-962 (Copenhagen V) Nörre Lyngby. The upper 4.5 cm of peat = Older Dryas.

4. Datings of Alleröd (zone II or AL): 9,800 to 9,000—8,950 BC

9,850 ±110 BC GrN-921 (Groningen II) Usselo Bb II. *Betula* phase of Alleröd.
9,750 ±140 BC K-547 (Copenhagen IV) Usselo Bb I. 1.0 cm of moss peat = *Betula* phase of Alleröd.
9,790 ±170 BC St-1683 (Berglund 1966) Lösensjön. 10 cm of clayey mud = lowermost part of Alleröd.
9,995 ±200 BC St-341 (Stockholm II) Toppeladugård. Alleröd mould.
9,895 ±180 BC St-345 (Stockholm II) Toppeladugård. Alleröd mud. The lake contained older carbon (St-342).
9,800 ±100 BC GrN-3585 (Groningen VI) Haskerveenpolder II, the Netherlands. Peat (= Alleröd) in coversand.
9,650 ±70 BC GrN-2136 (Groningen VI) Haskerveenpolder I. Peat of the same bed as GrN-3585.
9,820 ±120 BC GrN-4087 (Groningen VI) Alblasserdam, the Netherlands.
9,680 ±90 BC GrN-4900 (Groningen VI) Denekamp 2. Peat in coversand.
9,760 ±100 BC GrN-947 (Groningen II) Usselo Bc III. 4 cm of moss peat = *Betula* phase of Alleröd. The same level as K-553, GrN-933 (too old) and GrN-948.
9,670 ±140 BC K-553 (Copenhagen IV) Usselo Bc III.
9,805 ±130 BC GrN-948 (Groningen II) Usselo Bc III.
9,350 ±140 BC K-552 (Copenhagen IV) Usselo Bc I. 3 cm of moss peat = *Pinus* phase of Alleröd. The same level as GrN-925.
9,355 ±130 BC GrN-925 (Groningen II) Usselo Bc I.
9,220 ±240 BC St-2163 (p. 156, Fig. 37) Hålsjön B 574 :I. 2.0 cm of clayey mud and muddy clay = the upper part of Alleröd.
9,285 ±235 BC St-2168 (p. 162, Fig. 39) Lökeberga Mosse B 579. 3.0 cm of muddy clay = the uppermost part of zone II and the zone boundary II/III.
9,070 ±170 BC K-952 (Copenhagen V) Witow, Poland, Charcoal (= Alleröd) between sand of Older and Younger Dryas.

9,020 ±120 BC K-101, remeasured sample (Copenhagen VI) Ruds Vedby. Wood from peat = the zone boundary II/III.
9,020 ±300 BC K-110 (Copenhagen III) Bölling Sö. Mud = the zone boundary II/III.
8,965 ±230 BC St-2528 (p. 151, Fig. 35) Älgare Mosse, B 717 :II. 2.4 cm of clayey mud = the uppermost part of Alleröd.
8,850 ±220 BC St-1420 (Berglund 1966) Igelsjön. 6 cm of clayey mud = uppermost AL + lowermost DR-3.

5. Datings of Younger Dryas (zone III or DR-3): 9,000—8,950 to 8,050—8,000 BC

8,810 ±200 BC K-529 (Copenhagen IV) Krakow, Poland. Peaty mud probably = Younger Dryas.
8,450 ±170 BC St-1422 (Berglund 1966) Lösensjön 4.4 cm of muddy clay = upper DR-3.
8,275 ±120 BC St-2164 (p. 156, Fig. 37), Hålsjön B 574 :II. 1.5 cm of clayey mud below a more clayey layer, corresponding to the later part of Younger Dryas.
8,350 ±60 BC GrN-4723 (Groningen VI) Denekamp 9. Wood (= Younger Dryas) in coversand.
8,740 ±90 BC GrN-2137 (Groningen VI) Schelphoek, the Netherlands. 7 cm of mud = the zone boundary III/IV.
8,550 ±350 BC K-111 (Copenhagen III) Bölling Sö. Mud = the zone boundary III/IV.
8,260 ±140 BC U-426 (Uppsala IV) Långa Getsjön, Sweden. Clayey mud just above the zone boundary III/IV.
8,220 ±230 BC St-1337 (Berglund 1966) Hallarums Mosse. 8 cm of clayey mud = the lower part of DR-3 — PB.
8,050 ±170 BC St-1336 (Berglund 1966) Hallarums Mosse. 4 cm of clayey mud = transition between DR-3 — PB and PB. Age indicates zone boundary III/IV.
8,220 ±160 BC St-1778 (Berglund 1966) Slättmossen 2. 4 cm of clayey mud = upper DR-3.
7,750 ±150 BC St-1847 (Berglund 1966) Slättmossen 1. 4 cm of clayey mud = transition between DR-3 and DR-3 — PB.
7,710 ±240 BC U-419 (Berglund 1966) Storemosse 118. 2 cm of clayey mud = the uppermost part of DR-3 — PB. Age indicates early zone IV.
7,540 ±300 BC U-229 (Berglund 1966) Storemosse 119. 2 cm of clayey mud = the lower part of DR-3 — PB. Age indicates zone IV.
8,060 ±60 BC GrN-4722 (Groningen VI) Denekamp 6. Wood = end of Younger Dryas.
8,080 ±60 BC GrN-4731 (Groningen VI) Denekamp 7. Wood = end of Younger Dryas.
8,090 ±60 BC GrN-4724 (Groningen VI) Denekamp 10. Peat = end of Younger Dryas.
8,050 ±120 BC St-2346 (p. 141) Munkamjäll, B 711. The lowermost 2.0 cm of lake dy = the zone boundary III/IV.
8,030 ±140 BC Y-482 (Yale III) Varrassuo-Moor, Finland. Peat = uppermost zone III.
7,980 ±140 BC U-420 (Uppsala IV) Stuggölen, Sweden. Clay and clayey mud = earliest zone IV.
7,970 ±150 BC St-805 (T.Nilsson 1964a) Ageröds Mosse. 3.0 cm of mud = earliest zone IV.
7,965 ±180 BC St-2165 (p. 151, Fig. 35) Älgare Mosse, B 717 :IV. 1.4 cm of clayey mud = the very beginning of zone IV.

Summing up, the following C^{14} chronology is seen (non-marine deposits):

Oldest Dryas (Ia, DR—1)
10,300—10,350 BC
Bölling (Ib, BÖ)
9,950 BC

Older Dryas (Ic, DR—2)
9,800 BC
Alleröd (II, AL)
9,000—8,950 BC
Younger Dryas (III, DR—3)
8,050—8,000 BC
Holocene

It has often been stated that the C^{14} chronology fits well with the Swedish varve chronology. However, this is not true, unless one makes a correction between the two scales. Earlier, the Swedish time scale was extended down to Stockholm (De Geer 1940, Järnefors 1963), i. e. 8,015 BC. Now it is possible that E.Nilsson (1968) has succeded in extending it down to the southern end of Lake Bolmen. i. e. 9,984 BC. The older varve series must, in my opinion, not yet be regarded as connected in a reliable way (though this has been stated). The Swedish time ends today at southern Bolmen. The following comparisons between the C^{14} and varve chronologies are now possible:

The end of Younger Dryas C^{14} dated at 8,050—8,000 BC = the drainage at Billingen varve dated at 8,213 BC: i. e. a difference of about 165—215 years.

The beginning of Younger Dryas C^{14} dated at 9,000—8,950 BC = the Taberg readvance varve dated at 9,100 BC + the time of readvacce (about 9,200 BC according to E.Nilsson 1968): i. e. a difference of about 150—200 years.

The end of Older Dryas C^{14} dated at 9,800 BC = the recession from the Berghem line varve dated at 9,984 + some years: i. e. a difference of about 200 years.

This means that there is a difference of about 200 years between the two chronologies during these periods. It also means that there was almost no variation of the content of ^{14}C in the atmosphere during late Late Glacial.

This comparison also shows that the beginning of Younger Dryas (and the Middle Swedish terminal moraine complex) corresponds to the Taberg readvance or the 9,100 line and not to the 8,900 line as stated by E.Nilsson (e. g. 1960, 1968) and others. The 9,100 line is marked by a distinct terminal moraine zone in SW Sweden. In southern Norway this line lies within the Ra line.

In Sweden the Younger Dryas period is represented by 3—4 disinct terminal moraine lines (cf. G.Lundqvist 1961, the map; E.Nilsson 1968, Pl. 1). The following local names are proposed:

9,100 BC — Taberg Phase: a very distinct line

8,700 BC — Skövde Staffel: a very distinct line

8,500 BC — Vadstena Staffel(?): not well established

8,213 BC — Billingen Staffel: not so well established

In Finland the Salpausselkä terminal moraine complex is divided into three stages (or Phases), together covering 951 years (e. g. Sauramo 1918, 1940, Donner 1965). If the drainage at Billingen 8,213 BC is correlated to the year +292 in the Finnish time scale, the following chronology is found:

Finnish varve chronology		Swedish varve chronology	C^{14} chronol. in BC	
Sauramo e.g. 1940	age in BC	De Geer 1940, E. Nilsson 1968		
—659	9,164	Taberg Phase 9,100 + readv.	9,000—8,950	the Younger Dryas Stadial = 950 years
Salpausselkä I			(colder 1)	
—434	8,939		8,800—8,750	
recession (interval?)		recession (interval)	(warmer 1)	
—183	8,688	Skövde Staffel 8,700	8,550—8,500	
Salpausselkä II		recession	(colder 2)	
±0	8,505	Vadstena Staffel 8,500	8,350—8,300	
recession (interval?)			(warmer 2)	
+100—200	8,405-8,305	recession	8,250—8,100	
Salpausselkä III			(colder 3)	
+292	8,213	Billing Staffel 8,213	8,050—8,000	

This means that there seems to be a very good agreement between the Swedish and Finnish time scales and the C^{14} chronology.

If the "new" halflife of C^{14}, i. e. 5,730 years, is used the difference between the C^{14} chronology and the varve chronology is somewhat smaller and changes from minus to plus; about +150—100 years (Fig. 40.).

Fromm (1938) has analysed the pollen and diatom content in some varve series from Ångermanland that were closely dated by Lidén (1913). Some of Fromm's varve dated horizons can now be compared with C^{14} datings:

1. The onset of the *Alnus* curve, A^0, at 6,350 BC: Several C^{14} datings of this horizon have been made from different parts of Sweden. In most cases this horizon seems to give, 6,500—6,600 BC (with older as well as younger dates, however). This suggests a difference of −150—250 years (at least the difference is not positive).
2. The ingression of salt water, the beginning of the Litorina Sea, at 5,100—5,000 BC: Probably this event corresponds to PTM-2 at 5,000 BC (cf. p. 392). A difference of about +100 years (or less) seems probable.
3. A peak of saltwater diatoms at 4,600 BC: This peak probably corresponds to PTM—3 at 4,500—4,300 BC (cf. p. 392). A difference of at least +100 years is indicated.
4. The *Betula* maximum, "Niveau d", at 4.200 BC: This level is C^{14} dated by G.Lundqvist (1963, Fig. 121) at 3,535 ±115 BC. This suggests a dif-

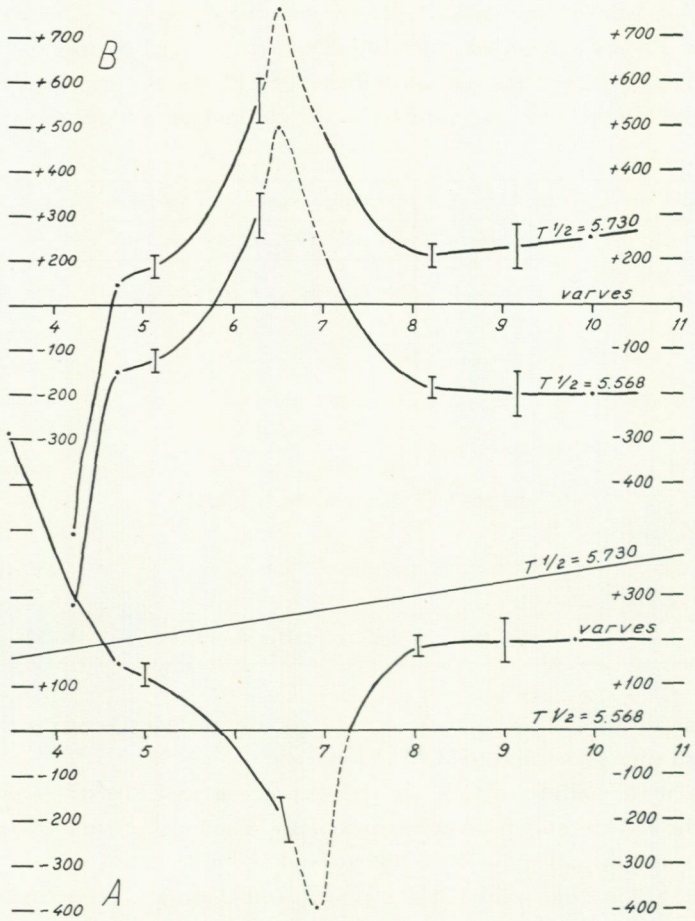


Fig. 40. *Comparisons between the Swedish varve chronology and the C¹⁴ chronology (the conventional as well as the "new" half-life of C¹⁴).*

ference of about +650 years. However, this horizon is metachronous and can thus not be used for a close comparison.

5. The difference for the younger horizons seems to be smaller, though exact figures cannot yet be given.

From these data a curve of the difference between the varve chronology and the C¹⁴ chronology has been drawn (Fig.40). This is of great importance for the discussion about the variations of ¹⁴C in the atmosphere during the past (Fig. 41). This curve is a serious contradiction to Stuiver's curve (Stuiver 1967), but in full agreement with and a continuation of Damon's curve (Damon 1965, Stuiver 1967) and Suess' curve (Suess 1967).

The changes during the period 8,000—5,000 BC (Fig. 40) are also illustrated by the C¹⁴ dated shorelevel displacement curves, where the time of ALV-1 is too long, the time of the transgression up to ALV-2 (= PTM-1) is too short and

the time of ALV-3 is too long. These changes are also suggested by abnormal dates in series of C^{14} datings from lake deposits, for example in Ageröd Mosse (T.Nilsson 1964a, e. g. St-797) and Lake Trummen (Digerfeldt in Lund I).

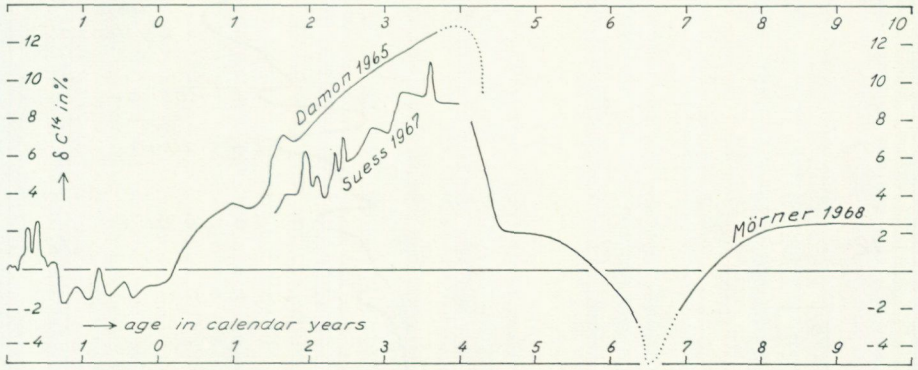


Fig. 41. *Atmospheric ^{14}C activity in per cent deviation from age-corrected oxalic-acid standard.*

Final remarks on the Late Glacial chronology

Summing up the results of deglaciation, shorelevel displacement and datings a very detailed glaciation curve has been drawn (Fig. 42). The following development is seen. The order of the thermomers and kryomers (Lüttig 1965) are sometimes not finally fixed. The chronology is given in C^{14} age.

The C line 18,000 BC to unknown age — the Middel Jylland Stadial = the Brandenburger/Frankfurther Stadial in Germany

Recession (CD lines)

Interstadial (the Smidstrup Interstadial) — in Mecklenburg probably corresponding to the interstadial described by Heerdt (1965), which can be termed the Kühlung Interstadial

The D line about 13,000—12,800 BC — the East Jylland Stadial, probably corresponding to the Pommerian (Pomeranian) Stadial in Germany

Recession (DE lines)

Interval or subinterval

The E1 line about 12,600 BC — the Rösnäs Phase or Staffel

Interstadial or interval

The E4 line about 12,400 BC — the Odden Stadial

Recession (E lines)

Interval or interstadial

The F2 line about 12,100 BC — the Langeland Phase (= the Rosenthaler Phase in Germany)

Recession (interval or subinterval)

The F5 line about 11,800 BC — the Ängelholm Phase (or Staffel)

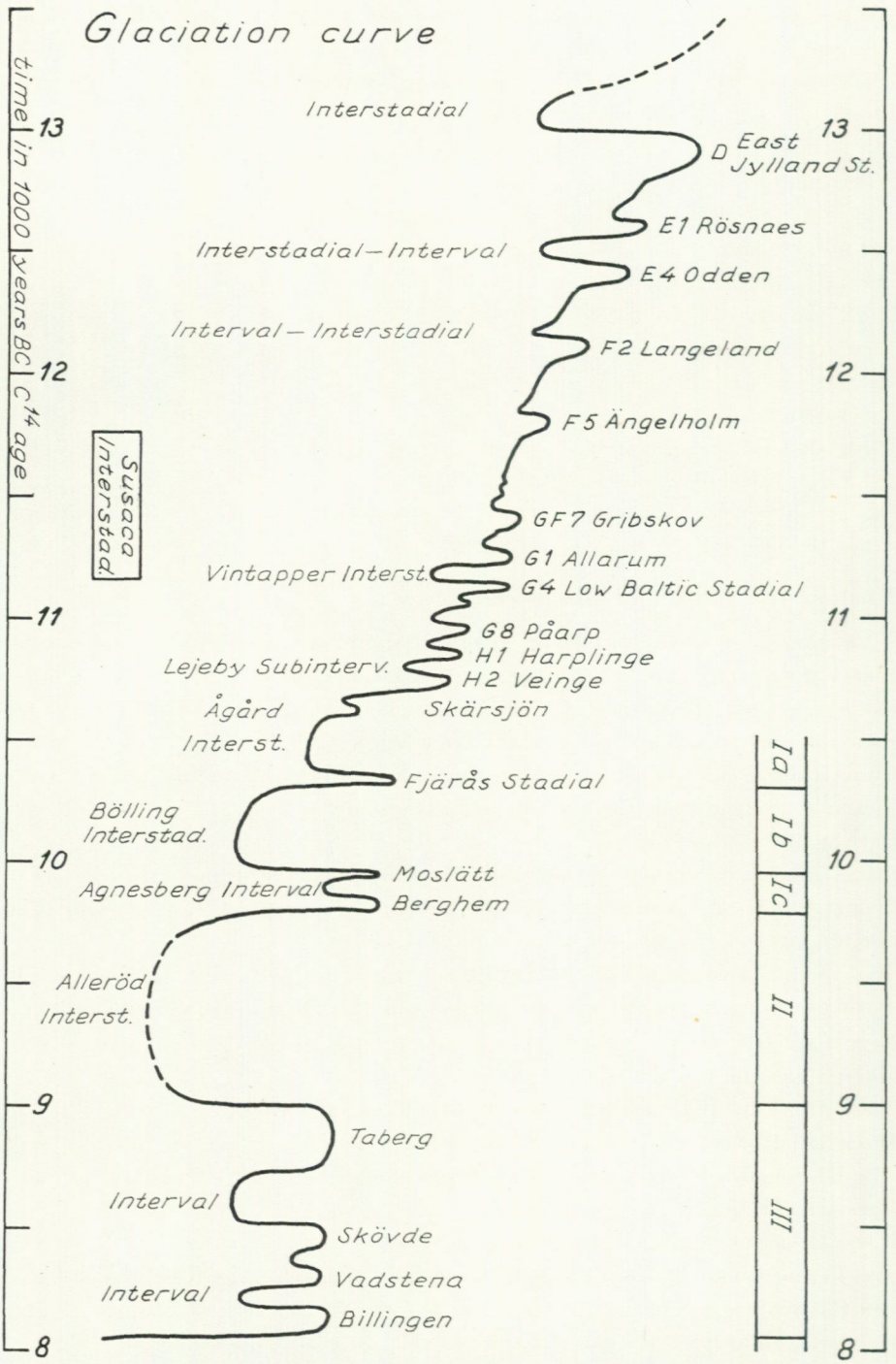


Fig. 42. *The glaciation curve for the time 13,500—8,000 BC in the Denmark-Kattegatt-Sweden area.*

Recession
Subinterval
The GF7 line about 11,400 BC — the Gribskov Staffel (or Phase)
Recession (subinterval)
The G1 line about 11,250 BC — the Allerum Staffel
Recession
Interstadial before 11,150 BC — the Vintapper Interstadial
The G4 line about 11,150 BC — the Low Baltic Stadial (= the Velgaster Stadial in Germany)
The G5 line about 11,080 BC — the Lomma Staffel
Recession
The G8 line about 10,950 BC — the Påarp Staffel
Recession
The H1 line about 10,850 BC — the Harplinge Staffel
Subinterval — the Lejeby Subinterval
The H2 line about 10,750 BC — the Veinge Staffel
Recession — the early Ågård Interstadial
The Skärsjön line about 10,600 BC — (the Skärsjön Staffel)
Interstadial — the Ågård Interstadial 10,700—10,350 BC
The Fjärås line about 10,350—10,300 BC — the Fjärås Stadial
Interstadial — the Bölling Interstadial 10,300—9,950 BC
The Moslätt line 9,950—9,925 BC — the Moslätt Phase
Interval — the Agnesberg Interval 9,925—9,850 BC
The Berghem line 9,850—9,800 BC — the Berghem Phase
The peroid 9,950—9,800 BC corresponds to Older Dryas Stadial or (local name) Berghem Stadial
Interstadial — the Alleröd Interstadial 9,800—9,000 BC
The Taberg Phase (the 9,100 line) about 9,000—8,800 BC, corresponding to the Salpausselkä I Phase
Recession — interval about 8,800—8,550 BC
The Skövde Phase (including the 8,700 line or Skövde Staffel and the 8,500 line or Vadstena Staffel) about 8,550—8,350 BC, corresponding to the Salpausselkä II Phase
Recession — interval about 8,350 to 8,250—8,150 BC
The Billingen Phase (including the 8,213 line or Billingen Staffel) about 8,250—8,150 BC to 8,050—8,000 BC, corresponding to the Salpausselkä III Phase.
The whole period 9,000—8,050 BC corresponds to the Younger Dryas Stadial or Ra-Billingen-Salpausselkä Stadial.
Recession — onset of the Postglacial; in this area also the most suitable boundary between the Pleistocene and Holocene Epochs and between the Würm Glacial and Flandrian Interglacial, though these boundaries are, for global climatic-eustatic reasons, proposed to be placed at about 7,330 BC (cf. p. 424).

The ALV shorelines

ALV stands for Ancient Lake Veselången, a valley lake that was isolated in the Viskan Valley during the transition between Late Glacial regression and Postglacial transgression. Three different stages and shorelines are distinguished, here called ALV-1, ALV-2 and ALV-3. These abreviations are also used to refer to the three periods in question.

As the ALV shorelines are now buried under the sediments of the Postglacial sea fiord, they must be studied by borings. However, this burial meant two very important things: that the shore features were preserved and that a stratigraphy was created that allows close datings by pollen analysis and C^{14} dating. The fact that the ALV shorelines belong to the Preboreal and Boreal periods is very important, as the pollen zonation is here very good: the *Betula* maximum (BM^0 and BM^1), the onset of the *Corylus* curve (C^0), the onset of the *Alnus* curve (A^0) and the development of the Oak Mixed Forest. Furthermore the stratigraphy is usually very clear and the Late Glacial clay can already in the field be distinguished from the Postglacial clayey mud or *Ruppia* mud (this does not apply to the reworked "blue-clay", cf. p. 193).

The Viskan Valley was thoroughly investigated by von Post over a period of almost 20 years. Von Post found the following main development of the Viskan Valley:

1. the Older Sea Fiord
2. the Ancient Lake Veselången, isolated at about BM^1 and transgressed shortly after A^0
3. the Younger Sea Fiord
4. the Recent Lake Veselången, isolated at about 2,400 BC (Wenner 1950) and drained in 1859 and 1917

Concerning the shorelevel displacement von Post never succeeded in getting the final solution of the problems. Von Post's investigation was definitely marred by two grave shortcomings; 1) the soil determinations by the students varied too much and one has to select between different possibilities when connecting up the layers — always a source of uncertainty, but extremely dangerous if one has a working hypothesis a priori, as von Post apparently had, 2) the datings did not hold (see my Preface in von Post † 1968). I think mainly three things made von Post interpret the results wrongly:

1. The Vänern extrapolation: Von Post wanted to show that his shorelines in the Vänern area (von Post 1929) also applied on the Swedish West Coast, which they apparently do not do. Von Post's Vänern shorelines have been seriously criticized by J. Lundqvist (1958) within the Vänern area itself.

2. The intersection of his PL 1 and PL 2: Von Post thought that the intersection found on Öland and Gotland should also apply in the Viskan Valley, which it does not. Von Post's "PL 1" belongs to the Late Glacial regression.
3. The shock transgression of F2e: At an early stage (1938) von Post thought he had proved this transgression by shore deposits below clay and clay above mud. This shoreline then made him postulate the other shock transgressions in his diagram. However, I have here shown that the "shore deposits" are not shore deposits, but were formed far below sea level (p. 148) and that the clay above mud corresponds to Younger Dryas and is a typical Dryas clay. On the whole no Late Glacial transgression was found.

However, von Post left important basic material. I have posthumously published von Post's chapter about the stage of Ancient Lake Veselången (von Post † 1968) in connection with the resumed investigation of the Viskan Valley. Von Post's borings and pollen diagrams have been used as basic material for my investigation too. Every section was redrawn exactly according to the old field notes, but only as far as the soil determinations allowed reliable connections. The pictures obtained often differed very much from those of von Post (e. g. Section 116, p. 189, and Section 45, p. 211). Insufficiently known or especially important points were checked by new borings. Suitable places were selected for sampling for close pollen and C^{14} datings. Several new sections were also bored. Concerning the ALV shorelines 210 new borings were made. Samples from 58 borings were brought to the laboratory for further analysis. The first summer all soil determinations in the field were made under the microscope. Samples from 42 boring points were pollen analysed. 32 samples from the Viskan Valley belonging to the ALV shorelines were C^{14} dated.

This resumed investigation resulted in the determination of the three ALV shorelines, very well fixed as to altitude and gradient and closely dated at several places along the shorelines. Also the direction of tilting was closely determined to 40° E. These results formed the ideal base for the amplified (in time and space) investigation.

The position of the sections and boring points are given in the map, Fig. 43 and the distance diagram of the ALV shorelines is given in Fig. 82 (cf. Pl. 5)

Description I: the ALV shorelines within the Viskan Valley

1. Section Getterön—Varberg (G—V)

A section was bored along the road from Getterön towards Varberg (Fig. 44). The section shows a submarine buried land surface in the form of a weathered blue-clay (a ground crust) down to at least –1.5 m and in a depression

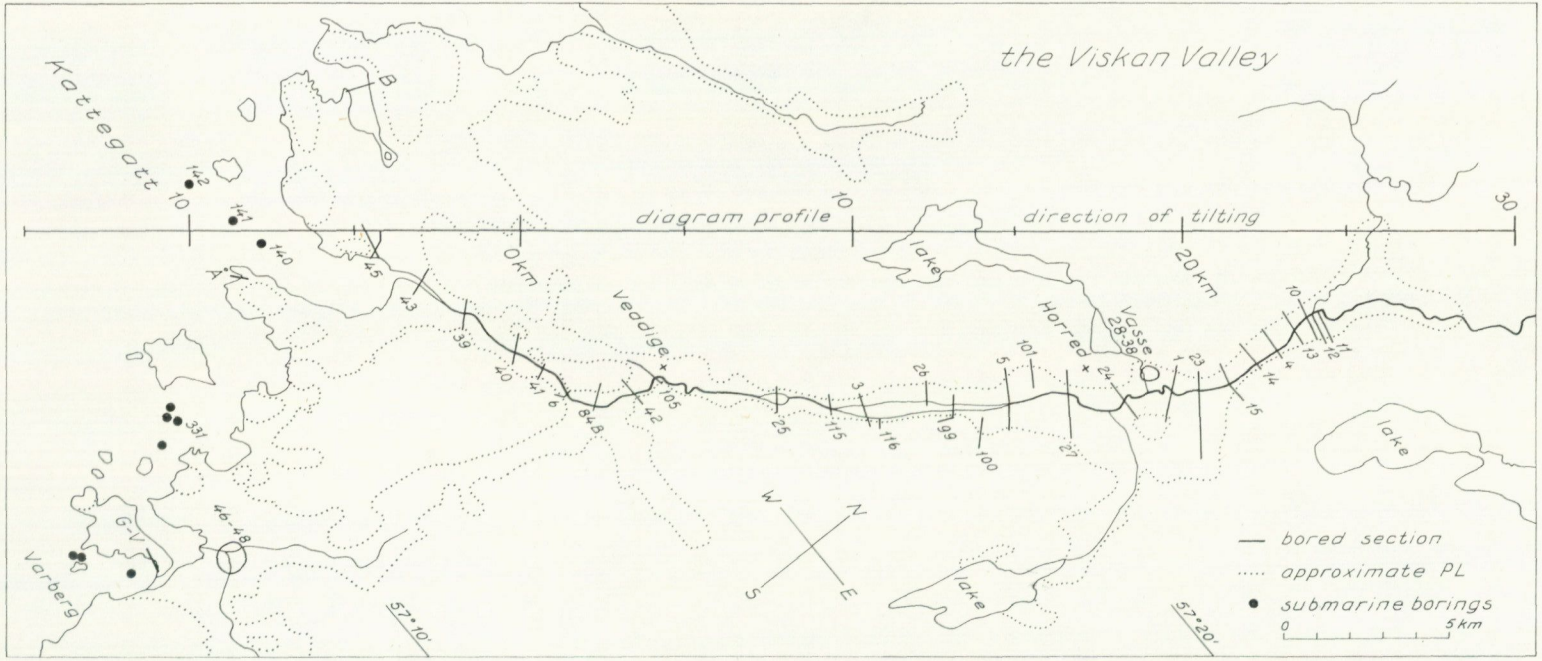


Fig. 43. *The sections and borings in the Viskan Valley in relation to the diagram profile line or direction of tilting. The O-point corresponds to Section 40, where ALV-1 intersects the present sea level.*

in this clay a thin peat layer at about –0.8—1.0. The peat was pollen dated (Fig. 45) to early zone V (BO-1). A C^{14} dating gave 7,205 ±120 BC.

Consequently, the shoreline ALV-1 here lay at least below –1.5 m and this peat layer was reached by the transgression up to ALV-2 shortly after C^0 or about 7,200 BC.

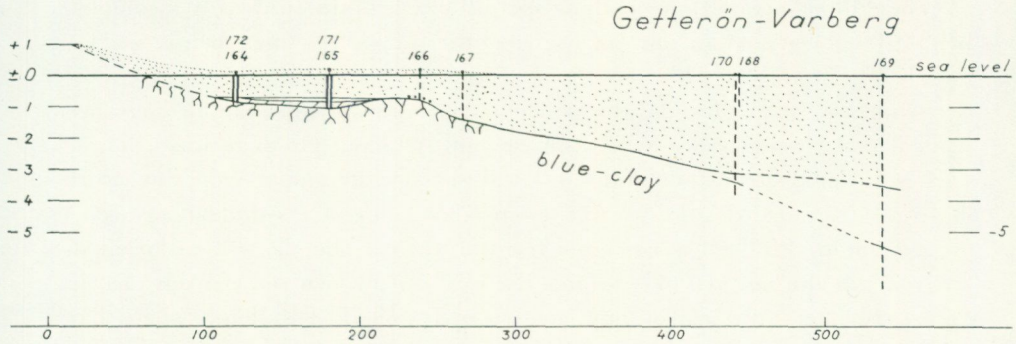


Fig. 44. *Section showing a buried submarine land surface.*

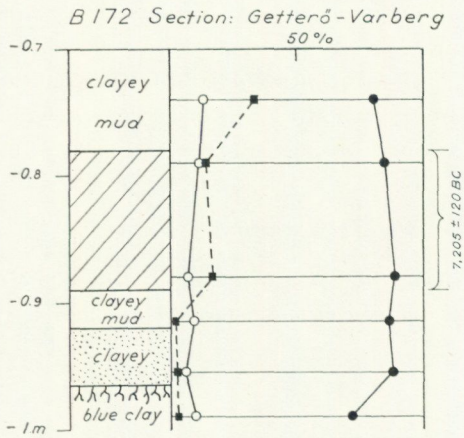


Fig. 45. *Pollen diagram from B 172 with C^{14} date from B 171. The peat was formed at the very onset of the first Postglacial transgression.*

2. The Getterön—Balgön area (B 331)

Between Getterön and Balgön there is a series of very well marked submarine till ridges (Fig. 30). In the depression behind these, four borings were made in order to find possible intermarine sediments (Fig. 43). Three of the borings gave sand and clay only.

B 331 at –6.5 m gave the following stratification:

A: to 6.60 m fine sand with shells
B: to 6.875 m clay, loose, flamed
C: to 6.91 m muddy clayey fine sand with shells
D: at least to 9.87 m glacial clay, semi-hard at the top and looser further down

The muddy clayey fine sand was pollen analysed: 62.3 % *Pinus,* 14.6 % *Betula,* 4.9 % *Alnus,* 2.5 % *Ulmus,* 4.1 % *Tilia,* 10.7 % *Quercus,* 0.8 % *Salix,* 9.8 % *Corylus,* 3.3 % NAP and 27.1 % *Hystrix.* The content of *Hystrix* shows

that it is a marine sediment, and the content of pollen dates the sediment to the earliest part of the Atlantic time (zone VII, AT-1), i. e. it was deposited in connection with the transgression up to PTM-2.

3. The Lindhov area, Section 46—48, BP 1194

These three sections have nothing special to tell, as they are fairly incomplete. BP 1194 (pollen and diatom analysed) is the interesting thing here (von Post † 1968, Figs. 1 and 33). The development has been summarized in Fig. 46, where the sediments, their altitude, the pollen index horizons and diatoms have been related to the found shore level displacement. At about C^0 there was a low sea level with mud formation and 20 % freshwater diatoms. According to the shoreline diagram, ALV-1 was only about 0.3 m above the sediment surface. As the altitude of PB 1194 is not quite fixed and it may be 0.2—0.4 m lower, the water depth during ALV-1 was about 0.3—0.7 m, which seems likely. During ALV-2 an alternating clayey mud/mud was deposited. The depth would have been 8.0 m. In connection with A^0 the sediments change to sandy clayey mud that contains a lot of shells and 10 % freshwater diatoms. Now the water depth should have been reduced to 5.2 m.

Consequently the stratification and diatoms do not contradict but support my interpretation of the development with the lowest shore level about C^0 and a second low stage from A^0 to shortly after.

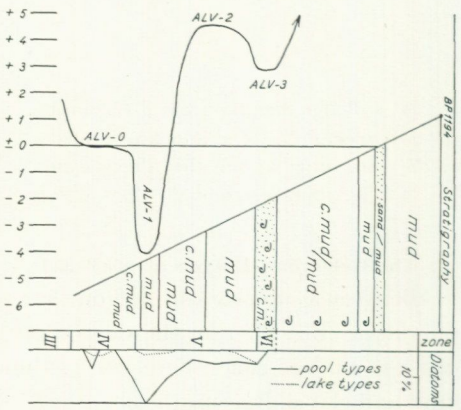


Fig. 46. *The shorelevel displacement curve in relation to the rising sediment surface, the stratigraphy, the pollen zones and the lacustrine diatoms in BP 1194.*

4. Klosterfjorden, B 140—142

Three borings were made in Klosterfjorden (Fig. 43) in order to find out whether any influence of the low shorelevel during ALV-1 could be found in the sediments.

B 140 at –9.0 m gave a 193.5 cm long core:

A: 4.0 cm of gravel with shells and algae. The grain size distribution curve (from the first boring, when the corer fell) gave a very uniform fine sand (97 %).

B: 189.5 cm of blue-clay with some shells. The uppermost 5 cm were lumpy.

B 141 at –13.0 m gave a 244.5 cm long core:

A: 6.0 cm of fine sand with single gravel grains and pebbles
B: 138.5 cm of loose homogeneous clay with sand-filled burrows. The clay contains shells and Fe S.

B 142 at –17.0 m gave a 237.5 cm long core:

A: (237.5 cm) a continuous transition from clay at the bottom to coarse silt at the top, i. e. from finer to coarser material. The shells are of Postglacial type at least in the upper part. A pollen analysis, 2.0 cm from the bottom, gave a flora that clearly belongs to zone V (BO-1), i. e. the time after ALV-1.

5. Båtfjorden (Bua—Videbergshamn)

Båtfjorden is a long, narrow and shallow bay, where submarine ground crusts and mud/peat layers ought to have been preserved from later erosion. A section was bored from the ice straight across the inner part of the bay. However, this section only shows a loose blue-clay covered by sand. The surface of the blue-clay was followed between –0.40 and –3.70 m.

6. Lahall at Klosterfjorden, Section 45

This locality is situated just outside the present mouth of the River Viskan. Here von Post has his Section 45 (von Post † 1968, Fig. 2). As this section is important a new section containing 30 boring points was made just north of von Post's section.

Von Post's section was redrawn exactly from the old field notes and reinterpreted (Fig. 47). According to this picture there is only one buried ground crust (except the recent one) which is covered by a more or less continuous layer of pitchy soil, the residue of a wet shore meadow, which has been transgressed and buried (cf. p. 13). As the dating of the pitchy soil and the clay above was important for this investigation, von Post's old samples were analysed once again. With differences in the percentage of *Betula* and *Corylus* (obviously due to confusion in identification) both diagrams show that the pitchy soil belongs to the earliest time of zone V (BO-1) and that the clay (probably muddy) belongs to zone V (BO-1) and (only the uppermost part) to zone VI (BO-2).

As von Post's "loam" (in this section) has turned out to be equivalent to my Late Glacial blue-clay, von Post's statement that it contained A^0 in BP 1197 was surprising. The lowermost sample in BP 1197 (just above the sand-gravel) was pollen analysed. Obviously it belongs to late zone VI (BO-2) or earliest zone VII (AT-1), i. e. about the onset of the transgression up to PTM-2. A microscopic soil determination gave: clayey mud, doubtless equivalent to von Post's "mud". This means that there is a marked notch at BP 1197 at +2.0 m. This notch in the blue-clay was, according to this interpretation, cut by a sea level in Preboreal time.

Von Post's buried till ridge has neither been found in my section nor by geotechnical borings in the same area.

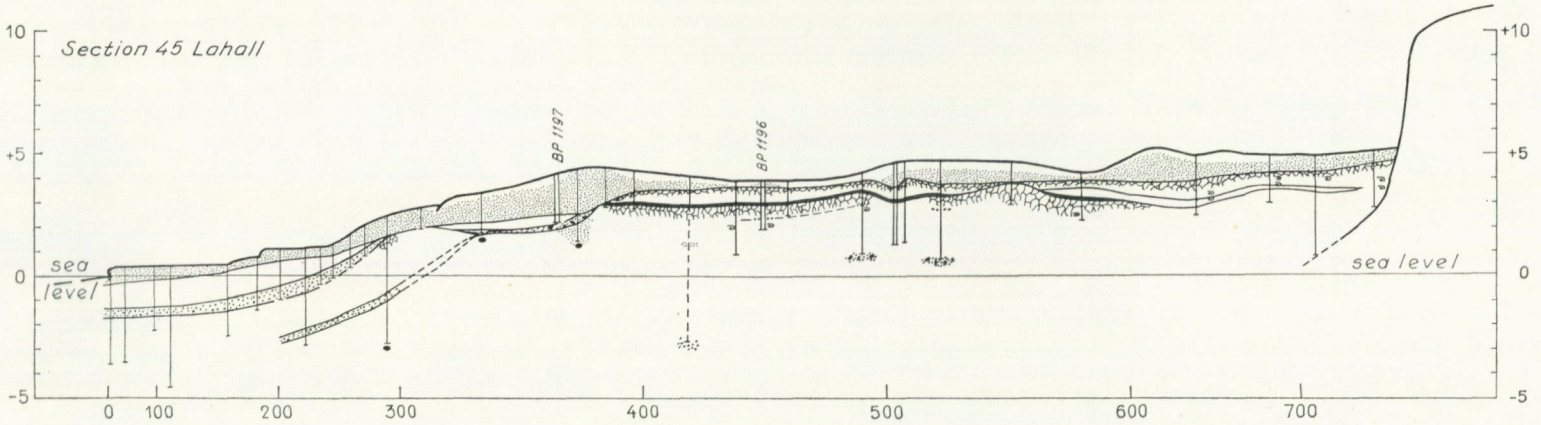


Fig. 47. *Von Post's section redrawn from the old field notes.*

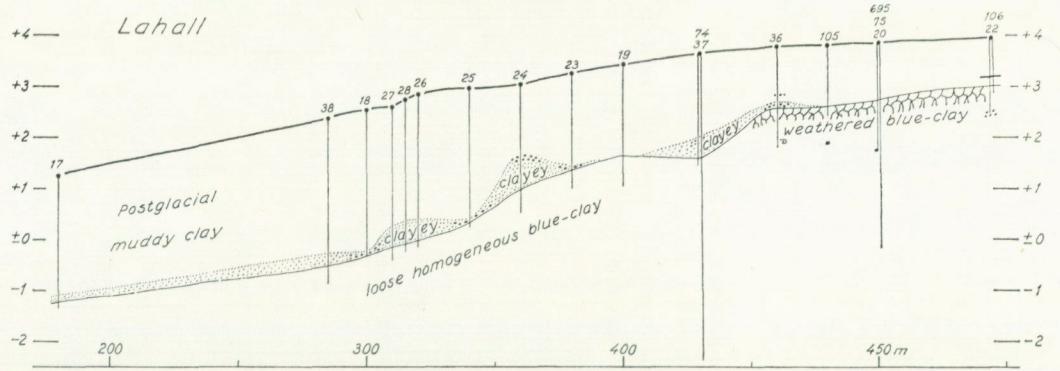


Fig. 48. *New section at Lahall showing a buried shore cut at +1.7 m, probably formed during ALV-0.*

In von Post's figure there is a submarine buried ground crust down to 1.80 m. However, the field notes only say: "lumps and pieces of harder clay in a loose blue-clay". In my section I have not found any traces of weathering of the clay surface between −2.25 and +2.00 m. However, there is, both in my section and in von Post's, a sandy-gravelly layer about 10 cm thick upon the surface, which could indicate a low shorelevel during ALV-1 — the shoreline diagram says −2.00 m.

My section has shown a clear notch in the blue-clay surface with its base at +1.60 m (Fig. 48). In B 36 to B 22/106 the blue-clay surface is highly weathered to a ground crust (as the layer just above is loose, it cannot be the recent ground crust). Later 27 samples from B 695 were geotechnically analysed, showing a quite obvious weathering of the blue clay surface; the H_3 and H_1 values are high and the water content (W) is low compared to the fineness numbre. In B 37/74 the blue-clay is loose and homogeneous, without any sign of ground crust. The notch in the blue-clay seems to me to be a shore cut. The interpretation as a shore is supported by the sand ridges which lie just outside the shore cut (Fig. 48) and which seem to be some kind of offshore bars. This shore cut is also seen in von Post's section, redrawn as described above.

The pollen diagram of B 105 (Fig 49) shows that the muddy clay just above the blue-clay surface belongs to the earliest part of zone VII (AT-1), i. e. the sedimentation started in connection with the onset of the transgression up to PTM-2. The pollen diagram of B 106 (Fig. 49) shows that the sediments above the blue-clay surface belong to zone V (BO-1) and that consequently the transgression started already in early zone V (BO-1).

In order to get a C^{14} date of the pitchy soil, samples were taken at a point B 1 about +2.95 m between von Post's and my sections. The pitchy soil was found 0.46—0.50 m down. The samples contained roots, which were removed. The C^{14} dating gave 5,845 ±150 BC. This should date the pitchy soil to the onset of the transgression up to PTM-2 and consequently the shore cut at +1.60—1.80 m would belong to ALV-3. Earlier I thought this was correct. However, new localities have fixed the ALV-3 shoreline at about +4.50 m. Furthermore, a pollen analysis of the C^{14} dated sample (Fig. 49) shows that it belongs to the early zone V (BO-1). As this was an important question, a new series of samples were taken at the same place, B 321. The pollen diagram (Fig. 49) clearly shows that the pitchy soil belongs to early zone V and the clayey mud above to zone V. This means that it was the transgression up to ALV-2 (=PTM-1) that caused the formation of pitchy soil and deposited the clayey mud. The C^{14} date gave too young an age, probably due to the contamination by roots (the misleading thing was that the age exactly agreed with the age of the onset of the transgression up to PTM-2).

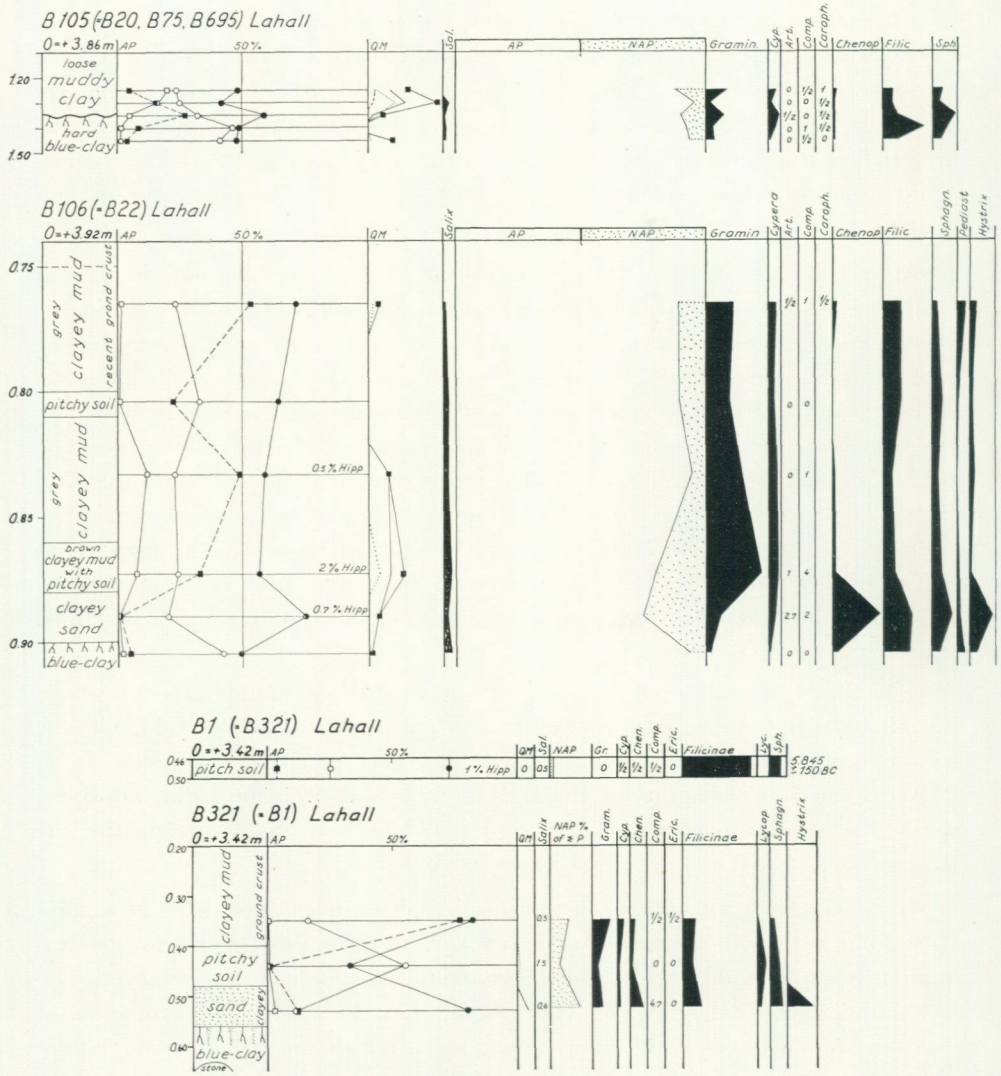


Fig. 49. *Pollen diagrams from the new section at Lahall.*

As there was no time for a stagnation in the transgression from ALV-1 to ALV-2, the shore cut at about +1.6—1.8 m must be older than ALV-1 and belong to a stagnation in the regression down to ALV-1 in Preboreal time. Corresponding shorelevels have also been found in other localities (Pl. 5).

7. The present mouth of River Viskan at Äskloster

Von Post's Section 43 (von Post † 1968, Fig. 2) only shows that a sandy-gravelly layer between the Postglacial mud and the Late Glacial silt reaches

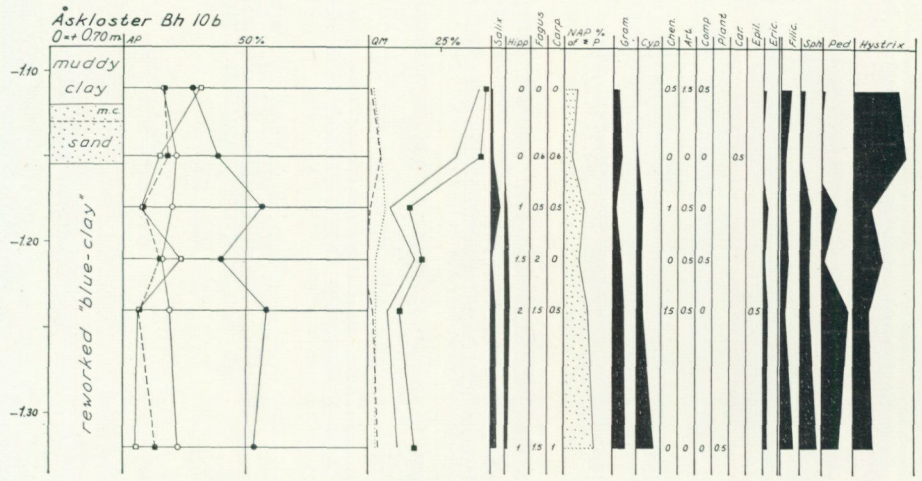


Fig. 50. *Pollen diagram from the mouth of River Viskan.*

down to –2.0 m and that there is layer of necron mud from ±0.0 to –0.9 m. I tried to find this layer of necron mud in order to date it, but did not succeed.

From geotechnical work at the mouth of River Viskan by the firm Vattenbyggnadsbyrån, I obtained three series of samples taken with a piston corer. The one of interest in this connection, Bh 10b, lies at the very mouth of River Viskan. In Bh 10b samples have been taken down to 11.58 m. The pollen diagram (Fig. 50) around the limit "blue-clay"/muddy clay shows that the "blue-clay" is a reworked "blue-clay", which was deposited in zone VI (BO-2). The limit between the reworked "blue-clay" and the real blue-clay could possibly be about 6.0 m down, as the occurrence of gravel grains 5.5—6.0 m down could indicate the stage of ALV-1. The sand layer below the muddy clay belongs to the very onset of the transgression up to PTM-2. Thus nothing can be said about the level of ALV-1 out of this boring.

8. Section 39

This section, as well as the following one, shows a buried stream channel, which has been eroded down to roughly the same depth as the one of the recent River Viskan (von Post † 1968, Fig. 3). Von Post found the following development:

1. shallow estuary at +1—2 m at about the time of C^0
2. transgression, the "*Corylus*-transgression", up to about +3 m
3. regression at about A^0 down to about ±0 m.

One of the first things that struck me was that this interpretation could not hold, as A^0 is found in free marine sediments at +2.35 m in BP 1233 (similar in other sections) and as the lowest shorelevel consequently must belong to the time about C^0.

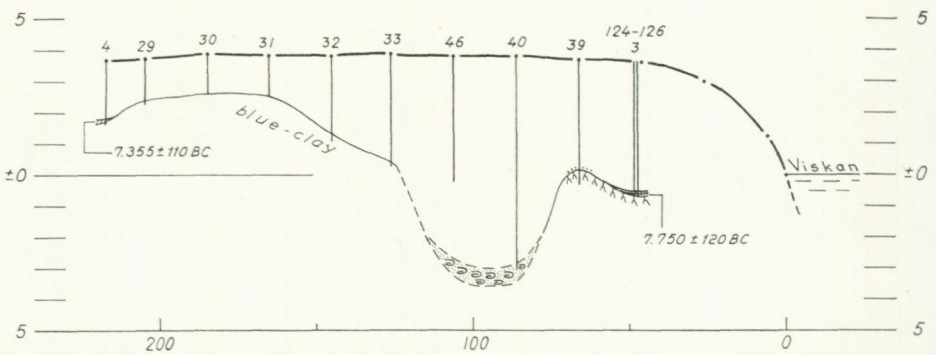


Fig. 51. *New section at Section 39 showing the buried ancient river bed of River Viskan and C¹⁴ dated organic layers from ALV-1.*

On both sides of the buried stream channel there are layers of *Phragmites* peat and mud. A new section (Fig. 51) gave roughly the same picture. In von Post's BP 1233 there is 10 cm of *Phragmites* peat resting upon a weathered blue-clay at +1.80 m. The pollen diagram dates this layer to the earliest part of zone V (BO-1), (von Post † 1968, Fig. 6.). In my B 4 (= BP 1233) there

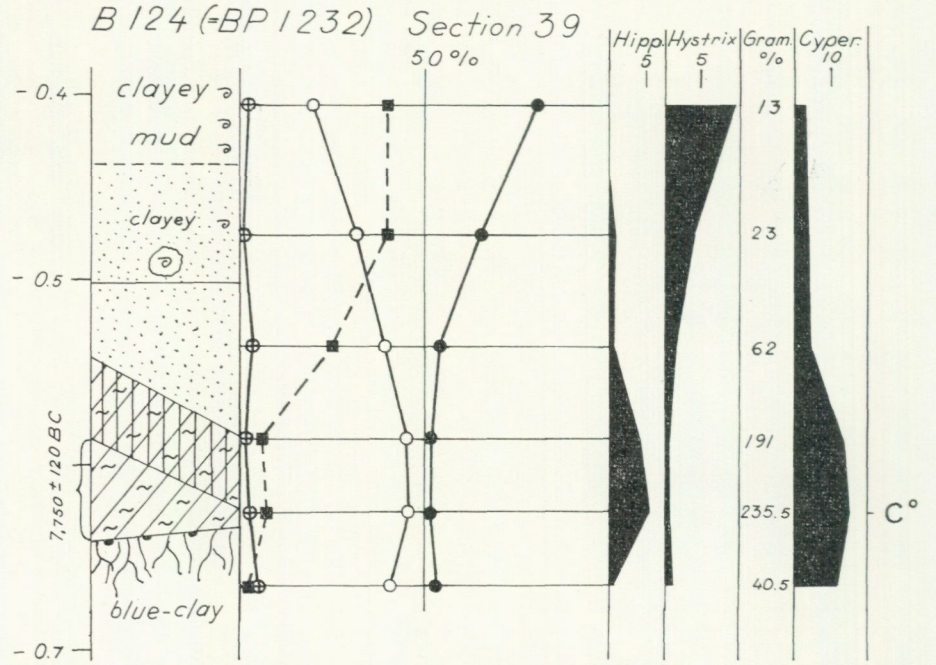


Fig. 52. *Pollen diagram of B 124 (= B 3). The intermarine detritus mud was formed in close proximity to the shore of ALV-1, as indicated by the content of Hippophaë. The subsequent transgressions is clearly shown by the sediments and the rising curve of Hystrix. The C¹⁴ date gives the age of C° on the Swedish West Coast.*

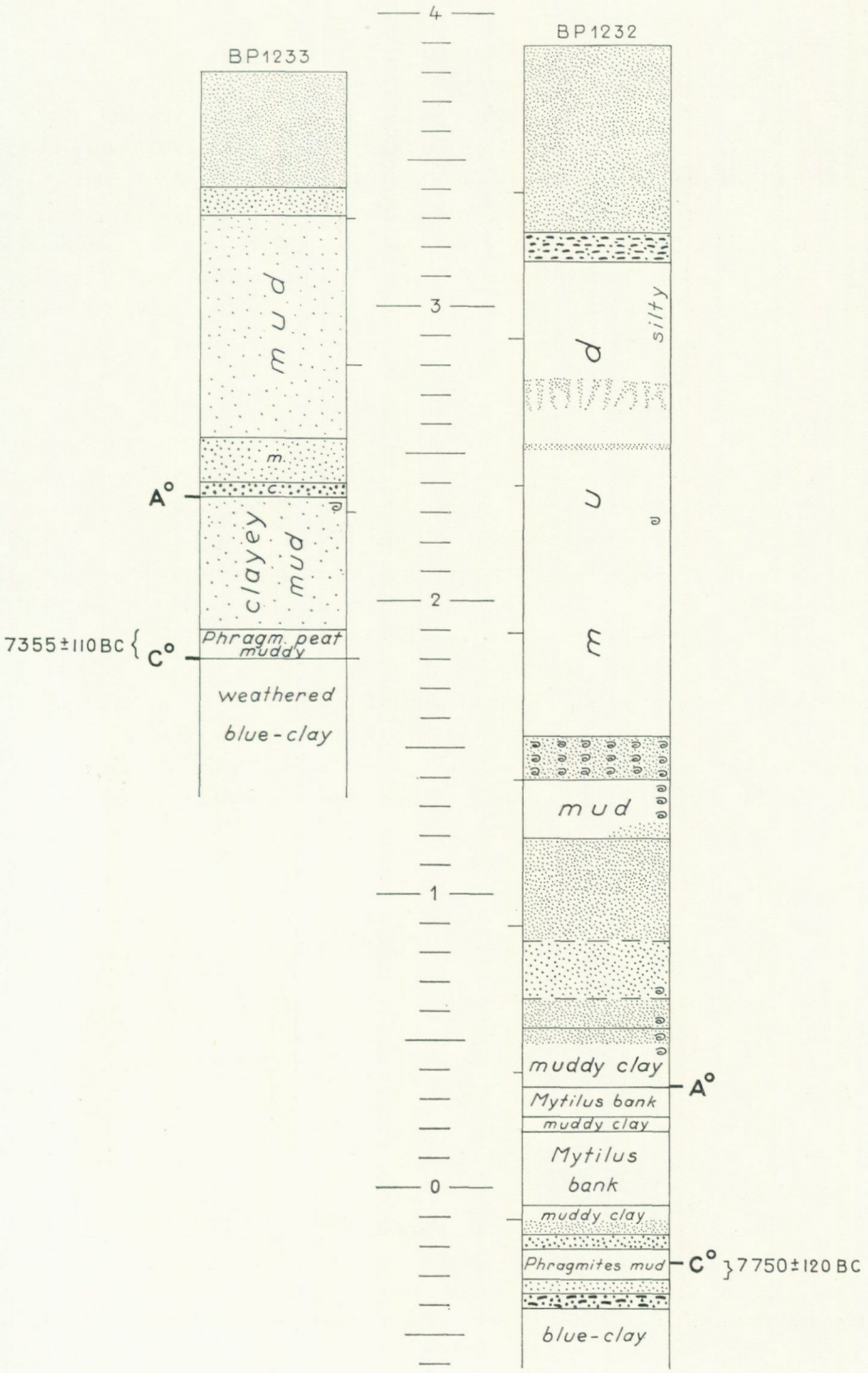


Fig. 53. *Von Post's pollen analysed borings with the C^{14} dates from my borings added. The marine transgression of ALV-2 (= PTM-1) is obvious. The aggradation during ALV-3 is seen in the sand layers at and just above A°.*

is 10 cm of *Phragmites* mud (almost peat) resting upon a loose blue-clay at +1.70 m. The mud in B 4 was C^{14} dated at 7,355 ±110 BC. In von Post's BP 1232 there is 10 cm of *Phragmites* mud resting upon 10 cm of sand and shingle on a blue-clay at –0.40 m. According to the pollen diagram (von Post † 1968, Fig. 5), the *Phragmites* mud was formed just around C^0, i. e. at the transition zone IV/V (PB/BO-1). In my borings B 3 and B 124—126 (=BP 1232) there are 2 cm of pitchy soil in detritus mud and 3 cm of coarse detritus mud (peaty, which rests upon a weathered blue-clay at –0.65 m. The *Phragmites* mud in B 3 contained a green wing of an unclassified insect and a shell of a freshwater mollusc (probably *Anodonta*). The microfossil content indicates a terrestrial or almost terrestrial formation very near the shorelevel. B 124 was pollen analysed (Fig. 52). The pollen diagram dates the *Phragmites* mud to the very onset of the *Corylus* curve. The high percentage of *Hippohaë* (and *Cyperaceae)* in the *Phragmites* mud shows close proximity to the shorelevel. The rise of *Hystrix* nicely illustrates the transgression, which is also seen in the sediment development, from sand to clayey mud with marine shells, and the formation of pitchy soil in the upper part of the mud. The lowermost part of the *Phragmites* mud was C^{14} dated at 7,750 ±120 BC. This date gives the age of C^0 on the Swedish West Coast. It also gives the time when the regression had brought the sea level down to the "regression maximum" or the ALV-1 shoreline.

Von Post's pollen analysed borings, BP 1232—1233, have been combined (in altitude) in Fig. 53 and supplied with the pollen index horizons C^0 and A^0 and the C^{14} dates from my borings. This combination and the diagram of B 124 (Fig. 52) beautifully show that a marine transgression started shortly after C^0 or, more exactly, 7,330 BC according to C^{14} dates. This transgression brought

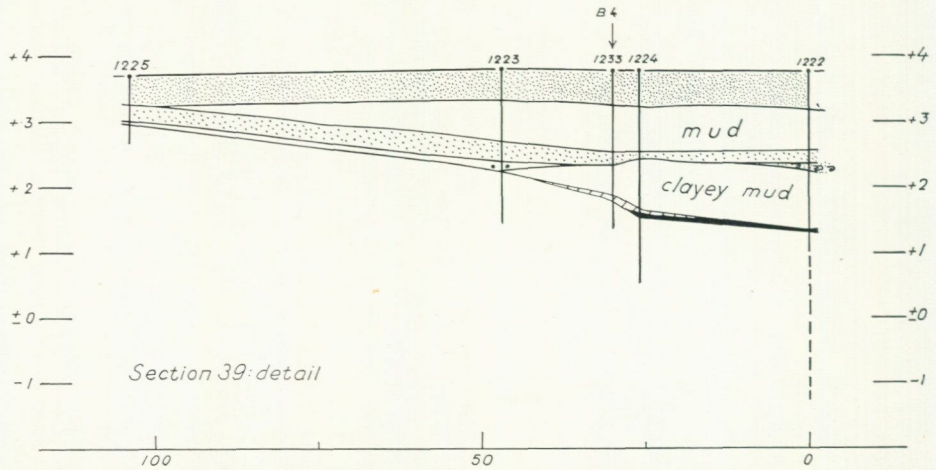


Fig. 54. *The sand layer of ALV-3 is here shown to have a wide distribution, indicating a distinct aggradation.*

the sea up to the shorelevel ALV-2 depositing clearly marine sediments in Section 39. In fact this is the first Postglacial transgression, and the maximum shall thus be named PTM-1, which consequently is equivalent to ALV-2. According to the shoreline diagram the transgression should have brought the sea up to about +7.00 m. However, this level cannot be fixed either by shore marks (later destroyed) or by sediments (only sand).

About the time of A^0 the sediments turned sandy — in BP 1233 coarse and medium sand (Fig. 53). The sand layer in BP 1233 can be followed laterally (Fig. 54), which shows that it is a real aggradation. I connect this aggradation with a small regression of about 1.5 m from ALV-2 down to ALV-3 (fixed in other localities). The sand was deposited during the syngression of ALV-3. The shorelevel of ALV-3 cannot be fixed closer than slightly above +3.0 m. In the middle of the buried stream channel, no sedimentation took place till the onset of the classical Postglacial transgression up to PTM-2 according to von Post's pollen diagram in BP 1231.

9. Section 40

This locality marks the place where the ALV-1 shoreline intersects the present sea level. This is nicely illustrated by Section 40 (Fig. 55), in which the ancient and recent stream channels of River Viskan are shown eroded down to roughly the same level (cf. von Post † 1968, Fig. 3). Section 40 is used as the zero point in the shoreline diagrams. Somewhere about BP 987 in von Post's section I have taken a sample (four cores with a piston corer) of the contact between the blue-clay and the superposed clayey mud. The surface of the blue-clay (here at +2.40 m) is strongly weathered into a ground crust and is covered by a thin layer of pitchy soil (Fig. 55). A pollen diagram (Fig. 56) dates this pitchy soil to the time just after C^0, and a C^{14} dating gave 7,330 ±110 BC, which must be regarded as a very good date of the onset of the transgression up to ALV-2, bearing in mind the genesis of the pitchy soil (p. 13).

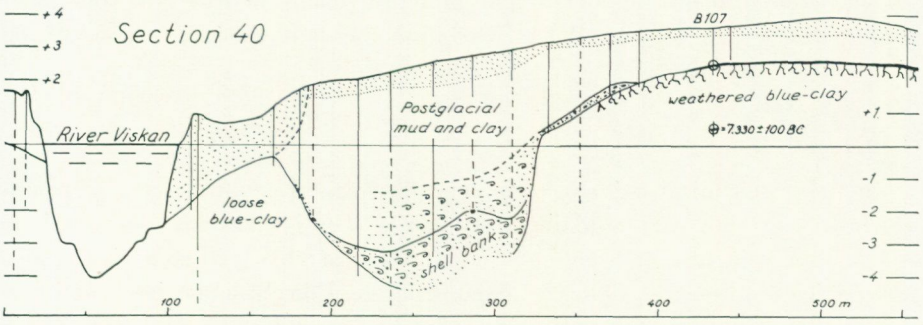


Fig. 55. *Section 40, the O-point in the distance diagrams, where ALV-1 intersects the present sea level. Note the equal depth of the present and buried river channels. The C^{14} date in B 107 gives the onset of the first Postglacial transgression.*

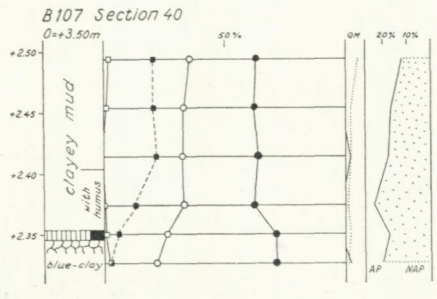


Fig. 56. *The C¹⁴ dated sample = 7,330 ± 110 BC.*

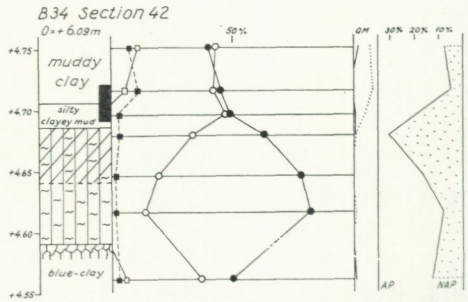


Fig. 57. *The C¹⁴ dated sample = 5,850 ± 330 BC.*

The short pollen diagram of B 107 does not clearly tell where A^0 lies — but it must be at least +2.50 m. The important thing is that A^0 lies in free marine sediments, i. e. where neither sand layers nor hiatus are found. This means that the ALV-3 shoreline must have been some metres above +2.50 m and this is evidence that I am right in thinking that the lowest shorelevel was at the time about C^0 and not about A^0 as von Post († 1968) thought. According to the shoreline diagram, ALV-2 falls at +7.8 m and ALV-3 at +6.3 m. These levels cannot be fixed in the field in this section.

10. Section 41

Von Post's section (von Post † 1968, Fig. 8) shows a ground crust down to at least +2.0 m and a probable shore mark at +0.30—0.40 m. This fits with my shoreline diagram where ALV-1 is at +0.45 m. The blue-clay surface is covered by a layer of sand, which towards the channel changes over into a shell bank of *Ostrea,* etc. Apparently this layer belongs to the stage of shallow water during ALV-2 and ALV-3 (+8.0 and +6.5 m, respectively). Consequently the shell bank formation gets an indirect dating. This means that *Ostrea edule* had reached the Viskan Valley already in Boreal time, or more exactly in zone VI (BO-2) or possibly even in late zone V (BO-1). Obviously the shell banks in Sections 39 and 40 are of the same age.

11. Derome

In the geotechnical archives of Statens Järnvägar I found a series of results which are very important for this investigation. Ten borings had been made in four sections south of Derome station. Six of these borings had been geotechnically analysed. All six analysed series very nicely show the presence of a double ground crust, viz. partly the recent one reaching about 1.0 m down in a clayey mud (surface at about 6.0 m) and partly a buried ground crust at +2—3 m in a clay. This is very good evidence of the buried land surface of ALV-1 —

found and proved entirely for geotechnical purposes. The figures of the analyses in two borings are listed below. There are 30 m between the borings. In both cases the present surface is at +5.9 m and the limit clayey mud/clay at +2.0 m.

Depth	Boring I					Boring II				
	V	W_F	H_1	H_3	S_t	V	W_F	H_1	H_3	S_t
+4.80	44	138	98	220	2.2	54	218	98	281	2.8
+4.30	56	136	12	51	4.3	54	145	19	58	3.0
+3.80	56	126	10	62	6.2	55	120	10	63	6.3
+3.30	56	119	8.6	69	8.0	55	127	11	65	5.9
+2.80	61	176	15	84	5.6	59	150	12	82	6.8
+2.30	44	85	14	109	7.8	60	166	14	75	5.3
+1.80	26	—	98	675	—	30	67	107	296	2.8
+1.30	31	68	93	349	3.8	31	68	104	241	2.3
+0.80	37	62	14	98	7.0	38	61	9.6	64	6.7
+0.30	41	65	8.1	62	7.7	40	63	6.7	56	8.4
—1.20	34	48	6.7	54	8.1	41	63	6.9	56	8.1
—1.70	35	52	8.0	71	8.9	41	65	7.8	52	6.7
—3.20	34	49	7.7	52	6.8	43	70	6.5	72	11.0
—3.70	33	47	8.0	59	7.4	42	67	6.8	64	9.4
—6.20	32	45	10.0	75	7.5	36	53	8.3	82	9.9
—6.70	30	44	11.0	84	7.6	36	53	8.4	62	7.4

These figures clearly speak for themselves and there can be no doubt about the presence of a double ground crust. The deepest level of the weathered clay surface is found at +2.0 m, but the weathering doubtless reaches down at least to +1.30 m. According to the shoreline diagram, ALV-1 here falls at +0.6 m, i. e. in very good agreement with these results. It also shows that von Post was correct in stating that the rapid at Åsbro was formed in connection with the classical "Postglacial transgression".

I have made a boring B 562 in the same area with the helical auger. This boring shows that the clayey mud is a Postglacial *Ruppia* mud (at the bottom) and clayey mud with shells and that the clay is a Late Glacial blue-clay. The blue-clay surface was found 4.25 m. down. It was clearly weathered and in the uppermost part impregnated by humus giving a pitchy soil.

12. Section 6, the rapid at Åsbro

With this section von Post († 1968, Fig. 8) found that the rapid at Åsbro is of a young age and did not exist at the time of Ancient Lake Veselången, when a stream channel was eroded down to at least −2 m. According to the shoreline diagram the sea level during ALV-1 was at +0.7 m, which means that there was no damming at Åsbro. This is proved by von Post's pollen diagram of BP 52 which already shows an Atlantic flora at the bottom of the boring.

13. Section 84B

Von Post († 1968, Fig. 7) thought he could follow a layer of "loam" with shells up to +10.6 m. According to von Post this layer, which rests upon a ground crust, is older than A^0. Thus von Post states that it is "evidently another record of the *Corylus* transgression". When I studied von Post's section more closely, I was surprised to find that A^0 was below this layer of "loam" in BP 1746. There must be a mistake somewhere. Thus I made a new drawing of von Post's section very carefully from the field notes. The picture obtained is in some places different from von Post's figure.

The pollen diagrams in this section are not of sufficient quality to help much in the estimation of the stratification.

I think the following development can be found in Section 84B: In the Older Sea Fiord a blue-clay and a thin layer of muddy clay, both containing shells, were deposited. During ALV-1 the surface of these layers was weathered into a ground crust. This weathering can be followed down to +3.5 m. A series of depressions in the outer part of the section could possibly represent a meandering brook. However, the field notes say nothing about a layer of sand and gravel in these depressions. According to the shoreline diagram ALV-1 lies at +1.2 m, ALV-2 at +8.6 m and ALV-3 at +7.1 m. A small shore cut at +7.3 m (not visible in von Post's section) could belong to ALV-3.

14. Section 42

Von Post's section († 1968, Fig. 8) shows a buried stream channel. He states that this channel "seems hardly capacious enough for a river of the size of River Viskan". However, the channel is 55 m in breadth and (according to my interpretation) 3.5 m deep, which means that it was most probably eroded by the predecessor to River Viskan during ALV-1.

The ancient channel is separated from the recent one by a marked terminal moraine. Topographically the buried channel ought to have had a rapid towards south. According to the shoreline diagram the sea level during ALV-1 was here crust can be followed down to at least +4.5 m. The lowermost layer of pitchy soil can be followed down to +4.55 m. The water level during ALV-1 was consequently somewhere below +4.5 m, probably about +4.0 m. This means that the water level was dammed about 2.2 m above the corresponding sea level, i. e. it was on a level with the well determined lake level, ALV-1b, of Ancient Lake Veselången (cf. Fig. 82).

A series of samples, B 34, was taken with a piston corer (Fig. 57), between von Post's BP 1040 and 1042. This boring shows a weathered blue-clay surface at +4.60 m, covered by 10 cm of "pitchy soil". This "pitchy soil" turns out on closer examination to be formed in a fine detritus and a coarse detritus mud, probably originally high-water sediments that, in connection with the transgression up to ALV-2, were impregnated by humus and received their character of pitchy

soil. According to the pollen diagram the black layer belongs to early zone V (BO-1). A^0 lies in free marine sediment at +4.71 m. This means that the sea level must have been some metres above this level during ALV-2 as well as during ALV-3. A C^{14} dating of A^0 gave 5,850 ±330 BC, which is younger — for some unknown reason — than one would expect.

ALV-2 should according to the shoreline diagram lie at +9.0—9.2 m in this section. Shore cuts at about +8.5—9.0 m are present in the NE as well as the SW valley slope.

ALV-3 ought to lie at +7.5—7.7 m. In the NE part of Section 42 there is a 0.35 m thick sandy-gravelly-stony layer, which seems to be a shore deposit and belong to ALV-3.

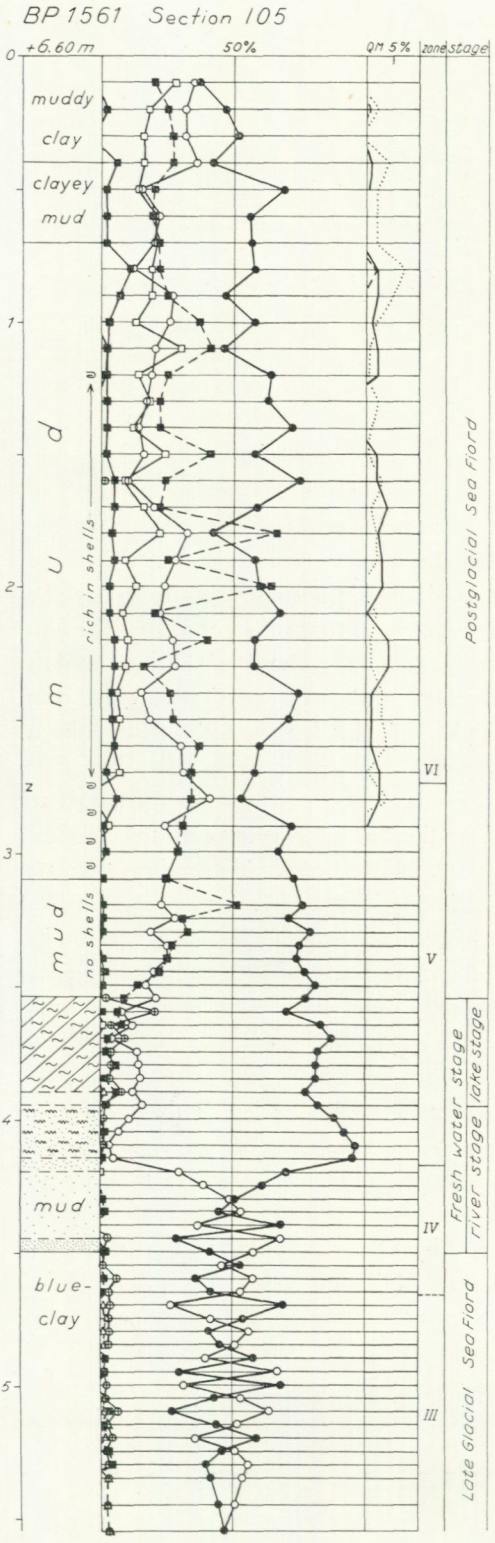
15. Section 105

This section shows three terminal moraine ridges with two depressions between, which von Post interpreted as separate lakes (von Post † 1968, Fig. 9). The glacial and Late Glacial deposits have been dealt with above (p. 148).

I interpret the SW depression as a separate lake called Lake II, which was formed in a kettle hole. The characteristics of a kettle hole can still be seen in the ground. The till ridge in south was a valley threshold that prevented River Viskan from taking this shorter and more natural way direct to the sea. The threshold of Lake II is a till ridge in NE that today reaches +9.2 m. As the shoreline diagram says +9.2 m for ALV-2 and +7.5 m for ALV-3, this lake would not have been transgressed until the transgression up to PTM-2.

The NE depression, called Lake I, is connected with the stream channel in Section 42. This connection is supported by the results of geotechnical investigations for the main road Veddige—Varberg. Now the question arises whether this Lake I was a separate lake emptying via Section 42 or was a broader part of the ancient River Viskan. The character of separate lake may be suggested by the absence of fluvial sandy sediments (according to new borings) and the presence of a layer of coarse detritus mud straight across the lake, which shows that there was not any strong stream in this lake. The character of a part of the ancient River Viskan is suggested by the obvious connection with the stream channel in Section 42 (Fig. 58). However, I think the best explanation is that this lake originally was a part of the ancient River Viskan, but that the river already in an early part of ALV-1 found — totally or partly — a new way across the till ridge between Lake I and the recent River Viskan and left Lake I to the first stages of overgrowth (cf. the last column in Fig. 59).

In Lake I von Post has pollen analysed BP 1561 (Fig. 59). In connection with these analyses the most characteristic diatoms were noted. Von Post's statement about "an indication of the *Corylus* 'transgression' ... Between BM^0 and C^0" is only based upon these diatoms (note that von Post in other sections placed this "*Corylus* transgression" between C^0 and A^0). This seems to me to be too loose a



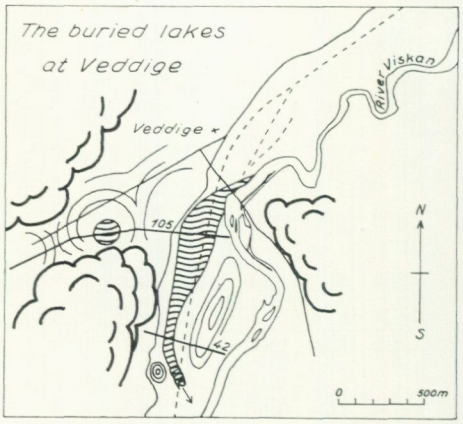


Fig. 58. *Wavy areas = buried lakes.*

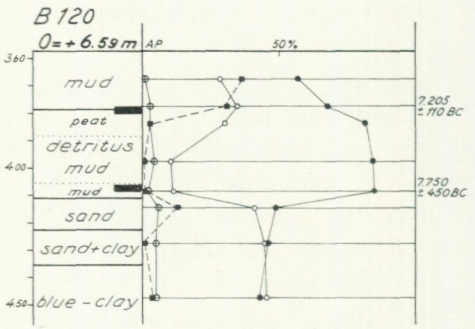


Fig. 60. *Pollen diagram from Lake I.*

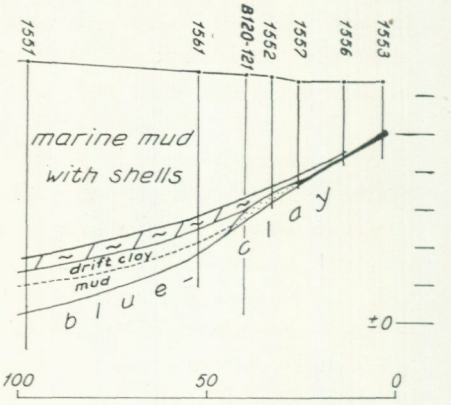


Fig. 61. *The western margin of Lake I.*

Fig. 59. *Pollen diagram from Lake I.*

foundation for such an important statement. Two continuous cores of 6 m length were taken near BP 1561 (Fig. 61) with a foil piston corer. These cores showed a layer of coarse detritus mud — in the upper part almost peat — which according to microscopic determinations must have been deposited in freshwater. A series around this intermarine layer was pollen analysed (Fig. 60). The diagram says about C^0, the age of the onset of the mud formation ought to be seems to have started with zone V (BO-1). The lake was transgressed by the sea in early zone V (BO-1), apparent in the change from peaty coarse detritus mud to mud. Two C^{14} datings were made. The upper 2.5 cm of the peaty coarse detritus mud gave 7,205 ±110 BC, i. e. the time of the onset of the transgression up to ALV-2. A sample of the lowermost 2.5 cm of mud was destroyed at the laboratory, but a new sample 2.5—5.0 cm above the limit mud/sand gave 7,450 ±450 BC. The margin of error is too great for a closer dating, but as the pollen diagram says about C°, the age of the onset of the mud formation ought to be about 7,700—7,600 BC. According to BP 1561 the isolation seems to have occurred in zone IV (PB). According to the layers of pitchy soil and sand (Fig. 61) the level of ALV-1 should be +4.0—3.5 m, which agrees with Section 42. The altitude of ALV-2 and ALV-3 cannot be fixed here but the shoreline diagram says +9.2 and 7.7 m respectively. In BP 1561 A^0 lies in free marine sediments (a mud rich in shells) at +3.55 m.

In Lake II the development was different according to von Post's pollen diagrams. A layer of coarse detritus mud reaches across the lake (Fig. 62). This layer was deposited in a freshwater lake according to diatom analyses in BP 1540. According to the pollen diagram of BP 1540 this lake was isolated in earliest zone IV (PB) or at the transition zone III (DR-3)/IV (BP) and was transgressed in zone VI (BO-2), clearly after A^0. With a foil piston corer two continuous cores 9.90 m down were taken near BP 1540. The lowermost 2.0 cm of the freshwater mud was C^{14} dated at 8,450 ±170 BC (closer dealt with on p. 165). The uppermost 1.5 cm of the freshwater mud (coarse detritus mud) was C^{14} dated at 7,380 ±200 BC. If this age is correct it would mean that marine conditions started in connection with the transgression up to ALV-2 and furthermore also persisted during ALV-3. This would be in strong disagreement with my shoreline diagram. However, it is also in strong disagreement with von Post's pollen diagrams in BP 1540 and 1542, where A^0 undoubtedly lies in the freshwater mud and the marine conditions did not start until during the transgression up to PTM-2, i. e. after 5,800 BC. Pollen analyses were made just above and just below the C^{14} dated sample in order to check the pollen determination and to check whether there could be a hiatus. Both analyses gave such a high percentage of *Alnus* (21.0 % and 31.5 % respectively) that the dated sample must belong to zone VI (BO-2). I do not think the pollen development can be ascribed to any nearby "pioneer" of *Alnus*. For some unknown reason the C^{14} dating must be

wrong (an explanation might be that the uppermost part of the detritus mud contains older material that drifted out into the lake in connection with the transgression). Anyhow, the lake was probably transgressed in zone VI—VII, i. e. by the transgression up to PTM-2.

About BP 1542 there is a possible notch in the blue-clay (Fig. 62). According to the pollen diagram the sand layer belongs to zone IV (PB). This sand layer might be a shore deposit, indicating an early low water level about +3.7—4.0 m. This would be the same level as in Lake I. However, this is not supported by any weathering of the blue-clay surface and must thus be regarded as a possibility only. The marine transgression up to ALV-2 caused a corresponding ground water rise in this lake. This level should be at about +9.0 m. The blue-clay can be followed up to the surface at +8.80 m (Fig. 62). During this high water level, coarse detritus mud was deposited at least up to +6.2 m in BP 1523 and +7.3 m in BP 1537. The marine regression down to ALV-3 is also found in this lake as a ground water fall. The corresponding marine level is +7.5 m. In BP 1537 a 0.5 m thick layer of alder brushwood peat grows out over the coarse detritus mud at least down to +7.5 m. In BP 1523, 13 cm of sand cover the coarse detritus mud at +6.2 m. In BP 1524 there is a 25 cm thick layer of sand at +7.0 m. In BP 1522 there is a 25 cm thick layer of sand containing lumps of eroded clay, gravel,

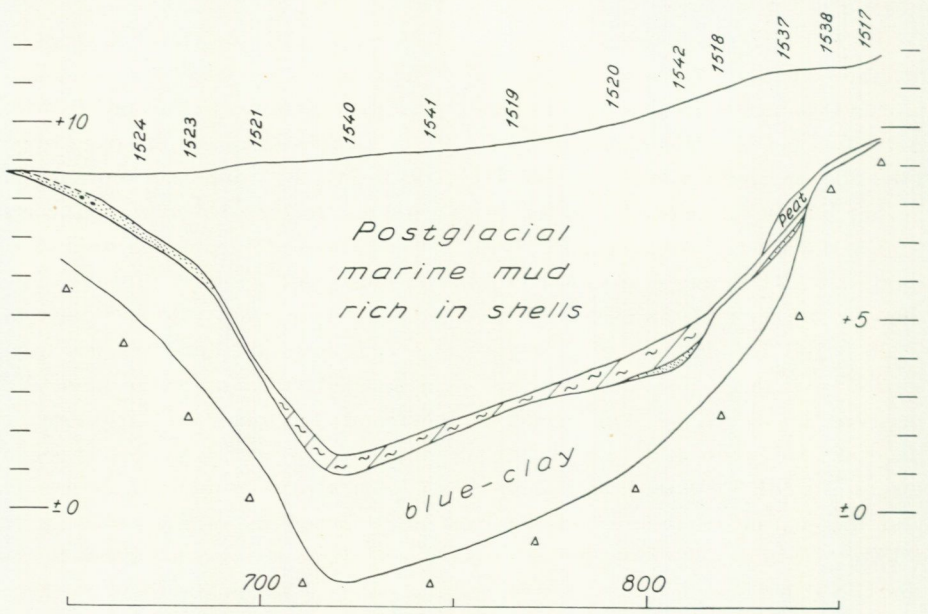


Fig. 62. *Lake II. The sand filled shore cut at about +3.5—4.0 m corresponds to ALV-1, dammed. During ALV-2, at +9.0 m, coarse detritus mud was deposited at least up to +7.3 m. During ALV-3, at +7.5 m, the mud of ALV-2 was covered with sand at BP 1523 and with alder brushwood peat at BP 1537, clearly indicating the regression of ALV-3.*

shingle and drift peat at +7.9 m. Consequently a water level at +7.5 m seems very likely. The age of this level must correspond to ALV-3, as the peat in BP 1537 is an alder brushwood peat.

As the ground water changes in Lake II thus seem exactly to have followed the changes of lake level during ALV-1 and of sea level during ALV-2 and ALV-3 in Lake I, though they were separated by a threshold, this lake has important information to give about the shorelevel displacement.

16. Section 25, Lake Dran

According to von Post's section, a sandy-gravelly-stony layer slopes down to at least −5.0 m. This layer is entirely covered by Postglacial sediments (12 m thick). I think Lake Dran is a kettle (cf. p. 146). However, this section has almost nothing to tell about the shorelevel displacement.

17. Section 115

The redrawn section shows a marked shore cut at +7.7 m (Fig. 63). In 3 m the blue-clay surface here rises 1.3 m to +9.0 m in BP 1643, where the blue-clay is weathered into a strong ground crust. Outside the shore cut, the blue-clay is quite loose. This shore cut obviously belongs to the shoreline ALV-1b, i. e. the shoreline within Ancient Lake Veselången proper that corresponds to the marine shoreline ALV-1.

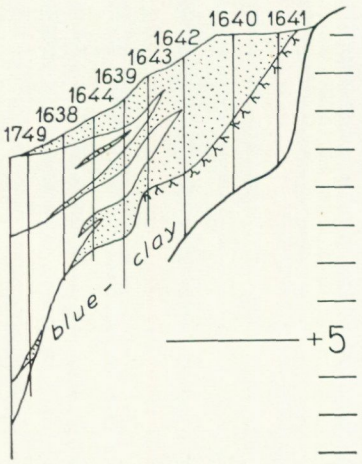


Fig. 63. *Detail of Section 115, showing a buried shore cut at +7.7 m, formed during ALV-1b. Horizontal scale: 1 cm = 20 m.*

ALV-2 cannot be fixed closely. It should be at +11.4 m according to the shoreline diagram. However, the 20—30 cm thick layer of sand containing lumps of eroded blue-clay ought to belong to this stage. This layer has been found at +11.2 m in BP 1640.

ALV-3 should be at +9.9 m. During this stage a thick layer of sand was deposited down to +7.4 m. The sand layer belongs to zone VI (BO-2) according to the pollen diagrams of BP 1644 and 1643.

18. Section 3, Albäck

The western part of this section has been described by von Post († 1968, Fig. 13). The eastern part and a newly bored section close to this will be discussed here.

The eastern part of the section is important (Fig. 64). The changes between marine and lacustrine stages are well indicated in BP 629 by the results of diatom and boron analyses (Landergren 1945, Fig. 2) and dated by pollen analyses (von Post † 1968, Fig. 14). Recently, activation analyses have been made on a series of the old samples (Landström *et al.* 1967).

In order to C^{14} date the main stages in BP 629, two continuous cores were taken with the foil piston corer 10.5 m down. These cores were synchronized with BP 629 through sediment limits, pollen analyses and diatom analyses. Four samples were C^{14} dated (marked with "x" in Fig. 64):

1. The limit marine/freshwater diatoms corresponding to the isolation of Ancient Lake Veselången (St-1502) gave 10,290 ±240 BC.
2. The small peak of marine diatoms between C^0 and A^0, i. e. von Post's "*Corylus* transgression" (St-1503) gave 8,600 ±145 BC.
3. The limit freshwater diatoms/marine diatoms corresponding to the transgression of Ancient Lake Veselången (St-1496) gave 7,560 ±135 BC.
4. The limit marine/freshwater diatoms corresponding to the isolation of the recent Lake Veselången (St-1505) gave 5,115 ±145 BC.

However, none of these dates seems reliable. The explanation appears to be that the mud contains a great deal of older redeposited material. In a river valley such as the Viskan Valley, a regression must mean a strong redeposition of older material, i. e. the inorganic and organic material as well as the fossils. In this connection it is interesting to note that the diatom analyses in Ancient Lake Veselången (von Post † 1968) give distinct transgression limits but indistinct isolation limits. Similarly, datings from BP 300 (p. 225) and B 95 in the northern part of Ancient Lake Veselången gave ages which were too old.

Thus the dating of the stratification must be based upon the pollen diagram, in this case BP 629. This diagram dates the stage of Ancient Lake Veselången to the time between about C^0 and a time after A^0. The isolation level is not well dated in this diagram and other diagrams in the northern part of the lake point to the middle or even the early part of zone IV (PB). The transgression is well dated in the delta of Ancient Lake Veselången and took place about 5,800 BC. According to the diatom diagram of BP 629, the stage of Ancient Lake Veselången can be divided into three parts:

1. 45 cm of muddy clay with low content of marine and brackish diatoms. Apparently this part corresponds to the pure lake stage of ALV-1b.
2. 20 cm of muddy clay with a peak of marine and brackish diatoms. Apparently this part corresponds to ALV-2 which reached above the thresholds.
3. 25 cm of muddy clay with low content of marine and brackish diatoms. This part roughly begins at A^0. Apparently this part corresponds to ALV-3, which meant a regression of about 1.5 m.

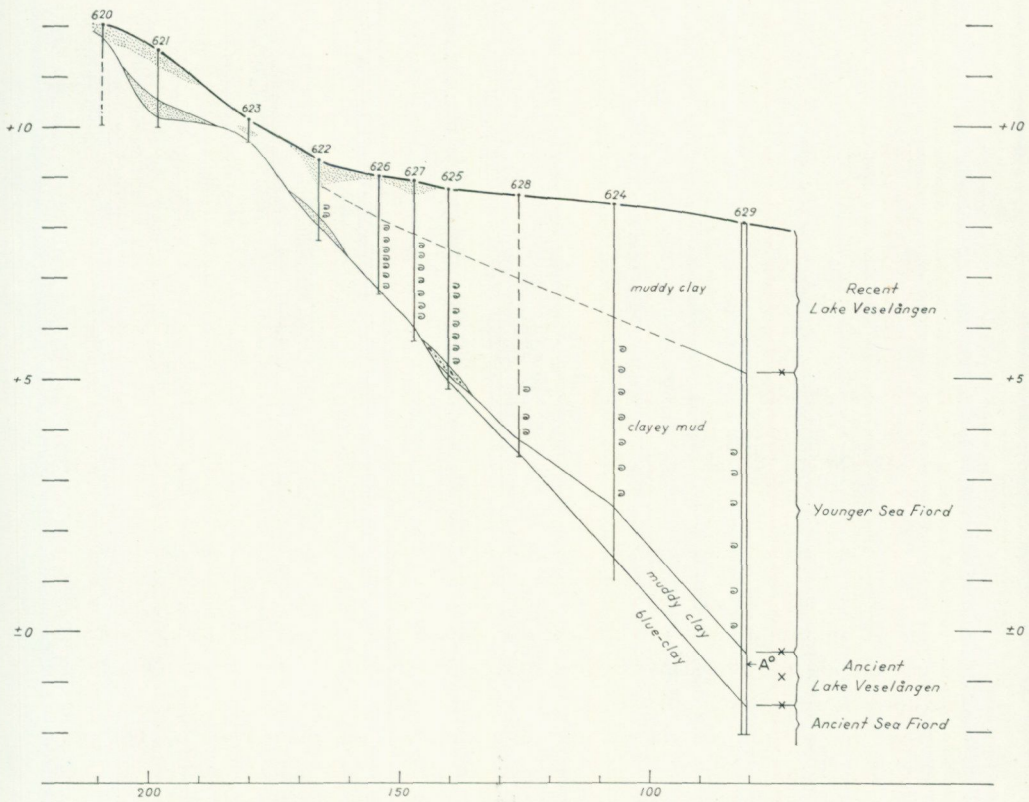


Fig. 64. *Eastern part of Section 3. The muddy clay of Ancient Lake Veselången is from BP 629 followed laterally up to about +5 m. The shore cut at +10.2 m belongs to ALV-3. The sand layer in BP 622 probably belongs to ALV-1b.*

Similar results are also found in BP 1511 and BP 300 (cf. below p. 226) and von Post † 1968, Fig. 33).

The lacustrine muddy clay of Ancient Lake Veselången can be followed laterally to about +5.2 m in BP 625, where a small layer of sand is found (Fig. 64). This sand layer could be a shore deposit (cf. below). Further up, another thin sand layer rests upon the surface of the blue-clay at +8.00—8.15 m in BP 622. According to the results in the new section, this layer is a shore deposit from ALV-1b. At +10.2 m there is a marked shore cut, which exactly fits with the ALV-3 shoreline.

In order to date the layers and if possible complete the results, I bored a new section (Fig. 65) close to von Post's section. The surface of the blue-clay slopes evenly down to B 73, where a marked notch is found at +5.15 m. Between +8.0 and 9.5 m the clay is covered by a thin sand layer. The blue-clay is loose throughout the whole section. The muddy clay in the notch is apparently equivalent to

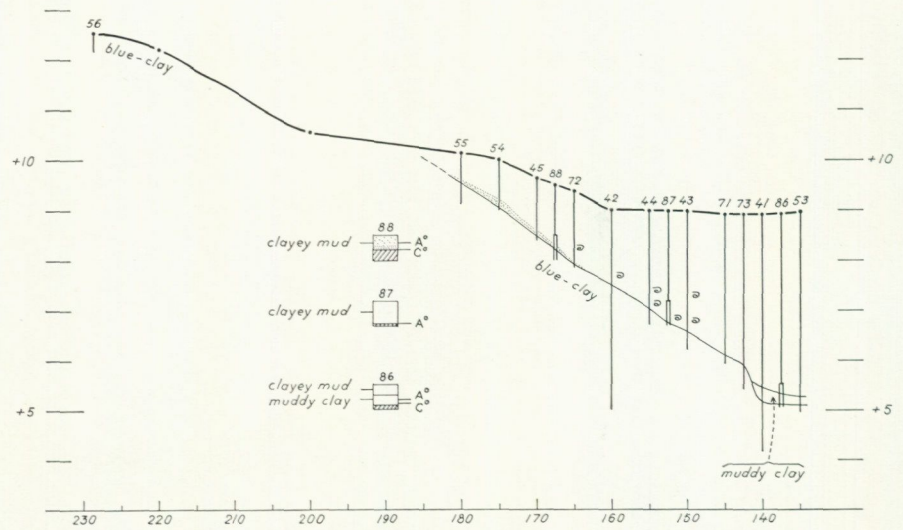


Fig. 65. *New section at Section 3. In the pollen analysed cores from B 86—88 the blue-clay is marked with hatched areas.*

the lacustrine muddy clay in von Post's section. Three cores, B 86—88, at various altitudes along the blue-clay surface were taken with a piston corer (Fig. 65). The cores were pollen analysed.

Now the question is whether the notch in the loose blue-clay is a shore cut or not. The notch is distinct, in 2.5 m the surface of the blue-clay rises 0.75 m from +5.15 to +5.90 m. According to the pollen diagram of B 86 (Fig. 66) the muddy clay in the notch belongs to zone V (BO-1) and VI (BO-2), i. e. the stage of Ancient Lake Veselången. The uppermost 4.5 cm of the blue-clay is muddy and separated from the pure clay by a marked limit, which consequently might be the real isolation level. If so, the isolation took place in early zone IV (PB), otherwise at the transition zone IV (PB)/V (BO-1). This means that the limit between muddy blue-clay and muddy clay might show either an erosional surface or a continuous sedimentation. If the notch is a shore cut it would fall exactly within the marine shoreline ALV-1, i. e. there should not have been any damming thresholds of Ancient Lake Veselången, which seems very improbable. This is mentioned as there are similar traces of an early low water level in Section 24 and the Vasse field (cf. below). However, these traces are exceptions among all the other localities which clearly show that ALV-1b was dammed about 2.2 m above the marine ALV-1. Consequently, the notch ought to have been formed in some other way. This is supported by the quite loose consistency of the blue-clay and the absence of any sand layer.

According to the pollen diagram of B 87 (Fig. 66), the surface of the blue-clay at +6.75 m is directly overlaid by marine muddy clay belonging to the Younger Sea Fiord, i. e. there is a big hiatus corresponding to the ALV time.

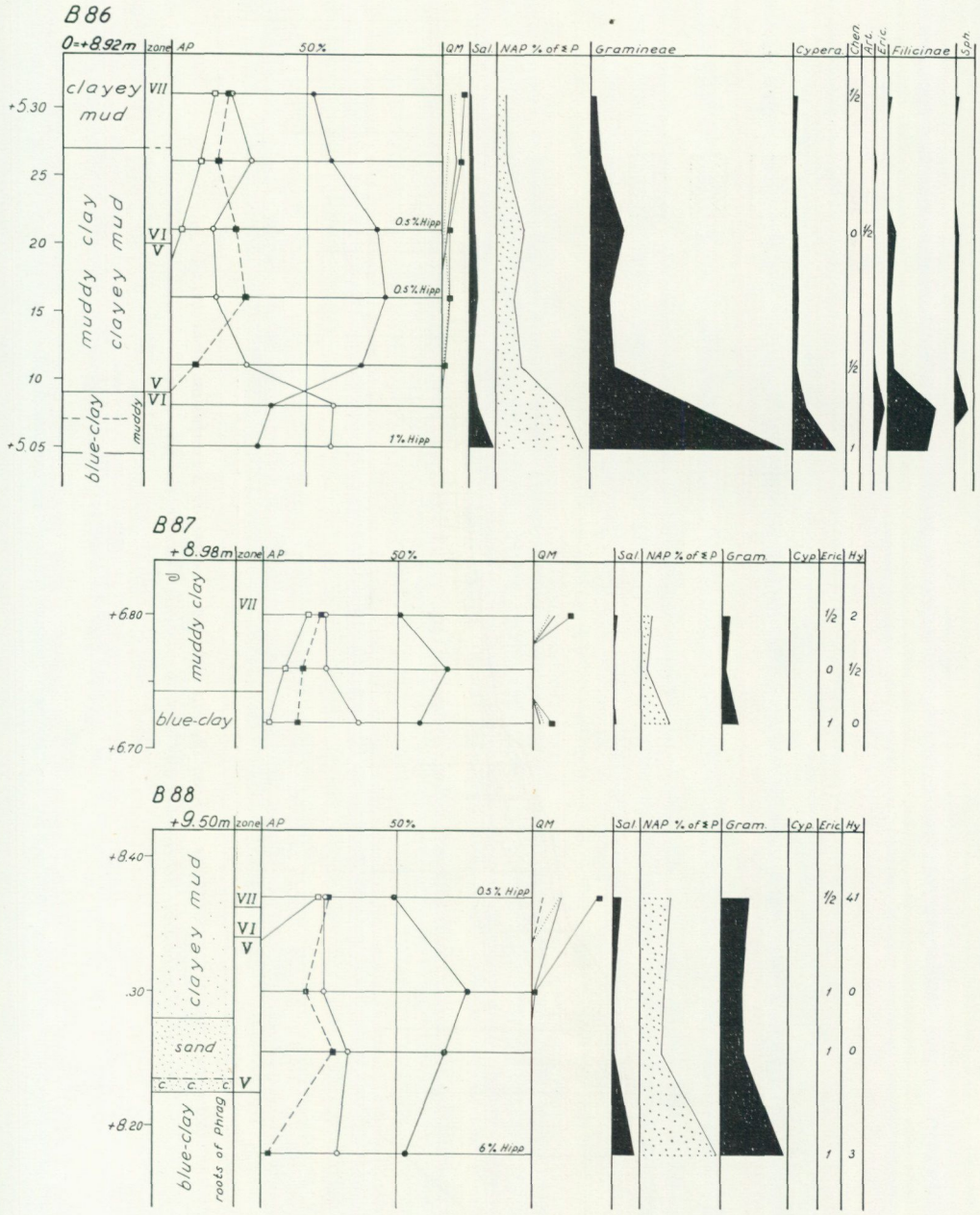


Fig. 66. *Pollen diagrams from "Section 3". The muddy clay to clayey mud in B 86 corresponds to the stage of Ancient Lake Veselången, here dated at between C° and a time after A°. In B 87 this stage is represented by a gap. The sand in B 88 is a shore deposit of ALV-1b and the lower part of the clayey mud above is a lake deposit of ALV-2 and ALV-3, while the sediments containing the uppermost pollen spectrum with 41 % Hystrix represent the subsequent fiord stage.*

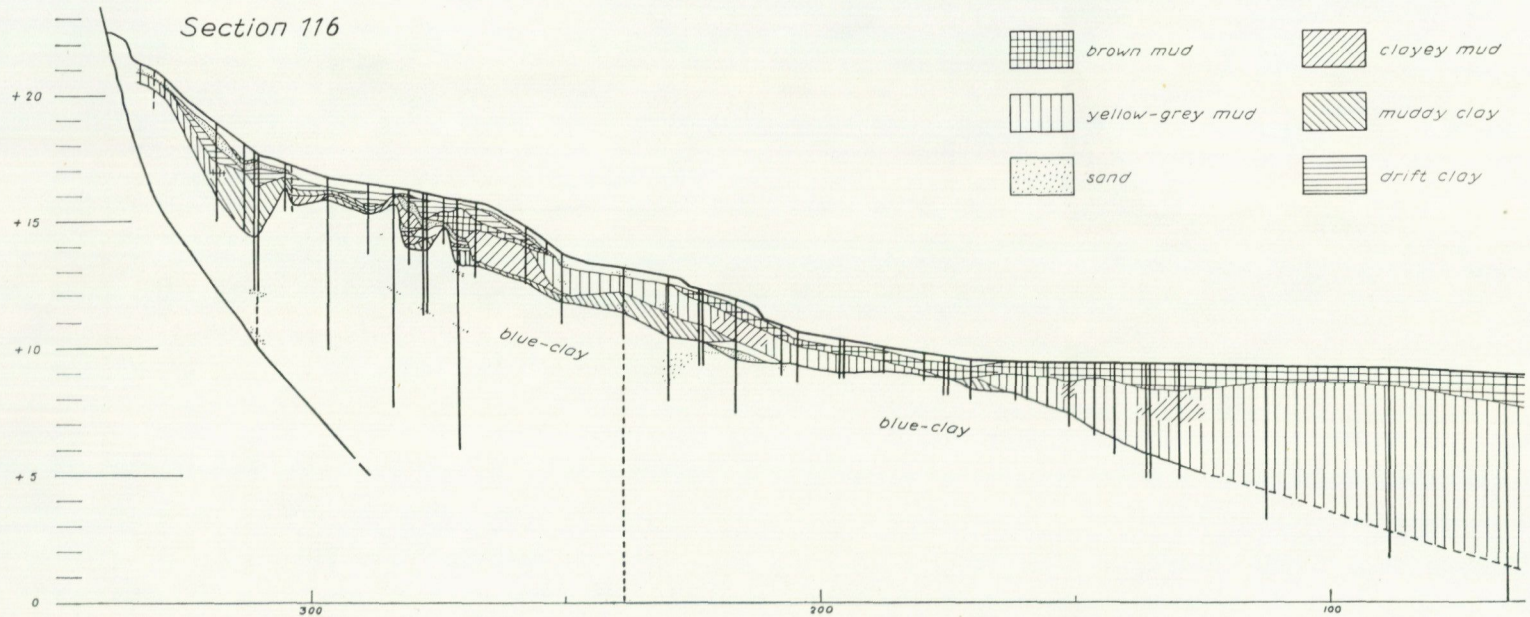


Fig. 67. *Von Post's section redrawn from the old field notes, showing a confusion of layers that seem impossible to connect and a probable earth slip in the left part.*

In B 88 the blue-clay surface, at +8.22 m, is covered by 5.5 cm of sand and above this a clayey mud. The pollen diagram (Fig. 66) dates the sand to early zone V (BO-1). Apparently it is a shore deposit of ALV-1b, which, according to the shoreline diagram, lies at +8.2 m. A corresponding sand layer is found in von Post's section. As A^0 is found at about +8.35 m in free lacustrine sediment, ALV-2 and ALV-3 must have been above this level. This agrees well with the statement that the shore cut at +10.2 m in von Post's section belongs to ALV-3.

19. Section 116, Hultahage

This section, which is one of the last von Post made, occupies a key position in his investigation, as this is the only section in which his whole FP system of shorelines is said to be present (von Post † 1968, Fig. 13). This section should be the final proof of the correctness of the extrapolation of the Vänern diagram.

In the Preface to von Post's posthumous paper (von Post † 1968), I have arrived at a quite different picture from that of von Post.

I have made a new drawing of this section exactly according to the field notes. The picture obtained is a confusion of layers that seem impossible to connect (Fig. 67). The pollen diagrams are very incomplete and thus give no help. The traces of ground crusts are distributed here and there in this confusion and are also impossible to connect. The upper part of the section is reminiscent of a buried earth slip. At any rate, I do not think von Post's stratification is as reliable as one would wish, considering its great importance.

However, I was not satisfied with such a negative reinterpretation of this important section. I wanted to find a positive solution to the problem. Thus I spent a lot of work on this locality. A new section, containing 15 borings, was bored about 20 m south of von Post's section (Fig 68). Pollen analyses were made in B 82, B 84 and B 218. Geotechnical analyses were made in B 82 in order to check von Post's ground crusts.

The picture obtained is quite different from that of von Post. My section shows an even surface of loose blue-clay without any traces of weathering, which is covered by sediments from the Younger Sea Fiord lacking any trace of ground crusts.

In B 82 the shear strength (Swedish fall-cone test), water content, fineness number (liquid limit) and loss on ignition were determined at every 3rd cm throughout the whole core. The results clearly show that there is simply one single ground crust, the recent one, and a sediment limit between muddy silt/clay and a loose homogeneous blue-clay. This is reliable evidence that there are no old ground crusts either in the blue-clay surface or in the sediments above (except the recent one).

In B 82 and B 84 some samples from just above and below the blue-clay surface were pollen analysed. The result is given in the list below. The figures of the samples give the position in cm above (+) and below (−) the blue-clay sur-

face, respectively. The samples are extremely poor in pollen and do not allow any good zonation. However, I think the general picture shows that the sediments above the blue-clay have been deposited in the Younger Sea Fiord, i. e. after the zone boundary VI (BO-2)/VII (AT-1).

Boring	B 84				B 82			
Sample	+22	+18	+12	+5	+19	+9	+1	−10
Pinus	0.5	8	3.5	5	1.5	3.5	10	1
Betula	—	5	—	1	1	3	9	1
Alnus	1	8	6	1	1	9	32	—
Ulmus	—	1	1	—	—	—	1	—
Quercus	—	1	2	—	—	—	—	—
Tilia	—	1	3	—	—	—	5	—
Fagus	—	1	2	1	—	—	1	—
Picea	—	0.5	0.5	—	—	—	—	—
Corylus	—	3	1	3	—	—	9	—
Σ AP	1.5	28	19	11	3.5	15.5	67	2
Gramin.	—	9	3	1	—	—	3	—
Cypera.	1	1	2	—	—	—	2	—
Chenop.	—	—	1	—	—	—	—	—
Erica.	—	1	2	—	—	—	—	—
varia	—	1	—	—	—	—	1	—
Σ NAP	1	12	8	1	0	0	6	0
Sphagn.	—	7	14	1	—	5	7	—
Filic.	2	13	14	4	1	3	18	—
Lycop.	1	1	—	—	—	—	2	—
Σ spors	3	21	28	5	1	8	27	0

An important thing for the understanding and determining of the development is the character of the sediments. A quite normal marine clayey mud of the Younger Sea Fiord was deposited in B 219. In the upper part of my section down to B 217 and partly also B 78, the sediments above the blue-clay surface consist to a very great extent of redeposited "blue-clay". This redeposited "blue-clay" is more silty, greyer and more muddy than the real blue-clay.

The possible ground crust in the blue-clay surface was in my section totally eroded away in connection with the transgression up to PTM-2, and a loose homogeneous clay surface was left. Large parts of this eroded and redeposited ground crust could explain the reports of traces of ground crusts here and there in von Post's section. As the redeposition must have been very rapid, it is not surprising that the sediments are unusually poor in pollen. Minor earth slips are also very likely to occur in connection with this erosion.

In B 222 the blue-clay surface at +8.8 m is harder, which could be a trace of weathering. In B 221 at +8.45 the blue-clay is lumpy, but in B 220 at +8.10 m it is quite loose. Possibly this could have something to do with the level of ALV-1b which was at +8.5 m.

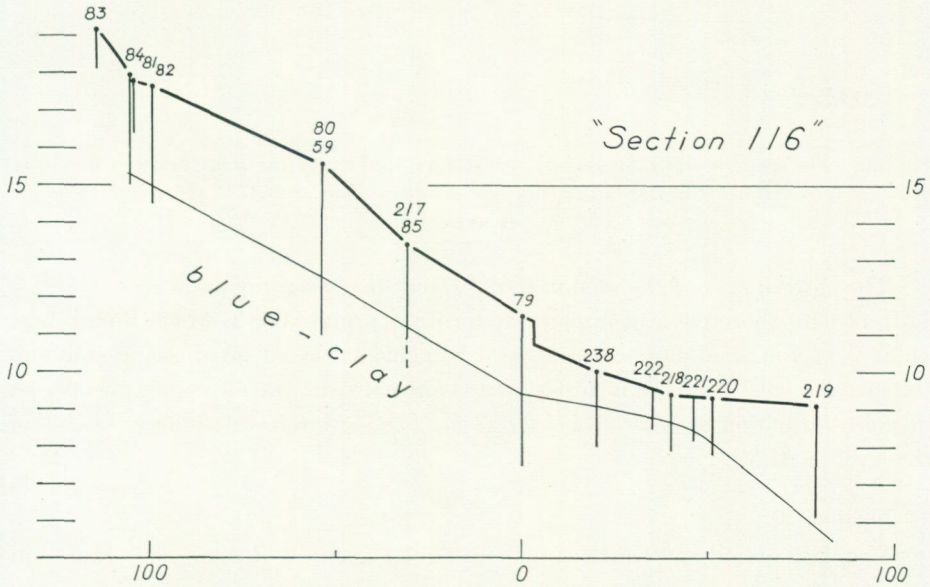


Fig. 68. *New section at Section 116, showing an even surface of loose blue-clay, directly overlaid by sediments from the Younger Sea Fiord.*

The final opinion must be that von Post's stratification in Section 116 cannot be correct and that the sediments above the blue-clay belong entirely to the Younger Sea Fiord (though a great deal of the material is redeposited "blue-clay"). The consequence of this must be that the correctness of the extrapolation of the Vänern shorelines down to the West Coast must be regarded as quite unproved.

20. Section 26

Neither von Post's section nor a newly bored section has anything of interest to tell except that there might be a shore cut somewhere between +9.5 and 11.0 m.

21. Section 5, Bosgården

Von Post did not describe this section, though it has some information to give (Fig. 69).

The western part of the section shows an evenly sloping blue-clay surface, along which sand and shingle occur at least down to +7.5 m. At +9.2 m the clay is covered by shingle and 15 cm of sand with lumps of loose clay. This is an indication of erosion of the blue-clay and of proximity to the water level, which ought to be ALV-1b at +10.3 m.

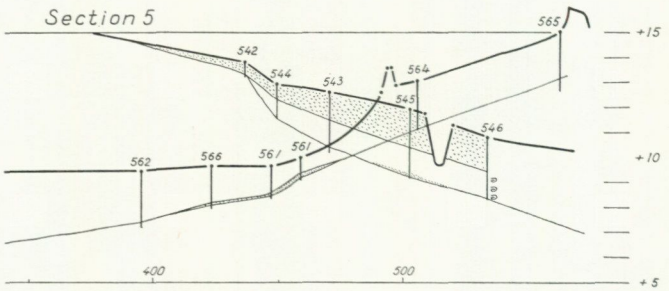


Fig. 69. *The western and eastern parts of Section 5, showing the limit between blue-clay and younger sediments at the altitude where features from the ALV shorelines could be expected.*

The eastern part of the section shows a very marked shore cut at about 11.5—12.0 m. This shore cut was apparently formed during ALV-3, which should here lie at +11.8 m. The shore cut is at +11.5 m covered by 10 cm of coarse sand and shingle. At +9.2 m, there is an isolated layer of 15 cm gravelly sand, possibly an offshore formation to ALV-1b at +10.3 m. The section has nothing to say about the level of ALV-2.

22. Section 27

Von Post stated that there is a shore cut at about +10.5 m. This shore cut could not be refound in the section.

The eastern part has very little to tell as the blue-clay is already at the surface at +11.3 m. A layer of sand and shingle covers the blue-clay surface at least between +10.5 and +8.2 m. This layer was probably formed during ALV-1b, which lay at +10.7 m (the low-water level would have been lower).

The western part is important (Fig. 70). Two depressions are seen in the blue-clay surface, which was probably eroded by a small brook (250 m south of this section there is a brook today). However, the interesting thing is that this possible brook was eroded down at least to +10.56 m. This means that the water level of Ancient Lake Veselången ought once to have been below or close to this level. The blue-clay is clearly weathered at least down to +13.5 m and semihard down to +11.0 m. There are stones at +10.4 m on the blue-clay surface, 10 cm of coarse sand with shingle at +10.1 m, and 30 cm of medium sand at +8.45 m. These facts show that the lowermost water level agrees well with the estimated level of ALV-1b, viz. +10.7 m (with lower low-water level).

In BP 656, there is a 30 cm thick layer of sand and shingle at +13.65 m, which could belong to ALV-2 at +13.6 m. The lower depression must have been filled with mud during this stage. Consequently, ALV-2 must be above the mud surface, i. e. +12.1 m. Later the regression to ALV-3 brought the level down to +12.1 m. This water level is seen as a thin layer of sand between +11.9 m (in BP 659) and +12.2 m (in BP 660) and a layer of pitchy soil between +12.0

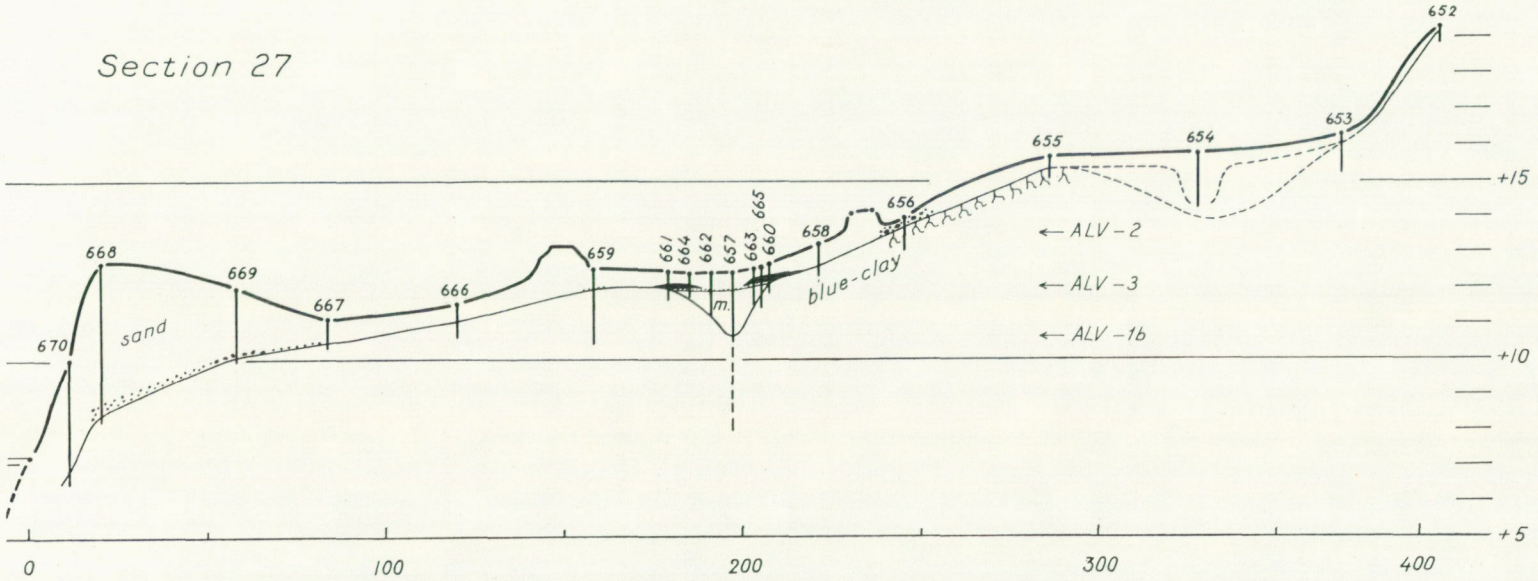


Fig. 70. *Section 27. The depression around BP 657 is a brook channel, eroded during ALV-1 b, filled with mud during ALV-2, and covered with sand and pitchy soil during ALV-3, thus nicely illustrating the whole shorelevel displacement during the ALV time.*

(in BP 661) and +12.3 m (in BP 660). This marks a good shorelevel at +12.0—12.1 m. The pitchy soil was formed in connection with the transgression up to PTM-2.

Unfortunately, this important development has not yet been proved by datings. However, the sediments clearly show the following development:

1. Lowermost water level at about +10.0—10.7 m, with brook erosion and shore formation(sand-shingle). Apparently equivalent to ALV-1b.
2. Transgression at least up above 12.1 m with a possible shore deposition at +13.65 m and mud formation in the old brook channel. This is the ALV-2 level.
3. Regression down to about +12.0 m with sand deposition at +11.9—12.2 m and a vegetation that, in connection with the subsequent transgression (up to PTM-2), was transformed into a layer of pitchy soil at +12.0—12.3 m. This is the ALV-3 level. The evidence of a real regression down to ALV-3 is important.

The sediments of the Younger Sea Fiord are the clayey mud to muddy clay above these layers.

23. Section 24, Horred

Von Post did not describe this section. He stated that there is a shore cut at about +10 m and shows the western part of the section (von Post † 1968, Fig. 15).

The western part (redrawn) shows a buried layer of mould or pitchy soil at +9.15—9.85 (in BP 554—555) between two sand ridges at +9.4—10.8 in BP 552 and at +9.9—10.3 in BP 517. This would point to a water level at about +9—10 m, which seems unprobable, however, as the extrapolated marine level of ALV-1 here falls at +9.0 m and the corresponding level of Ancient Lake Veselången was dammed some metres above the sea level. The following can be said about the pollen diagram of BP 555: T^0 is at 3.10 m, QM^0 at 3.45 m, the diagram stops at 4.00 m (with 3 % *Alnus*) and the mould layer is at 4.20 m. Consequently the mould layer is not dated, but it must belong either to zone VI (BO-2) or to zone V (BO-1). It is important that 0.6—0.8 m of the clayey mud above

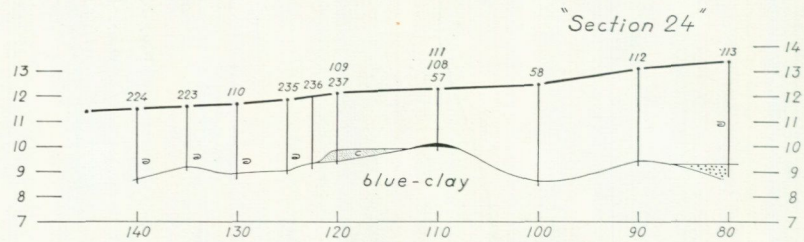


Fig. 71. *New section at Section 24.*

the mould ought to have been deposited in Boreal time, which means that the ALV-3 level must have been some metres above this clayey mud (uppermost part at about +10.3 m and ALV-3 estimated at +13.0 m). The problem of the lowermost level remains unsolved. The estimated level of ALV-1b is +11.85 m. However, explanations as earthslip or alluvial formation of the mould cannot be precluded.

A new section was bored close to von Post's section (Fig. 71). This section shows an undulating blue-clay surface that is hard down to B 110 at +8.0 m and quite loose in B 223—224. In B57/108/111 there is a 25 cm thick black pitchy soil like layer at +10.05—10.30 m. A pollen analysis in the upper part of this layer (B 111) clearly shows pollen zone VII (AT-1), while a pollen analysis in the middle of the same layer (B 108) shows zone VI (BO-2) or V (BO-1). In B 110, a pollen analysis in the clayey mud just above the blue-clay clearly shows that this belongs to zone VII (AT-1) and consequently was deposited in the Younger Sea Fiord. This is supported by the presence of 6 % *Hystrix*. These things seem to point to a waterlevel at about +9 m, but, as such a level corresponds to the extrapolated marine ALV-1 level and we must consider the damming of Ancient Lake Veselången, this section must yet be looked upon as unsolved.

The eastern part of von Post's section gives too incomplete a picture to be of any use.

24. The Vasse field, Section 28—38

In this area von Post had such a great number of borings made that it has been possible to map the buried surface of the blue-clay. Von Post hoped to find a buried delta, which here ought to have been built out into the Ancient Lake Veselången by the joining brook, the Vasse brook (Swed: Vasseån or Hornån), Von Post did not find any delta, but a system of channels in the surface of the blue-clay (von Post † 1968, Fig. 17). Von Post thought these channels were eroded by a brook during a low water level.

I, too, have done a lot of work in this area: all the sections were redrawn, a model of the blue-clay surface was built, 25 new borings were made, new levellings were made, and the newly dredged ditches were gone through.

In this connection it can be mentioned that von Post's Section 38 must be wrongly levelled and placed (von Post † 1968, Figs. 16—17). This is proved by a new levelling and a series of borings.

As von Post had not fixed the positions of the mouths of these "channels", I made a series of borings in places where the channels could have dodged through von Post's section system. However, no continuations of the northern and middle channels were found. They end blindly. This makes it very improbable that they really are stram channels.

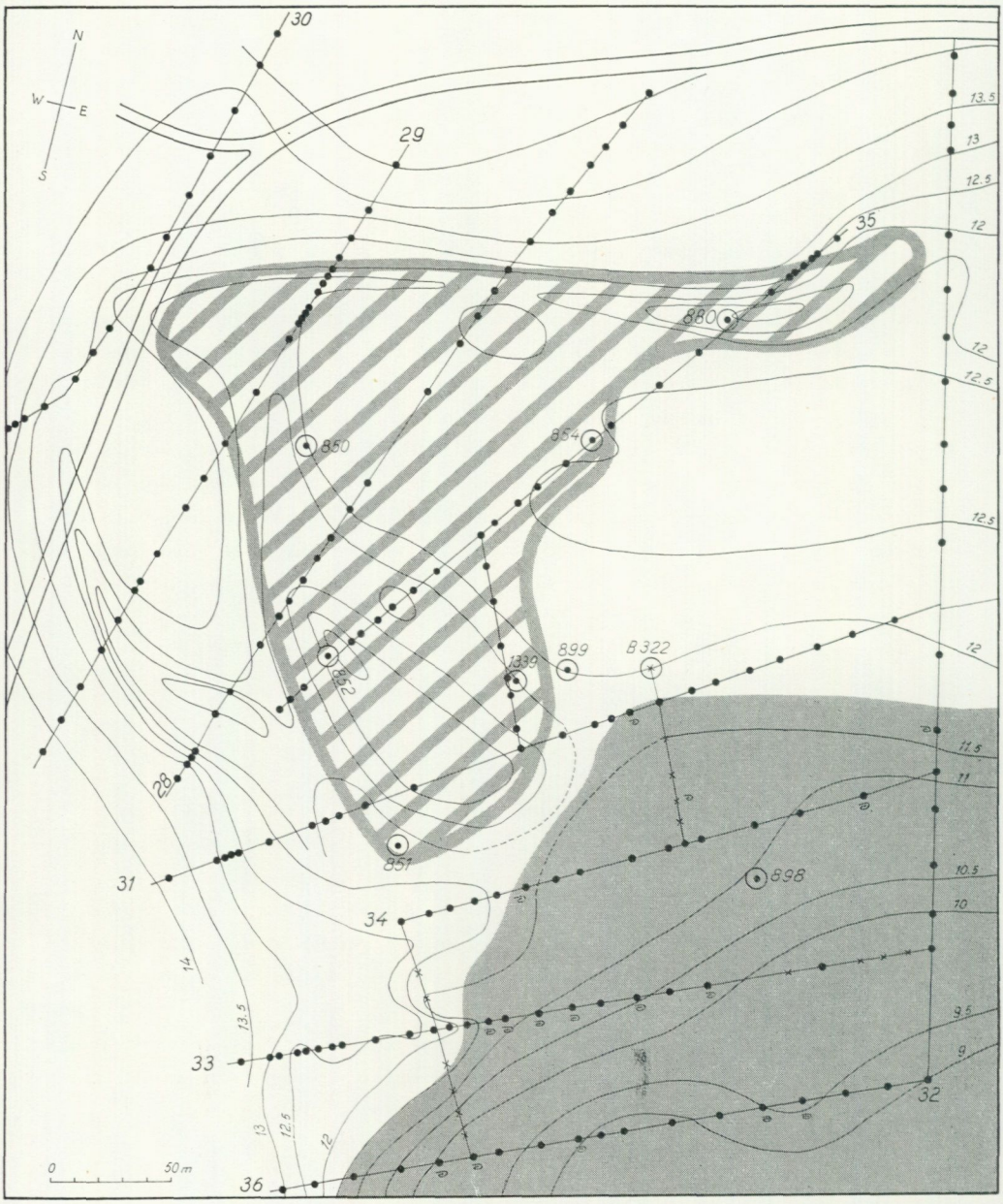


Fig. 72. *The Vasse field. Contours of the Pre-ALV sediment surface. Numbered lines with black dots = bored sections. Crosses = new borings. Encircled and numbered boring points are pollen analysed (cf. Fig. 73).*

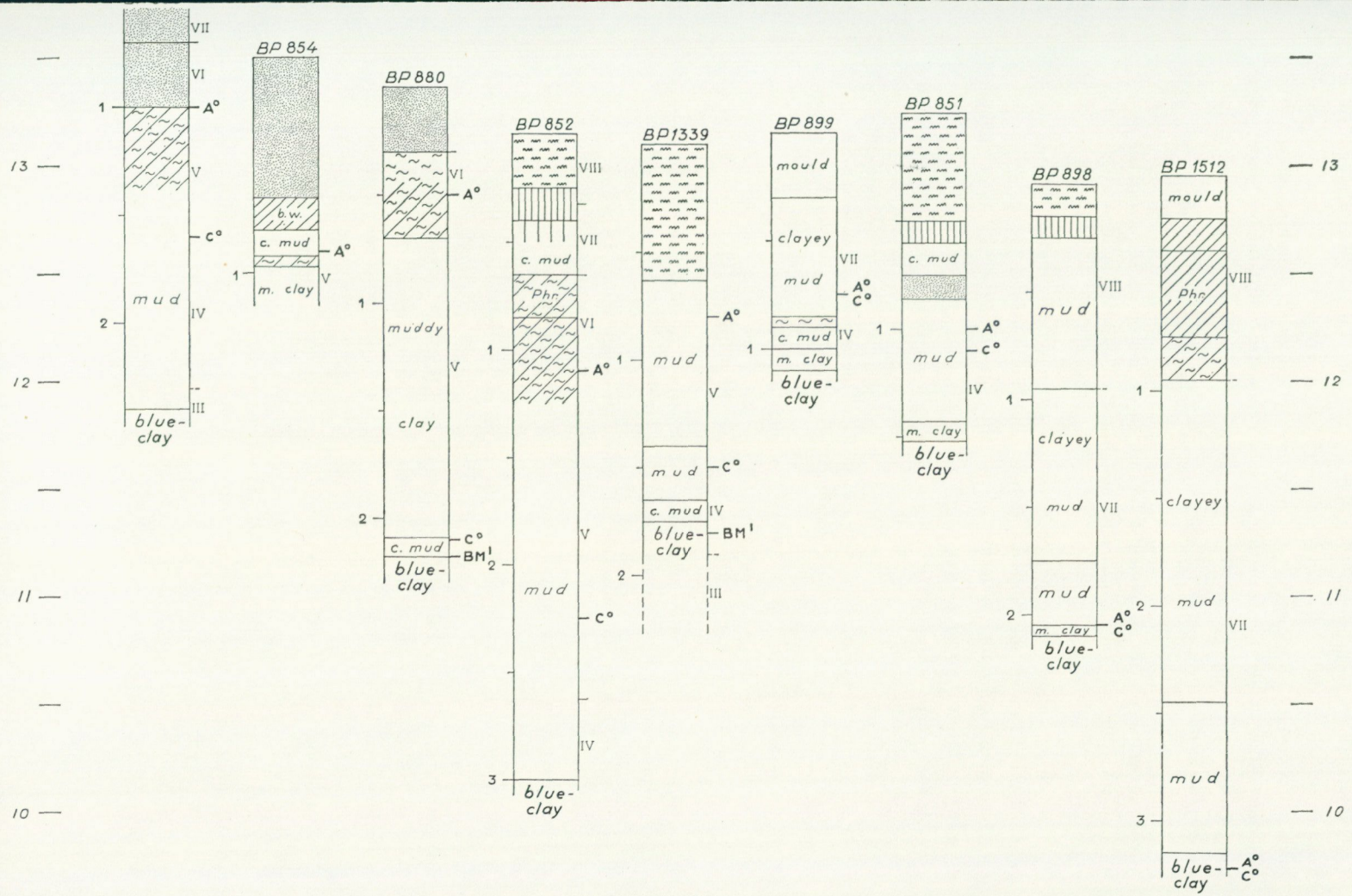


Fig. 73. *Synthesis of pollen analysed borings in the Vasse field.*

The northern and middle "channels" do not contain any alluvial river sediments. The middle "channel" has more the form of a depression and reaches such a low level (+9.6 m) that it would require almost no damming of ALV-1b. All these things make me sure that these are not stream channels. Neither can they be kettles, as more than 16 m of clay have been found in BP 1339 and no coarser material is present.

I interpret the northern and middle "channel" as the margin of an old earthslip. According to the pollen diagrams, this earthslip must have taken place in zone IV (PB), i. e. in connection with the low water level of ALV-1b (Fig. 72).

The eastern channel on the other hand is a true brook channel, the mouth of which I think I have found in the area between Section 34 and 33.

According to my interpretation of the Vasse field, the area can be divided into five main areas (see Figs. 72 and 73).

1. The eastern area which is characterized by brook erosion and delta deposition.
2. The heavily hatched area on the map, which is characterized by lake deposits (complete) that in zone VI (BO-2) show a tendency towards overgrowth.
3. The area between the above-mentioned and the screened area to the SE. This area shows incomplete series of sediments (mud and clayey mud) of Ancient Lake Veselången (e. g. BP 899).
4. The screened area to the SE, which is characterized by a lacustrine erosion during Ancient Lake Veselången, so that the blue-clay is directly overlaid by marine sediments of the Younger Sea Fiord (BP 898 and 1512).
5. The area still further out (below about +7—8 m) with an undisturbed sedimentation during the whole stage of Ancient Lake Veselången. This area is represented by BP 1511 (von Post † 1968, Fig. 18).

In Fig. 73 I have put together all von Post's pollen dated borings (except BP 1511 and 936, which lie lower and further out). This figure clearly shows that the lacustrine sedimentation started in zone IV (PB) and during the time of Ancient Lake Veselången filled the depressions with muddy sediments. The highest levels of the zone boundaries also have a lot to tell about the water level.

Zone boundary IV (PB)/V (BO-1) lies in mud at +12.68 (12.48) m in BP 850, +12.40 m in BP 899 and +12.05 in BP 851. Unfortunately the zone boundary is not quite fixed in these diagrams. Nevertheless, the corresponding waterlevel should have been at at least +12.5 m. ALV-1b is here estimated at +12.45—12.65 m.

Zone boundary V (BO-1)/VI (BO-2) lies in detritus mud at +13.38 m in BP 851. ALV-2 is here estimated at +14.8—15.0 m.

Zone boundary VI (BO-2)/VII (AT-1) lies in sand at +13.58 m in BP 851 and in mud at +13.10 m in BP 880. The estimated level of ALV-3 is here +13.40—13.55 m.

The bottom of the stream channel along the eastern side lies at +11.25 m in Section 29, +10.9 m in Section 28, +11.00 m in Section 31 (Fig. 74) and

+11.3 m between Section 34 and 33. This channel probably belongs to ALV-1b, estimated at +12.45—12.65 m. The low bottom level suggests that the low-water level sometimes reached below the estimated level of ALV-1b (cf. Fig. 82). No deltaic sediments from this stage are found in or outside the channel. In Section 25 a sand layer enters the section from east. This layer reaches +12.45 m and apparently belongs to ALV-1b.

By the transgression up to ALV-2 the water level was displaced up to +14.8—15.0 m according to the shoreline diagram. Now a lacustrine mud was deposited in the old stream channel. This is seen in Section 31 (Fig. 74), but also partly in Section 28 and 29.

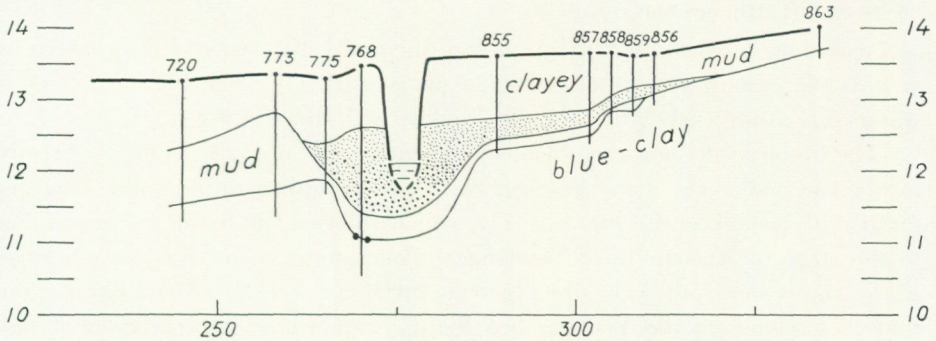


Fig. 74. *Detail of Section 31, showing the buried brook channel of ALV-1, filled with mud during ALV-2 and sand during ALV-3.*

After the regression down to ALV-3 the erosion cut down in the mud in the old channel and later more or less filled it with sand (Fig. 74). In the eastern part of Section 33 there is a sand body reaching +13.4 m, which probably belongs to this stage and marks the outermost part of the sand sedimentation. In Section 31 (Fig. 74) the sand almost entirely fills the channel. There the sand reaches up to +13.4 m. In Section 35 a sandy layer enters the section from the east. This layer reaches +13.2 m and lies on mud of ALV-2 age. The stream channel in Section 28 is almost entirely filled with sand, and only a small trace of a channel is left. The sand reaches at least +12.8 m. In Section 29 the sand layer is spread like a delta over the whole section and reaches up to +13.6 m. In BP 850 this sand layer is pollen dated to zone VI (BO-2), i. e. ALV-3. The top level of all these sand layers fits extremely well with the estimated level of ALV-3, viz. +13.40—13.55 m.

As a whole the development in the Vasse field fits nicely with my shoreline diagram (Fig. 82).

Von Post's BP 1511 has been pollen and diatom analysed (von Post † 1968, Fig. 18). Activation analyses have recently been made on a series of the old samples (Landström *et al.* 1967). According to the pollen and diatom diagrams, the stage of Ancient Lake Veselången can be divided into three parts, as it could in BP 629 (p. 206):

1. 15—20 cm of clayey mud belonging to late zone IV (PB) and early zone V (BO-1) and containing only a few per cent of brackish diatoms. This part corresponds to the pure lake stage of ALV-1b.
2. 14—22 cm of clayey mud belonging to zone V (BO-1) and containing about 30 % of brackish diatoms and a few per cent of marine diatoms. This part belongs to ALV-2 or the first Postglacial transgression.
3. 8—28 cm of clayey mud belonging to the time around A^0 and containing 10—20 % of brackish diatoms and a few per cent of marine diatoms. This part would correspond to ALV-3, though neither the diatoms nor the pollen give as good an indication of this as in BP 629 (p. 206) and BP 300 (p. 226).

25. Section 1, Hinnarehult

According to von Post's interpretation, there are shore cuts in the western as well as the eastern valley side at +12.7 m (von Post † 1968, Fig. 15). Such a water level would exactly fit with my shoreline ALV-1b.

The western side shows an obvious shore cut at +12.6—12.7 m. This is directly overlaid by sediments of the Younger Sea Fiord according to the pollen diagram of BP 301 (von Post † 1968, Fig. 22), which shows a big hiatus corresponding to the stage of Ancient Lake Veselången. Pollen analyses in three new borings in the clayey mud just above the blue-clay surface at +11.2, 9.3 and 8.6 m show that this belongs to the Younger Sea Fiord. Furthermore, the clayey mud just above the blue-clay surface at +8.8 m contains shells of *Mytilus edulis, Cardium edule* and *Macoma baltica*. Consequently, the hiatus of Ancient Lake Veselången is large vertically as well as horizontally. The blue-clay surface is lumpy and semihard down to about +12.6 m. A thin cover of sand, gravel and shingle reaches at least down to +12.0 m. A new boring with the blue-clay at +11.2 m (B 215) shows a grainy blue-clay (at least 32 cm), where the "grains" are hard and sharp edged and embedded in a very loose clay. This is a typical macerated ground crust in clay (cf. p. 18). This means that the low-water level ought to have reached down below the stated level of ALV-1b, probably to about +11.5 m, i. e. 1.2 m below the stated ALV-1b level. In this section there are no traces of ALV-2 and ALV-3.

The eastern side shows a shore cut (von Post † 1968, Fig. 15), the water-level of which is more hard to fix. It ought to be somewhere between +11.0 and 13.0 m, probably about +12.0—12.7 m. At 12.1 m (BP 529) the blue-clay is covered by 20 cm of stones, which means proximity to the shore. The stated level of ALV-1b is +12.8 m. In order to clarify the picture, a new section (of 11 boring points in 194 m) was bored close to von Post's section. However, this section did not show any shore cut, only a change in slope at +10.5 m. Samples were taken with a piston corer in three boring points (B 89—91). The pollen diagram of B 89 with the blue-clay surface at +9.1 m shows that the uppermost part of the blue-clay belongs to zone IV (BP) and at least the lowermost 5 cm of the clayey mud above belongs to zone VI (BO-2) with no *Hystrix*, or at most

0.5 %, i. e. the late part of Ancient Lake Veselången. Zone V and early zone VI are not represented. In B 90 with the blue-clay surface at +10.0 m, the lowermost part of the clayey mud belongs to zone VI and contains 24 % *Hystrix,* which means a marine environment of the Younger Sea Fiord (though this really means zone VII, which shows that the zone boundary VI/VII is not well marked here and that T^0 is of varying age on the West Coast). In B 91 with the blue-clay surface at +11.2 m, the lowermost part of the clayey mud belongs to zone VII and contains 60 % *Hystrix*. These concentrations of *Hystrix* are interesting and I think they show that *Hystrix* lived in the sea, at least in Atlantic time (cf. p. 14).

26. Section 23, Segerstad

According to von Post († 1968, Fig. 15) there is a marked shore cut in the western side at +13.5 m. This level would fit with the estimated level of my shoreline ALV-1b at +13.3 m. However, a redrawing of the section exactly according to field notes changes the picture. There is no shore cut in the blue-clay. This is also shown by new borings. Von Post's shore cut is only based upon the occurrence of stones 0.5 m down in a typical blue-clay in two out of five borings. The blue-clay surface is clearly weathered into a ground crust down to +14.1 m (a hard clay containing sand filled fissures and woody roots). The blue-clay is semihard and contains roots of *Phragmites* and *Equisetum* down to at least 13.6 m. Furthermore the uppermost 7—8 cm of the blue-clay at +13.6 m show traces of pitchy soil formation. At +12.75 m the blue-clay is quite loose. At +11.7 m it is overlaid by clayey mud of the Younger Sea Fiord according to the occurrence of shells and the content of pollen and of *Hystrix* (6 %) in a new boring. These things could point to a low level below 13.6 m but above +12.7 m, which could fit well with a water level at +13.3 m during ALV-1b. Nothing is known about the level of ALV-2. The blue-clay is covered by a 10—20 cm thick layer of sand between +13.7 m and +14.3 m, in which a notch is seen at +14.0 m. This seems to belong to ALV-3, which is estimated at +14.1 m. Consequently, the levels of ALV-1b and ALV-3 seem fairly well fixed in this section.

The eastern side of the section is not mentioned by von Post. It shows a long and flatly rising blue-clay surface. A shore cut is found at about +13.1 m. This is emphasized by sand and shingle in and just outside this shore cut and the limit of a weathered blue-clay surface at +13.5 m. This fits well with the estimated level of ALV-1b at +13.3 m. Furthermore, there seems to be an incompletely known shore cut at about +14.0—14.5 m, which probably belongs to ALV-3, estimated at +14.1 m.

27—33. The delta area of Ancient Lake Veselången, Section 15—11

This is an important area for the investigation of the shorelevel displacement during the time of Ancient Lake Veselången. Thus von Post had no less than

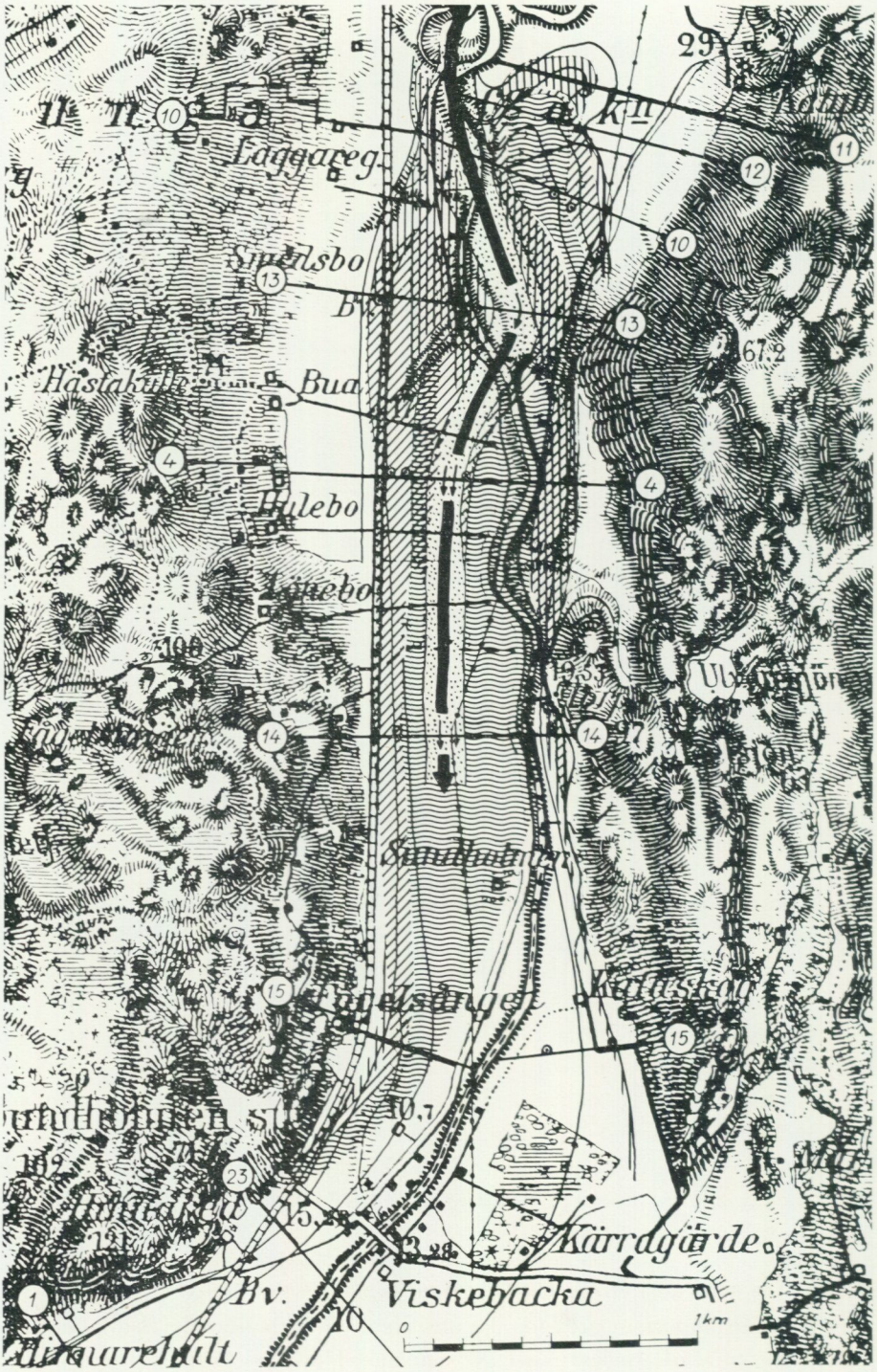


Fig. 75. *Map of the buried delta of Ancient Lake Veselången at about 5,800 BC. Symbols: arrow and dotted areas = river bed with levéls, diagonal lines = peat, vertical lines = pitchy soil, wavy areas = mud deposited in open lake water.*

seven sections made here, containing five pollen diagrams and two diatom diagrams. Von Post's material has a lot to tell. However, the sections were very hard to draw and von Post only showed one section († 1968, Fig. 24): the sections were incomplete at important points, the soil identification varied and the datings were too few.

In order really to succeed in interpreting and dating the important development in the delta area — first the sections individually, later the delta area as a whole — I have done a lot of work here. All the sections were redrawn exactly according to the old field notes, but only as far as the stratigraphy was obvious. The unsure or weak points were later checked in the field by numerous borings. Pollen analyses were made in nine borings points. 16 C^{14} datings were made. Now the stratification in the seven sections seems obvious (Pl. 8), making possible a detailed map of the delta area at the time just before the onset of the transgression up to PTM-2 (Fig. 75).

27. Section 15, Fågelsång

This section shows the lacustrine environment just outside the real delta. However, the lacustrine layers of Ancient Lake Veselången reach a higher altitude in the western side than in the eastern side. The explanation of this seems to be partly that the river bed of Ancient Lake Veselången followed the western side and partly that the common wind direction was from SW (this statement is supported by the fact that the shore cuts of Ancient Lake Veselången usually are more marked on the eastern side of the valley).

In BP 300 the stratification is well pollen and diatom analysed (von Post † 1968, Fig. 26). In order to C^{14} date the main stages in BP 300, two continuous cores (B 114—115) were taken with the foil piston corer 11.45 m down. These cores were synchronized with BP 300 through sediment limits, pollen analyses and diatom analyses. Four samples were C^{14} dated:

1. The limit marine/freshwater diatoms corresponding to the isolation of Ancient Lake Veselången (St-1491) gave 13,240 ±260 BC.
2. The small peak of brackish diatoms between C^0 and A^0 corresponding to von Post's "*Corylus* transgression" and my shoreline ALV-2 (St-1498) gave 7,860 ±100 BC.
3. The limit freshwater/marine diatoms corresponding to the transgression of Ancient Lake Veselången (St-1492) gave 5,700 ±100 BC.
4. The limit between the falling curve of marine diatoms and the rising curve of freshwater diatoms 3.90 m down (St-1500) gave 5,020 ±90 BC.

The first two dates are definitely too old (cf. p. 41). The third date fits extremely well with the other C^{14} dates of the onset of the transgression up to PTM-2, which say about 5,800 BC. The fourth date is harder to interpret. It fits well with the age of the end of the second Postglacial transgression wave, PTM-2 (cf. p. 333).

According to von Post's pollen and diatom diagram of BP 300, the stage of Ancient Lake Veselången can be divided into three parts, as it could in BP 629 (p. 206) and BP 1511 (p. 221):

1. 150 cm of muddy clay belonging to zone IV (PB) and V (BO-1) and containing only a few per cent of brackish diatoms. Apparently this part corresponds to the pure lake stage of ALV-1b. The isolation seems to have taken place in early zone IV (PB) or at the zone boundary III (DR-3)/IV (PB).
2. 30 cm of muddy clay and clayey mud belonging to the late part of zone V (BO-1) and containing a peak of marine diatoms. Apparently this part corresponds to the transgression of ALV-2, i. e. the first Postglacial transgression.
3. 35 cm of clayey mud belonging to the latest part of zone V (BO-1) and zone VI (BO-2) and containing only a few per cent of brackish diatoms. This part corresponds to ALV-3, which meant a small regression of about 1.5 m. According to the C^{14} date, this part ended about 5,700 BC.

The western side shows a weathered blue-clay surface at least down to +14.8 m. The blue-clay is covered by a thin layer of pitchy soil from +15.6 m to +14.7 m, where it changes over to a thin layer of *Phragmites* peat that in its turn changes over to a *Phragmites* mud at about +13.7 m. This fits with the estimated level of ALV-3 at +14.25 m. The details of the shorelevel displacement cannot be followed here.

In the eastern side the blue-clay is weathered at least down to +14.8 m. A thin layer of pitchy soil is found at about +14.7—15.1 m, with a thin sand layer outside at about +14.4 m. This probably gives the level of ALV-3. According to pollen analyses in B 97 and B 96 the blue-clay surface at +10.90 and 11.65 m respectively is directly overlaid by sediments of the Younger Sea Fiord.

In B 98 I dug down to the pitchy soil and blue-clay and took a series of samples. After a careful soil determination with a microscope, the following detailed stratigraphy was found:

A: 110 cm of sand (the upper 70 cm coarser and the lower 40 cm finer) = shore or delta deposition.
B: 1 cm of pitchy soil in lacustrine muddy clay/clayey mud = transgressed shore meadow in an earlier lacustrine deposition.
C: 1.1 cm of lacustrine muddy clay/clayey mud = lacustrine deposition.
D: 1.9 cm of fine sand containing plant fragments and (at the contact to the blue-clay) grains of fine gravel = shore deposition.
E: Below +14.9 m a weathered blue-clay = weathering, during a land period, of earlier deposit of the Older Sea Fiord.

Unfortunately no pollen analyses have been made in B 98. However, the stratigraphy suggests the following development:

1. ALV-1b (estimated at +13.5 m) below +14.9 m, as the blue-clay is weathered.

2. ALV-2 (estimated at +15.65 m) above about +14.95 m, as the lacustrine muddy clay/clayey mud reaches this level (consequently, 0.7 m water depth).

3. ALV-3 (estimated at +14.25 m) below +14.95 m, as this is the level of the pitch soil, which was most probably formed in connection with the transgression up to PTM-2.

28. Section 14, Torp

This section cuts the outermost part of the delta (Pl. 8). The middle part of the section shows the following main sequence:

1. Blue-clay = the Older Sea Fiord.
2. Muddy clay and clayey mud = the open lake stage during the earliest part of Ancient Lake Veselången.
3. A slightly vaulted layer of sandy mud (and muddy sand) that reaches about +13.0 m = the most distal part of the older delta during the later part of ALV-1b, estimated at +14.1 m.
4. A layer of *Phragmites* mud without content of sand = the transgression to ALV-2, estimated at +16.1 m.
5. Erosion of delta beds down to +12.2 and 11.7 m respectively and deposition of sand (the levé-like layers on each side reach +13.5 m) = the distal part of the younger delta during the latest part of ALV-3, estimated at +14.7 m.
6. Mud containing fruits of *Ruppia maritima* = the Younger Sea Fiord.
7. Sand = the delta of the Recent Lake Veselången after the second isolation (in Sub-Boreal time).

In the western side the blue-clay surface is weathered into a ground crust at least down to +15.8 m. From about +16.3 m a layer of *Magnocaricetum* peat (max. 0.8 m thick) reaches down to about +15.0 m, where it changes over to a *Phragmites* peat (max. 1.1 m thick) between +15.1 and +14.0 m. Below the *Phragmites* peat there is a layer of alluvial peat at +13.7—14.0 m. At about +14.2—14.4 m the *Phragmites* peat changes over to a *Phragmites* mud. This limit was just below the level of ALV-3, which falls at +14.7 m according to the shoreline diagram.

The stratification is well dated in B 99, taken with a piston corer. According to the stratigraphy and pollen diagram (Fig. 76), there could be a hiatus between the clayey mud and the peat. However, this is not suggested by the C^{14} dates. The *Magnocaricetum* peat belongs to zone VI (BO-2). The uppermost 2.0 cm was dated at 6,035 ±155 BC. This agrees well with the onset of the transgression up to PTM-2, which was dated at about 5,800 BC. The lowermost 2.0 cm coarse detritus mud was dated at 7,030 ±170 BC. This sample should date the onset of the *Alnus* curve, but is apparently a little too old. The third C^{14} dated sample is 3.0 m thick and was taken 3—6 cm down in the clayey mud. It gave 6,670 ±170 BC. This agrees well with its position just below the onset of the *Alnus* curve, which in the peat bog Långaredsmossen has been C^{14} dated by Wenner at 6,495 ±110 BC (St-173), and with the dating in B 427 of a sample just before the onset of the *Alnus* curve, which gave 6.645 ±100 BC (cf. p. 251) The clayey mud probably entirely belongs to zone V (BO-1) though this is only obvious in the upper part.

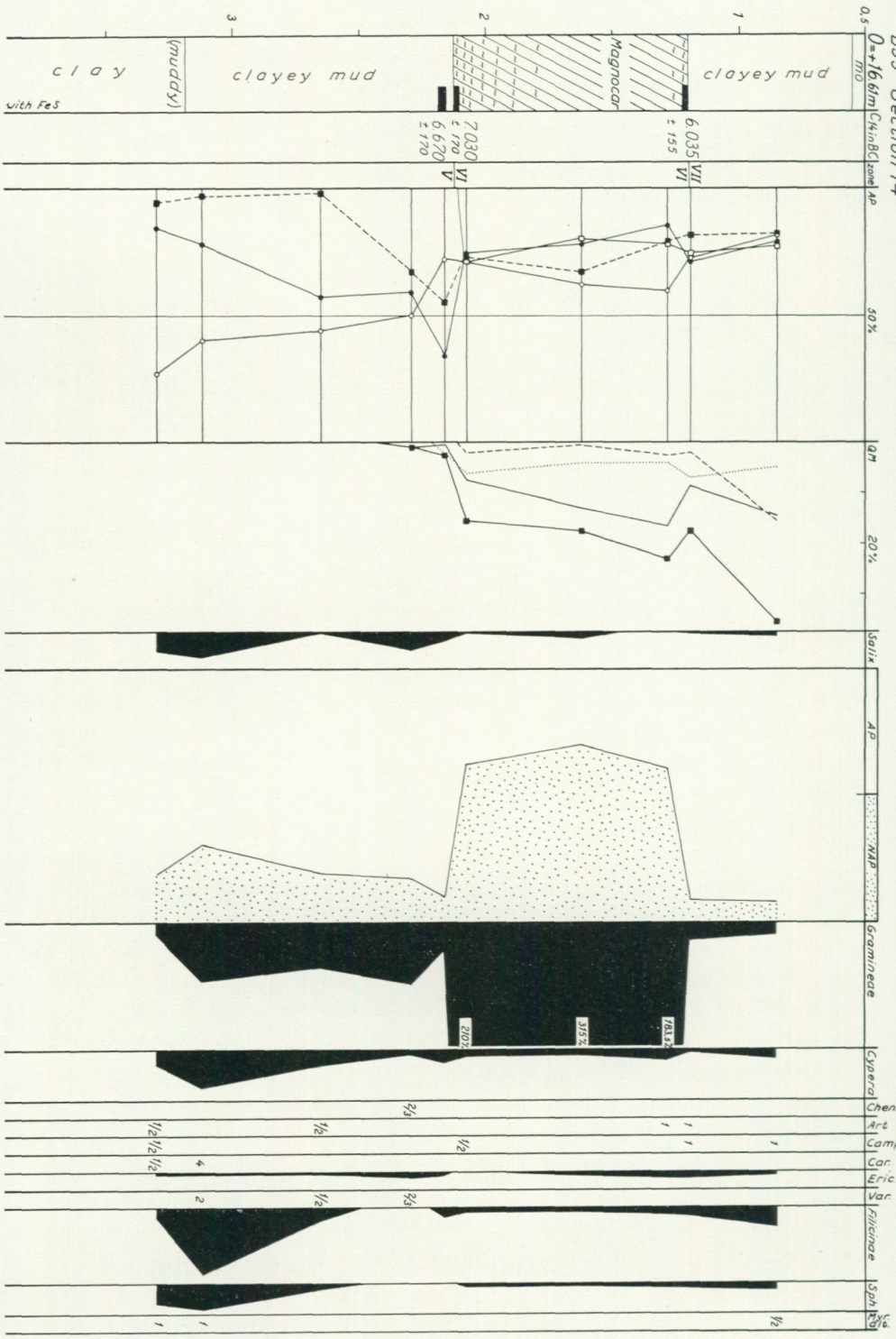

B99 Section 14
0=+16.61m
clay
(muddy)
clayey mud
Magnocar
clayey mud
with FeS
7.030 ± 170
6.670 ± 170
6.035 ± 155
C14 in BC
zone
AP
50%
QM
20%
Salix
AP
NAP
Gramineae
210%
315%
183.5%
Cypera
Chen.
Art
Camp.
Car.
Eric.
Var.
Filicinae
Sph.
Myr. alt.

Fig. 76.

In the eastern side the blue-clay surface is weathered into a ground crust at least down to +12.8 m. However, this seems a bit too low for weathering during the time of Ancient Lake Veselången. It was probably formed in the river slope after the final regression. At +15.5 m there is a 30 m wide terrace in the blue-clay. The corresponding water level should have been just above this level. Between +17.4 m and +15.6 m there is a 10 cm thick layer of sand, apparently a shore deposit. This well defined shore mark was apparently formed during ALV-2 here estimated at +16.1 m. According to von Post's section the shore mark is covered by 10—30 cm of pitchy soil (according to the old field notes). In order to date this layer I took a series of samples with a piston corer in B 100. After soil determination under the microscope the following stratification was found:

A: 163 cm of sand = the delta of the Recent Lake Veselången.
B: 7 cm of clayey fine detritus mud = the Younger Sea Fiord.
C: 7 cm of brushwood peat without any trace of water sediment or water fossils = land period.
D: 5 cm of humified peat = land period.
E: 13 cm of sand = shore deposit.

The pollen diagram (Fig. 77) clearly shows that the peat belongs to zone VI (BO-2), i. e. the time of ALV-3. The uppermost 1.0 cm of brushwood peat was C^{14} dated at 5,845 ±90 BC. This is a very good date of the onset of the transgression up to PTM-2, i. e. the classical Swedish Postglacial transgression. However, the most important thing is that we here have evidence that there was a regression between ALV-2 and ALV-3: the former shore cut is covered by a clear land formation and the clay is strongly weathered. According to the shoreline diagram, ALV-3 was at +14.7 m.

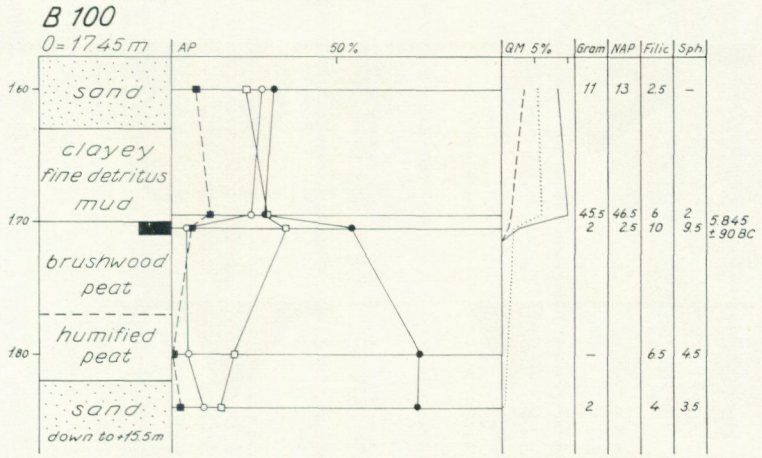


Fig. 77. *Pollen diagram (B 100, Section 14) of the layers covering the old shore cut of ALV-2. The intermarine peat belongs to ALV-3. The C^{14} date gives the age of the very onset of second Postglacial transgression.*

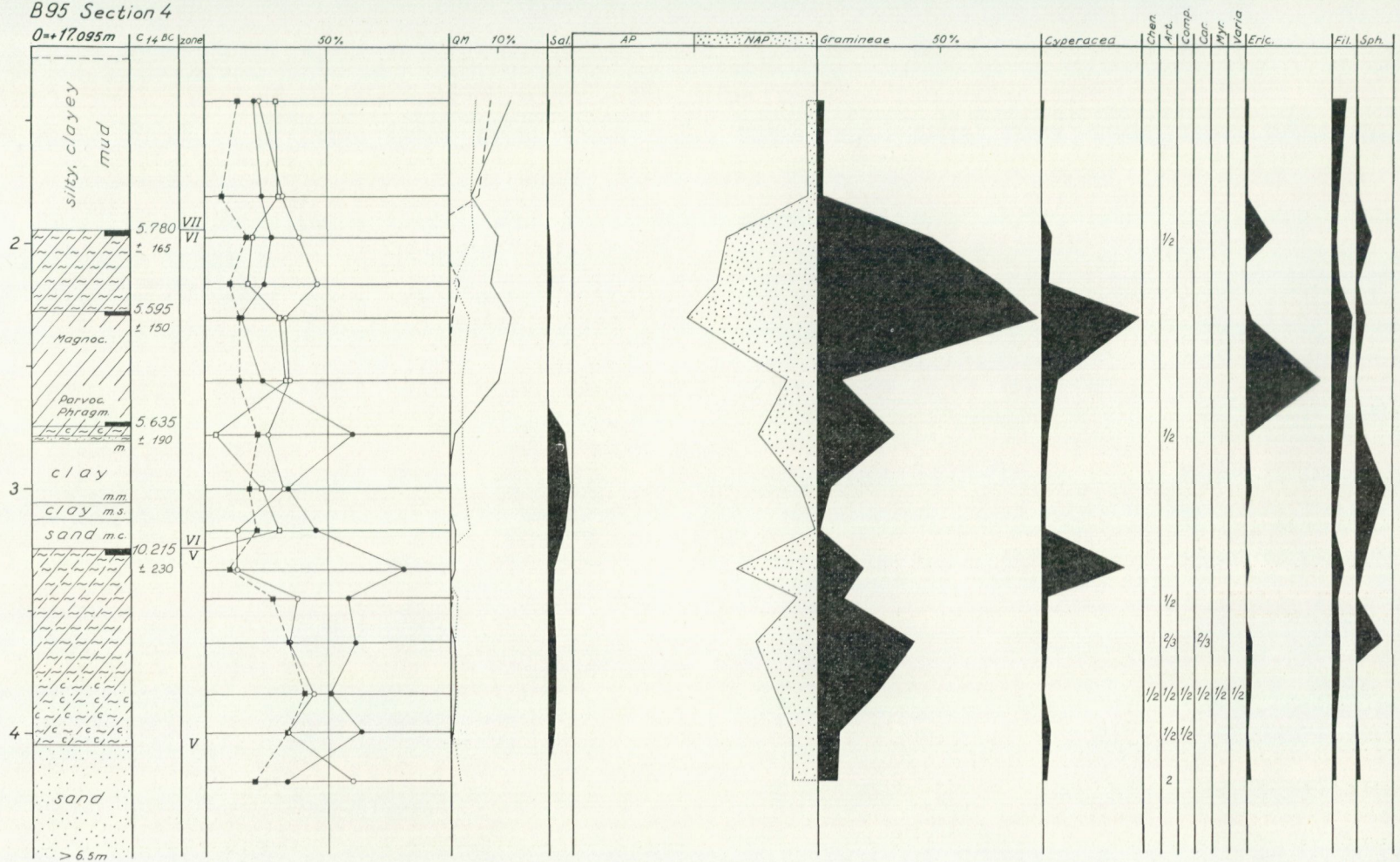

B95 Section 4
0=+17.095m
C 14 BC
zone
50%
QM
10%
Sal
AP
NAP
Gramineae
50%
Cyperacea
Chen.
Art.
Comp.
Car.
Myr.
Varia
Eric.
Fil.
Sph.
silty, clayey mud
5.780 ± 165
VII
VI
5.595 ± 150
Magnoc.
Parvoc. Phragm.
5.635 ± 190
m
clay
mm.
clay ms.
sand mc.
10.215 ± 230
VI
V
V
sand
> 6.5m
2
3
4
1/2
1/2
1/2
2/3
2/3
1/2 1/2 1/2 1/2 1/2 1/2
1/2 1/2
2

Fig. 78.

29. Section 4, Hulebo

This is an important section, which cuts the double delta of Ancient Lake Veselången (Pl. 8). However, the section could not be fully drawn until I had made a series of new borings and dated the layers by pollen analyses (B 95 and B 210) and C^{14} datings (B 5 and B 95). The picture obtained (Pl. 8) differs in many important respects from that of von Post († 1968, Fig. 24), above all concerning the lower delta.

The section shows the following sequence, which is well confirmed by the datings:

1. The blue-clay = the Older Sea Fiord.
2. The clayey mud = the open lake stage during the earliest part of Ancient Lake Veselången.
3. The lower delta = ALV-1b, estimated at +14.35 m. A muddy sand/sandy mud is spread in the eastern part and reaches +14.1 m in BP 23. In the middle there is a river bed with levés reaching about +14.1 m and the bottom of the stream beds at +9.2 m, 9.4 m, 10.5 m and 12.4 m, respectively. In the eastern side there seems to be a marked shore cut at +14.3 m. However, the shape of this notch is highly dependent upon the position of B 5, which cannot be fixed exactly. In the western side there are no special shore marks. A thin sand layer in B 206 at +14.6 m could be a shore deposit. The blue-clay surface is hard (but not clearly weathered) down to +14.0 m.
4. The mud = the more or less open lake stage in connection with the transgression up to ALV-2, estimated at +16.3 m. No obvious shore mark is found. Von Post's shore cut at +17.0—17.2 m with alluvial peat is not obvious from the old field notes. On the eastern side a sandy mud (muddy sand) was spread due to the proximity to the delta mouth, which by this transgression was displaced up to Section 13.
5. The upper delta = the regression down to ALV-3, estimated at +14.9 m. The delta seems to have been rapidly built out and to have passed Section 4. The delta is seen as a river bed with marked levés (= roddons or delta strings) on each side, reaching +15.4 and 16.0 m respectively. The bottom of the stream channels are at +12.0 and 14.0 m respectively. On both sides of the delta there were swampy areas rich in reeds. However, much of the peat and mud was formed rapidly in connection with the onset of the transgression up to PTM-2.
6. The *Ruppia* mud = the Younger Sea Fiord.
7. The sand = the delta of Recent Lake Veselången.

In B 210 the pollen analyses show that the mud and peat formation here clearly belong to zone VI (BO-2), i. e. ALV-3.

The pollen diagram of B 95 is important (Fig. 78). It shows:

1. that the lower delta belongs to zone V (BO-1) and possibly IV (PB), i. e. ALV-lb,
2. that the mud belongs to the later part of zone V (BO-1), i. e. ALV-2,
3. that the distal sediments of the levé of the delta started to be formed at A^0, i. e. the beginning of ALV-3,

4. that the peat and coarse detritus mud belong to the later part of zone VI (BO-2). The three C^{14} dates of these layers show a very rapid formation in connection with the onset of the transgression up to PTM-2,
5. that the clayey mud of the Younger Sea Fiord belongs to zone VII (AT-1).

The C^{14} dating of the uppermost 2.0 cm of the lower detritus mud gave 10,215 ±230 BC. Apparently this is too high an age, probably due to contamination by older organic material of interstadial or interglacial age. The three datings in the peat and detritus mud are all from 2.0 cm thick samples. The results show a very rapid formation. The mean value of these dates is 5,675 ± 160 BC.

Von Post's pollen diagram of BP 299 shows that the mud in the stream channel belongs entirely to the Younger Sea Fiord.

In B 5 the blue-clay surface, which in the uppermost part is transformed into a pitchy soil, is covered by a 5—10 cm thick layer of *Phragmites* mud with layers of *Amblystegium* peat. This layer was C^{14} dated at 5,800 ± 110 BC. As this layer must have been formed in close connection with the very onset of the transgression up to PTM-2, it can be held as a very good date of the onset of this transgression.

Von Post's BP 16 has been pollen and diatom analysed (von Post 1929, Fig. 12, and 1968 †, Fig. 25). Recently activation analyses have been made in a series of the old samples (Landström *et al.* 1967). The pollen zonation of the older part is not obvious and the zone boundaries III/IV and IV/V cannot be closely fixed. However, I think von Post's index horizon BM^1 would be better placed at 6.35 m. Thus I would give the following interpretation of the sequence in BP 16:

1. The blue-clay = zone III (DR-3).
2. The muddy clay — clayey mud = zone III (DR-3) — IV (PB).
3. The lower delta (alternating sand/mud) = zone IV (PB), i. e. ALV-1b.
4. The mud = (latest zone IV and) zone V (BO-1), i. e. ALV-2.
5. The brown mud-dy = A^0, transition zone V (BO-1)/VI (BO-2), i. e. ALV-3.
6. The grey (drift) clay = zone VI (BO-2), i. e. ALV-3.
7. The brown dy = late zone VI (BO-2), i. e. latest part of ALV-3.
8. The brown mud-dy with *Phragmites* = early zone VII (AT-1), i. e. the earliest part of the Younger Sea Fiord. This is supported by the diatom diagram (and the activation analyses).
9. The grey mud = the Younger Sea Fiord.
10. The muddy sand = the Younger Sea Fiord with an approaching delta.
11. The delta of alternating sand/mud = the delta in the Younger Sea Fiord.
12. The sand and muddy sand = the very end of the Younger Sea Fiord and the very beginning of the Recent Lake Veselången.

30. Section 13, Smedsbo

This section shows a compact delta body on the eastern side and a lake swamp area on the western side (Pl. 8).

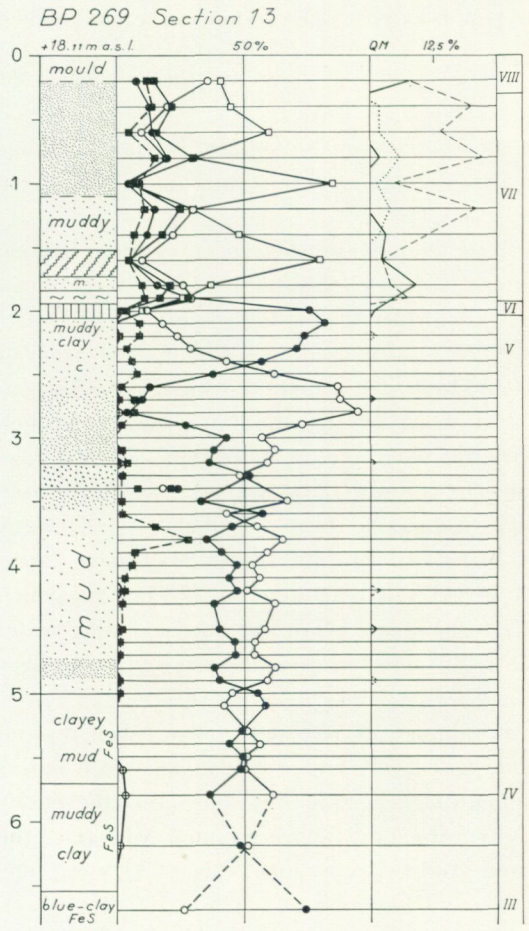


Fig. 79. *The pitchy soil at about +16 m was formed in connection with the onset of the second Postglacial transgression.*

The stratification is dated by von Post's pollen diagram of BP 269 (Fig. 79). The zonation of the oldest part is not quite obvious. However, the following datings seem likely:

1. The blue-clay belongs to zone III (DR-3).
2. The muddy clay and clayey mud belong to zone IV (PB). As these layers reach +14.8 m in the western side and +15.4 m in the eastern side they must have been deposited during a higher water level prior to ALV-1b.
3. The sandy mud and coarse sand belong to early zone V (BO-1). The coarse sand lies at +14.6 m and could correspond to the low water level during ALV-1b, estimated at +14.5 m.
4. The sandy drift clay belongs to the later part of zone V (BO-1). This layer can be followed up to +16.3 m and was probably formed during ALV-2, estimated at +16.4 m.
5. The pitchy soil belongs to zone VI (BO-2) and was apparently formed in connection with the transgression up to PTM-2.

6. The thin layer of *Phragmites* peat belongs to zone VII, i. e. the very earliest part of the Younger Sea Fiord.
7. The upper sediments belong to the Younger Sea Fiord and the isolation of the Recent Lake Veselången.

The level of ALV-1b cannot be closely fixed in this section. During this stage the eastern part was probably an area of land and river bed and the western part a shallow lake area.

By the transgression up to ALV-2 the delta was displaced up to about Section 13. Delta sediments were deposited and a drift clay was spread over large areas. The levé-like ridge in B 227 was probably formed during this stage.

During the lower water level of ALV-3 (estimated at +15.0 m) the river cut down into the older delta sediments and built out its delta downstream to Sections 4 and 14. A stream channel is seen at about BP 186, the bottom level of which is at +11.6 m. In the eastern part the older sediments became at this stage more or less weathered. The western part was a shallow swampy lake that started to be overgrown. Here a layer of pitchy soil reaches from +15.1 m to +13.9 m. A layer of brushwood peat lies at +14.4—14.7 m. The altitudes of these layers are surprisingly low, as the level of ALV-3 was here at +15.0 m, which means that these layers were mostly formed just below the corresponding water level (suggesting that these layers in reality are fen dy and peaty fen dy to dyey fen peat, respectively).

In the river slope, two series of samples, B 103—104, were taken around this layer of pitchy soil. The altitude was levelled to +13,935 m, which agrees well with von Post's section. The pollen diagram (Fig. 80) shows that the pitchy soil belongs to zone VI (i. e. ALV-3), the sand above to zone VII (i. e. the Younger Sea Fiord) and the clay and sand below to zone V (i. e. ALV-2). The lowermost 1.0 cm of the pitchy soil was C^{14} dated at 5,825 ±100 BC, which means that the pitchy soil was formed in connection with the transgression up to PTM-2.

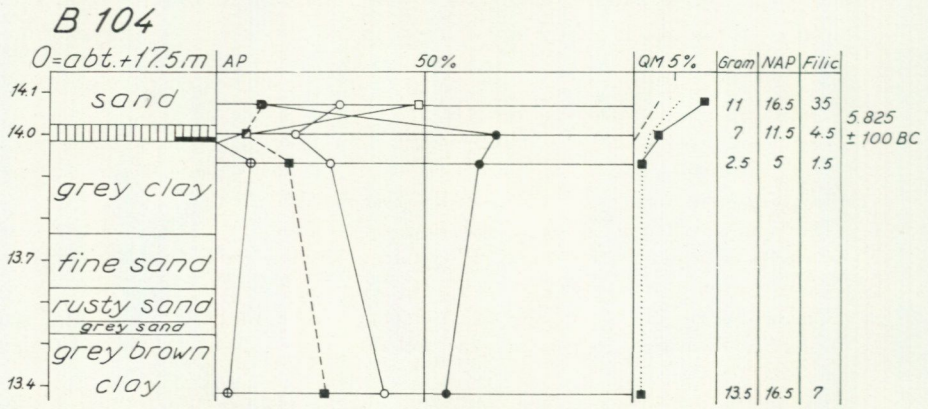


Fig. 80. *Pollen diagram from Section 13.*

In B 102 four cores of the sediments around the pitchy soil were taken with a piston corer. The microscopic soil determination gave the following stratification.

A: 9 cm of clayey fine detritus mud = the onset of the transgression up to PTM-2.
B: 3.5 cm of brown fine detritus mud = the very onset of the transgression.
C: 3.5 cm of brown clayey fine detritus mud, apparently lacustrine = the very onset of the transgression (ground water rise).
D: 10 cm of pitchy soil in clay (or muddy clay). The black humus content decreases with depth, indicating impregnation from above. The upper contact is at +16.7 m.
E: 7 cm of silty clay (= von Post's drift clay) deposited during ALV-2.

31. Section 10, Kattunga Mosse

This section cuts the peat bog "Kattunga Mosse" (Pl. 8). At the beginning I had difficulty in connecting the different layers. Luckily, however, the bog had been drained, and a 2 m deep ditch had been dug with an excavator around the bog. After having gone through these ditches, it was obvious how to connect the different layers. Thus the picture obtained seems well founded.

Four main stages are seen (cf. Fig. 81):

1. The recent peat bog, Kattunga Mosse, with a short initial lake stage.
2. The Younger Sea Fiord.
3. The Ancient Lake Kattunga, a swampy peat area with an open lake in the middle.
4. The Older Sea Fiord.

According to the shoreline diagram, ALV-1b here falls at +14.7 m. However, neither sediments nor weathering from this stage are seen in this section.

During ALV-2 the delta mouth was displaced up to about Section 13 and levés were built up in this section. As the river bed of Ancient Lake Veselången must have had roughly the same position as the recent river bed, much of the material is eroded away. West of River Viskan the levé of ALV-2 is seen below the layer of pitchy soil. This levé reaches +18.0 m, which agrees well with the estimated level of ALV-2, viz. +16.6 m. East of River Viskan only the distal part of the levé remains, in which the following transition is seen: silt — sandy clayey mud — clayey mud. In BP 273 (Fig. 111, p. 307), the clayey mud is dated to the late part of zone V (BO-1), i. e. ALV-2. As the clayey mud reaches +15.0 m, the corresponding water level must be above this level, which may fit with the estimated level of +16.6 m.

By the regression down to ALV-3, a small lake was isolated between the eastern valley side and the delta material, here called the Ancient Lake Kattunga. The pollen diagrams of von Post's BP 273 and my B 229 clearly show that the formation of a pure mud started at A^0, i. e. the very beginning of ALV-3. This lake soon started to be overgrown. A brushwood peat was formed on the western side of the lake and a "*Phragmites*" peat containing stumps on the eastern side

(in B 101 the uppermost part of the peat is an *Amblystegium* peat). Probably the lake was almost entirely surrounded by a swampy peat area (Fig. 75). The level of this lake was about +16.0 m, which means that it was dammed 0.8 m above the corresponding level of ALV-3.

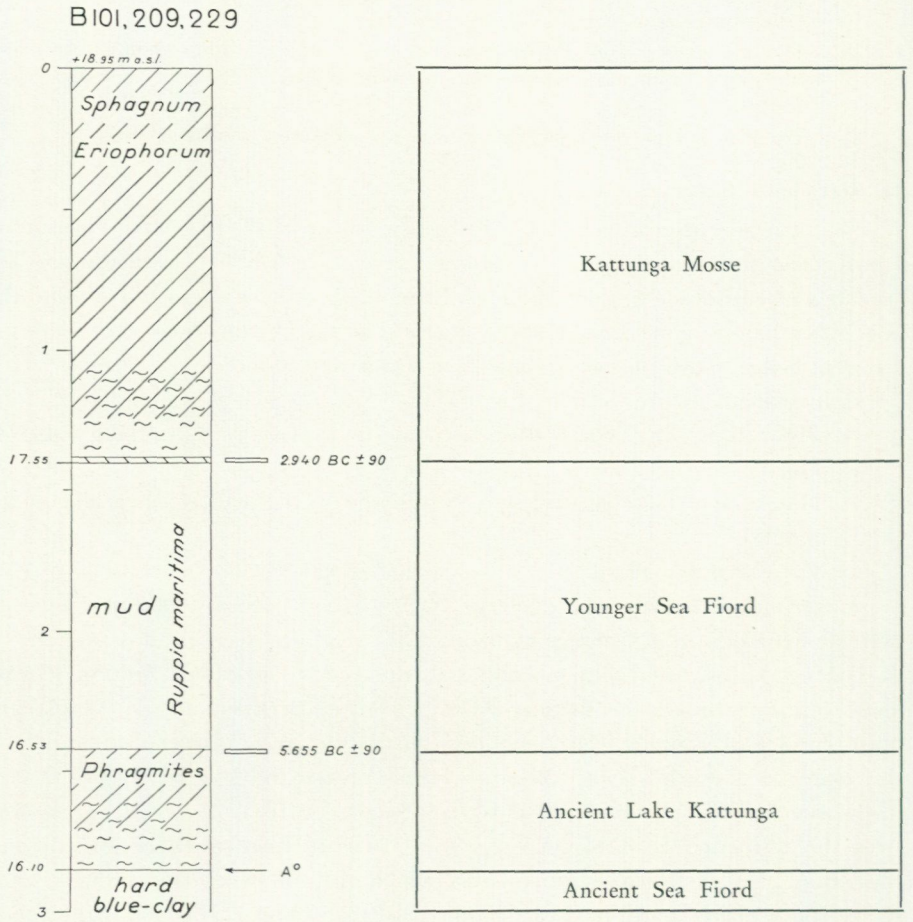


Fig. 81. *The stratigraphy in Kattunga Mosse. The beginning and end of the Younger Sea Fiord are closely dated in B 101.*

In B 101 a series of samples were taken with a piston corer in order to C^{14} date the layer just above and just below the marine *Ruppia* mud of the Younger Sea Fiord (four cores around the upper level and three cores around the lower level). A careful soil determination under the microscope gave the following stratification (Fig. 81):

A1: 13 cm of highly humified peat containing spores of *Sphagmum* and a Copepod spermatophore, but no diatoms.
A2: 2.0 cm of black lacustrine fine detritus mud with *Pinnularia*. The lowermost 1.5 cm of this layer was C^{14} dated at 2,940 ±90 BC.
A3: 30 cm of muddy clay with *Campylodiscus echeneis*.
B1: (above) clayey fine detritus mud.
B2: (below) *Amblystegium* peat Palso other plant remains). The uppermost 1.5 cm of this peat was C^{14} dated at 5,655 ±90 BC.

The upper date must be regarded as very good date of the end of the Younger Sea Fiord and the beginning of the Recent Lake Veselången. The age obtained is in very good agreement with my zonation of von Post's pollen diagram of BP 273 (Fig. 111), as the isolation should here have taken place in early zone VIII (SB-1) and T. Nilsson (1964) has dated the zone boundary VII (AT-2) /VIII (SB-1) in Skåne at about 3,100 BC (cf. p. 308).

The lower date must be regarded as a good date of the onset of the transgression in this place, about 1.2 m above the level of ALV-3. This age is a little younger than the age of the very onset of the transgression up to PTM-2, which was found in samples from the level of ALV-3.

32. Section 12, Kattunga Mosse

This section cuts the northern margin of Kattunga Mosse as well as the Ancient Lake Kattunga. The following stratification and development is found (confirmed by observations in a new ditch):

1. Blue-clay of the Older Sea Fiord.
2. A small layer of pitchy soil at +15.2 m apparently formed in connection with the transgression up to ALV-2 and indicating that the level of ALV-1b was below (estimated at +14.9 m).
3. A thin layer of clayey mud apparently belonging to ALV-2.
4. A levé that can be followed up to +18.4 m (or about +17.5 m). This belongs to ALV-2 (here estimated at +16.7 m).
5. 25 cm of brushwood peat at +16.25 m, probably belongs to ALV-3, which here should be at +15.3 m.
6. Sediments of the Younger Sea Fiord.
7. The peat bog Kattunga Mosse and sediments from the isolation.

33. Section 11, Kattunga

This section cuts the area just above the shore of the Ancient Lake Kattunga. The stage of Ancient Lake Veselången is only represented by a probable levé that reaches about +18.7 m and drift sediments associated with this levé (apparently belonging to ALV-2) and a marked layer of pitchy soil that reaches 300 m between +17.4 and 18.0 m. This layer of pitchy soil was apparently formed in connection with the transgression up to PTM-2. An attempt to date the drift sediment below the pitchy soil in a new boring did not succeed as the sediments were extremely poor in pollen.

34. "Meander 23" and "Meander 27"

Wenner (1950) tried to combine the alluvial terraces of the River Viskan into a diagram, showing that the large meander plains belong to stages of increased meandering in connection with transgressions and stagnations in the Younger Sea Fiord, the isolation of the Recent Lake Veselången and some later lake stages. The sections through the meander plains (Wenner 1950, Fig. 9) show a series of river beds, which Wenner interpreted as having been formed during the Postglacial regression. Recently Widell tried to date the meander plains with C^{14} datings of organic material in the alluvial sediments (Widell 1966, unpubl.). Eight C^{14} dates showed that the meander plains contain material of quite different ages. According to my interpretation they also clearly show that there are two quite different systems, viz. partly the Late Glacial/Preboreal regression and the stages of Ancient Lake Veselången and partly the Postglacial regression down from the PTM-2 level.

Three C^{14} datings (Stockholm VII) below Meander Plain 6 in Meander 23 gave ages that belong to the older system:

1. "Clay" (organic material in silt) +18.5—18.4 m, i. e. 2.0—1.9 m above the river bed, gave 7,965 ±130 BC (St-2038).
2. Wood +17.6—17.4 m, i. e. 1.1—0.9 m above the river bed, gave 7,380 ±110 BC (St-1899).
3. "Clay" (organic material in silty fine sand) +17.0—16.8 m, i. e. 0.5—0.3 m above the river bed, gave 8,450 ±120 BC (St-2021).

These dates show that the river bed at about +16.5 belongs to the older system. In Meander 27 the two systems of river beds are obvious. The bottom of the river beds of the older system lie at about +18.6 m, +16.2 m and +14.2 m, respectively. The lowermost river bed should correspond to the level of ALV-1b and the other to the preceding regression. This makes it probable that the river bed at +14.4 m in Meander 23 also belongs to the older system (there is also a trace of a river bed at about +18 m).

The shoreline diagram gives the following shorelevel displacement at Meander 23: ALV-1b = +16.1 m, ALV-2 = +17.65 m and ALV-3 = +16.2 m. This means:

1. that the river bed at +14.4 m lies 1.7 m below ALV-1b (probably less during low-water), which shows that it should belong to ALV-1b;
2. that the river bed at +16.5 m lies 0.3 m above ALV-1b and 1.15 m below ALV-2. This means that a minor deposition of alluvial material could have started already during ALV-1b and that a major deposition took place during ALV-2. This agrees very well with the C^{14} dates obtained;
3. that the Meander Plain 6 at about +20.25 m lies 2.6 m above ALV-2, which seems a little too much to have been deposited entirely during ALV-2.

The real meander plain of ALV-2 could very well have been covered by some younger sediments of the Younger Sea Fiord. There is a colour change at +18.6 m, i. e. 0.95 m above ALV-2, and a sediment limit (silt/silty fine sand) at +18.8 m, i. e. 1.15 m above ALV-2, which could mark the limit of the alluvial sedimentation of ALV-2. This means that we have a meander formation at least 1 m above the mean sea water level of ALV-2. If we now turn to the C^{14} dating, the upper and lower samples consist of quite undetermined organic material, obviously redeposited from older sediments, while the middle sample consists of wood that was probably part of a branch. This branch ought to be roughly the same age as the deposition of alluvium, or just slightly older. The age, 7,380 ±110 BC, also agrees very well with the time of the onset of the transgression up to ALV-2. During ALV-3 the river probably eroded down roughly to the same level and at the same position as during ALV-1b.

At Meander 27 the shorelevel displacement would have been: ALV-1b = +16.5 m, ALV-2 = +17.9 m and ALV-3 = +16.5 m. This means:

1. that the river bed at +14.2 m lies 2.3 m below ALV-1b (probably less during low-water level);
2. that the river bed at +16.2 m lies 0.3 m below ALV-1b and 1.7 m below ALV-2. This means that the deposition of alluvial sediments should have started during ALV-1b and have been strong during ALV-2;
3. that Meander Plain 6 at about +20.5 m lies 2.6 m above ALV-2 (cf. above.)

As a whole this shows that Widell's C^{14} dates and the development found in the river area upstream of the real delta, fits very well with the development found in Ancient Lake Veselången.

Final remarks on the ALV shorelines in the Viskan Valley

Three different ALV shorelines (excluding ALV-0) were found and closely fixed as to gradient and age along the valley, i. e. 30 km in the direction of tilting. A distance diagram was made (Fig. 82) on the basis of the closely determined direction of tilting.

Earlier von Post († 1968) found (combined into a relation diagram) a low level before C^0, a transgression about C^0 and a second low level, = the regression maximum, about A^0. However, pollen and C^{14} datings have clearly shown that the real regression maximum belongs to the time about C^0. Most of von Post's evidence of his "*Corylus* transgression" has been reinterpreted. However, there is a fully proved transgression starting shortly after C^0 but having quite another gradient and usually based upon quite separate and clear evidence. The following development was found (Fig. 82):

1. ALV-0: Some fairly distinct shoremarks corresponding to a stagnation (or even minor fluctuation) in the Preboreal regression.

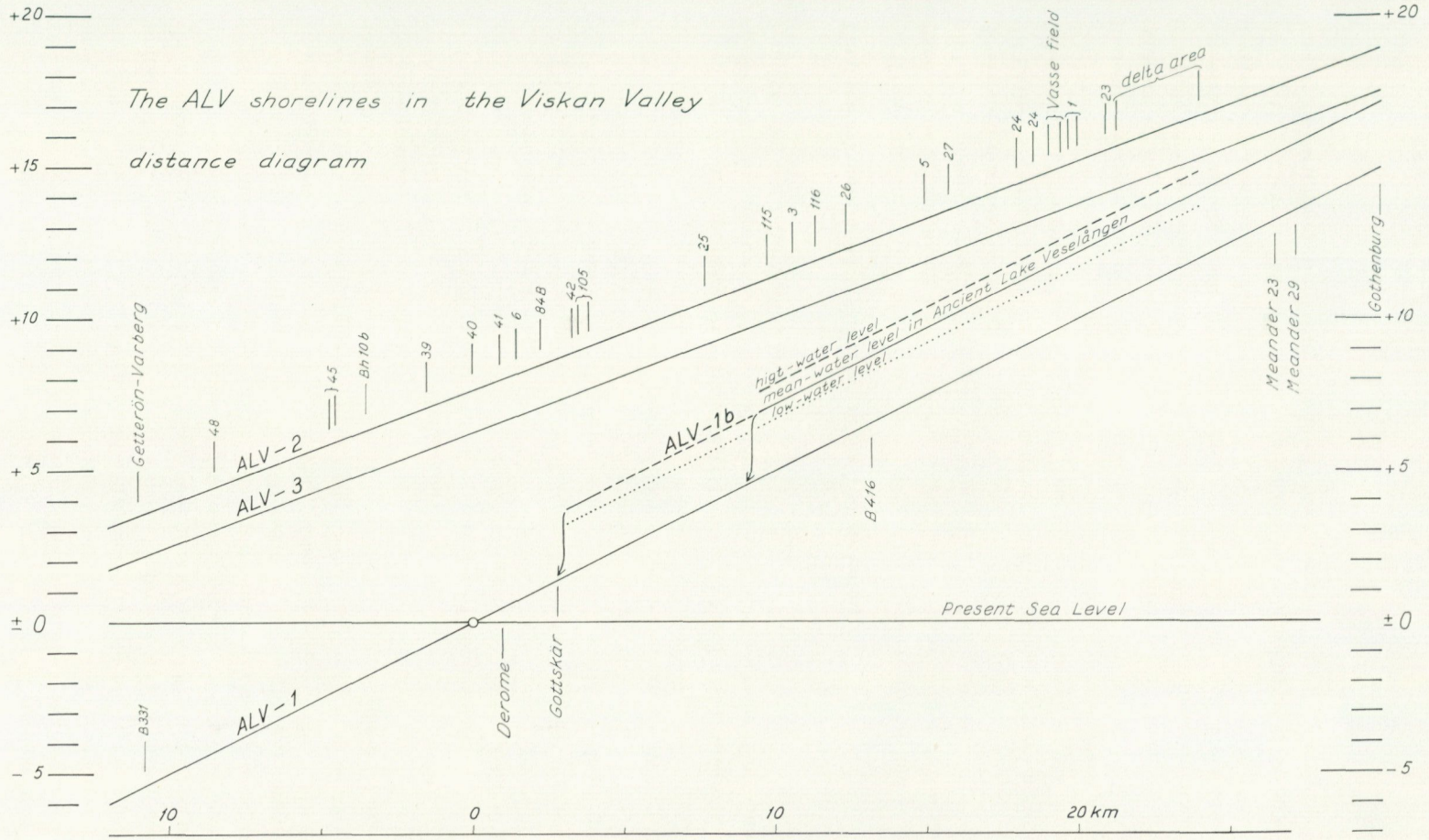


Fig. 82. *Compare Fig. 43 with the same distance scale.*

2. ALV-1: A very distinct shorelevel of the regression maximum. The age is C^{14} dated at 7,750—7,330 BC. During this period the sea level remained quite stationary (= syngression) without any observable changes either from eustatic or isostatic causes. The Ancient Lake Veselången was now dammed 2.2 m (mean-water level) above sea level, as ALV-1b (mean high-water level 0.6 m higher and mean low-water level 0.5 m lower). In the Veddige area a shift in the position of the river is seen. In the delta area an advance of the delta sediments is seen, and still further upstream the old river beds were found. The intersection between the present sea level and ALV-1 in Section 40 was used as the O-point in my distance diagrams.
3. ALV-2 (= PTM-1): A marine transgression started at 7,330 BC and brought the sea level up to ALV-2, which meant an ingression of salt water in Ancient Lake Veselången. In fact, this is the first Postglacial transgression. The maximum was reached not long before A^0 (in other areas fixed at about 6,900 BC). This transgression was found outside as well as within the Ancient Lake Veselången proper, in the delta area, as well as in the old river channels still further upstream. During the transgression up to ALV-2, there was a rapid eustatic rise of sea level, but also an isostatic land upheaval.
4. ALV-3: A marine regression (not isostatically caused) brought the sea level down to ALV-3. This occurred at A^0, i. e. about 6,550 BC. ALV-3 ends at 5,800 BC, when the second Postglacial transgression starts. During ALV-3 no changes of the sea level can be observed (= syngression), either from eustatic or isostatic causes. The Ancient Lake Veselången was then almost entirely lacustrine, though it was on a level with the sea. The regression down to ALV-3 is seen in the delta area as well as in many other localities within or outside the Ancient Lake Veselången proper.

Description II: the ALV shorelines outside the Viskan Valley

1. The Gothenburg area (+30 km)

From the Kungsladugård-Änggården area in Gothenburg, several important localities with intermarine layers from the ALV time have been described (Munthe *et al.* 1923, Alin 1934a, Thomasson 1934). In order to take samples for C^{14} datings and pollen analyses, I have made several new borings in the same area. The samples were taken with a piston corer. All older and new localities have been combined in Fig. 83. Thanks to all these localities, it was possible to reconstruct the details of the development during ALV-time.

Intermarine layers of mud and peat from the time of ALV-1 have been found down to +15.31 m at "Kungsladugårdsgatan 30" (Thomasson 1934, Fig. 69). I have a new boring B 449 ("Snäckgatan"), in which I found a thin layer of

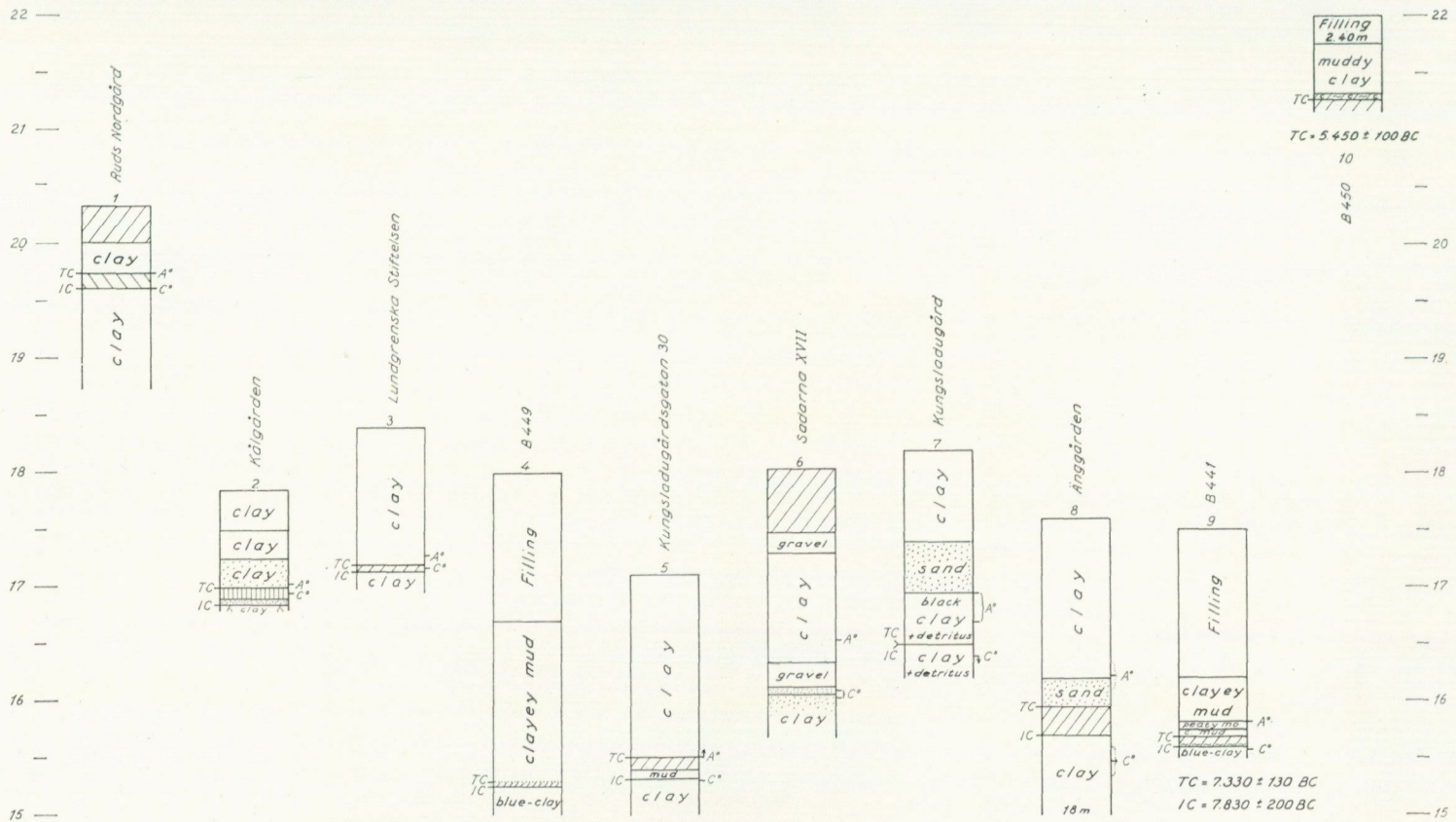


Fig. 83. *Synthesis of intermarine layers in the Gothenburg area. IC = isolation contact. TC = transgression contact.*

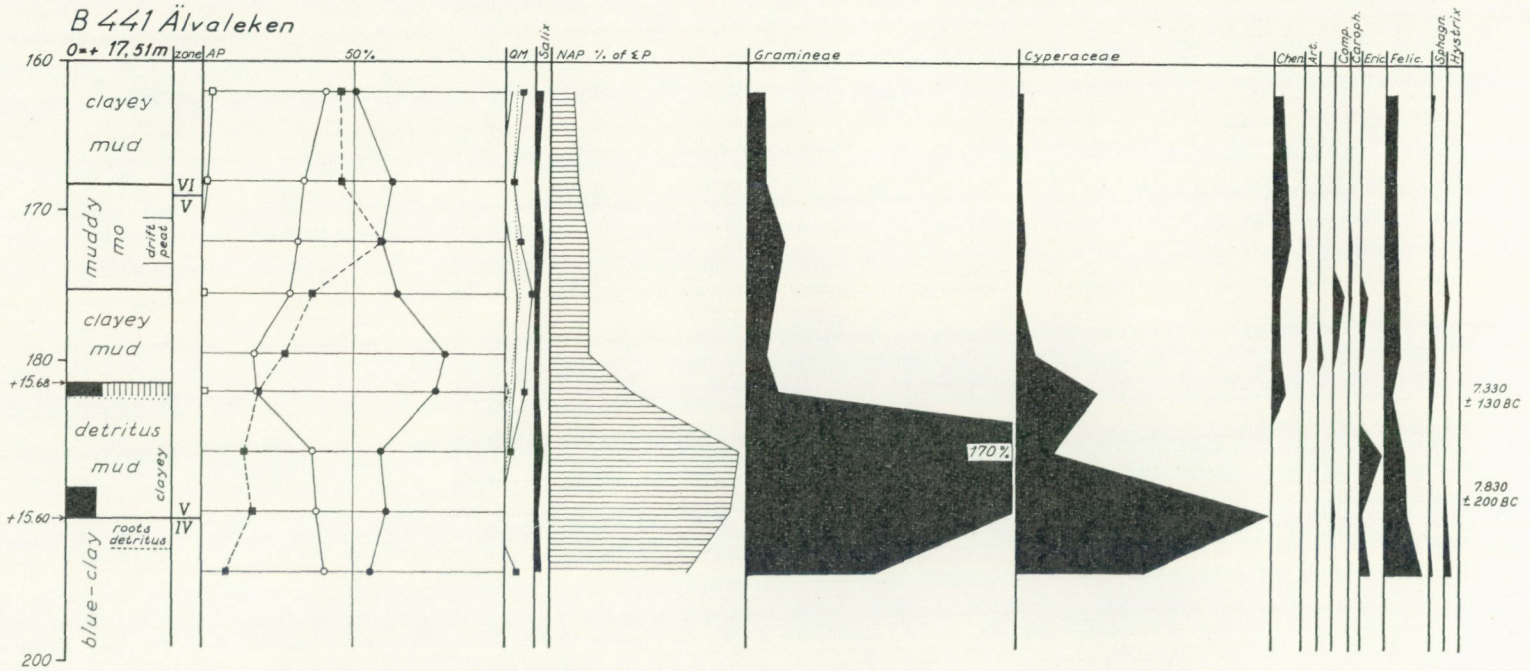


Fig. 84. *Pollen diagram of B 441. The intermarine detritus mud at +15.60—15.68 m corresponds to ALV-1, which is here closely dated. The muddy "mo" with drift peat may correspond to ALV-3, though the pollen content indicate a formation during ALV-2.*

peat (or peaty detritus mud) at about +15.25 m. This peat layer shows signs of having been formed very close to the shorelevel, and the blue-clay below is quite loose. These observations indicate a shorelevel at about +15.0—15.3 m. Pollen-analytically, these intermarine layers belong to zone V (BO-1). In "Kålgården and "Lundgrenska stiftelsen" (Thomasson 1934), C^0 lies a bit up in the intermarine sediment. However, the *Pinus* curves show that these layers ought to be placed entirely in zone V (BO-1).

Concerning the datings of the intermarine layers, I think my locality B 441, "Älvaleken", gives the final solution. This boring was made in the playground Älvaleken in the Änggården area. The surface of the boring point was later kindly levelled by Stadsbyggnadskontoret in Gothenburg. Six cores of the sediments around the intermarine layer were taken here with a piston corer. The pollen diagram (Fig. 84) shows that the intermarine detritus mud belongs to the older part of zone V (BO-1) and that A^0 lies in free marine sediment. The uppermost 1.0 cm of detritus mud is black and more or less transformed to a pitchy soil. This uppermost 1.0 cm of the detritus mud was C^{14} dated at 7,330 ±130 BC, i. e. exactly the same age as I have found in the Viskan Valley for the very onset of the transgression up to ALV-2. Consequently, we here have the real evidence that the first Postglacial transgression started exactly at the same time in Gothenburg at about +15.0 m as in the outer part of Viskan at about ±0 m. As the material is a pitchy soil (in detritus mud) and the sample was only 1.0 cm thick, this date must be regarded as a very good date of the very onset of the first Postglacial transgression. The lowermost 2.0 cm of the detritus mud was C^{14} dated at 7,830 ±200 BC, which should mean that the stage of the intermarine layer lasted about 500 years. The pollen diagram suggests that this time should be shortened to about 400 (possibly 300) years. Anyhow, it shows the same thing as I have found in the Viskan Valley, viz. that there was no visible shorelevel displacemant during the whole time of ALV-1.

The marine transgression up to PTM-1 (= ALV-2) seems to have reached up to about +19.0 m. The intermarine layers were now transgressed. At Ruds Nordgård (Thomasson 1934), however, which in the diagram lies 2 km outside the Kungsladugård-Änggården area, the transgression did not reach +19.75 m, as the peat formation here seems to have continued until the onset of the transgression up to PTM-2. At Sandarna (Alin, Niklasson and Thomasson 1934), the earliest culture layer and artefacts were now buried by beach sand and shingle up to +20.5 m.

In the localities in the Kungsladugård-Änggården area (Fig. 83), A^0 is found in free marine sediments, the highest of which lies at +17.28 m in "Lundgrenska Stiftelsen", i. e. the shoreline of ALV-3 must lie at least above +17.3 m. In the locality "Kungsladugård" (Munthe *et al.* 1923) A^0 lies just below a layer of sand at +16.95—17.40 m, which suggests that the corresponding shore was not far

away/above. At Sandarna this regression-syngression is seen in the fact that the culture layers and hearths move down again and out on the beach of PTM-1/ ALV-2. The shoreline of ALV-3 ought thus to have been at about +17.5 m.

According to this interpretation the shorelevel displacement in Gothenburg fits exactly with the one I found in the Viskan area, i. e. a syngression during "regression maximum" = ALV-1, a transgression of about 4 m up to PTM-1 = ALV-2, and a regression of about 1.5 m followed by a syngression = ALV-3. The only thing is that I have had to introduce the Kungsladugård-Änggården area into the Viskan diagram at a point 6 km north of the one at rightangles to the direction of tilting in the Viskan Valley (Fig. 82). The same applies to the Late Glacial part (p. 127) and the PTM shorelines. With this correction the Viskan diagram says: ALV-1 = +15.0 m, ALV-2 = +19.0 m and ALV-3 = +17.5 m, which is exactly the same shorelevel displacement as I found in the Kungsladugård-Änggården area. Here I would draw attention to the interpretation given by Thomasson in 1934 and his shorelevel displacement curve (Thomasson 1934, Fig. 70).

In this connection, the archeologically as well as geologically very important locality Sandarna (Alin, Niklasson and Thomasson 1934) is well worth a closer examination.

As this locality is best interpreted as a whole, I will now also deal with the part of the younger Postglacial transgressions that by rights belongs to a later chapter (p. 311). A main question is the genesis of the beach ridge. According to the older description, this should be called an offshore bar. However, I think this ridge is a true beach ridge formed by a younger transgression. The shape of the ridge, with a steep inner slope shows that it has been pushed up over land during a transgression.

I find the following succession in the profile at Sandarna (Fig. 113, p. 312):

1. "ALV-0" = shorelevel at about +21.4 m where a probable shore cut is seen in the Late Glacial clay. According to Alin (1934), there was a transgression from a level below +19.3 m. However, a transgression does not seem necessary to explain the ground crust formation below a 10—30 cm thick layer of sand. It ought only to be a question of a stagnation, which corresponds to the shore cut at +1.6—1.8 m at Lahall (p. 192). The shore cut is filled with sand and shingle.
2. ALV-1 = shorelevel at about +15.0 m. This level cannot be fixed in this section. The earliest settlement occurred at the central culture layer. This can now be given an exact dating, viz. between 7,700 and 7,300 BC. The surface of the Late Glacial clay is weathered down to +19.6 m. The absence of a ground crust further out must be due to the ground water that, following the lower sand layer, poured out on the clay surface below +17—19 m.

3. ALV-2 = shorelevel at +19.0 m. A beach ridge was now formed up to +20.6 m, i. e. 1.6 m above the sea level. This ridge partly covered the old culture layer of ALV-1. It contains ash layers, hearths and artefacts, which must consequently be contemporary with the formation of the beach ridge. The lowermost ash layer is at +18.84 m.
4. ALV-3 = shorelevel at +17.5 m. The regression is proved by the fact that the central culture layer moves out onto the beach ridge of ALV-2. The ash layer number 2 roughly marks the limit of the older beach ridge. Shore material seems to have been thrown at least up to +19.6 m, i. e. 1.1 m up.
5. PTM-2 = shorelevel at about +25.5 m. The shore cut at +25.5 m in the glacifluvial material at Carnegieska Bruken was now formed. In this section sand and shingle were thrown up to +27.0 m, i. e. 1.5 m above sea level. In connection with the onset of this transgression the older beach ridge was raised to +21.5 m (ash layer number 4).
6. PR-3 = shorelevel at 21.0 m. A beach ridge was formed up to +22.5 m, i. e. 1.5 m above the sea level. On the top of this ridge there are ash layers. Inside the ridge a thin clay layer was formed — probably a drift clay. The lowest point inside the ridge is at +21.4 m.
7. PTM-4 = shorelevel at +22.5 (—23.0) m. Now the marked beach ridge was formed up to +24.5 m, i. e. 2.0 m above the sea level. The steep inner slope marks the transgressional character of this ridge. The lowest point inside the ridge is at +23.1 m.
8. PTM-5 = shorelevel at +18.0 m. A shore cut was formed in the shore material. This is about 1.5 m high. According to the pollen diagram of point XVII (Thomasson 1934, Fig. 72), this belongs to the time about the zone boundary VII (AT-2)/VIII (SB-1).

According to this interpretation the culture layers, hearths and artefacts belong mostly to the ALV-time, i. e. 7,700—5,800 BC.

From Bräckemotet in the southern part of Hisingen, G.Persson (in Lund I) has given the following stratigraphy and dates:

A: 100 cm of sand and gravel.
B: 27 cm of marine mud. A^0 was stated to lie 7 cm up in the mud. A sample taken 12 cm up was C^{14} dated at 6,580 ±100 BC (Lu-20).
C: 15 cm of peat with pieces of wood. Wood from 1 cm down in the peat was C^{14} dated at 7,110 ±105 BC (Lu-21) and peat from 4 cm down at 6,910 ±100 BC (Lu-22).
D: 3 cm of mud.
E: sand and gravel.

Apparently, layers C and D corresponds to ALV-1 and layer B to ALV-2 and ALV-3. Layer A is most probably younger.

In the Ljungskile area about 90 km N of Gothenburg G. Persson (1968) has found a series of alternating marine and lacustrine layers. According to Persson, Kolbengtserödsjön at about +38 m has probably been isolated five times. Between C^0 and the PTM-2 transgression (at T^0 in this area) there would have been three minor transgressions. These are not seen in Vassbosjön at +43.5 m. During this stage my investigation only shows one transgression, viz. ALV-2. Persson's investigation may indicate that the syngressions of ALV-1 and ALV-3 at higher isobase latitudes, where the land upheaval was going on, might have involved minor fluctuations. However, the stratification may also depend on local ingressions not corresponding to changes in the sea level. The nature of these three ingressions, one of which apparently corresponds to ALV-2, will probably be solved by further investigation.

2. The Rya mire (+33.3 km) and Lake Lygnern

Lygnern is a big valley lake, dammed by the marked terminal moraine at Fjärås, in the valley parallel to the Viskan Valley. The Lygnern outlet passes two thresholds; the one of Lygnern-Sundsjön allowing a present waterlevel at about +15.1 m and the one of Stensjön allowing a present waterlevel at about +11.1 m.

The Rya mire in the delta area of Lake Lygnern has been investigated by means of stratigraphy and pollen and diatom analyses by von Post (unpublished, chapter VIII in the "Viskan investigation") and recently by G. Smedman (1967, unpublished). Von Post's as well as Smedsman's sections show a very varying delta stratigraphy, which is difficult fully to interpret. However, we must consider that a delta stratigraphy is in fact very inconvenient for diatomological investigations of the shorelevel displacement. The interpretation is also complicated by the fact that we have to consider the ancient damming of Lake Lygnern, which as we have seen in the Viskan Valley, was not by any means necessarily the same then as now.

Von Post's section shows a very varying delta stratigraphy with peat, mud and "mixed delta deposits". The layers can be connected in many different ways. Samples from three borings have been pollen and diatom analysed. The following can be said:

1. The blue-clay surface lies at about +18.0 m and is quite loose. However, it could be a redeposited "blue-clay".
2. About 2.5 m of marine deposits belonging to zone IV (PB) is seen in one boring. This suggests a lower threshold of Lygnern than today's.
3. The isolation seems to have occurred in latest zone IV (PB) or at the zone boundary IV (PB)/V (BO-1). The diatom diagrams show 100 % freshwater species in the part just above the isolation level. This part corresponds to ALV-1.
4. Zone V (BO-1) is in two borings characterized by minor peaks of marine and brackish diatoms. The uppermost of these lies at +20.0 m. This would correspond to ALV-2 and shows that the sea level now reached above the threshold.

5. Zone VI (BO-2) is characterized by 100 % freshwater species. Apparently this corresponds to ALV-3. If Smedman had not obtained a different result, this could have been regarded as evidence of the regression; now it can only be looked upon as a possible indication of this.
6. Zone VII (AT-1) is (in two borings) characterized by a marked peak of the marine and brackish diatoms. The admixture of salt water diatoms starts at the zone boundary VI/VII and apparently is equivalent to the very onset of the transgression up to PTM-2.

Smedman's section gives the same changing delta picture. Samples from one boring point have been pollen and diatom analysed and C^{14} dated. The following could be said:

1. The blue-clay surface is quite loose. The content of pollen suggests that it is a redeposited "blue-clay" of zone IV—V. The waterlevel corresponding to ALV-1 should nevertheless be found above this level, viz. +17.6 m. This suggests that Lygnern was dammed above the sea during ALV-1.
2. The clay is covered by a layer of mud with an admixture of brackish diatoms (and a few marine) and a pollen flora that says zone V (BO-1), though *Alnus* continues further down. This suggests that a transgression, apparently equivalent to that of ALV-2, brought the level a little higher up, which meant an ingression of salt water and less influence of the delta with a deposition of mud. A C^{14} dating in the middle of the mud gave 6,955 ±170 BC, agreeing well with this statement.
3. Zone VI (BO-2) contains a small layer of *Sphagnum* peat (probably alluvial) and "mixed delta deposits". Both layers contain an admixture of brackish diatoms (and a few marine). This does not agree with von Post's diagrams where zone VI contains freshwater species. However, it suggests that ALV-3 reached above the thresholds, which must consequently have been lower then than today. The lowermost part of the "mixed delta deposits" has been C^{14} dated at 6,415 ±60 BC.
4. In the lower part of zone VII (AT-1) there is 100 % freshwater species, which Smedman interprets as a regression. As von Post's diagrams clearly show that the transgression started at the zone boundary VI/VII, Smedman's results are apparently due to the delta conditions. The maximum of this transgression was C^{14} dated at 5,095 ±100 BC, in very good agreement with my age of PTM-2 (cf. p. 333).

The above facts show that Lygnern must have been dammed above the sea during ALV-1, but that salt water reached into Lygnern during ALV-2 and probably also during ALV-3. This means that the threshold of Lygnern during ALV time must have been lower than today. According to the following table, Lygnern was dammed 2.3 m above the ALV-1 shoreline and the threshold of Lygnern was about 2.6 m lower than today:

	ALV-1			
	Sea	Lake	ALV-2	ALV-3
the Rya mire, +33.3 km	16.7	19.0	20.85	18.75
the threshold of Lygnern, +20.5 km ..	10.2	12.5	15.2	13.9
the threshold of Stensjön, +18.0 km .	9.0	11.3	14.4	13.0

3. Hjälmeskulla (+17.8 km)

In order to fix the "regression maximum" outside the outlet of Lygnern-Stensjön, I bored a section down the valley slope at Hjälmeskulla to River Rolfsån. The stratigraphy was:

A: Postglacial clayey mud, thin in the slope but thicker near Rolfsån.
B: 20—30 cm of sand of the time of ALV-1. This layer ends at +7.1 m.
C: Late Glacial (— Preboreal) blue-clay.

According to the shoreline diagram, ALV-1 would lie at +8.9 m. However, this level cannot be fixed by this section, though the sand layer tells us that there has been a low sea level here before the transgressions.

4. Hanhals (+13.2 km)

Geotechnical borings in connection with the main road crossing the railroad (Statens Geotekniska Institut, no. G. 96) attracted my attention to a layer of "plant remains" 1—2 m below a "grey-clay" that contained shells.

Three borings were made in this area at roughly the same position. The series of samples which was pollen analysed was taken in B 416, the supplementing pollen samples at 1.60 m in B 698 and the C^{14} samples with a piston corer in B 701. The stratigraphy is (Fig. 85):

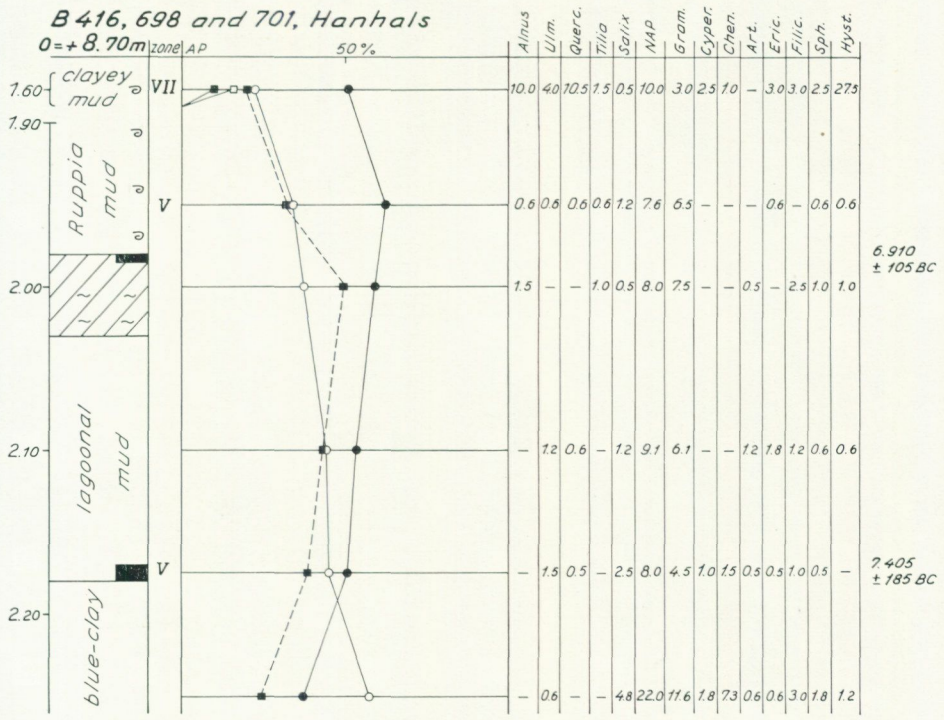


Fig. 85. *The lagoonal mud and detritus mud correspond to ALV-1 and possibly also early ALV-2.*

1. Blue-clay below +6.52 m, the uppermost part of which belongs to zone V (the earliest part).
2. 15 cm of mud up to +6.67 m, which is probably lacustrine or lagoonal and entirely belongs to zone V (BO-1). The lowermost 1.0 cm was C^{14} dated at 7,405 ±185 BC.
3. 5 cm of peaty detritus mud up to +6.72 m belonging to zone V (BO-1). The uppermost 0.5 cm of this layer was C^{14} dated at 6,910 ±105 BC.
4. 16 cm of *Ruppia* mud up to +6.88 m that contains shells and belongs to zone V (BO-1), at least in the lower part.
5. (above) A clayey mud with shells that 1.60 m down at +7.10 m contains a pollen flora belonging to the earliest part of zone VII (AT-1), which is supported by the high percentage, 27.5 %, of *Hystrix*.

Consequently, we have here a lacustrine or lagoonal mud and a detritus mud at +6.52—6.72 m, probably formed in close proximity to or even at sea level. This is important as the shoreline diagram says ALV-1 = +6.60 m. The pollen diagram proves that these layers belong to ALV-1 (and early ALV-2). The C^{14} dates are both a little younger than I would have expected. The *Ruppia* mud with marine shells is good evidence of the first Postglacial transgression up to PTM-1 (= ALV-2). The clayey mud with high percentage of *Hystrix* belongs to the transgression up to PTM-2.

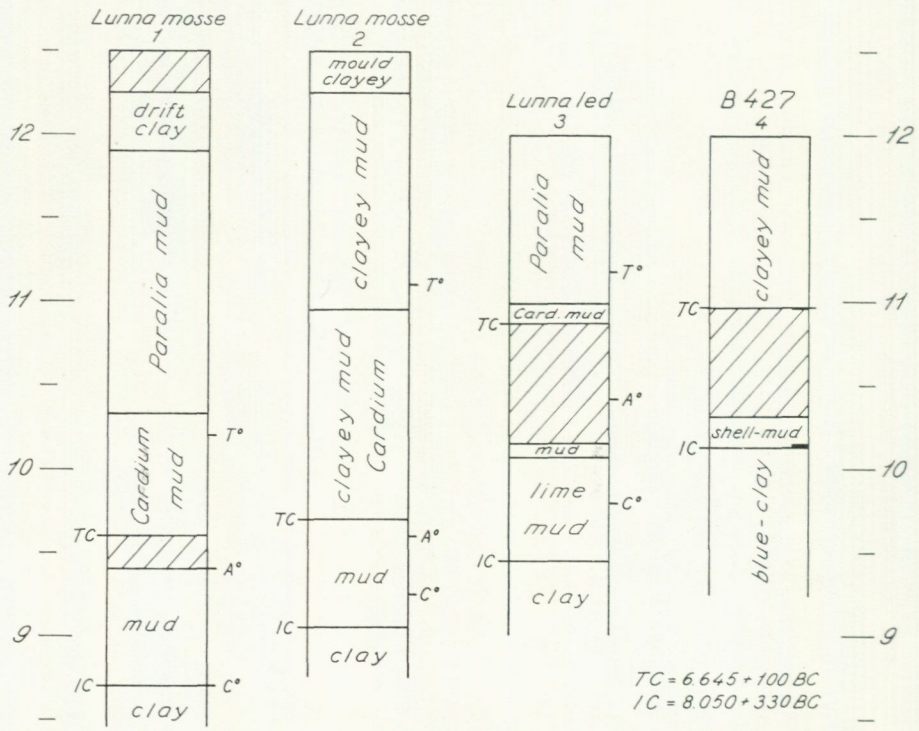


Fig. 86. *Synthesis of intermarine layers on the Onsala peninsula. IC = isolation contact. TC = transgression contact.*

5. The Lunna Mosse-Lunnaled area (+7.5—8.5 km)

The intermarine peat in Lunna Mosse was first described by G. Andersson (1893). Later the stratification was pollen and diatom analysed by Halden (1922). A pollen diagram has also been published by Thomasson (1934). The stratification at Lunnaled is described by Sandegren (Sandegren and Lundegårdh 1952). At Lunnaled I made the boring B 427 (sampling with a piston corer). In Fig. 86 I have combined these borings. The isolation took place in early zone IV (PB) and the C^{14} dating gave 8,050 ±330 BC. This has been dealt with above (p. 164). The transgression occurred some time after A^0 and obviously in connection with the onset of the transgression up to PTM-2, i. e. about 5,800 BC. A C^{14} dating of the uppermost 0.5 cm of peat in B 427, however, gave 6,645 ±100 BC. A pollen analysis of the dated sample shows that this belongs to the latest part of zone V (BO-1) and that the uppermost part of the peat must consequently have been eroded away in this boring. Anyhow the date gives the time immediately before A^0, which ought to be about 6,550 BC (cf. p. 227).

Consequently, the development does not show any influence of the transgression up to ALV-2, which in the northern end should lie at +10.85 m, but as the pass threshold here lies at about +12.0 m, this is not what you would expect either.

6. Gottskär (+2.8 km)

This locality was described by Alin (1934b). The section "Boplatsen Onsala 136" can be reinterpreted in the light of the now known shorelevel displacement. I would give the following interpretation of the stratification:

1. The Late Glacial — Preboreal regression = deposition of blue-clay containing a Late Glacial mollusc fauna (*Balanus hammeri* and *Saxicava aretica)*, sand and shingle. These sediments do not contain any artefacts.
2. Shorelevel at +1.40 m during ALV-1 = deposition of sand containing a boreal mollusc fauna (*Astarte borealis, Mya truncata* and *Saxicava arctica*) and shingle close to the sea level. The sand layer might also partly be older. Further inland settlements occurred and artefacts and flints were left on the land surface of that period. One relic of this land surface is probably the "dark soil-mixed gravel" at +2.53 m in the pit named "Grop 1" (possibly also seen in the occurrence of thin layers of rusty material).
3. Transgression up to +8.7 m during ALV-2. Now the marked layer of shingle was deposited and mixed with artefacts from the eroded land surface of ALV-1. This erosion of the old land surface is seen in the content of pieces of weathered clay in the shingle. The settlement must have been moved inland.
4. Regression to +7.3 m during ALV-3. This event is not directly seen in this section. The deposition of shingle with artefacts and pieces of clay probably continued.

5. The classical "Postglacial transgression". According to the pollen diagram of the pit "Grop 7" and the mollusc fauna (Alin 1934b, p. 18), the sand above the shingle belongs to the transgression up to PTM-2. Flints and artefacts occur in this sand layer. Later the layers of mud and clay were deposited. In the inner part of the section there is a layer of shingle with a lot of artefacts between the sand and clay, which belongs to an unfixed part of the "Postglacial transgression". The sediments above the clay belong to the following regression.

This means that it can now be shown that a settlement must have existed during ALV-1, which agrees well with the settlement in Sandarna. In this connection it can be pointed out that a lot of the flints may have nothing to do with human activity, being a usual component of the shore material.

7. Västra Hagen (+2.5 km)

This locality was described by Fredsjö (1953). Between two layers of shore deposits, Fredsjö found a black culture layer containing Mesolitic artefacts. The following stratification was found:

A: shingle
B: about 1 m of unstratified mixture of sand, gravel and stones containing washed artefacts
C1 (above about +12 m) a 10—20 cm thick black layer containing Mesolitic artefacts and two hearths. Some shell of *Ostrea edulis* and *Litorina litorea* were found in this layer
C2 (between about +12 m and +11.21 m): white-grey fine sand
C3 (below +11.21 m): coarser sand
D: unstratified mixture of sand, gravel and stones
E: stratified gravel, finer and more clayey downwards
F: blue-clay with *Saxicava arctica*

Layers F—D belong to the Late Glacial and Preboreal regression down to ALV-1 at +0.65 m (F = deep water, E = shallow water, D = shore). Layer C was either formed as a final stage of the regression or in connection with the transgression up to ALV-2 at +8.15 m. The blackness of the sand indicates — at least partly — formation of pitchy soil in connection with the transgression up to PTM-2. Layers B—A were formed in connection with the transgression up to PTM-2 and during the younger Postglacial transgression waves.

Fredsjö stated that shells of *Ostrea edulis* and *Litorina litorea* were found in the black layer (C1). This is important as *Ostrea edulis* cannot belong to the Preboreal regression before ALV-1, but to the Boreal time during ALV-2 and ALV-3. Thus this could show that layer C is younger than ALV-1. The limit finer/coarser sand at +11.21 m in layer C could correspond to the limit of the wave actions during ALV-2 at +8.15 m, i. e. 3.06 m above mean sea level. Fredsjö considered for topographical reasons, that the sea level was probably not below + 7 m during the settlement. Thus it seems very probable that the occupation by

man here took place during ALV-2 at +8.15 m and ALV-3 at +6.75 m. Below the culture layer itself there is a hearth, which is separated from the culture layer above by a layer of sand. Fredsjö regarded this as evidence of two periods of settlement. The sand layer could either belong to the transgression up to ALV-2 or just be an accidental filling with eolian sand. Charcoal in the hearth was C^{14} dated by Fredsjö at 800 ±150 BC (St-945, Stockholm V). However, this cannot be the correct age of the settlement, which must belong to the time about ALV-2 and ALV-3.

8. The Varberg-Falkenberg area and the water outside

In this area, intermarine layers occur at a lot of places (cf. p. 321). However, all these localities were isolated in Younger Dryas or Preboreal time and transgressed in connection with the transgression up to PTM-2, i. e. they have nothing direct to tell about the development during ALV time.

In Varberg, a geotechnical investigation by the harbour (Orrje & Co. no. 57.1122) has shown a 1.0—1.5 m thick layer of sand between the Late Glacial clay and the Postglacial muddy clay. The lowest point of the blue-clay surface lies at −2.8 m. The occurrence of vertical sand layer (= sandfilled weathering fissures) and geotechnical analyses suggest that it is a ground crust. The shore-level during ALV-1 here falls at −6.1 m. Similar sand layers are also seen in other sections in Varberg.

At the clay pit Fajans the uppermost part of a peat layer at +4.64 m has been C^{14} dated at 6,250 ±140 BC (Caldenius *et al.* 1960). However, the level of ALV-2 here falls at +0.4 m, which means that this layer was not transgressed until the transgression up to PTM-2, i. e. after 5,800 BC. The age obtained is probably due either to contamination by older material or to the presence of a hiatus.

In connection with geotechnical work around the harbour of Falkenberg, submarine ground crusts have been found at least down to −3.0 m and organic layers (probably pitchy soil) at least down to −0.4 m (e. g. Orrje & Co., no. 67.0226 and 57.1163). In the surface of the deepest crust at −3.0 m, the shear strength is 7.25 t/m² (the H_3-value is 605), which means that we here have good evidence of a real ground crust. This is to be expected, as the level of ALV-1 here falls at −11.0 m. According to the shoreline diagram ALV-2 lies at −0.4 m and ALV-3 at −2.2 m. However, these levels have not yet been fixed at Falkenberg.

Along the coast between Klosterfjorden and Halmstad about 65 submarine borings were made with the Kullenberg piston corer in places where intermarine layers could be expected, e. g. in the depression inside the terminal morain ridges. However, the covering sand almost always prevented the corer from penetrating further down.

At the shoal Marstenrevet, B 375 at –11.0 m gave a core about 50 cm long containing sand/gravel and gravelly clay. ALV-1 here falls at –12.3 m. A contour map (every full metre) of this area shows that a shorelevel somewhere between –10.0 m and –13.0 m seems very likely (the map was drawn after the fundamental charts).

Outside Skallen, B 387 at –12.5 m gave a 128 cm long core with 10 cm sand and 118 cm semihard clay with burrows. ALV-1 here falls at –15.9 m.

9. Halmstad (—27.0 km)

Caldenius and Linnman (1949) described three series of samples, taken in connection with geotechnical investigations in Halmstad. The geotechnical analyses show that down to a depth of at least –12.0 m the buried clay surface is weathered into a ground crust — but not down to –16.0 m in borehole 3 as the authors say: in this borehole there was a "hard glacial clay-silt" (according to the original notes by Dr. Wenner), which is not at all the same thing as a ground crust. A low sea level with ground crust weathering in borehole 2 is also indicated by a "dyey" layer at about –12.0—12.5 m. According to the given description, it seems to me to be a layer of pitchy soil from a buried shore meadow. Consequently the shore level ought to be found in the neighbourhood of this level. This shorelevel certainly corresponds to ALV-1. In borehole 3 there is about 2.0 m of medium sand (with some drift peat and drift wood) on the clay surface, which here lies at about –13.4 m (this statement is taken from the original analyses notes by Wenner). This sand layer could very well be a shore deposit from ALV-1, which according to the shoreline diagram here falls at –13.5 m.

The ground crust is covered by sandy-muddy-clayey sediments, which according to the diatom analyses have been deposited in the sea under the influence of the freshwater outflow of the River Nissan. Consequently, the stratigraphy shows a transgression of the sea. According to the pollen diagram this started in early zone V (BO-1) and is therefore identical with the one up to ALV-2, which according to the shoreline diagram here lies at –2.2 m.

A^0 lies in free marine sediments at –7.5 m. The fluctuating diatom curves show a peak of 50 % freshwater species at A^0. Above A^0 there is a relatively thick layer of sand (hypothetically extended in the section). The rise of freshwater diatoms at A^0 (and brackish diatoms between A^0 and the sand layer) and the sand layer above seem to be a result of the small regression down to ALV-3 and the syngression during that stage, which according to the shoreline diagram here lies at –3.7 m.

The sediments above the sand layer are quite dominated by marine diatoms. According to the pollen diagram they belong to zone VII (AT-1) and consequently must have been deposited after the onset of the transgression up to PTM-2.

Von Post (1928) described a lacustrine drift peat at about –6.5 m in the harbour of Halmstad. A pollen analysis of this peat indicates formation in late

zone V (BO-1), i. e. the time of ALV-2. As it is an alluvial material, it is hard to draw any conclusions about the corresponding sea level.

As a whole the development found fits very nicely with the shoreline diagram that says: ALV-1 = −13.5 m (shore deposits in borehole 3, pitchy soil and ground crust in borehole 2), ALV-2 = −2.2 m (transgression settled in borehole 2) and ALV-3 = −3.7 m (aggradation confirmed in borehole 2).

10. Laholmsbukten (the Bay of Laholm)

The geological conditions in this bay must now be regarded as well investigated, as I have no less than 46 borings in this relatively small area. The borings are mostly arranged in sections. Several important echo diagrams were obtained.

According to the nautical chart (mapped in 1813) a submarine ridge extends straight across Laholmsbukten, roughly from Hovs Hallar to Påarpsreven. The ridge should reach about −14 m and consist of stones. Inside the ridge there should be a depression down to −17—18 m. According to De Geer (in Ahlmann 1916, p. 307) this is a beach ridge, but according to Linderkrantz (1944) a terminal moraine — however, both these statements are only hypotheses. This ridge was not refound — only a string of coarser material resting upon glacial clay. The seabed slopes more or less evenly. Consequently, it is not a terminal moraine but probably a shore deposit. As the nautical chart in the middle of Laholmsbukten is only based upon very few soundings, and the "ridge" is only found in one sounded line, the map could be wrong. In B 151 (Fig. 93) the "ridge" was found to be a stony gravelly sand resting upon a weathered glacial clay. Grain size distribution curves from B 151, B 144 and B 153 (Table 2), show that the grain size grows finer towards the coast (the same applies seawards). This indicated that it is a shore deposit that has been washed towards the coast by streams. The corresponding shorelevel was the shoreline of ALV-0 or the one of the zone boundary III (DR-3)/VI (PB), which is supported by the age of the pieces of peat described above (p. 165).

One of the first stated pieces of evidence of a Postglacial transgression in Sweden was the buried old stream channel of River Stensån described by De Geer 1893 from the results of a still older mapping at Skottorp (Holmström and Lindström 1871). De Geer found that the bottom of the old stream channel lay at about −9 m at Skottorp. Furthermore, V. Ewald (1926) described a buried peat with artefacts at about ±0 m in Båstad (p. 334).

All the geotechnical data obtained in connection with the work on the motor highway Ö.Karup—Halmstad (Allmänna Ingenjörsbyrån AB) were gone through. Buried organic layers and ground crusts are present, but usually not of interesting depth. At River Stensån numerous borings have been made. These show a buried stream channel down to at least −10 m. The channel seems to be eroded in glacial clay. The channel is filled with muddy-sandy Postglacial sediments. In two analysed boreholes the clay surface seems to be weathered into

a ground crust at −10.1 and −10.2 m, respectively. Here the shear strength is high (8.0—9.5 t/m², compared with normally 4—5 t/m²) and the water content is low compared with the fineness number. Consequently, we have in the River Stensån area (in Skottorp) evidence of an old sea level at least below −10 m.

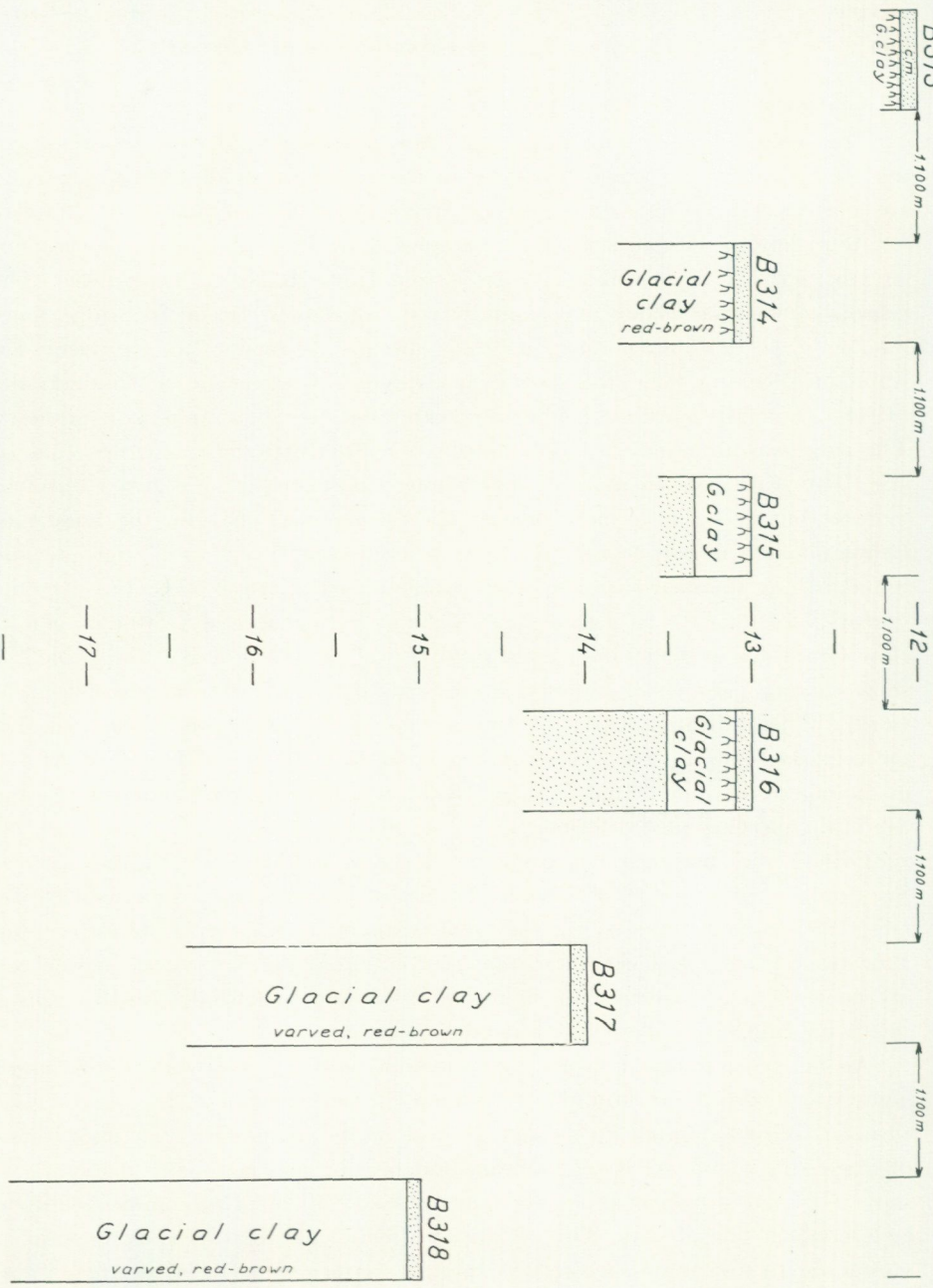


Fig. 87. *Submarine cores of weathered and unweathered glacial clay from Laholmsbukten.*

If we now turn to the submarine borings, the level of the "regression maximum" can be fairly well settled. These borings are below dealt with from north to south.

Behind and across the "Påarpsreven" nine borings were made. However, these have very little to tell, as the bottom was usually covered by a sandy layer that the corer did not penetrate. In B 395 there was 31 cm of hard, probably weathered, glacial clay at –11.5—12.0 m.

Outside the mouth of River Lagan a section of six borings (B 313—318) were made, and later one more boring (B 500). This section (Fig. 87) shows a hard, probably weathered, glacial clay down to –13 m in B 316, into which the corer could only be forced a little way. At –14 m in B 317, the corer was forced fully into the clay, which apparently was not weathered. In B 317 and B 318 the glacial clay is clearly varved and varve diagrams were made (Fig. 88).

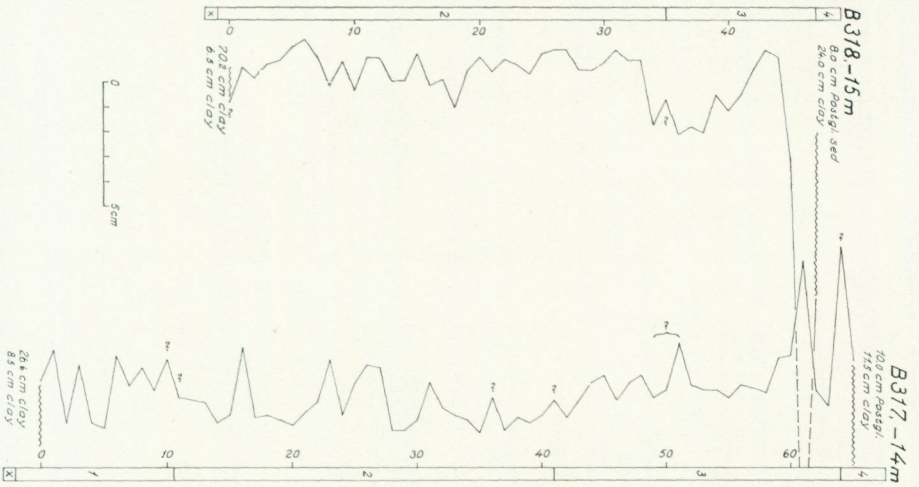


Fig. 88. *Varve diagrams of two cores in Laholmsbukten, not correlated mutually.*

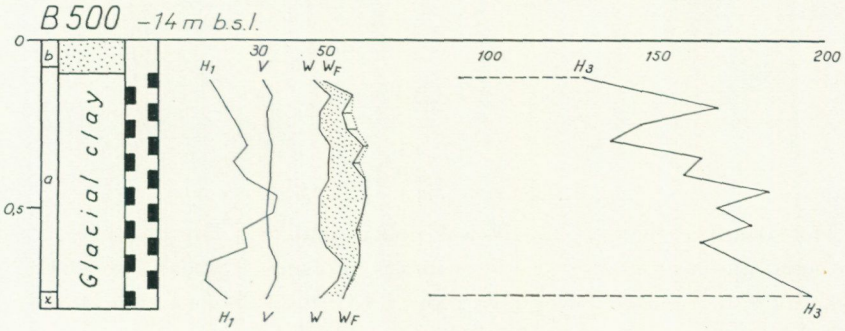


Fig. 89. *Geotechnical analyses of a submarine ground in glacial clay from Laholmsbukten. cf. Fig. 92.*

Forty-six varves were counted in B 317 and sixty-five in B 318. However, these could neither be correlated mutually or with known diagrams from land (e. g. the series at Lejeby). In B 315 and B 316 a black (FeS) slightly muddy silt to fine sand was found below the glacial clay. However, everything points to the fact that this is due to a misleading sucking effect by a falling piston corer (cf. p. 22). B 500 was taken at the same position as B 316. This core was geotechnically analysed. These analyses (Fig. 89) seem to show that it is a ground crust: H_3 is high (but not H_1) and the water content (W) is low in relation to the fineness number (W_F). Sample 8 was mineralogically analysed (see the table on p. 261).

The next section, which lies in the middle of the bay, is very important. It was the first one made and the results inspired continuous work in Kattegatt. Nineteen borings were made in this section, which however, is not a quite straight line. The stratification can be summarized as follows:

A: sand
B: clayey mud — muddy clay
C_1: sand or a mixture of sand, stones, silt and shells
C_2: (inside the "ridge") a series mud — peat — dy
D: blue-clay (strongly weathered)
E: (thin layer) sand and humus
F: glacial clay

These layers have the following distribution in the borings, which here are listed from the coast out to sea:

	depth	A	B	C	D	E	F	=	A—F
B 395	16	10	—	—	—	—	—	=	10.0
B 392	16	—	—	—	—	—	—	=	—
B 143:H	15	10	34	25	39	5.5	39.5	=	143.0
B 145:L	15—16	5	21	21	63.5	—	—	=	110.5
:M	15—16	—	—	—	+	—	—	=	10.5
:N	15—16	7.5	28.5	32	108.0	5	95.5	=	276.5
B 501	14	23	—	+	77.0	(33)	—	=	133.0
B 153:Å	16	+	—	—	—	—	—	=	+
:Ä	16	+	66.5	(17)	—	—	—	=	83.5
B 146	17	6.5	45.0	10.0	—	—	—	=	61.5
B 144:I	16	+	—	—	—	—	33	=	33.0
:K	16	10	—	—	—	—	13	=	23
B 152	17	3	—	—	—	—	11	=	14
B 147	17.5	+	—	—	—	—	21	=	21
B 151	18	10	—	—	—	—	16	=	26
B 150	19	—	15	+	—	—	228.5	=	243.5
B 148:R	19	3.5	74.5	9.5	—	—	5	=	92.5
:S	19	5.0	79.5	7.0	—	—	99.5	=	191.0
B 149	21	7.0	222.8	38.5	—	—	—	=	268.3

The stratification in B 145:N was pollen analysed. The blue-clay is totally weathered into a ground crust and crumbles into small angular pieces (Fig. 90); furthermore it contains downgrown roots, i. e. it is an obvious ground crust. The ground crust decreases with depth but is still seen in the uppermost part of the glacial clay. This land surface is covered by an intermarine series; pitchy

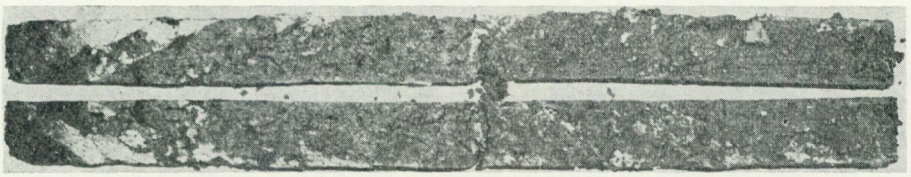


Fig. 90. *B 145:N part 3 (cf. Fig. 91) split up longitudinally (length 60 cm). The weathering of the blue-clay is clearly shown. To the left the covering pitchy soil is seen.*

soil — peat or peaty detritus mud — mud with small detritus lenses. i. e. a series showing a ground water rise in connection with the very onset of the transgression. The pollen diagram (Fig. 91) shows that the intermarine layers belong to zone V (BO-1). The uppermost 2.6 cm of the pitchy soil was C^{14} dated at 7,485 ±180 BC. A reserve sample of the lowermost 2.0 cm of the pitchy soil was by mistake C^{14} dated as a separate sample at 7,330 ±300 BC. Consequently, we have here good evidence of the same transgression as I have found on the Swedish West Coast, and as a whole the pollen analyses and C^{14} datings (cf. below) show that this transgression started at the same time, viz. about 7,330 BC. The ground crust, the downgrown roots and the continuous sediment series of the commencing transgression are clear evidence of a land period during the time of ALV-1 with a sea level at least below –16 m.

Curious stratifications were obtained in B 143:H and B 501, viz. intermarine layers were also found below the blue-clay. However, these are obviously misleading results due to the vacuum effect of the corer penetrating only a little down in a hard clay (cf. p. 23), which means that the loose layers below the blue-clay in reality come from the intermarine layers above the blue-clay. In B 143:H the following layers were found below the blue-clay:

2.5 cm of pitchy soil and 2.0 cm of mud, which together were C^{14} dated at 7,180 ±120 BC.

39.5 cm of clayey mud and mud, a reserve sample of the uppermost 2.5 cm was by mistake C^{14} dated as a separate sample at 7,280 ±500 BC.

These dates are good evidence that there is not also an intermarine bed below the blue-clay, but that, due to the sampling method, these layers are sucked in from the intermarine layers above the blue-clay. The dates agree well with the time of the onset of the first Postglacial transgression. In B 501 the following layers were found below the blue-clay:

10 cm of dy
2 cm of drift clay
21 cm of sand, coarser downwards

These layers show a continuous gradation to heavier and coarser material downwards — apparently a result of sucking. According to a pollen analysis the dy belongs to the late part of zone V (BO-1), roughly corresponding to the pollen

flora at the limit peat/mud in B 145:N (Fig. 91). The uppermost 5.0 cm of the dy was C^{14} dated at 7,330 ±125 BC, i. e. the age of the very onset of the first Postglacial transgression.

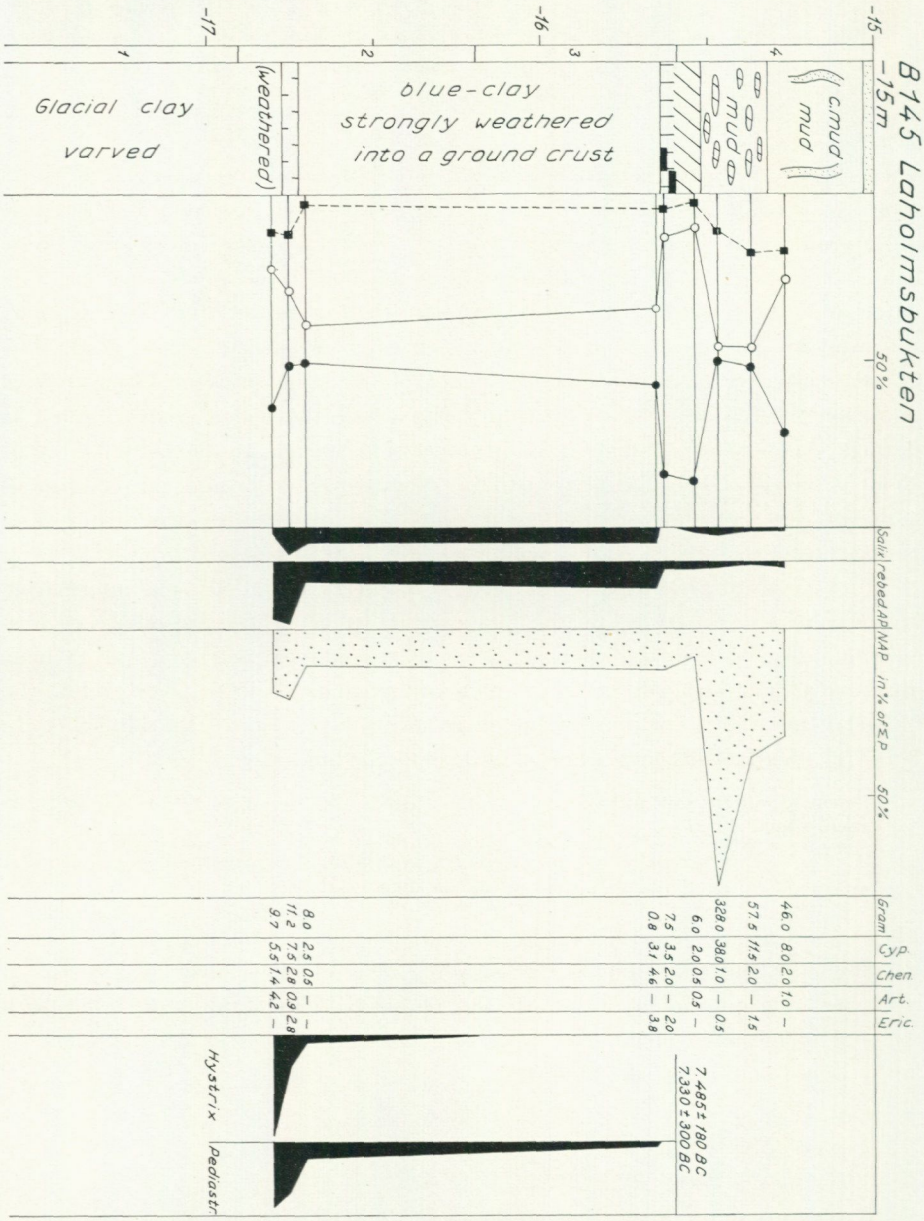


Fig. 91. *Pollen diagram of B 145:N. A distinct submarine ground crust is here covered with intermarine layers, clearly formed in situ and showing a continuous transition to marine mud.*

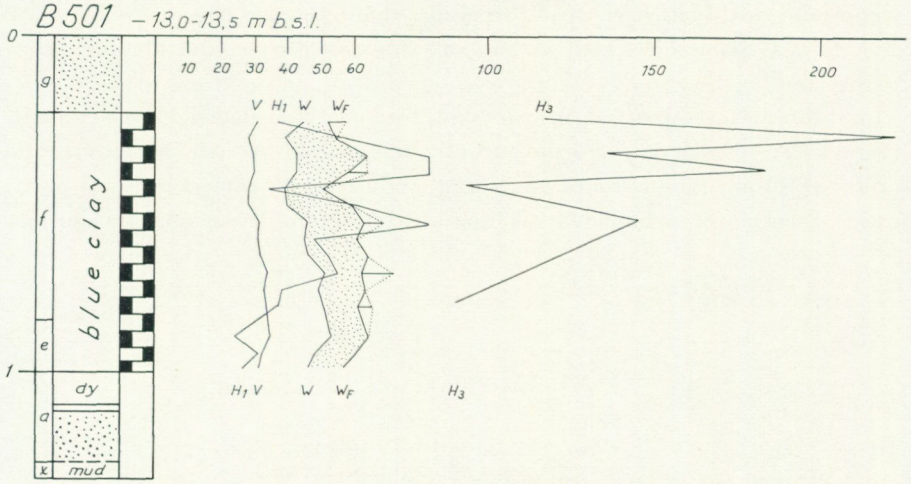


Fig. 92. *Geotechnical analyses of a submarine ground crust in Late Glacial blue-clay from Laholmsbukten. The H_3 figures are high and the water content (W) is compared to the fineness number (W_F), clearly showing the weatering during ALV-1. Black areas denote position of analysed samples (cf. Figs. 89 and 107).*

B 501 was geotechnically analysed. These analyses clearly show that it is a ground crust (Fig. 92): the H_3 figures are high and the water content (W) is low compared with the fineness number (W_F). This agrees well with the ocular determination. Samples 4, 8 and 12 have also been mineralogically analysed at the Norwegian Geotechnical Institute (Rapport: 66/310). The results are listed below together with the similar samples from B 500 and B 504.

Mineralogical composition (in %)	B 504:1	B 500:8	B 501:4	B 501:8	B 501:12
Montmorillonite, 16.7 A, glycol	4	7	3	4	5
Chlorite, 14.2 A	3	5	5	5	5
Swelling mixed-layer minerals, 14—10 A	1	1	1	4	4
Mica, 10.1 A	10	16	18	25	22
Amphibole, abt. 8.5 A	0	3	3	3	1
Kaolin, 7.1 A, HCl	0.5	1	0	0	4
Quartz (X-ray)	18	16	20	16	14
Quartz (D.T.A.)	(10-13)	(13-16)	(21-24)	(13-16)	(10-13)
K-Feldspar, 3.25 A	8	8	15	20	26
Na-Feldspar, 3.18 A	7	5	9	15	12
$CaCO_3$ (chemically determ.)	7.4	6.6	6.2	2.7	0.0
Organic C (chemically det.)	0.5	0.3	0.3	0.3	0.0
Totally about (%)	60	70	80	96	94

It is apparent that the blue-clay and intermarine series are in most cases eroded away and are only found occasionally. If the pieces of peat described by Fries (1964) really occur in situ, they ought to represent a more central part of

a depression with an older peat formation than the one I have found. In B 153:Ä Late Glacial shells such as *Balanus hammeri* were found in sand below (?) the clay.

In the outermost part of the section (Fig. 93) the glacial clay is directly overlaid by Postglacial marine sediments of two types, partly older coarser material (a mixture of silt, sand, stones and shells) indicating smaller depth and partly younger, finer clayey sediments indicating greater depth. The glacial clay surface

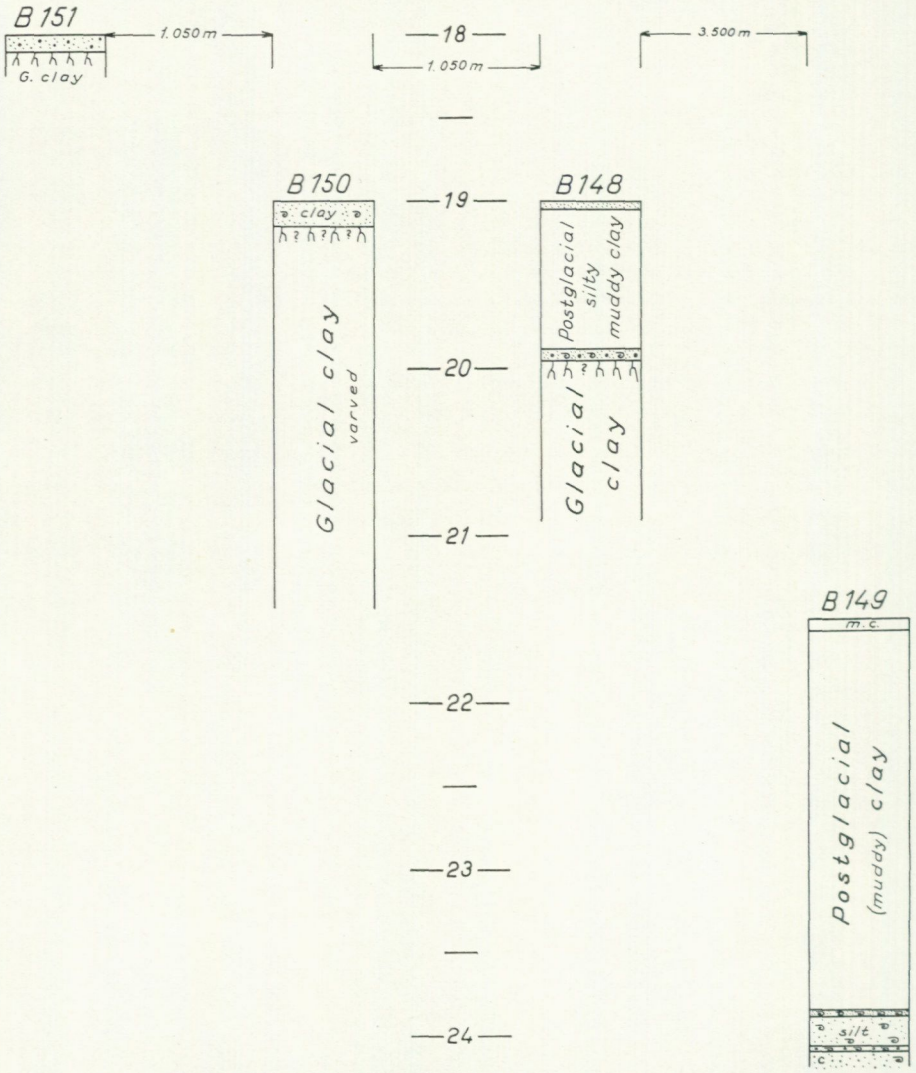


Fig. 93. *Submarine cores from Laholmsbukten. The glacial clay is clearly weathered at -18 m and probably weathered at -20 m in B 148. The sandy layers below the Postglacial clay correspond to the shallow sea during ALV-2 and ALV-3.*

is clearly weathered at least down to –18 m in B 151 and probably weathered down to –20 m in B 148, which is the lowest indication of the land surface of ALV-1. According to the shoreline diagram, ALV-1 lies at –21.3 m between B 148 and B 149. The coarser sediments in the bottom of B 149 contain the following layers (listed downwards):

2.0 cm of shell bank of *Macoma* sp., *Litorina litorea, Buccinum* sp. A pollen analysis of this layer shows a flora of zone VI (BO-2). The clear marine environment is apparent from the content of 50 % *Hystrix*. However, some per cent *Nymphaea, Nuphar* and *Pediastrum* show influence of freshwater.
23.0 cm of shell-rich silt (*Macoma* sp.).
2.0 cm of stones, sand and shells (*Macoma* sp.). A pollen analysis shows a flora of late zone V (BO-1) that is apparently younger than the uppermost one in B 145:N (Fig. 91). It also contains 5.5 % *Hystrix,* 0.5 % *Pediastrum* and 0.5 % *Nymphaea.*
8.5 cm of gravelly clayey fine sand with shells (*Macoma* sp.).

These sediments consequently belong to the Boreal time and thus apparently were deposited during ALV-2 and ALV-3 (according to the shoreline diagram here at about –8—10 m), which meant shallower water than later on, when the muddy clay was deposited. In B 148 the coarser sediments between the glacial and Postglacial clay layers consist of:

3.2 cm of stony clayey mud with shells. This layer was pollen analysed to the earliest part of zone VII (AT-1), i. e. the very onset of the transgression up to PTM-2 (or the very end of ALV-3). It contains 28 % *Hystrix.*
3.8 cm of stony silt to fine sand with shells. Pollen analysis gave the very beginning of zone VII (AT-1) or the very end of zone VI (BO-2). It contains 30 % *Hystrix.*

In B 150 it was possible to count at least 30 varves. The rest is more or less unvarved. The thickest varve (16 cm) contained a pebble of chalk.

Taken as a whole, this section has given the following for the determination of the shorelevel displacement:

1. Fries' C^{14} date of a loose piece of peat points to a shorelevel below –17 m already at the transition zone III (DR-3)/VI (PB).
2. The "ridge" or rather string of sandy, stony material at –18 m could fit with the level of ALV-0 from early zone IV (PB).
3. Clear evidence came forth of a shorelevel during ALV-1 at least below –18 m and probably below –20 m.
4. Stratigraphical indications were found of shallow water during the Boreal time (late zone V + the whole of zone VI), i. e. during ALV-2 and ALV-3.
5. The stratigraphy in B 148 indicates an onset of the transgression up to PTM-2 in early zone VII (AT-1).

In the southern part of Laholmsbukten, I have a section containing nine borings. The inner part only shows a weathered surface of a glacial clay (of the usual brownish-pinkish type). The outer part is more interesting (Fig. 94).

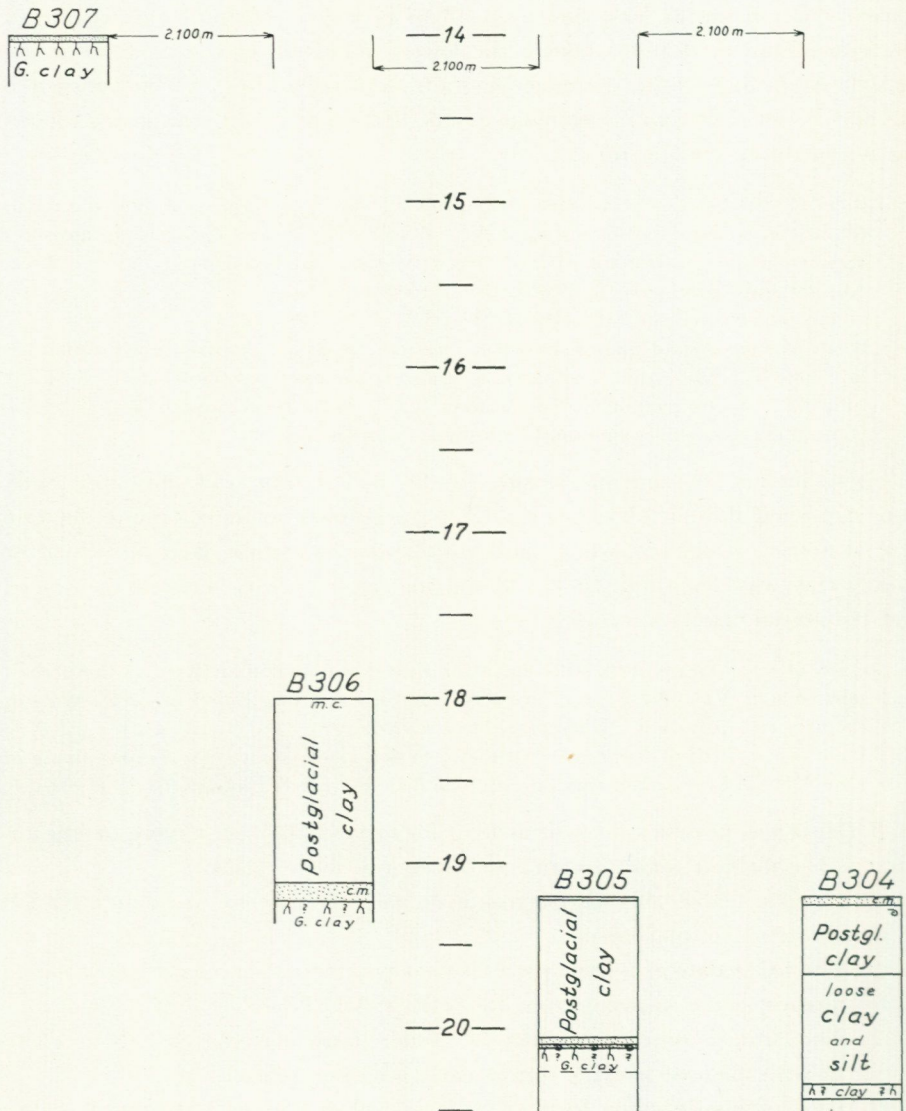


Fig. 94. *Submarine cores from Laholmsbukten. The sandy sediments between the two clay beds correspond to the shallow sea during ALV-2 and ALV-3. The weathering of the surface of the glacial clay can probably be followed down to -20 m in B 305.*

The surface of the glacial clay is clearly weathered at least down to –14 m in B 307 and probably weathered at –19.2 m in B 306 and –20 m in B 305. According to the shoreline diagram, ALV-1 lies at –22.6 m between B 305 and B 304. There are curious layers of a quite loose clay below the glacial clay in B 305 and around the glacial (?) clay in B 304. However, it does not seem to be a true stratification, but the result of some sort of sucking effect in the corer (cf. p. 23). In B 306 there is 11.7 cm of clayey muddy fine sand with shells between the glacial clay (hard and probably weathered) and the Postglacial clay. A pollen analysis in the uppermost part of this layer shows a pollen flora of the latest part of zone VI (BO-2) with marine environment (48 % *Hystrix*) and some minor freshwater influences (2.5 % *Pediastrum,* 0.5 % *Nymphaea,* 1.0 % *Nuphar*). In B 305 the following sediments were found between the glacial and Postglacial clay layer:

4 cm of fine sand.

3.0 cm of silty clayey mud + stones and shells of *Cardium edule* (many), *Macoma baltica* (2), etc. A pollen analysis in this layer shows a flora of earlier zone VI (BO-2) with 16 % *Hystrix,* i. e. early ALV-3, 2.5 % *Pediastrum* and 1.0 % *Nymphaea.*

A pollen analysis 0.5 cm from the bottom of the Postglacial clay (silty) shows a flora of latest zone VI (BO-2) with 26 % *Hystrix,* i. e. the very end of ALV-3 (or the very beginning of the transgression up to PTM-2). Consequently, we have also here sediments that indicate a stage of shallow water equivalent to ALV-2 and ALV-3 before the transgression up to PTM-2. According to the shoreline diagram ALV-2 lies at –8.5 m and ALV-3 at –10.0 m.

11. The Torekov-Hallands Väderö area

Eight submarine borings were made here. However, these borings are of very little interest as they either gave almost no sample in sand or almost full cores in a quite loose Postglacial clay. Just outside the harbour of Torekov a grain size distribution curve of the material from B 390 at –6.5 m shows a badly sorted stony gravelly sand. Furthermore it contains small pieces of old wood. Probably it is a washed till or a shore deposit. Further towards the coast there is a submarine peat bog down to at least –2.5 m, formed in connection with or just before the onset of the transgression up to PTM-2 (cf. p. 340).

Several echo diagrams were taken in this area (Fig. 96, no. 1 and 2). A very detailed contour map of every full metre was drawn of this area (Fig. 95) based on the fundamental charts. This map shows that the western side of Hallands Väderö is steep down to about –23 m, the level outside which there is a flat clayey plain. This is also well shown in the echo-diagrams (Fig. 96, no. 1), where a cliff is seen at –22.5 m. This level apparently corresponds to the shorelevel during the "regression maximum". ALV-1 here falls at –24.2 m

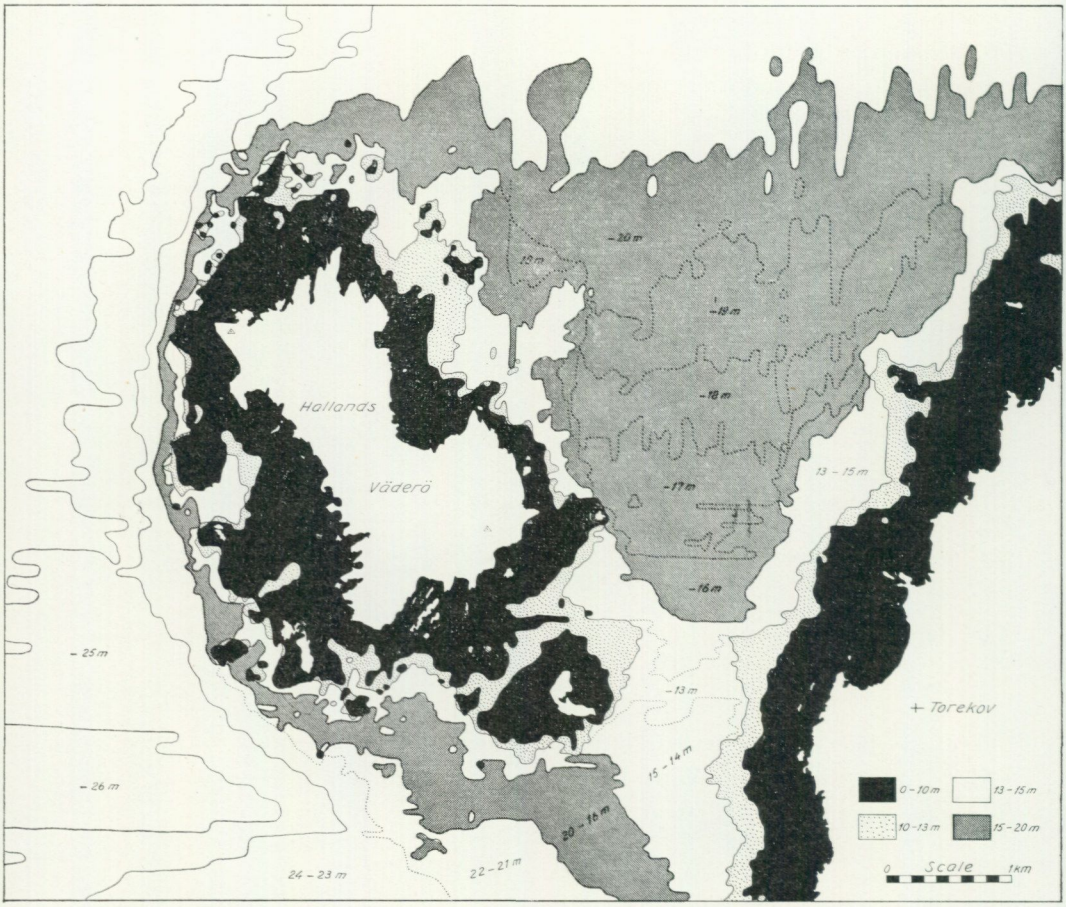


Fig. 95. *Contour map of the bottom in the Torekov — Hallands Väderö area. The western side of Hallands Väderö formed a dramatic cliff during ALV-1 at -24.0-24.6 m (cf. Fig. 96). During ALV-2 and ALV-3 the sea was at about the -10 m contour.*

according to the shoreline diagram. This means that Hallands Väderö was connected with the Bjäre peninsula during the time of ALV-1 (also earlier) and that it had a steep dramatic cliff on the western side very similar to the present cliff at Hovs Hallar.

As the bottom of the strait between Hallands Väderö and Torekov at its most shallow part (today) lies at –13 m and ALV-2 falls at –9.2 m and ALV-3 at –10.7 m, Hallands Väderö has been an isolated island ever since the transgression from ALV-1. This could also be of faunal interest. SW of Hallands Väderö there is a depression at –11 m, which seawards is "dammed" by a ridge up to –10—9 m. This could be a result of the shorelevel during ALV-3 (here at –11.2 m).

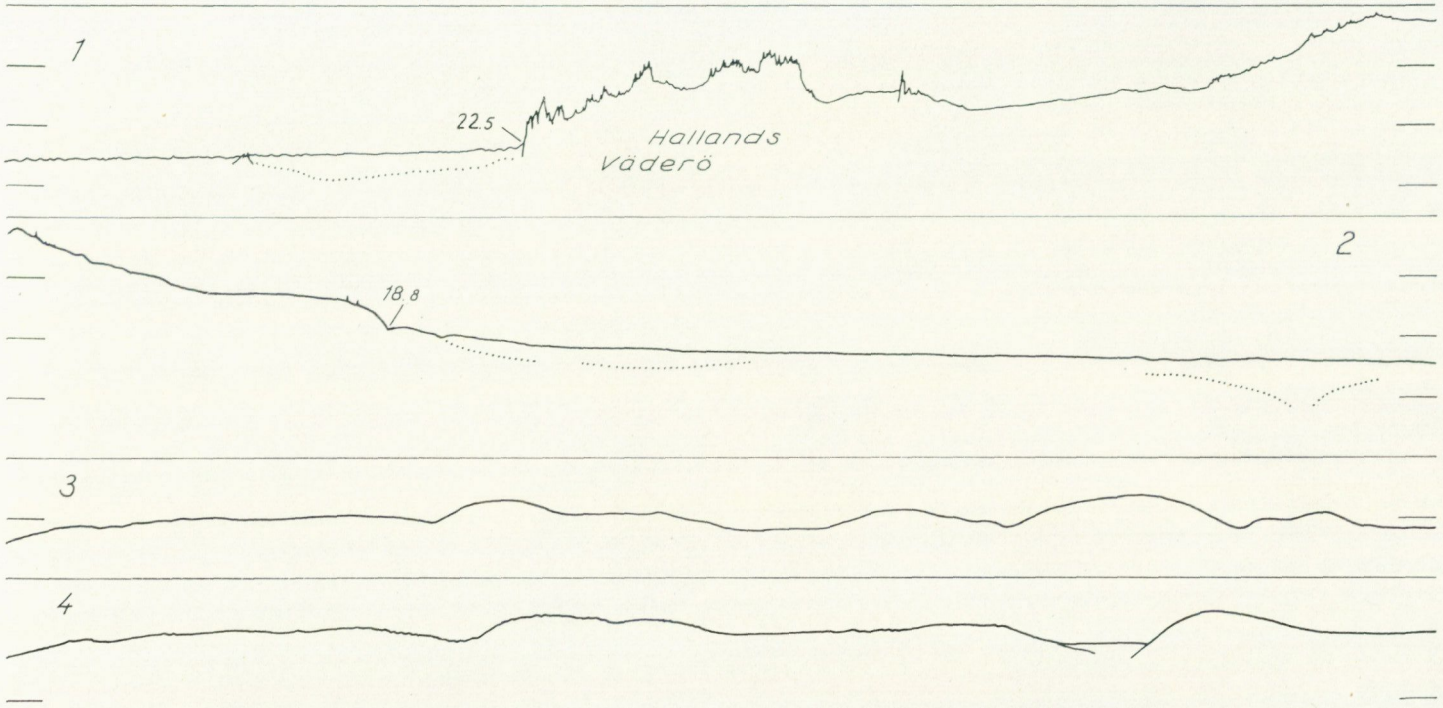


Fig. 96. *Echo diagrams from the area around (1 and 2) and NW of (3 and 4) Hallands Väderö. According to the shoreline diagram ALV-1 here falls at -24.0 m, the level of which corresponds to the foot of the cliff. Vertical scale: depth in tens of meters (excluding the uppermost 20 m in diagrams 3 and 4). Horizontal scale: 1.7-1.8 cm = 1 km.*

12. The Bay of "Skälderviken"

In this bay 27 submarine borings and a lot of echo soundings were made.

In the northern part of Skälderviken I have an important section of six borings (B 288—293). The ground crust can clearly be followed down to –20.8 m in B 392 (Fig. 97). There is no trace of any ground crust in B 293 at –21.0

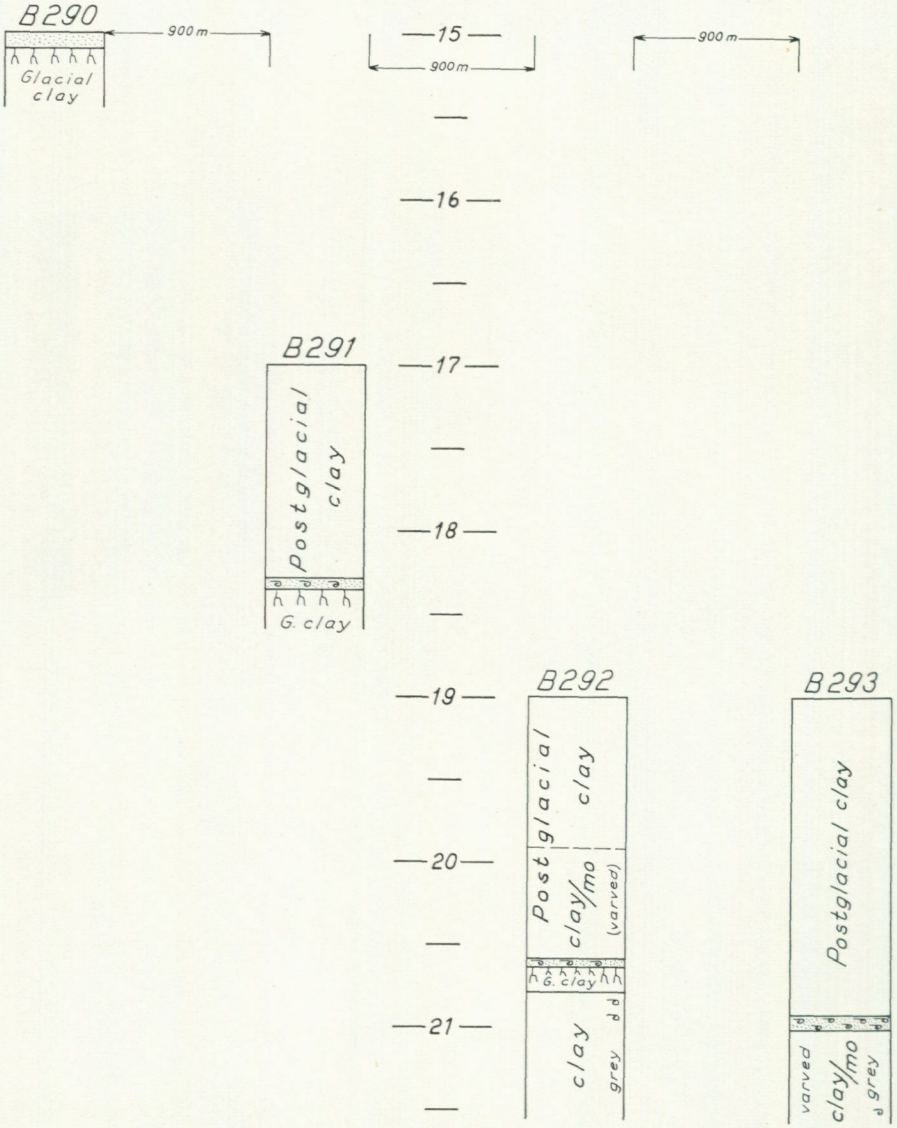


Fig. 97. *Submarine cores from Skälderviken. The ground crust of ALV-1 can clearly be followed down to -20.8 m in B 292. The sandy sediments between the two clay beds correspond to the shallow sea during ALV-2 and ALV-3.*

m, but this could have been eroded away, as there seems to be a hiatus. According to the shoreline diagram ALV-1 lies at −25.4 m at B 293. The core of B 290 offers good illustration of the possibility of getting wrong a stratification with the piston corer due to sucking, i. e. there were stones, lumps of clay and a living *Buccinum undatum* below the glacial clay. Apparently this is due to sucking in connection with a falling corer. B 291 shows the following stratification (Fig. 98):

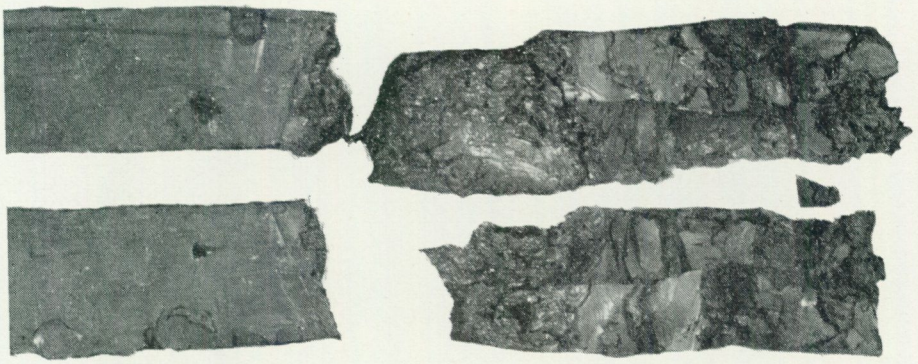


Fig. 98. *Detail of B 291 (about 41 cm long) showing: quite loose Postglacial clay (left), 7 cm of sandy sediments and a very clearly weathered glacial clay (of the pinkish-brownish type).*

A: 6.0 cm of silty clayey mud (probably due to modern change of sedimentation).
B: 123.0 cm of Postglacial clay.
C: 7.0 cm of muddy clay + fine sand + gravel + pebbles + shells, indicating a stage of shallow water before the transgression up to PTM-2.
D: 24.0 cm of clearly weathered glacial clay of the brownish-pinkish type.

B 292 is an important core (Fig. 99). It shows the following stratification (total core length 256 cm):

A: 3.5 cm of Postglacial clayey mud with shells = zone IX (SA-2).
B: 98.5 cm of Postglacial clay, somewhat silty and muddy with shells = zone VI—VII (BO-2 to AT-1).
C: 67.0 cm of Postglacial alternating clay/silt (thin varves) with shells (e. g. *Cardium edule*) = zone V—VI (BO-1 to BO-2).
D: 6.0 cm of pebbly gravelly silty clayey mud = zone V (BO-1).
E: 15.6 cm of very hard and apparently weathered glacial clay of the brownish-pinkish type. Probably equivalent to the Low Baltic readvance to the G4 line (p. 92). The weathering occurred during ALV-1.
F: 72.0 cm of grey loose silty clay, containing some thin white shells = early zone VI (BO-2), sucked into the corer by the vacuum effect.

The pollen diagram (Fig. 99) reveals that the clay in the bottom was sucked into the corer by the vacuum effect (p. 23) and does not correspond to an open sea stage before the Low Baltic readvance. The pollen diagram also shows that there is a big gap between the Postglacial clay (ending in zone VIIa) and

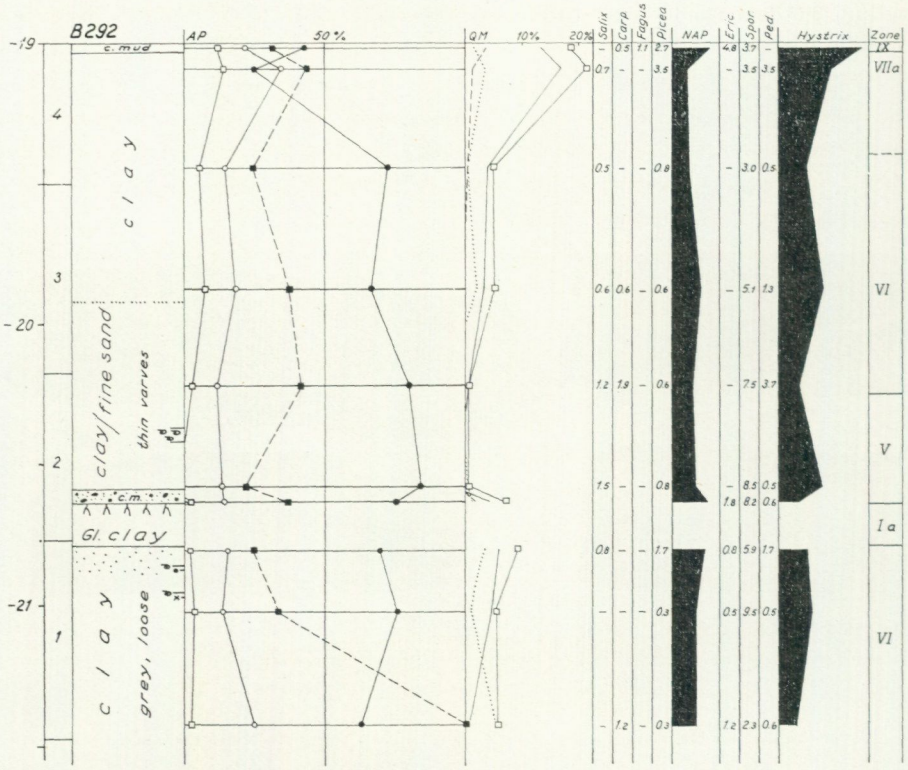


Fig. 99. *The sediments below the glacial clay are sucked into the corer, as revealded by the pollen flora. The Postglacial sediments belong to the Boreal and Early Atlantic time and are with a big gap covered with a thin layer of modern mud.*

uppermost clayey mud, which is probably the result of modern pollution. Equivalent layers are also present in Laholmsbukten and outside Frederikshavn. The weathering of the glacial clay took place during ALV-1. Most of the Postglacial sediments were apparently deposited during ALV-2 and ALV-3 when the water was still shallow. ALV-2 here falls at –9.4 m and ALV-3 at –10.9 m. The onset of the second Postglacial transgression at 5,800 BC probably falls somewhere between the second and third pollen spectrum from the top.

In B 293 the following stratification was found totally (257.5 cm):

A: 4.0 cm of clayey mud
B: 188.5 cm of Postglacial clay
C: 8.5 cm of sandy shell bank of *Cardium edule*
D: 56.5 cm of grey stratified clay/silt, semihard, with some shell fragments (and a small piece of organic material), possibly sucked in from above

A pollen analysis of the shell bank gives a flora of the earliest part of zone VI (BO-2), i. e. it belongs to the time of the regression from ALV-2 to ALV-3, an event which must have caused erosion and redeposition of littoral sediments. A

pollen analysis in the lowermost part of the Postglacial clay gave a flora that belongs to early zone VI (BO-2), which shows that this layer started to be formed already during ALV-3.

Between and across the two ridges of shoals, Grytgrunden and Bergströmsgrunden, two sections containing nine borings were made. Special echo soundings and diving were also used in this area. A special contour map was drawn (Fig. 100) based on the fundamental charts.

It was established by diving that the shoal Grytgrunden consists almost entirely of Archaean rock. "Grytskären" are rock skerries, though the northern one contains a lot of well rounded stones on its eastern side. Some glacial striae from N 26° W were found. The line of shoals, including Bergströmsgrunden, and stones, on the other hand, form a continuation of terminal moraine fork of the F5 line (p. 70). The borings in this area are not of great interest, as the weathered clay surface here forms the seabed. Between Grytgrunden and Bergströmsgrunden, a weathered Late Glacial blue-clay was found at −11.5 m and −13.0 m. A clearly weathered glacial clay of the brownish-pinkish type was found in the

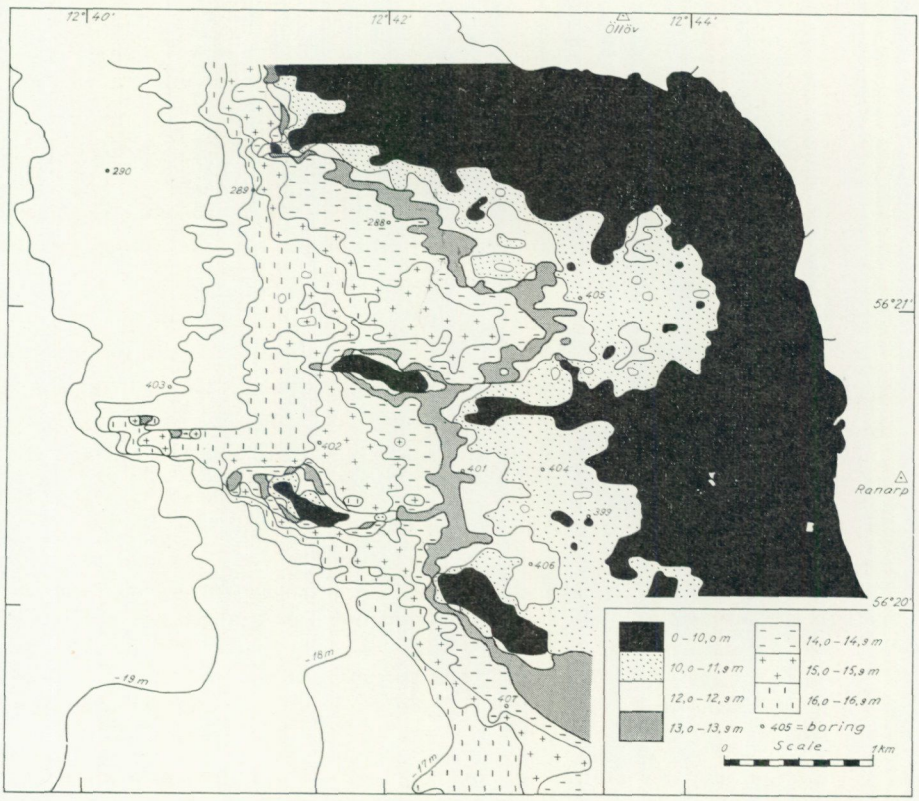


Fig. 100. *Contour map of northeastern Skälderviken. The ridges and depressions about -11 m and -12 m, respectively, are probably shore features of ALV-3.*

other cores, the deepest find of which lies at −18.5 m in B 403. No intermarine layer has been found. The contour map (Fig. 100) shows in the area between Grytskär and Öllöv a ridge with its top at about −11.0 m and depressions inside this with a bottom level at about −11.7—12.0 m. As ALV-3 according to the shoreline diagram lies here at −10.85 m, there is not a ful correlation with this shoreline. It could be an indication that ALV-2 and ALV-3 should be lowered by about 1.5 m, though this is precluded, for example, by the facts from the area outside Copenhagen (p. 276). The grain size distribution of samples from B 399, B 401 and B 406 (Tab. 2) suggest a littoral formation.

In the southern part of Skälderviken 12 borings were made. A weathered glacial clay was only found outside Häljaröd at −13.5 m. In most of the other cores the Postglacial clay is so thick that this layer was not bored through despite almost full cores. B 285 (Fig. 101) shows the following stratification:

A: 3.0 cm of clayey mud
B: 103.5 cm of Postglacial clay
C: 2.5 cm of shell bank of *Cardium edule, Mytilus edulis,* etc.
D: 19.0 cm of fine sand + pebbles, gravel and shells; apparently a shore deposit
E: 150.0 cm of grey loose clay with pebbles and gravel (a glacial clay of the grey stratified type or a clay sucked in from above)

B 286 (at the same position as B 287, Fig. 101) shows the following stratification:

A: 3.0 cm of Postglacial clay
B: 6.0 cm of clayey "dy" (or black fine detritus mud) with shells
C: 16.0 cm of clayey mud — muddy clay with shells

The following shells were found in the lower 22.0 cm: *Mya truncata* (5), *Astarte montagui* (1), *Astarte elliptica* (1), *Balanus creneatus* (1) and *Balanus* sp. (1), i. e. a fauna suggesting a Preboreal-Boreal environment.

The sediments 14—22 cm up (i. e. 2 cm of clayey mud +6 cm of "dy") and all the shells were together C^{14} dated at 1.305 ±80 BC (originally the material was planned to be dated as two separate samples, but were mixed at the laboratory). Now the explanation of this result is apparent: the "dy" and clayey mud belong to a burrow filled with modern muddy sediments from the surface. The shells must be older.

In B 287 the following stratification was found:

A: 9.0 cm of clayey mud.
B: 19.0 cm of Postglacial clay with some shells (e. g. *Balanus* sp. and *Mya truncata*).
C: 92.0 cm of shell bank with a continuous gradation with depth from finer to coarser. The upper part contains small shell fragments + fine sand, while the lower part contains bigger shell fragments of *Mytilus edulis* (and a few of *Macoma* baltica and *Cardium edule*) whole shells of *Litorina litorea* (only in the lower part) and pebbles + gravel.

This gradation as well as the occurrence of *Litorina litorea* may indicate a rising sealevel (but could also be an effect of sucking in the corer). The shells in the lowermost 22.0 cm, i. e. *Litorina litorea* and bigger fragments mostly of

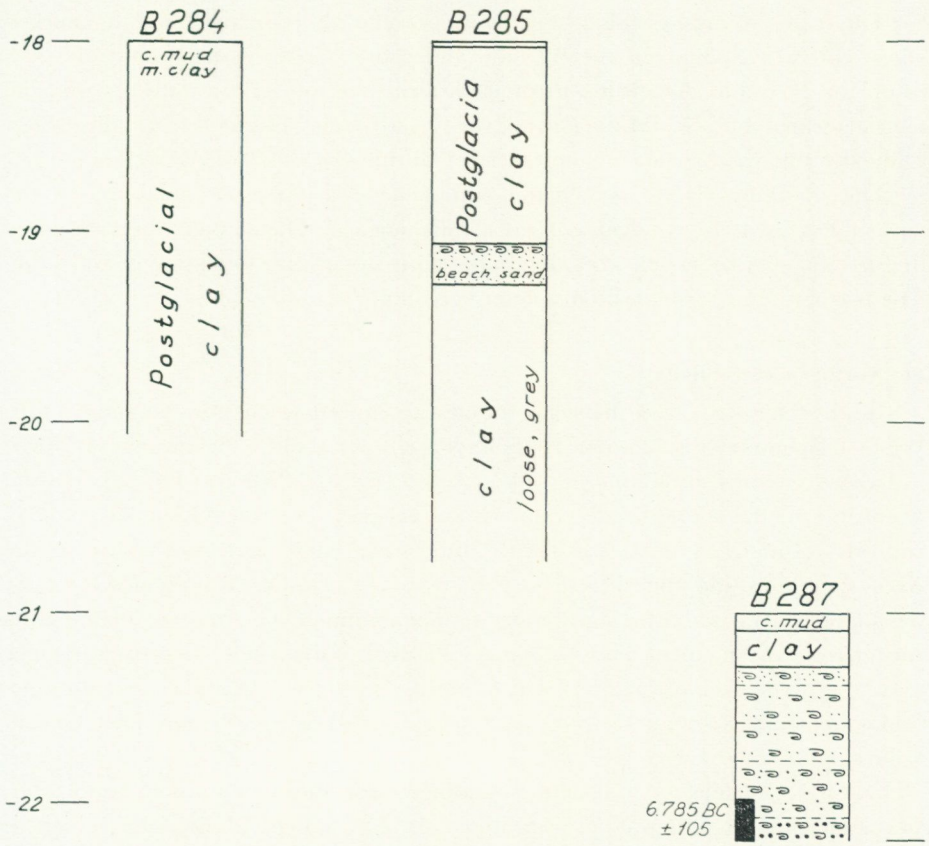


Fig. 101. *Submarine cores from southern Skälderviken. The C¹⁴ date indicate that the shell bank belongs to the transition between ALV-2 and ALV-3. The corrected age is 6,480* ±130 BC. Pollen analyses indicate early zone VI (BO-2).*

Mytilus edulis, were C¹⁴ dated at 6,480* ±130 BC, i. e. the earliest part of zone VI (BO-2). Two pollen analyses, in the upper and lower part of the shell bank, show a flora that clearly belongs to the early part of zone VI (BO-2), i. e. in very good agreement with the C¹⁴ date (and the correction of the age of shell material by 305 ±25 years). This means that the shell bank seems to have been formed in connection with the regression from ALV-2 down to ALV-3, which according to the shoreline diagram here lie at –9.9 m and 11.4 m, respectively (ALV-1 falls at –26.6 m).

13. The shoal St. Middelgrund

This shoal was crossed with echo sounding three times (Fig. 6). One boring (almost empty) and one dredging (important) were made. De Geer (1890) stated that a find of *Litorina litorea* between Anholt and Kullen (probably at St. Middelgrund) indicates proximity to the shore.

The echo soundings (Fig. 6) show possible shore marks, viz. a marked shore cliff at –21.8 m on the SE side and shore marks at –22.8 m and –26.3 m on the NW side. According to the shoreline diagram ALV-1 falls at –26.3 m, which means that St. Middelgrund was a fairly big island during this stage. Only the top reached above the sea level during ALV-2 and ALV-3.

The dredging B 557 was made with a pipe dredger at –22.0 m. In the wire it felt as if the dredger crossed a rock surface. The sample (everything in the dredger was collected) contained abundant stones and some gravel and sand. The petrographical composition is described on p. 33.

14. Northern Östersund

In the Höganäs area the echo soundings showed some possible shore cliffs. West of Höganäs (Fig. 22, no. 3) there is a cliff at about –21.4 m. SE of Höganäs there are two cliffs, one at –14.1 m and one at –23.0 m (Fig. 23, no. 2). According to the shoreline diagram ALV-1 falls at –29.3 m, ALV-2 at –10.8 m and ALV-3 at –12.4 m. Consequently, there is no close agreement between the ALV shorelines and the cliffs. However, it is not usually possible closely to fix the shorelevel in the cliffs, as younger sediments may cover the foot of the cliffs and change the picture. The submarine channel "Öretvisten" lies much deeper than the shorelevel of ALV-1, which marks the lowest shorelevl in this area. Consequently, this channel cannot have been formed or used by any Late Glacial or Postglacial river (cf. p. 35).

Outside Gilleleje, several echo soundings have shown a marked shore cliff. The foot of this cliff was measured to –20.2 m (Fig. 22, no. 1), which is apparently too high due to younger Postglacial sediments, –24.7 m (Fig. 22, no. 3) and –27.5 m (Fig. 22, no. 3). According to the shoreline diagram ALV-1 falls at –31.1 m (and ALV-0 at –28.0 m).

15. The area outside Landskrona

The marked submarine channel outside Landskrona is a submarine continuation of River Saxån (or Heljarpsån). Sundelin (1925) found that the corresponding sea level was at least at –8 m and probably at –12 m.

According to the nautical charts there is a channel in the 20 m contour just north of the mouth of the submarine river channel. This channel was echo sounded (crossed five times) in a zig-zag line, the position of which could be very easily determined thanks to the Decca navigator. Obviously it is a river channel (Fig. 22, no. 4). However, this has today no visible connection with the continuation of River Saxån. The bottom of this channel was in the outer part found at –21.0 m, –21.4 m and –24.1 m (Fig. 22, no. 4). Consequently, ALV-1 ought to lie at least below –24.1 m. According to the shoreline diagram ALV-1 falls at –31.0 m.

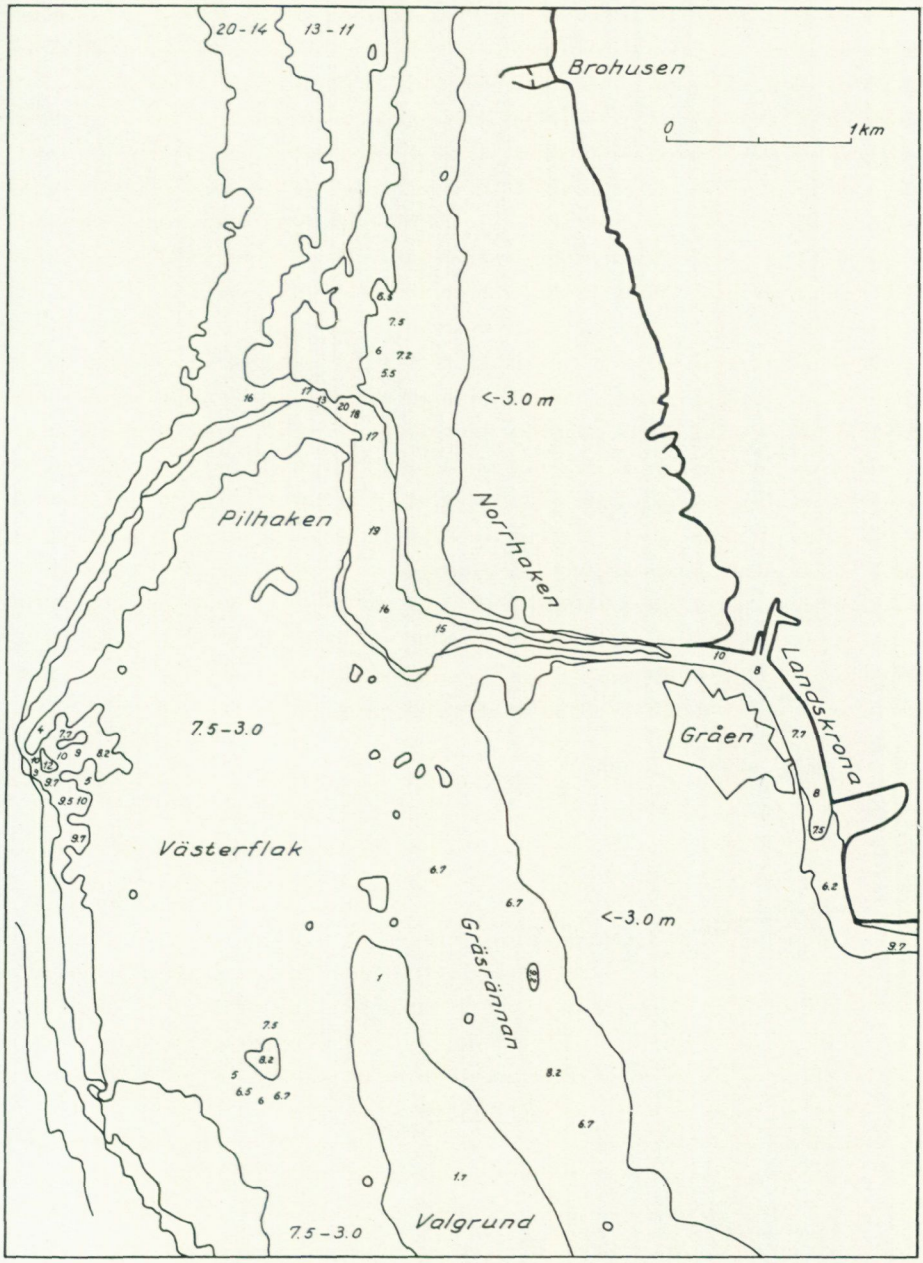


Fig. 102. *Contour map (-3.0, -7.5, -10.0, -13.0 and -20.0 m) showing the submarine continuation of River Saxån. A shorelevel at about -12—13 m, corresponding to ALV-2 and ALV-3, is indicated by the probable bar ridge north of the river mouth and the probable beach ridge NW of "Västerflak".*

A contour map was drawn (Fig. 102) based on the fundamental charts. However, there are many areas not covered by the fundamental charts, including the area of the above-mentioned outer channel. The submarine river channel is quite clear. The deepest point today lies at –20 m, which is a minimum figure of the "regression maximum". The contour map (Fig. 102) clearly indicate a shorelevel at about –12—13 m. At this level there is a trace of a bar ridge north of the river mouth. NW of the name "Västerflaket" on the map (Fig. 102), there is a trace of a beach ridge with a top level at about –10—9.7 m and a depression inside at –12 m. Such a shorelevel fits very well with the estimated level of ALV-2 and ALV-3, viz. –12.0 m and –13.5 m respectively.

It now seems probable that, during ALV-1, River Saxån debouched via the channel at –24.1 m with some damming material just outside the younger river mouth. During ALV-2 the sea rose to –12.0 m and caused a displacement of the river mouth to the area just north of Pilhaken. The older river channel was destroyed by erosion and filling in the area nearest the new river mouth.

The deep channel between Ven and Landskrona lies far below the level of ALV-1 and has apparently not been used by any Late Glacial or Postglacial river. The shape of the sea fiord that occupied the area south of Ven during ALV-1 is hard to fix, as Postglacial sediments have changed the old bottom topography. The channel across the bay Lundåkrabukten could very well have been used to discharge the water from the rivers Kävlingeån, Höljeån and Segeån.

16. The area outside Copenhagen

K. Jessen (1920 and 1935) has described older finds of submarine peat outside Copenhagen. In Fig. 103 the known stratifications of importance for the fixing of the ALV shorelines have been put together.

Krog's boring no. 1 (Ödum 1951, Krog 1965) shows 4.6 m of brackish clayey mud that would belong entirely to zone V (BO-1). However, there are only four analyses and the basis for the statement of brackish environment is not described. This boring shows that the shorelevel during zone V (apparently the middle and late part that correspond to ALV-2) stood above –14.0 m.

The boring "1942" is a geotechnical drilling analysed by A. Andersen and described by Krog (1965). A layer of forest peat reached down to –19.64 m. A pollen analysis in the upper part shows a flora of the beginning of zone V (BO-1), i. e. the time of ALV-1. Consequently, –19.64 m is a minimum figure of ALV-1. The peat is overlaid by a brackish-marine clayey mud that in the lower part is brackish and belongs to zone V (BO-1) and at –15.0—15.7 m is marine and belongs to the zone boundary VI (BO-2)/VII (AT-1). This means that the registered transgression must be equivalent to the one of ALV-2 and that ALV-3 must be found above –15.7 m.

The boring "1947" is another geotechnical drilling analysed by Iversen and described by Krog (1965). A peat layer at –14.05—15.10 m belongs to early

zone V (BO-1) and was apparently formed during ALV-1. The peat is covered by a marine clayey mud (at –13.40—14.05 m) that in the upper part contains a pollen flora of the zone boundary V (BO-1)/VI (BO-2). Doubtless this layer belongs to ALV-2, which must consequently have been at least above –13.4 m. The sand layer (with shells) at –12.8—13.4 m indicates an aggradation or even small regression. Apparently it belongs to ALV-3, the level of which must have been close to this sand layer.

"Jessen-35" refers to a layer of peat about 2 m thick from –13 m to –15.25 m (partly *Phragmites* peat) described by K. Jessen (1935). One pollen analysis has been made but at an unknown level. This shows a flora that probably belongs to the zone boundary V (BO-1)/VI (BO-2), but also could be older. The macroscopic plant remains include branches of *Alnus glutinosa,* which supports the dating to V/VI, i. e. the earliest part of ALV-3. Consequently, the level of ALV-3 must have been close to this layer. However, the sample was not taken for scientifical purposes and the description is sketchy.

In connection with works for the sewerage from Copenhagen in 1899 a peat bog at least 90 m wide was found (K. Jessen 1920). This peat bog lies to the west at –12.0 m and to the east at –12.9 m, where it is at least 0.9 m thick, reaching down to –13.8 m. The macroscopical plant remains point to an age of early zone VI (BO-2). Consequently, ALV-3 ought to have been at least below –13.8 m.

In the channel "Kongedybet" outside Copenhagen four borings were made (B 644—647). B 644 and 645 gave only small samples of no interest. The other two are important.

B 646 at –13.2 m shows the following stratification (core length 141 cm):

A: 82.0 cm of silty mud, probably brackish (diatoms). Two pollen analyses were made, one in the top and one in the bottom of this layer. Both show a flora that belongs to zone VI (BO-2).

B: 9.0 cm of chalk sand.

C: 32.0 cm of chalk gravel to pebbles (sharp-edged grains) with mud and pieces of peat.

D: 18.0 cm of silty mud with some pebbles and pieces of peat. The upper part is probably brackish (diatoms), while the lower part is probably lacustrine. At the limit D/C there was a shell of *Cardium edule.* A pollen analysis in the middle of this layer gave a flora of early zone VI (BO-2). A pollen analysis in the bottom of this layer gave a flora of late zone V (BO-1) or earliest zone VI (BO-2).

B 647 at –13.0 m shows the following stratification (core length 98 cm):

A: 66.5 cm of grey-black silty clayey mud. A pollen analysis 1.5 cm from the bottom gave a flora of zone VI (BO-2). The uppermost 60.0 cm sediments contain pebbles (chalk) and shells and could be the result of a recent mixing of material for example in connection with the sewerage just in this area. 28 cm below surface there is a shell of *Mya arenaria,* which means historical time, and 12 cm down there is a piece of slag,which means the age of steamships.

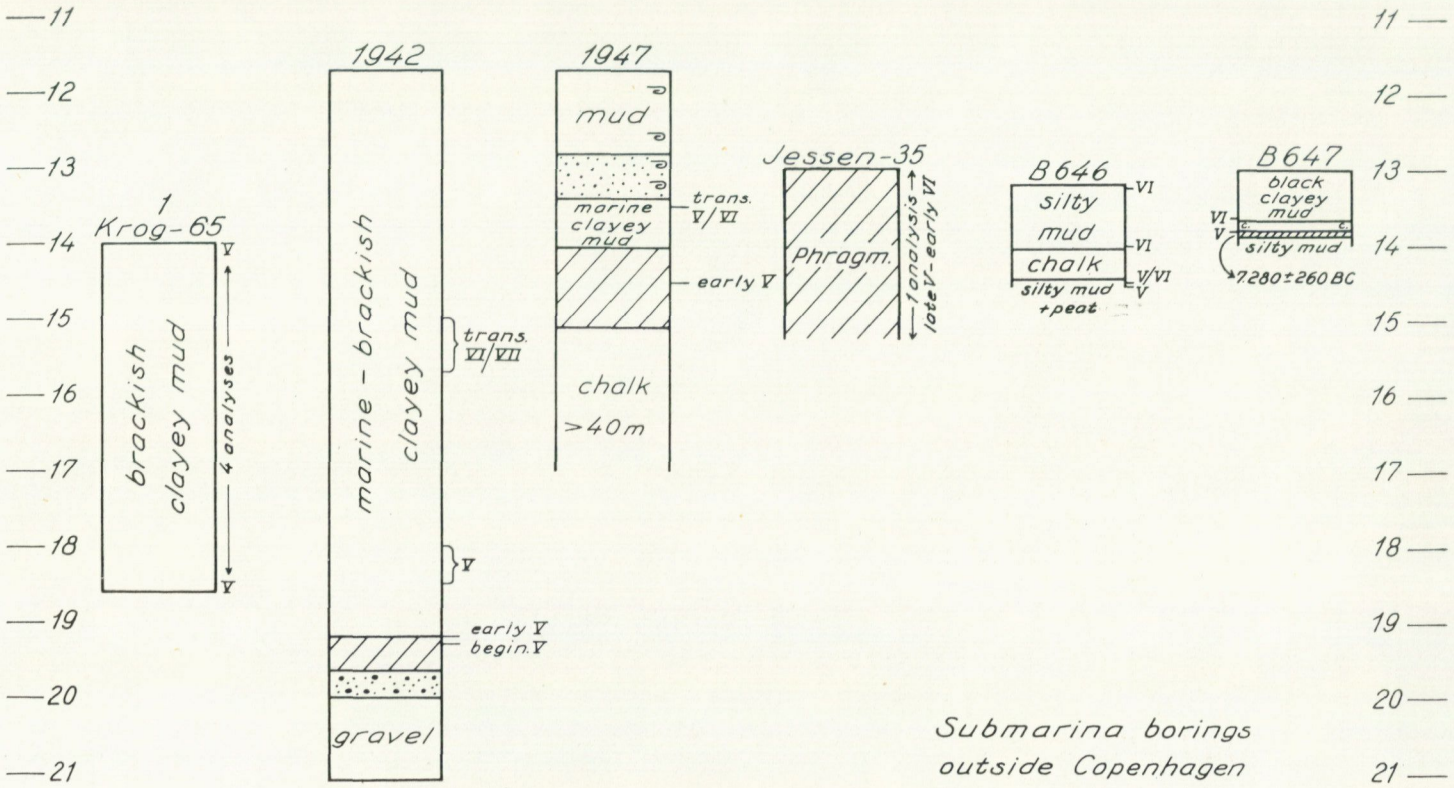


Fig. 103. *Synthesis of borings outside Copenhagen. ALV-2 and ALV-3 can be fixed to -13-15 m.*

B: 13.0 cm of grey clay, probably brackish (*Campylodiscus echeneis*).

C: 6.0 cm of dark peat with sedge and *Phragmites*. A pollen analysis gave a flora of late zone V (BO-1). The uppermost 4.0 cm of the peat was C^{14} dated at 7,280 ±260 BC, i. e. the very end of ALV-1 or the very beginning of ALV-2.

D: 12.5 cm of silty mud with FeS, in the lower part dark, dyey and containing drift wood and drift peat. Probably lacustrine (mirofossils).

These cores consequently show:

1. the occurrence of intermarine layers of ALV-1 age,
2. that the transgression reached the area in zone V (BO-1) and according to the C^{14} date simultaneously to the onset of the transgression up to ALV-2 (=PTM-1),
3. a shore material in B 646 and a corresponding drift clay in B 647 that probably belongs to ALV-2,
4. brackish environment in zone VI (BO-2), which points to a corresponding sea level at least at −13.2 m.

Before summing up the data, it must be pointed out that the given depth is probably not quite exact. Usually the depths may be wrong by a metre or so. B 646, B 647 and probably also Krog's boring no. 1 are measured with the echo sounder, which means a margin of error of about 1 m. K. Jessen's old statements probably also involve a margin of error. I am not able to judge the borings "1942" and "1947".

As a whole the following can be said about the shorelevel displacement in the area just outside Copenhagen:

ALV-1: at least below −19.64 m in "1942 (the diagram says −36.7 m).

ALV-2: probably just above −13.4 m according to "1947" (the diagram says −13.4 m). According to Krog's boring no. 1 at least above −14.0 m. In B 646—647 there are indications of a shore formation at about −14.0 m.

ALV-3: about −13.0—14.0 m. However, the level is hard to fix more closely (the diagram says −14.9 m) as the borings contradict each other (by some dm). "Jessen-35" speaks for a level below −13.0—15.25 m. Jessen's (1920) peat at −12.0—13.8 m suggests a level below this peat. The boring "1947" suggests a level close to the sand layer at −12.8—13.4 m. This sand layer is an indication of regression or anyhow an aggradation in zone VI (BO-2). B 646—647 suggests a level at about −13.2 m.

The transgression up to ALV-2 (=PTM-1) is also seen as a ground water rise in localities above the corresponding sea level, e. g. K. Jessens locality "Frihamnen III, profil c" and "Hovenge" (K. Jessen 1920). Similar results were found at Torekov (B 676, p. 343) and NW of Ängelholm (B 670, p. 343). From Limhamn, SE of Malmö, G. Persson (1962) describes a submarine peat at −8 m, which according to the C^{14} dates was transgressed by the transgression up to PTM-2 (cf. p. 361). This is evidence that ALV-3 must have been at least below −8 m.

17. The area outside NE Sjaelland

Here I have an important core B 502 with a clear ground crust and organic layers and a profile of three cores, B 648—650 (Fig. 104). B 502 at –25.8 m shows the following stratification (core length 250.0 cm):

A: 100.0 cm of somewhat muddy clayey silt with shells, e. g. *Turritella tenebra.*
B: 5.0 cm of silty clayey mud — clayey muddy silt with thin layers of peat.
C: 65.0 cm of clayey mud and silt with a shell bank (mostly of *Mytilus edulis)* 13—17 cm from the bottom.
D: 4.0 cm of black wood and dyey peat in silt or containing silt of the same type as layer C.
E: 76.0 cm of weathered Late Glacial blue-clay with a varying amount of silt. In the most clayey parts the ground crust is distinct. The ground crust is emphasized by roots in situ. Geotechnical analyses were made at 10 different levels (however H_3 was only determined in the lower part). These analyses give no proof of the ground crust, but leave a possibility of this.

Layer D was C^{14} dated at 8,870 ±200 BC. This might indicate the isolation of this area and would thus fit extremely well with the shoreline diagram that shows an isolation of this level in earliest zone III (DR-3). The organic material could of course have drifted to the area later. However, this seems to be contradicted by the roots in situ, which are exactly of the same type as the material in layer D. A pollen diagram of five analyses did not clear up the picture, but rather complicated it. Layer C (2 analyses), D (1 analysis) and E (1 analysis in the uppermost part) show floras that point to zone VI (BO-2) with a high content of *Hystrix*. Layer B has a flora that points to the zone boundary V (BO-1)/VI (BO-2) with only 0.7 % *Hystrix*.

According to the shoreline diagram ALV-1 here falls at –33.6 m. The ground crust shows a water level at least below –27.5 m (–28.3 m). The ground crust probably corresponds to the land period between early zone III (DR-3) and late zone V (BO-1). Layers C and B seem to belong to the time about ALV-2 and ALV-3 and layer A to the later periods after the onset of the transgression up to PTM-2.

B 650 at –25.8 m, which was later made at the same position as B 502, shows 123.0 cm of grey clayey silt with shells. Apparently it is equivalent to layer A in B 502.

B 649 at –24.0 m and about 3 km inland shows the following stratification (core length 96.5 cm):

A: 28.0 cm of clayey muddy silt with shells. Apparently equivalent to layer A in B 502.
B: 4.0 cm of brown mud — clayey mud with a probable brackish (or lagoonal) diatom flora. Probably equivalent to layer B in B 502.
C: 64.5 cm of alternating silt/clayey mud (at least 23 "varves", probably 32) with a probable marine diatom flora in the bottom and a probable brackish one higher up. This layer probably corresponds to layer C in B 502.

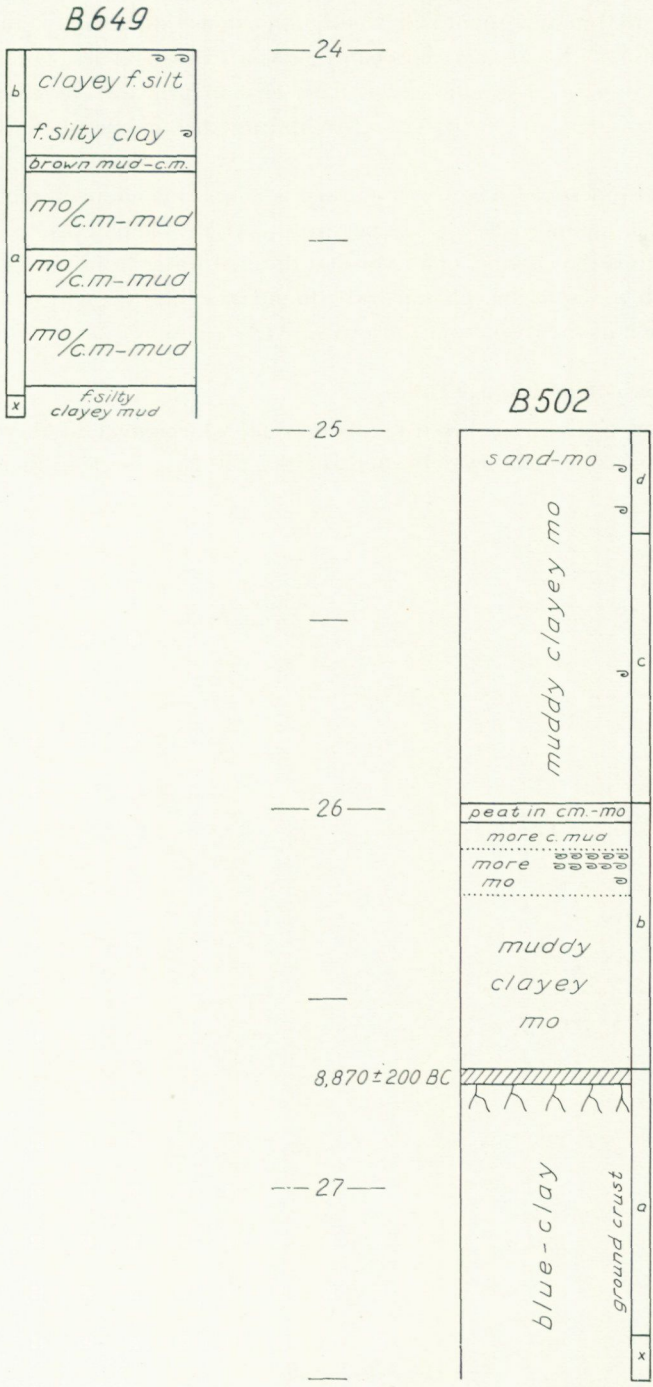


Fig. 104. *Submarine cores taken outside NE Sjaelland.*

B 648 at –18.0 m and about still 3 km inland shows 105.0 cm of silt with a lot of small balls of hard clay (probably glacial clay). These balls indicate proximity to an eroded ground crust. This erosion probably took place either during the transgression up to ALV-2 or during the shorelevel of ALV-2 and ALV-3.

NNW of Hundested I have twice crossed a submarine channel, measuring the depth at –22.3 m and –24.0 m respectively (ALV-1 here falls at –36.7 m). Apparently this is the channel of a river that drained water from the Isefjord area. SE of Hesselö a submarine channel was found at –32.0 m, which obviously is the continuation of the river from Isefjorden. ALV-1 here falls at –34.9 m.

18. B 504 between Hundested and Grenå

The bottom is usually covered by a fine sand which prevents the corer from penetrating the sediments. Seven borings B 504—510 were made in the mineswept

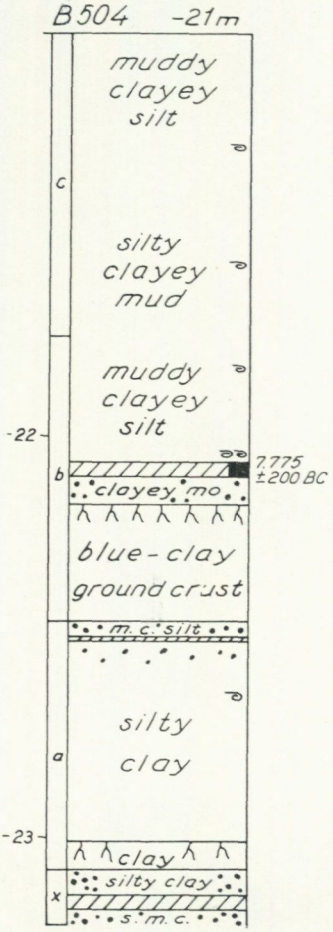


Fig. 105. *Submarine core from between Hundested and Grenå, showing three thin peat layers. The stratigraphy can be interpreted in different ways.*

fairway 28k (on the nautical chart), but only B 504 is of any interest, B 504 at –21.0 m gave an interesting core of 222.0 cm (Fig. 105):

A: 106.5 cm of Postglacial muddy clayey silt with shells. A pollen analysis 0.5 cm from the bottom gave a flora of early zone VII (AT-1) with 16.4 % *Hystrix*.
B: 3.5 cm of black peat and wood. A C^{14} dating of this layer gave 7,775 ±200 BC. A pollen analysis shows a flora of zone V (BO-1, or the very beginning of zone VI, BO-2) with 6.2 % *Hystrix*.
C: 7.0 cm of clayey silt with pebbles (sharp-edged).
D: 29.0 cm of weathered silty blue-clay, cracked into pieces (more or less sharp-edged) and with precipitation of iron. A pollen analysis 1.0 cm from the bottom shows a flora of zone VI (BO-2) with 19.5 % *Hystrix*.
E: 4.0 cm of silt with pebbles.
F: 1.0 cm of black coarse detritus mud or peat (+ pebbles).
G: 63.5 cm of silty clay, with some pebbles, especially in the uppermost and lowermost parts, and some shells. 55—62 cm down there is a more pure clay that is clearly weathered into a ground crust (cracked, precipitation of iron).
H: 3.5 cm of black peat or coarse detritus mud (+ pebbles). A pollen analysis shows a flora of earliest zone VI (BO-2) with 4.0 % *Hystrix* and 39.5 % *Pediastrum*.
I: 4.0 cm of muddy clay with pebbles (sharp-edged).

The water content (V and W) was determined at 14 levels below layer B. The shear strength of remoulded samples (H_1), the fineness number (W_F) and the loss on ignition were determined at three levels. These analyses support the statement of a ground crust. A sample in layer D was mineralogically analysed (see the table on p. 261).

According to the shoreline diagrams the area was isolated in early Alleröd and possibly the place for some minor Late Glacial fluctuations. The ALV-1 shoreline falls at –37.0 m.

Now there are two major explanations to the stratigraphy: According to alternative I:

layer A = the time after the onset of the transgression up to PTM-2,
layer B and the weathering below = the land period during Late Glacial and ALV-1 time,
layer C—I = Late Glacial clay, the stratigraphy of which can be explained either as being due to real fluctuations in Alleröd time or as being due to weathering only of the more clayey parts and gathering of roots and infiltrated humus in the more silty pebbly parts. See also B 654 (p. 284).

According to alternative II:

layer A = the time after the onset of the transgression up to PTM-2,
layer B—I = the time of ALV-2 (–13.5 m) and ALV-3 (–15.0 m), which the pollen analyses suggest. This means that the sediments would be a mixed redeposited material brought out into the sea by the erosion in the older land surfaces. Thus the ground crust in B 504 would only be derived from minor balls or lumps of weathered clay. Similar redeposition of "clay boulders" was described by Hansen and Ödum (1960) from the Lille Belt, Store Belt and Öresund areas.

However, the problem of the interpretation of the stratigraphy must be solved by further borings in the same area (such borings were planned, but had to be omitted due to bad weather and trouble with the boat).

19. The area north of Sjaellands Odde

Krog (1965) describes a submarine peat at about –15.5 m just north of the harbour of Odden. Krog's boring no. 234 shows a peat covered by mud. Preliminary pollen and diatom analyses were stated to show a transgression of the level –15.5 m at the zone boundary V (BO-1)/VI (BO-2), and a continuous change into marine environment.

The shoreline diagrams give the following shorelevel displacement: isolation at about 11.200 BC, ALV-1 at –41.6 m, ALV-2 at –15.15 m and ALV-3 at –16.65 m.

As Krog's statement of marine environment in zone VI does not fit with the estimated level of ALV-3, I went to the same area and took five cores within a small area (B 651—655). B 655 gave the most complete core.

B 651 at –15.8 m gave a core of 65.0 cm:

A: 11.0 cm of silt.
A2: 19.0 cm of shell-rich silt.
A3: 12.5 cm of silt + organic material (probably drifted).
D: 22.5 cm of clearly weathered blue-clay; fissures filled with silt, roots in situ and some precipitation of iron.

B 652 at –14.5 m gave only 35 cm of silt.

B 653 at –15.0 m gave a core of 111.8 cm:

A: 14.5 cm of silt.
B: 97.3 cm of clayey mud with *Phragmites* roots (in situ). Apparently a lagoonal formation (possibly lacustrine).

B 654 at –14.8 m gave a core of 116.5 cm:

A: 28.5 cm of Postglacial silt with shells. The lowermost part contains organic material (probably drifted).
D: 36.5 cm of weathered blue-clay (a clear ground crust) with at least one shell.
D2: 51.5 cm of silt and clay with pebbles and some shells. The parts of more pure clay are clearly weathered.

B 655 at –15.0 m (14.8 m) gave the most complete stratification with a 141.0 cm long core:

A: 33.0 cm of Postglacial marine silt with shells. A pollen analysis 1.0 cm from the bottom (Fig. 106) shows a flora of early zone VII (AT-1), i. e. the time of the onset of the transgression up to PTM-2.
B: 89.5 cm of alternating layers of clayey mud (without silt grains) and coarse detritus mud and peat with a lot of drift wood. The uppermost 5.0 cm have an admixture of silt grains and may portend the regression. Five pollen analyses in this layer (Fig. 106) clearly show that layer B entirely belongs to zone V (BO-1).

This type of sediment can definitely not have been formed in an open sea. It was probably formed by fluctuations between sedimentation and drifting, probably in a shallow lagoonal environment. The microfossils suggest a lacustrine-lagoonal environment.

C: 9.8 cm of peat of terrestrial-telmatic type.

D: 8.7 cm of somewhat silty clay (probably Late Glacial blue-clay), weathered, containing roots in situ and in the uppermost part impregnation of humus to a pitchy soil.

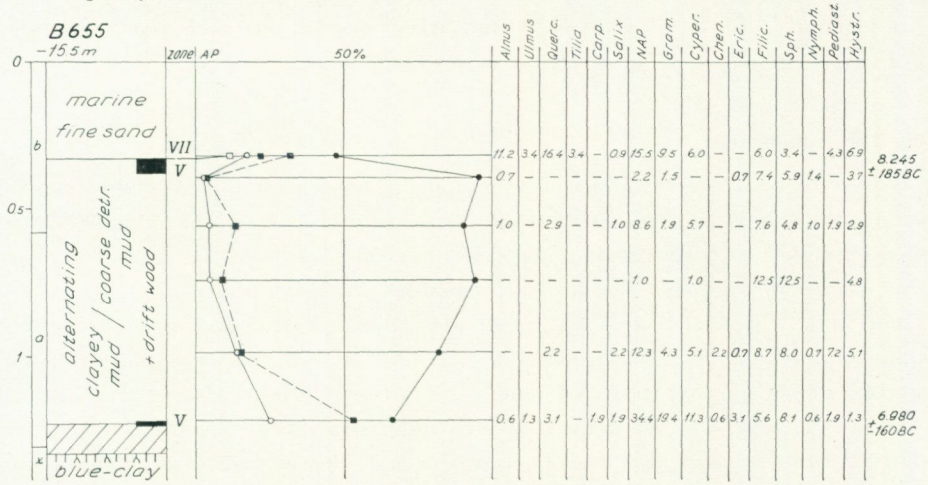


Fig. 106. *The first Postglacial transgression rose to -15.1 m (ALV-2) creating a lagoon with deposition of alternating layers of clayey mud and coarse detritus mud. By the regression down to -16.6 m (ALV-3) the lagoon dryed out.*

The pollen diagram (Fig. 106) shows a distinct hiatus between layers A (= zone VII) and B (= zone V) that corresponds to zone VI (BO-2), i. e. the time of ALV-3.

The uppermost 1.0 cm of layer C + the lowermost 1.0 cm of layer B was C^{14} dated at 6,980 ±160 BC, i. e. about the estimated time of the maximum level of ALV-2 (= PTM-1). The uppermost 5.0 cm of layer B (a silty clayey mud) was C^{14} dated at 8,245 ±185 BC. However, this age is apparently too old, which is probably due to contamination by older material. The C^{14} date and the pollen diagram consequently show that layer B belongs to the maximum level of ALV-2 (= PTM-1).

If we now turn to the shoreline diagram the expected shorelevel displacement fits very nicely with the stratigraphy:

ALV-2 at −15.1 m means a level 1.1 m above layer C and 0.2 m above layer B. However, the type of sediment shows that an open sea is out of the question. A marked terminal moraine (Fig. 14, no. 3) was found just east of this area with a NW direction which means that it would pass just outside this area. Today this ridge has not been refound north of

this area, but it is still highly probable that it was this ridge that caused the obvious lagoonal conditions of this area during the maximum level of ALV-2.

ALV-3 at –16.6 m means a level 1.3 m below the top of layer B, thus the hiatus of zone VI (BO-2) is explained. There are no traces of a corresponding land surface in B 655, but in B 653 the roots of *Phragmites* in situ could be an indication of this.

Consequently, the levels of ALV-2 and ALV-3 were very well fixed by these borings.

20. The Anholt area

The nautical chart and the echo soundings have a lot to tell about possible submarine shorelines. As a whole, the 20 m contour line on the nautical chart seems roughly to correspond to the coast line of ALV-1, as for great distances this is formed by a more or less distinct cliff, which continues right up to the Laesö area. The Anholt area was investigated during four expeditions. Numerous echo soundings and 22 borings (besides the ones on Anholt) were made. During storms, pieces of hard peat are sometimes brought ashore along the coasts of Anholt (A. Jessen 1897). I have myself found one piece. Apparently they are derived from submarine peat beds, probably not far away, as a large stone was found in one of the pieces of peat (A. Jessen 1897).

NNE of Anholt there is a lagoonal "bay" in the 20 m contour line. It seems to be a washed terminal moraine ridge (probably later emphasized by a bar ridge transportation). This area was investigated in detail by five echo sounded profiles combined with six borings (B 638—643). However, none of the borings were able to penetrate the covering fine sand. In B 642 some small pieces of wood were found. In B 640 at –23.0 m old white worn shells including one shell of *Litorina litorea*, which may indicate a corresponding low sealevel, were found. In this area the shoreline diagram says –25.8 m for ALV-1 and –22.2 m for ALV-0. These levels seem very likely, but cannot be proved.

Further towards NE I have two borings (B 279—280), one inside and one outside the 20 m contour. B 279 at –22.0 m gave a 61.0 cm longe core:

A: 57.5 cm of shell bank, finer material at the top and coarser material with pebbles at the bottom. A pollen analysis 4.0 cm from the bottom gave a flora of zone VI (BO-2) with 39.2 % *Hystrix* (ALV-3 here falls at –10.8 m).

B: 3.5 cm of very hard (probably weathered) glacial clay.

ALV-1 here falls at –24.6 m. The hardness of the clay may indicate a land surface. The shell bank indicates a shallow water deposit from ALV-3 or the onset of the transgression up to PTM-2.

East of Anholt the present foot of the cliff was measured to –20.0 m (Fig. 13, no. 4). ALV-1 here falls at –26.2 m.

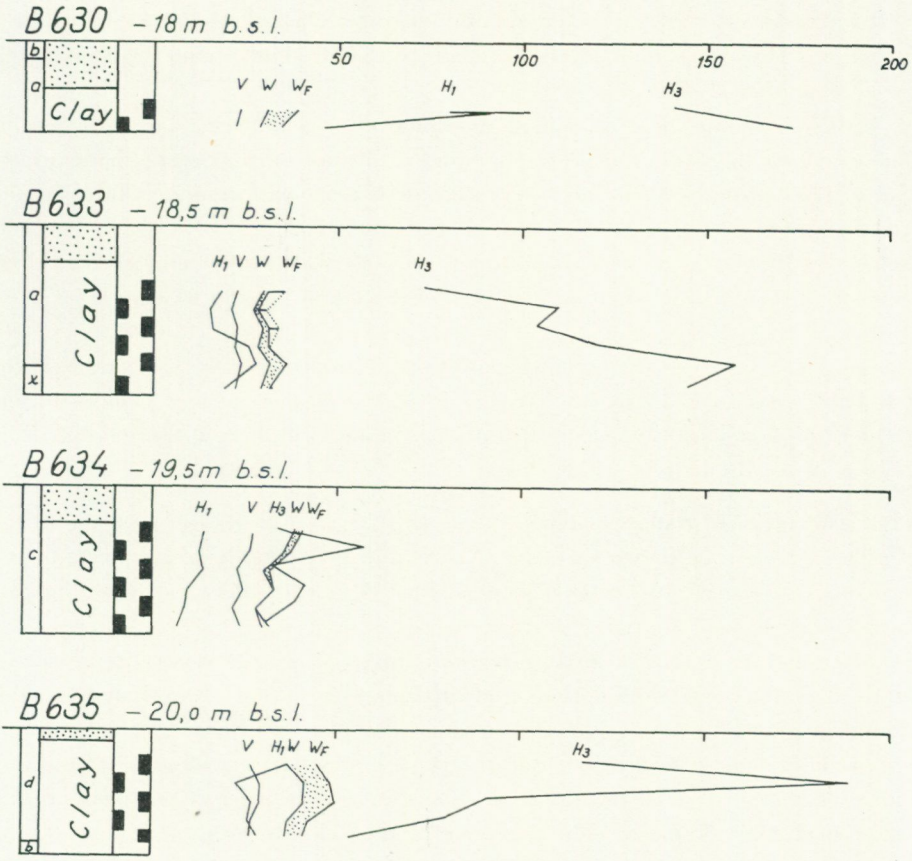


Fig. 107. *Geotechnical analyses of submarine ground crusts in Late Glacial blue-clay from the area NW of Anholt (cf. Fig. 92).*

SW of Anholt there is also a marked cliff. This was measured to –18.7 m, –17.7 m and –17.7 m (Fig. 13, no. 1—3). ALV-1 here falls at –29.0 m. In this area there is a "lagoon" in the 10 m contour. It is a depression with its bottom at about –10.0 m, which is separated from the deeper areas by a ridge at about –5.0 m (Fig. 13, no. 3). ALV-2 here falls at –11.7 m and ALV-3 at –12.2 m. Two borings (B 636—637) were made in this "lagoon". However, fine sand prevented the corer from penetrating. The fine sand contains small pieces of black wood and peat.

NW of Anholt weathered blue-clay was found in four cores (B 630—635) at –18.0 m to –20.0 m. The cores were only a few dm long, due to the hardness of the clay (and the covering fine sand). Nineteen samples in four cores were geotechnically analysed. These analyses (Fig. 107) show that there really are ground crusts in B 630, B 633 and B 635 (not obvious in B 634). In B 633 at

–18.5 m ALV-1 falls at –28.3 m and in B 635 at –20.0 m, ALV-1 falls at –29.0 m. However, these levels were already isolated at about the time of the zone boundary II (AL)/III (DR-3).

SW of Anholt there is a marked submarine channel with a bottom level at about –25.0 m. Numerous echo soundings and six borings were made in this area. The bottom is hard and no core of importance was obtained. Three borings in the middle of the channel all gave a coarse material, e. g. B 517 gave a gravelly sand (see Table 2). B 282 shows a lucitanic shell fauna in the channel. East of the mouth of this channel there is a marked cliff with its present foot at –25.0 m. At the mouth ALV-1 falls at –31.1 m (ALV-0 at –27.9 m). The level –25.0 m was already passed by the sea in the latest part of zone III (DR-3). It seems highly probable that this channel is a river channel or rather a river valley, through which the water from Mariager fjord and Randers fjord (and possibly also Limfjorden) was discharged into Kattegatt (cf. Pl. 7).

21. "Törvegraven" NW of Anholt

For a long time the fishermen of Anholt and Bönnerup have got pieces of peat and logs in their trawls from a depression NW of Anholt, which they therefore call "Törvegraven".

In this area I have a lot of echo soundings, 10 borings, three dredgings and six longer trawlings. The borings and dredgings did not give anything but a fine sand with small pieces of peat (common). With a fisherman from Bönnerup I made six trawlings in order to find the peat. Four of the trawlings gave pieces of peat (B 702—705). In the third trawling there was a big piece of peat (B 703) and several minor pieces. The big piece of peat clearly shows that only the top

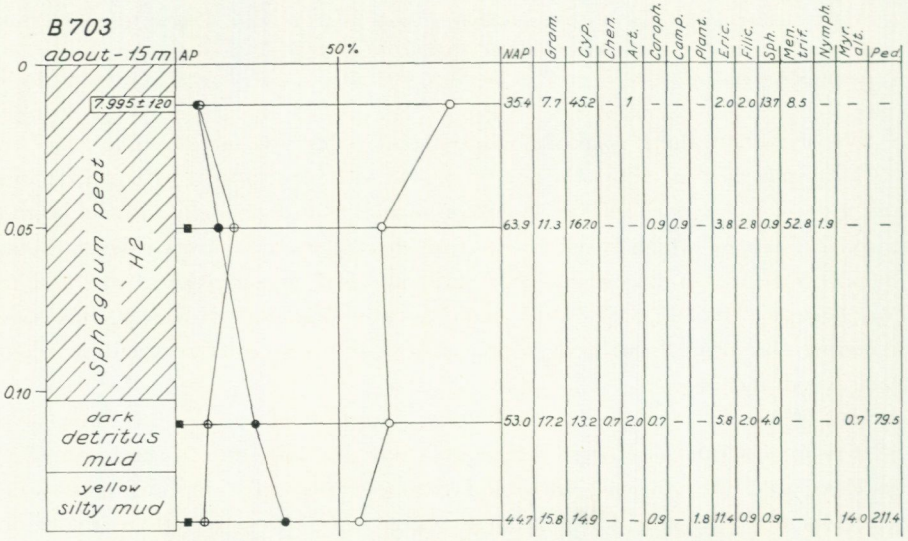


Fig. 108. *Submarine Preboreal mud and peat from "Törvegraven".*

has been exposed above the seabed, and the lower part is a mud. The peat in "Törvegraven" is definitely in situ. The piece of peat called B 703 is 14.3 cm thick and consists of:

A: 10.3 cm of *Sphagnum* peat
B: 2.2 cm of dark detritus mud
C: 1.8 cm of yellow silty mud

The pollen diagram (Fig. 108) dates the whole series to early zone IV (PB). Note the high per cent of *Pediastrum* in the mud (79.5 % and 211.4 % respectively), which is good evidence of lacustrine environment. A C^{14} dating of the peat 1.0—1.5 cm from the top gave 7,995 ±120 BC, i.e. early zone IV (PB). The peat was found at about −15.0 m (−14.0—17.0 m).

According to the shoreline diagrams: "Törvegraven" was isolated in late zone II (AL), ALV-1 falls at −28.5—29.6 m, ALV-2 at about −10.5 m and ALV-3 at about −12.1 m. This fits well with the age of the intermarine layers; only the uppermost part of the peat seems to have been eroded away.

22. The Bay of Aalborg Bugt

During ALV-1, which here falls at about −30.3—35.0 m, the whole area was situated above the sea level, as a landmass traversed by terminal moraine ridges and rivers. During ALV-2 (at −11.2—12.8 m) and ALV-3 (at −12.7—14.3 m), a large part was probably a shallow bay of the sea. This bay roughly corresponds to the present 10 m contour (Fig. 110).

The fishermen often get pieces of peat in their trawls. These pieces of peat are always found at certain places, the positions of which are well fixed thanks to the Decca Navigator. The occurrence of peat is marked on (Pl. 7). As most of the peat found in this area has been at a depth of about −7.5—11.0 m, it could have given very important information about the time of the transgression. However, I have only got peat in the trawlings in the above mentioned "Törvegraven" and at the shoal Dameboxerne (B 702, 704). In the area of Aalborg Bugt, I made 15 dredgings and two borings (embracing all the places with reported peat finds), without finding any peat. The investigation of this area is obstructed by the fact that the fine sand that covers the bottom prevents the corer from penetrating deeper down.

Between the southern parts of Lange Revle and V. Knold (just east of B 743), the echo sounding showed a clear river channel. This channel is about 116 m wide and reaches from −13.0 m down to at least −15.8 m. It seems to be partly filled by younger sediments. Similar but not so well developed channels are also seen outside the mouth of Limfjorden.

In the dredging B 747 at −11.5—11.6 m between Lange Revle and V. Knold, I got a sandy shell bank material, dominated by shells of *Ostrea edulis* and containing one fairly big flint. Probably it is a real shell bank, but it may also be a kitchen midden.

Submarine dune ridges frequently occur in this area (Pl. 7), mainly down to ALV-2/3 (Fig. 110). They are easily identified with the echo sounder. This is illustrated in Fig. 109; two dredgings (B 750 and B 751) were made in a clear dune field, both giving eolian sand (Tab. 2).

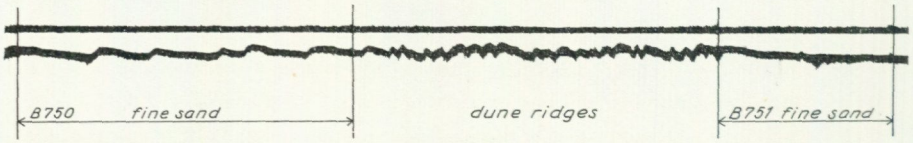


Fig. 109. *Echo diagram from the shoal Svitringen, indicating a submarine dune field. Dredging B 750 and B 751 gave eolian sand. The distance between B 750 and B 751 is 4.0 km. The depth varies between -4 and -7 m.*

23. Laesö and the shallow areas around Laesö

It is hard to fix the shorelevel displacement at Laesö, as the information is not as good as elsewhere, and as it is not at all sure that the isobase system and the shoreline diagrams apply in this area.

At the SE point of the 10 m contour around Laesö I have an echo sounding and a boring (B 774). The shoreline diagram says ALV-1 = – 23.0 m, ALV-2 = –8.6 m and ALV-3 = –10.2 m. The echo sounding (Fig. 17, no. 1 B) shows a possible shore mark at –10.0 m outside two ridges. This could agree with the level of ALV-3. The level of ALV-1 falls just inside the "knee" in the bottom line at –23.0 m.

At Laesö Trindel the shoreline diagram says ALV-1 = –12.6 m, ALV-2 = –1.4 m and ALV-3 = –3.0 m. A shorelevel at about –12 m fits well with the topography according to the echo soundings. Laesö Trindel has been a shoal below the sea level ever since the transgression up to ALV-2.

In the areas of B 602 and B 603, dune ridges were found down to –11.5 m and –12.5 m, respectively. According to the shoreline diagram ALV-1 falls at –14.1 m and –16.7 m, respectively. A grain size analysis of B 603 shows that 86 % of the material is 0.5 to 0.125 mm large, which supports the interpretation as eolian material.

North of Laesö there is a distinct shoal curving away from the NW side of Laesö. This shoal seems to have been formed by streams carrying material from south towards NE and building up this spit-like shoal in connection with the ALV shorelines. This shoal was crossed five times. The echo sounding always suggested a bottom of fine sand, often in the form of dune ridges. The grain size analysis of B 605 on the top of the shoal gave 86 % of the material between 0.5 and 0.125 mm, also indicating dune sand. The dunes were found down to at least –12.3 m and –12.8 m (Fig. 12, no. 2 and 3, respectively). In another profile the dunes were found down to about –13—14 m. Here ALV-1 should fall at about –18.0 m.

West of the harbour Västerhavn on Laesö, a cliff was found at about –17.8 m with the crest at –8.0 m and the dunes inside going down to at least –10.7 m (Fig. 12, no. 1). The shoreline diagram says ALV-1 = –23.0 m, ALV-2 = –8.6 m and ALV-3 = –10.2 m. A boring in this dune field (B 613) gave a quite uniform fine sand that apparently could be an eolian deposit.

Borings in the middle of Laesö have shown the Late Glacial clay surface, covered by a shore deposit of sand, stones and shells at –3.8 m (O. Mickelsen 1967), which is a minimum level of the regression maximum. In the cliff north of Västerbyhavn I have found a similar stratigraphy (B 754, closer dealt with on p. 388).

The submarine borings around Laesö have not given any direct indication of the level of the regression maximum. In the clay areas the whole corer (in B 527 a 476 cm long core), contained younger Postglacial silty clay or clayey silt (e. g. B 526—528). In the sandy areas the corer could not penetrate.

As a whole the NE and SE parts of the area seem roughly to fit with the shoreline diagram, while the NW and W parts do not show any traces of such a low level of ALV-1 as the shoreline diagram suggests.

24. Vendsyssel and the sea around Vendsyssel

From a comparison between the shoreline diagrams and the shore marks in Vendsyssel, it is apparent that my diagrams do not apply in this area. There must be isostatical differences (cf. p. 429). The shoreline diagram of Vendsyssel (Fig. 11) is found on p. 50.

Outside Frederikshavn several borings were made in order to find intermarine deposits, ground crusts or shallow-water deposits from the ALV time. However, the corer did not reach down through the thick layers of younger sediments.

In B 612 at –15.3 m I got a 267 cm long core containing a fine silty clay rich in Postglacial shells (e . g. *Turritella tenebra)*. A pollen analysis of a sample 3 cm from the bottom gave a pollen flora of zone VI (BO-2). The content of *Hystrix,* 23.4 %, indicates marine environment, while the content of *Pediastrum,* 10.5 %, indicates influences of freshwater.

In the area west of Frederikshavn and south of Hirsholm a bored (B 755—760) and echo sounded (two lines) section was made. A distinct cliff is seen here, probably in the slope of a terminal moraine. Three borings and one dredging on the steeper part at –10.4 to –14.7 m gave a hard bottom covered with fine sand. In B 758 at –12 m the fine sand contained very small pieces of peat. In the outermost part of the cliff two borings were made. B 757 at –17.6 m gave 252 cm of Postglacial clayey silt to silty clay with shells. B 756 at –19.2 m gave 265 cm of Postglacial silty clay with shells of *Turritella tenebra.* Consequently, the cliff may correspond to a shorelevel at about –21—22 m, if it does not correspond to the primary slope of a terminal moraine. ALV-1 here falls at –22.2 m.

In Saeby, lacustrine detritus mud has been found at –4.5 m (A. Jessen 1936).

In relation to the tilted shorelines, this is the deepest position of a submarine lacustrine or terrestrial deposit. At Östrup a lacustrine dyey peat has been found at –5.9 m (A. Jessen 1899) and on Egholmen peat has been found at –6 m (A. Jessen 1936).

Limfjorden is eroded down to about –16 m. During ALV-1 it was occupied by a river, debouching south of Anholt or between Laesö and Vendsyssel.

At Tvaersted in NW Vendsyssel, shells of *Cardium edule* in sand below Postglacial marine clay have been C^{14} dated (Copenhagen VII) at 6,025* ±165 BC. The shells apparently belong to the onset of the transgression up to PTM-2.

The buried cliff (S. A. Andersen 1969) from Frederikshavn (about +6 m) to Hirshals (about +4 m) and Lökken (about +1 m) is older than ALV-1 and belongs to the Late Glacial part (Figs. 11 and 151).

25. The islands and skerries between Anholt-Laesö and the Swedish Coast

During ALV-1, Laesö and Anholt were connected with Jylland. The coast of ALV-1 roughly corresponds to the 20 m contour between Anholt and Laesö. This means that there were only 40 km between "Jylland" ("Stor-Jylland") and Sweden during ALV-1, which is important for the immigration of plants, animals and man. Also, this water contained several islands, which made the way still shorter. These are dealt with below (the figures in parentheses behind the ALV shorelines give the corrsponding depth according to the shoreline diagram):

1. The shoal La. Middelgrund: mainly a rock shoal with its top at –6.2 m. During ALV-1 (–20.0 m) this area was a fairly big island. During ALV-2 (–6.9 m) and ALV-3 (–8.4 m) it was a small island.

1b. SSE of La. Middelgrund there is a shoal at –15 m, which was a small island or skerry during ALV-1 (–16.4 m).

1c. The shoal Morups Bank at –12 m was a small island during ALV-1 (–16.2 m).

1d. NNE of La. Middelgrund there is a shoal at –16 m, which was a skerry during ALV-1 (–16.4 m).

1e. NW of La. Middelgrund there is a shoal at –19 m, which was a skerry (or a shoal) during ALV-1 (–19.0 m).

2. The shoal Korallgrundet: This has a series of peaks (probably of Archaean rock) at –13, –15, –17 and –18 m, which during ALV-1 (–21.3 m) were a series of small island. They were shoals during ALV-2 and ALV-3.

3. The shoal Groves Flak: It contains peaks at –20, –13, –13 and –20 m, which during ALV-1 (–20.0 m) were two islands and two skerries.

4. The shoal Fladen: The southern part has peaks at –9.5, –7.5, –8.0 and –6.5 m, which during ALV-1 (–13.2 m) were two islands. The northern part of Fladen has peaks at –10.0, –8.7 and –14 m. During ALV-1 (–9.5 m) the peak at –8.7 m was a small skerry.

These islands and skerries mean that the crossing of Kattegatt need never have involved more than 10 km of open sea between areas of dry land. The following immigration routes seem possible:

A. "Jylland" — Grovers Flak — S Fladen — N Fladen — Nidingen — the Onsala peninsula. This was the easiest way to cross Kattegatt with a lot of islands and skerries on the way and never more than 10 km of open sea.
B. "Jylland" — La. Middelgrund — the −15 m shoal — Morups Bank — Morups Tånge. This was a good way with never more than 10 km of open sea (via Morups Bank).
C. Laesö Trindel — Styrsö — the Gothenburg area. This way meant about 37 km of open sea.

Concerning the immigration of many animals and man, we must, however, also consider the immigration via winter ice. Since Kattegatt has been completely frozen twice during the 20th century, the much smaller sea of ALV-1 must have been frozen every winter. This must also have been the case in the cold period of Younger Dryas and most probably also in the still older periods. Why should the reindeer not have crossed the ice searching food on the Swedish West Coast and why should man not have followed them for hunting? A horn of a reindeer at Edared (cf. p. 154) was C^{14} dated to Alleröd. At Blomvåg (near Bergen, Norway) a fossiliferous marine bed containing bones of reindeer has been C^{14} dated at the Bölling Interstadial. In the northern parts of the Swedish West Coast there are many traces of man as old as from the Late Glacial. However, no exact or close dating is yet possible. The settlemen at Tosskärr (cf. p. 161) seems to belong to the later part of Younger Dryas. During ALV-1 man definitely lived on the Swedish West Coast. This is evident from the localities at Sandarna (p. 245) and Gottskär (p. 251), which through this investigation have been given an exact dating. It seems more likely that this immigration occured across Kattegatt than via Öresund. However, the corresponding settlement at the ALV-1 shore south of Varberg must today be looked for below the present sea level.

26. The submarine channels between Sjaelland and Jylland

In the straits Store Belt and Lille Belt there are marked submarine channels (K, Jessen 1926, S. A. Andersen 1927). These also continue in SW Kattegatt. In the area of the bouy "Kattegatt SW" the channel divides into two branches (Pl. 7). These channels can be followed right up to the mineswept fairway no. 36

NW of Lilla Lysegrund echo soundings were made across the channel. The echo diagram (Fig. 14, no. 2) shows a broad channel with its bottom level at about −35.0 m. At −34.0 m the channel is 185 m wide, at −32.0 m 1110 m wide and at −24.0 m 1570 m wide. The bottom of the channel seems to consist of moraine or rock. ALV-1 here falls at −33.4 m. Further towards SE the bottom of the channel lies at −50 m and here ALV-1 falls at −35.6 m. This means that the channel was a shallow strait or fiord, not a river, during the "regression maximum" (= ALV-1)

SE of Lilla Lysegrund a buried channel was found with the echo sounder (Fig. 14, no. 1). The bottom of this channel seems to lie at about –31.2 m. ALV-1 here falls at –35.2 m. In an outer part the bottom is at –35 m with a corresponding level of ALV-1 at –32.8 m. The fact that this channel is buried shows that it has nothing to do with Postglacial bottom stream erosion, but is an earlier formation. Probably it was mainly formed during ALV-1 and then later buried.

At the bouy "Kattegatt SW" the bottom lies at –43—47 m. ALV-1 here falls at –41.0 m.

Seen as a whole, these channels are not river channels or river valleys, but narrow straits or fiords, in which the strong bottom streams caused an erosion far below the sea level. This in its turn points to a strong outflow.

27. The Store Belt (Great Belt) area

In this area Krog made several borings, some of which he has described (Krog 1960 and 1965). However, only two complete pollen diagrams have been published (Krog 1960). The other cores are as yet incompletely described. Thus I eagerly await Krog's final description with complete pollen and diatom diagrams and maybe with closer determination of the peat layers. Krog's hitherto described cores show the following:

1. a land period in zone IV to early zone V, which is apparently equivalent to ALV-1,
2. a ground water rise starting in early zone V at 7,110 ±120 BC (boring no. 271), i. e. (more or less) simultaneously with the onset of the transgression up to ALV-2 (=PTM-1),
3. deposition of freshwater sediments during late zone V and zone VI, i. e. during the time of ALV-2 and ALV-3,
4. onset of a marine sedimentation in zone VII, i. e. in connection with the transgression up to PTM-2.

Krog's borings are briefly dealt with below. The levels of the ALV shorelines according to the shoreline diagram are given for each boring point.

Boring no. 238 at –23.2 m: ALV-1 = –42.6 m (?), ALV-2 = –15.5 m and ALV-3 = –17.0 m. The position SE of Djursland and outside the Store Belt area proper is important, as the environment during ALV-2 and ALV-3 must here have been marine or at least brackish. However, this part is missing and there is a big hiatus between the 25 cm thick freshwater sediments of (early) zone V and the marine sediments of zone VII. This means that the very onset of the transgression up to ALV-2 is registered in the change from peat to mud, but that nothing contradicts my opinion that the transgression reached above the level of this core and caused marine or at least brackish environment in this area. Incidentally, the stated 2 m of sand in the bottom of the core must mainly be the result of a sucking effect of the falling piston corer (cf. p. 22).

Boring no. 153 at –23.0 m: ALV-1 = –49.0 m (?), ALV-2 = –17.7 m and ALV-3 = –19.2 m. A pollen diagram of this core has been published (Krog 1960). The peat formation starts about 6,610 ±140 BC. But is it a telmatic peat or only a peaty detritus mud as it seems to be in boring no. 96? In this core the freshwater sediments should continue up in zone VII. However, this seems very improbable. The transgression up to PTM-2, which started about 5,800 BC, must have caused a marine or brackish environment in this area. Thus the pollen zonation or the identification of environment (not dealt with by Krog 1960) is probably wrong.

Boring no. 96 at –28.0 m: ALV-1 = –54.8 m (?), ALV-2 = –19.7 and ALV-3 = –21.2 m. A pollen diagram of this core has been published (Krog 1960). In the bottom of the core there are 63 cm of peat (the lowermost 26 cm with increasing content of sandy clay), which according to Krog belongs to zone IV. Then there is a marked hiatus, probably equivalent to the low water level during ALV-1. A new "peat" formation starts at about 6,600 ±140 BC. However, it is a peat with thin layers of mud, i. e. what I would call a peaty (coarse) detritus mud or an alluvial peat in mud — in any case not a telmatic, but a littoral formation. The rest of the core was reported to contain only freshwater sediments belonging to zone V, VI and VII. However, a brackish or marine environment is expected during zone VII.

Boring no. 219 at –29.0 m: ALV-1 = –55.0 m (?), ALV-2 = –19.8 m and ALV-3 = –21.3 m. A thin peat layer in the bottom of the core at –31.5 m is the hitherto deepest find of intermarine deposits in the Store Belt area. The peat is covered by lacustrine sediments from early zone V to early zone VI.

Boring no. 271 at –27.0 m: ALV-1 = –55.4 m (?), ALV-2 = –19.9 m and ALV-3 = –21.4. The core is important and shows:

A: a clayey mud of zone VII with "a slight admixture of brackish and marine" diatoms
B: a lacustrine series of zone V and VI
C: 25 cm of peat (no close determination) of latest zone IV and early zone V. Three C^{14} datings have been made in this layer:
0—4 cm down = early zone V gave 7,110 ±120 BC
4—9 cm down = early zone V gave 7,350 ±150 BC
21—25 cm down = late zone IV gave 7,780 ±130 BC
D: 1 cm of sandy mud

The change from mud (D) to peat (C) may indicate a regression down to the level of ALV-1. The onset of this peat formation is simultaneous with the regression down to ALV-1 in Gothenburg (p. 244) and the outermost part of the Viskan Valley (p. 196). The change from peat (C) to lacustrine sediments (B) is simultaneous with the onset of the transgression up to ALV-2 (= PTM-1).

Boring no. 207 at –23.0 m: ALV-1 = –57.0 m (?), ALV-2 = –20.5 m and ALV-3 = –22.0 m. A layer of peat is found at –25.0 m resting upon boulder

clay. The peat is covered by freshwater sediments of late zone V to early zone VII. The freshwater sediments are separated by a hiatus from a marine clayey mud of zone VII. This core consequently shows that the marine environment reached this area at least in zone VII.

South of Fyn, Krog has an important boring no. 263 at –19.2 m: ALV-1 = –66.8 m (?), ALV-2 = –23.7 m and ALV-3 = –25.2 m. The data given below are derived from personal communications and from the radiocarbon list (Tauber 1966).

A: marine mud
B: lacustrine mud
C: peat
D: lacustrine mud of zone V and VI
E: peat 132—171 cm down. Three C^{14} datings have been made:
132—148 cm down = middle zone V — gave 6,960 ±140 BC (K-857)
158—165 cm down = early zone V gave 7,040 ±140 BC (K-1028)
165—171 cm down = just above the zone boundary IV/V gave 7,600 ±140 BC (K-852)
F: mud of zone IV
G: sand

The change from mud (F) to peat (E) corresponds in time to the regression down to ALV-1 in Gothenburg and the outermost part of the Viskan Valley. The change from peat (F) to mud (D) corresponds in time to the maximum level of ALV-2, e. g. found in B 655 (p. 285). As the core falls just above the level of ALV-2 and ALV-3, the change from mud (D) back to peat (C) may correspond to the small regression down to ALV-3 or a normal overgrowth, which at least indicates that the transgression was interrupted. The change from peat (C) to mud (B and later A) ought to correspond to the onset of the transgression up to PTM-2.

In the area outside Store Belt it was found that the transgression from ALV-1 up to ALV-2 took about 400 years, viz. from about 7,300 to 6,900 BC. The same age seems to apply for the Store Belt area. The difference between the levels of ALV-1 and ALV-2 in the Store Belt area according to the shoreline diagram is definitely too great for a likely rate of the rise of sea level. This means that the ALV-1 shoreline must bend somewhere and the shoreline must consequently be at higher levels than the straight line of the shoreline diagram. This is supportd by the stratigraphy and the C^{14} datings in the Store Belt area. Consequently, it is no longer a question of finding intermarine layers, but marine layers and shore features of ALV-1 in order to fix the real course of the ALV-1 shoreline in the Store Belt area. According to the eustatic curve presented here (Fig. 145) the Ocean level was at about –38.0 during ALV-1 (p. 421). The ALV-1 shoreline is supposed to bend somewhere between –80 km and –150 km, though this is not yet established.

The ALV-2 shoreline falls in the Store Belt area at about –17.5 to –20.5 m. ALV-3 falls about 1.5 m lower. However, no marine or brackish sediments were found by Krog in the Store Belt area proper, but only lacustrine sediments. This might not be so surprising, as the Store Belt area during ALV-2 and ALV-3 was very narrow, at least at the mouth, and the outflow must have been very strong. Between Sejerö and Samsö Flak, at the mouth of the Store Belt area proper, there was only 2 km of water during ALV-2 and ALV-3. The outflow of fresh-water must have been very great as the thresholds in Öresund were situated above the level of the Ancylus Lake and as the Ancylus Lake with a lot of water from the melting land ice discharged its water through the Belts (at an early stage probably also via Svea Älv in Middle Sweden). With such a big outflow there ought to have been a salt reaction current in the deepest part of the channels in the Belts. This reaction current could have brought brackish water into Mecklenburger Bucht, where Kolp (1964, 1965) thought he found a brackish environment in zone V and VI.

The whole picture was changed in connection with the transgression up to PTM-2. The thresholds in Öresund were submerged. The Ancylus Lake turned into the Litorina Sea. The Store Belt area turned into a broad strait.

28. The Mecklenburger Bucht and Darsser Schwelle area

Kolp *et al.* (1965) studied this area. Their information was based upon numerous borings, echo soundings, etc. The datings are the weak point, however. Only one whole core was pollen analysed (Lubliner-Mainowska 1965). In the other cores only the peat layers were analysed. Only two C^{14} dates are given. No information about the presence or absence of weathering below the peat layers is given. Many peat layers are drift peat of more or less unsure relation to the corresponding water level or coarse detritus mud. The high water level in Younger Dryas and Preboreal time is not fully proved. The find of *Cardium edule* obviously does not belong to Younger Dryas. The stones of *Potamogeton vaginatum* in the peat of Younger Dryas age seem not to be evidence of a high water level with brackish environment. Krog's (1960) pollen diagram from Store Belt shows a low water level in Preboreal time. Probably the whole area was situated above the sea level all the time from zone Ic, as the pollen diagram of the peat layers in Kolp's boring KR 3 suggests. During early Boreal time (= ALV-1) the sea level stood below –30 m which agrees well with Krog's results and my shoreline diagram. In the later part of the Boreal time (= ALV-2 and ALV-3) Kolp's sea level at –23 m seems very likely. This level agrees well with my shoreline diagram. The suggested slight admixture of brackish diatoms in late Boreal time is contradicted by Krog's borings in the Store Belt area, but could have been brought into Mecklenburger Bucht by salt reaction currents following the deep channels and not affecting Krog's more shallow areas. The area was finally transgressed by the transgression up to PTM-2.

The questions about the levels of the marine and Baltic shorelines older than the ALV-1 shoreline cannot be solved until more facts are available (more dates, a closer description of the borings and further diatom analyses).

29. The ALV shorelines and the Ancylus Lake

During Younger Dryas the Baltic Ice Lake had its outlet via Öresund and maybe also via Darsser Schwelle and Store Belt. When the ice receded from Billingen in Middle Sweden at the end of Younger Dryas, the whole Baltic Ice Lake was drained 26 m down to the sea level. In Öresund the shoreline of the zone boundary III/IV (DR-3/PB) lies at –32.5 m. As the thresholds in Öresund today lie at –7 m, there is a 25.5 m difference between the highest possible damming of the Baltic Ice Lake and the corresponding sea level. This means full agreement between my shorelines and the figure found at Billingen (e. g. G. Lundqvist 1961 and Strömberg 1968). North of Billingen the sea reached, as the Yoldia Sea, into the Baltic area. Due to the isostatic land upheaval, the marine strait across Middle Sweden, the Närke Sound, grew narrower and was finally restricted to the area of Svea Älv, with the threshold at + 105 m.

In the southwestern Baltic Sea, very low early Postglacial shorelevels have been proposed by E. Nilsson (e. g. 1968) and Kolp (1967). E. Nilsson's figures are only hypotheses derived from extrapolted shorelines and thus of very little interest. Kolp has put together the known occurrences of submarine stumps and "peat" in the Arkona area. These finds have been made down to –60—80 m. This would mean a position far below the corresponding sea level which seems quite unrealistic. These stumps and "peat" layers must have drifted out and been redeposited at greater depths in connection with the first Postglacial transgression up to ALV-2 (= PTM-1). No ground crusts or stumps or peat in situ have been found at these depths. Stumps from Karlskrona, Kåseberga and Bornholm have been C^{14} dated at about 7,300—7,400 BC, i. e. the time just before the onset of the first Postglacial transgression. The peaty mud at –59.5 m described by Kolp (1967) seems to be a typical drift peat (deposited at the end of the Yoldia Sea).

Kolp (1965) found a shore mark at –38 m in the SE part of the shoal Kriegers Flak. Here ALV-1 would fall at –44.0 m. This obviously gives the real regression maximum in this area. A peat layer at –30 m between Rügen and Gedser was C^{14} dated at 7,152 ±350 BC (Kolp 1967), i. e. the time of the first Postglacial transgression, by which it was submerged.

The first Postglacial transgression up to ALV-2 (= PTM-1) of course also affected the Baltic area. In fact this was — totally or mainly — the well known Ancylus transgression. The Baltic area was then probably more or less lacustrine. This is suggested by the shore deposits that Königsson (1964, 1967) described up to 20 m below the Ancylus Limit (AG) on Öland and Gotland — which, according to my interpretation, would belong to the shorelevel equivalent to ALV-1 before the transgression. It may also be suggested by an extrapolation of the ALV

shorelines to Svea Älv; ALV-2 here falls at +107 m, i. e. just above the threshold. Hörnsten (1964) found influences of salt water at least up to 7,223 BC and quite fresh water at 6,823 BC in the varved sediments in Ångermanland.

Many C^{14} dates in the Baltic area confirm (e. g. Berglund 1964, G. Lundqvist 1965, Königsson 1968) that the Ancylus transgression started simultaneously to the transgression up to ALV-2 (= PTM-1).

However, when the threshold of Svea Älv was isostatically lifted above the sea level, the Ancylus Lake started (or continued) — now for isostatical causes — to rise in the south searching for a new outlet. This seems to have occurred at about A^0, i. e. in connection with the regression down from ALV-2 to ALV-3.

The thresholds in Öresund lie 8.5—7.7 m above ALV-3, while the thresholds in Darsser Schwelle lie about 3.3—4.3 m (in N) and 4.6—5.6 m (in S) above ALV-3 respectively. From the Faxe Bay, S. A. Andersen (1936) described submarine beach ridges resting upon peat at about −10 m, which in the upper part had a pollen flora of zone V to V/VI. This shore lies about 8.5 m above ALV-3.

Consequently, it seems likely that this isostatically caused transgression brought the lake level about 8.5 m up above the corresponding sea level, where the lake could drain via Öresund and Darsser Schwelle. This agrees with G. Lundqvist's (1965) C^{14} dates of the Ancylus Limit (AG) on Gotland at about 6,500 BC.

However, the erosion in the thresholds of Darsser Schwelle lowered the lake level by at least about 4 m. This regression was proved by T. Nilsson (1935) and Berglund (1964). As Berglund (1964) found a regression of about 7 m and a possible ingression of salt water at about 6,200 BC, the erosion may even have brought the waterlevel down to the sea level (though the thresholds today are some metres higher), cf. Fig. 149.

To summarize, the following development seems likely:

1. Low level during Preboreal (IV) and early Boreal (V) time, with the regression maximum corresponding to ALV-1 and probably more or less fresh water at the final part.
2. Eustatically caused transgression = the first Postglacial transgression up to ALV-2 (PTM-1). The Baltic area was probably still connected with the sea at Svea Älv. As the transgression made the marine strait in the Göta Älv River valley larger, an increase of the salinity (= the Echeneis Sea?) is probable in the Svea Älv area, though no transgression occurred here.
3. When the threshold at Svea Älv was lifted above the sea level — which probably occurred during the regression from ALV-2 to ALV-3 — the Ancylus Lake started a second transgression. This was entirely isostatically caused. The Ancylus Lake was now dammed about 8.5 m above the sea level.
4. Erosion in the thresholds of Darsser Schwelle brought the lake level down about 4 m or even right down to sea level.



Fig. 110. *The extension of the sea (dark areas) in the Kattegatt area during ALV-2 and ALV-3, i.e. about 6,900—5.800 BC.*

Final remarks on the ALV shoreline

The shorelevel displacement and the three shorelines during what I call the ALV time must be regarded as well determined and dated (Pls. 5 and 7, Fig. 110). The following can be summarized:

1. A regression brought the sea level down to ALV-1 at about 7,750 BC from a shorelevel, called ALV-0, that lies about 4.0 m above and parallel to ALV-1. This regression was found and dated in Gothenburg, along the whole Viskan Valley and in the Store Belt area. This simultaneous regression points to a eustatic cause.
2. ALV-1 lasted from about 7,750 to 7,330 BC. Neither isostatic nor eustatic changes of the level can be seen during this time. The sea level was constant in this area. The ALV-1 shoreline seems to bend just before the Store Belt area.
3. The sea started to rise at 7,330 BC. This occurred simultaneously along the whole shoreline according to a large number of C^{14} dates along the diagram. In fact this was the onset of the first Postglacial transgression. During this transgression, the land was also lifted up isostatically, so that there is a difference in gradient between ALV-1 and ALV-2.
4. The maximum level of this transgression, the PTM-1 or ALV-2 level, was reached at about 6,900 BC.
5. A regression of about 1.5 m brought the sea level down to ALV-3 at about the time of A^0 or 6,550 BC. This regression is seen in Gothenburg, throughout the whole Viskan Valley and also in the submarine cores outside Copenhagen and Odden. As there is no difference in gradient between ALV-2 and ALV-3, this regression seems to have a eustatic cause.
6. The level of ALV-3 lasted till about 5,800 BC. During the whole time of ALV-3 (and ALV-2), no isostatic upheaval can be seen anywhere in the diagram. The sea level remained constant in this area.
7. At about 5,800 BC the second Postglacial transgression started and brought the sea level up to PTM-2. During this transgression, there was a strong reactivated land upheaval. This caused the distinct bend of the shorelines in the area of Laholmsbukten, as the outer part did not follow this upheaval. All the older shorelines were now bent.

The PTM shorelines

PTM stands for Postglacial transgression maximum. By PTM shorelines I mean the shoreline of the maximum level of each Postglacial transgression wave, into which the classic "Postglacial transgression" nowadays can be split up. The following terms have been used earlier: 1. Postglacial Limit, PL (Swed: Postglaciala gränsen, PG), 2. Litorina Limit, LL (Swed: Litorinagränsen, LG) and 3. Tapes Limit, TL (Swed: Tapesgränsen, TG). However, these terms have been used both for shorelines and for the metachronous highest level of the postglacial sea and the morphological features showing this limit. I use PL for the metachronous morphological limit in the field of the Postglacial sea younger than the regression maximum.

Along the whole Swedish West Coast the PL is mostly very beautifully developed as a beach ridge or as a shore cliff or shore cut. However, the PL is metachronous and formed by younger PTM shorelines the further out from the centre of the land upheaval you go. There are a lot of older determinations of the altitude of this limit (both along the Swedish and Danish coasts of Kattegatt). However, one of the first things that caught my attention concerning the measurings of PL, was that usually no regard was taken to the mean sea level in relation to the type of shore mark measured. For example, the top level of the beach ridges of shingle at Torekov has been used in shoreline diagrams as the shorelevel. Such a mistake is important as the difference in altitude between the different PTM shorelines is often very small. Especially the older figures of PL on the Bjäre peninsula and the Kulla peninsula have to be reinterpreted.

As my investigation of the PTM shorelines is based to a great extent (at least in the southern part) upon shore marks, it is very important to distinguish between different types of shore marks and measure the altitude of the corresponding real mean sea level. A comparison with recent shore processes is necessary. However, all recent shore marks around Kattegatt have been formed by a stationary or slightly regressive sea. Thus a full comparison with the transgressive shore marks of the PTM shorelines can never be made. Sinking areas such as the Dutch coast cannot be used for comparison, as there we have strong tidal water, which gives quite different shore marks. Also it is necessary to consider that youger PTM shorelines may have destroyed or reshaped the older shore marks. Furthermore offshore bars and dune ridges must not be confused with beach ridges. The type of material at the shore mark is a major question for the fixing of the sea level. The degree of exposure must of course be considered (in this area the shore marks are usually all well exposed). A very important thing for the determination of how high up the wave action reached is the depth outside the shore mark. Also the gradient of the slope inside the shore level must be considered.

On the whole I do not think it is so hard to make a good determination of the mean sea level in the PTM shore marks, if one only makes careful field observations. When levelling a section, I always make a determination of the mean sea level in the field and note it down, before I know anything about the altitude. Consequently these determinations are only based upon clear field observations. That these determinations of the mean sea level are correct with a very small margin of error (within about 0.5 m) is apparent from the almost identical figures in sections at the same isobase latitude and the fact that the shore marks can now be placed into shorelines which apply along the whole diagram.

Concerning the recent shore formation the following was found in the sections (see also Pl. 9 and Figs. 117—129) distinguishing between "recent" and "this year":

Norrviken (7): this year's shingle and wood to +2.42 m (20 m inland).

Kattvik (8): this year's ridge of shingle to +2.75 m (11 m inland), but recent material higher, probably to +3.39 m (20 m inland).

Ripa (9): recent shingle to +2.44 m (21 m inland).

N. Ängalag (11): recent rock beach (Cambrian sandstone) to +1.07 m (20 m inland) and recent beach ridge to +3.05 m (30 m inland).

Perstorp (12): shingle to +2.54 m (24 m inland) and recent shingle to +3.34 m (30 m inland).

Torekov (13): sand beach with normal sea level mark at +0.12 m and the limit flat beach/dunes at +1.58 m (23 m inland). The waves reach about +2.0 m.

Öllöv (18): recent shingle (this year's) at least to +2.08 m (26 m inland) and probably to +3.39 m (38 m inland).

Nyhamnsläge (23): limit for this year's wave action at +2.09 m (26 m inland). Recent limit probably at +3.07 m.

Viken (26): sand beach with recent wave actions at least to +1.72 m (8.5 m inland and dunes above this level.

As a whole these facts show the following about the recent shore processes:

1. On a sand beach the limit between wave washed beach and dunes lies about 1.5—2.0 m above mean sea level.
2. On a coast of shingle, the shingle is moved about 2.5—3.4 m up above mean sea level. In this connection ice pushing plays an important part.

The shore marks of the PTM shorelines are of four types, described below:

1. *Shore cuts:* Shore cuts are small notches in the slopes. The mean sea level is placed in the notch (or in the bigger cuts just outside it). This type of shore mark is most often found in the fiords.

2. *Shore cliffs:* Shore cliffs mark strong erosion in the slopes. There are small ones more of the type of big shore cuts, but there are also big cliffs rising 10 m or more above the sea (e. g. Fig. 117, Ripa). Many authors have placed

the mean sea level in the "foot" just below the steep cliff. However, this is definitely wrong. The eroded material always builds a plain below the cliff. This can be seen in all the big cliffs around Kattegatt. The mean sea level must be placed about 2 m (1—3 m) below the foot of the cliff. Usually the exact position is hard to fix. The section in Hälsingborg (Fig. 129) suggests a mean sea level at +5.67 m (between +5.92 and +5.51 m) with the foot of the cliff at +7.86 m, i. e. 2.24 m between mean sea level and the foot of the cliff.

3. *Beach ridges of sand:* Sand was deposited above older land surfaces in marked ridges by the Postglacial transgression waves. Often these ridges contain stones. As the sand was often blown together in dunes, it is sometimes hard to see the real shape of the ridge formed by wave actions. Often the inland side is steeper, showing that the material was pushed up by a transgressive sea. I find this steeper inland side a good sign that the beach ridge was formed by a transgression, excluding the possibility of an offshore formation. When fixing the mean sea level one must also consider the conditions in the lagoon or fen that was often formed inside the beach ridges. Usually a weak notch just outside the ridge itself shows where the mean sea level is to be placed. This is usually 1.5—2.0 m below the top of the beach ridge (excluding the dunes).

4. *Beach ridges of shingle*: These ridges are very marked features in the field. The inland side is steeper indicating formation by a transgression. Lagoons and fens are common behind these ridges. The mean sea level is placed in or just below the notch which is usually seen just outside the beach ridge itself. This usually lies about 3 m below the top level of the beach ridge. A beach ridge of shingle is not only formed by direct wave action but also by ice push. This type of shore mark is very common on the Bjäre peninsula and it has usually turned out to be the best type of shore mark for an exact determination of the mean sea level.

In Plate 9 the PL on the Swedish West Coast south of the Gothenburg area has been mapped. North of the Varberg area PL is formed by PTM-2 and south of the Varberg area it is formed by PTM-3 (and the still younger ones). Important borings and levelled sections are marked on this map. The map shows a rocky fiord coast north of Varberg and a lowland coast south of Varberg with several lagoons between Varberg and Falkenberg (Fig. 114) and big spits in Laholmsbukten (similar to the ones along the northeastern coasts of the North Sea).

1. The PTM shorelines in the Viskan Valley

Von Post (1968 †, Fig. 35) had several levelled sections made across the valley containing a lot of shore marks, which he combined into a relation diagram. However, von Post's first Postglacial transgression, the so-called PL 1, is definitely wrong. The Postglacial sea never reached as high up as PL 1. The

shore marks of his PL 1 are older and belong to the period before ALV-1. In connection with von Post's investigation of the Viskan Valley, M.-B. Florin made diatom analyses of some borings (e. g. von Post † 1968, Figs. 1, 14, 18, 25, and 26). Von Post planned a separate diatomological description by M.-B. Florin. However, this description is not yet published, so that we today only have the main salinity curves published by von Post (op. cit.) which may hide separate transgression waves. In the delta area Wenner (1950) studied the deltas and terraces (cf. p. 238). Wenner connected the meander plains into a distance diagram. He found that the meandering increased in connection with transgression of the sea, the isolation of the valley lake and some later lake stages. Wenner found four transgressional and two stationary levels of the sea before the isolation which he dated at about 2,400 BC according to the rapidity of the advance of the delta into the lake (about 1.5 m per year). It is interesting to note that Wenner's highest line (no. 9) does not correspond to von Post's PL 1 line, but my PTM-2 shoreline. Recently Widell (1966, unpublished) tried to date these meander plains by C^{14} dating alluvial organic material (wood, mud etc.) in the meander plains. Eight C^{14} dates have shown that the meander plains belong to two systems, viz. the regression down to ALV-1 (3 dates, p. 238) and the regression down from PTM-2 (5 dates). The following C^{14} dates belong to the younger system (the numbers of the meanders and meander plains refer to Wenner's work):

Meander 41, plain 8: 1.50—1.60 m down (wood) 1,230 ±75 BC
Meander 41, plain 8: 2.50—2.60 m down ("clay") 3,105 ±80 BC
Meander 41, plain 5/6: 4.50—4.60 m down (wood) 2,455 ±80 BC
Meander 41, plain 5: 4.40—4.50 m down (wood) 1,800 ±70 BC
Meander 23, plain 5: 4.80—4.90 m down ("clay") 1,510 ±105 BC

These dates show that the meander plains are younger than Wenner (1950) thought. Together with the earlier described dates (p. 238) they obviously show that the meander plains are not synchronal formations.

The onset of the second Postglacial transgression, the one up to PTM-2, was C^{14} dated at several places in the inner part of the Viskan Valley. These have earlier been described and will here only be listed (B 1, BP 1196 = 5,845 ±150 BC not included, cf. p. 191):

BP 300:3 (B 114—115)	5,700 ±100 BC
B 100 (BP 217)	5,845 ± 90 BC
B 99:1	6,035 ±155 BC
B 95:1	5,780 ±165 BC
B 95:2	5,595 ±150 BC
B 95:3	5,635 ±190 BC
B 5 (BP 22)	5,800 ±110 BC
B 104	5,825 ±100 BC
B 101:B	5,655 ± 90 BC

These figures put the onset of this transgression at about 5,800 BC. This transgression is also seen as a ground water rise in areas far above the PL (cf. p. 157). The onset of this transgression seems to be a better boundary between

the Boreal and Atlantic time than the onset of the *Tilia* curve, which has shown to be of fairly different age in Southern Sweden and Denemark. This transgression seems, without interruption, to have brought the sea level up to PTM-2 (equivalent to the classic first Postglacial transgression, PL 1), which was reached about 5,000 BC according to C^{14} dates at Eskiltorp (p. 333). Just north of Björketorp there is a marked delta at about +25.8—25.0 m which corresponds to this level. In the area around Björketorp there are shore marks at +25.2, +24.6 and +24.4 m which all fall in the shoreline of PTM-2. The highest river beds in the meander plains (Wenner 1950) seem to belong to this stage.

The delta between Berghem and Björketorp lying at +31.0—29.5 m (i. e. von Post's "PL 1") is older and belongs to the Late Glacial regression or more exactly the Younger Dryas period.

At Björktorp there is a delta plain at +23.0—23.6 m. This seems to correspond to PTM-3. A shore mark at +22.8 m could belong to this level. In meander 41 (Wenner 1950) this level probably corresponds to the incomplete river bed at +23.0—22.5 m (i.e. 1.0 m below the shorelevel).

Just south of Björketorp there is a delta plain at +21.4 m which corresponds to PTM-4. In meander 41, the distinct river bed at +20.0—19.0 m belongs to PTM-4A + B (i. e. 2.5—3.5 m below the level of PTM-4A).

The Atlantic is a long period, without good pollen index horizons allowing a clear zonation. This makes a synchronization based only upon pollen fairly uncertain. The diatom diagram of BP 629 (von Post † 1968, Fig. 14) shows an unbroken sea stage (hiding the changes in salinity) — the Younger Sea Fiord — from the onset of the PTM-2 transgression to the PR-6 regression. Further inland the diatom diagrams BP 1511, BP 300 and BP 16 (von Post † 1968, Figs. 18, 26 and 25) indicate changes in salinity. In BP 1511 (loc. cit.) the marine stage 5.8—7.3 m down probably corresponds to PTM-2, PTM-3 and PTM-4A, while the brackish stage 4.5—5.2 m down seems to correspond to PTM-4B. In BP 300 (loc. cit.) the marine stage 4.9—5.9 m down corresponds to PTM-2 and PTM-3. PTM-4A and PTM-4B seem to correspond to the part 3.2—4.4 m down, while PTM-4.5 probably corresponds to the brackish stage 3.2 m down. PTM-5A and PTM-5B are well registered in this diagram (see below). In BP 16 (loc. cit.) the three salinity peaks 2.5—3.4 m down correspond to PTM-2, PTM-3 and PTM-4A, while PTM-4B probably corresponds to the peak at about 1.5 m down and PTM-4.5 to the peak at about 1.0 m down.

In early Sub-Boreal time the development is much more easily fixed. Three pollen horizons can be used in this area, (Fig. 111), viz:

1. The zone boundary VII (AT)/VIII (SB) about 3,100 BC in this area is characterized by the fall of *Ulmus*, a decrease of *Pinus* and usually also a decrease of *Tilia* and a rise of *Betula*.

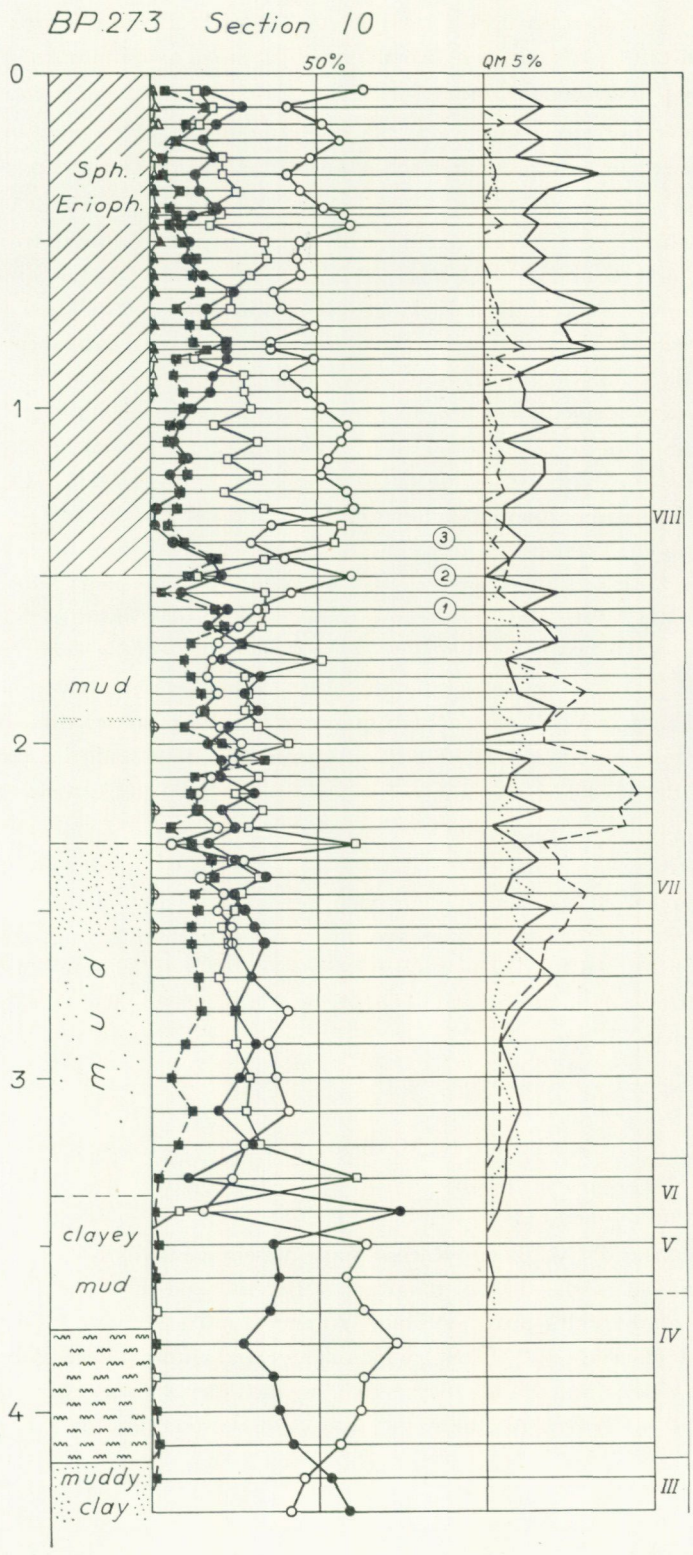


Fig. 111. *Pollen diagram from Kattunga Mosse. In earliest zone VIII (SB-1) three local pollen horizons are used. No. 1 corresponds to the zone boundary VII/VIII (AT-2/SB-1) and is dated at about 3,100 BC. No. 2 corresponds to the final isolation of Kattunga Mosse and is C¹⁴ dated at 2,940 ±90 BC. No. 3 is estimated at about 2,700 BC.*

2. The C^{14} dated horizon 2,940 ±90 BC (in B 101) is characterized by a minimum of *Alnus* (between two maxima), a small maximum of *Betula* and a low percentage of *Pinus*.
3. The distinct horizon about 2,700 BC is characterized by a minimum of *Betula* (increases upwards) and a maximum of *Alnus* (decreases upwards).

In B 101 the isolation level at +17.55 m was C^{14} dated at 2,940 ±90 BC (Fig. 91). The same level is pollen dated by BP 273 (Fig. 111) to the horizon no. 2 just after the zone boundary VII/VIII (AT/SB). From the Torekov area (p. 345) and Berglund's work in East Blekinge (Berglund 1964), it is known that PTM-5A was reached about 3,000 BC. In the valley south of Björketorp (between section 10/13 and 14/15) there is a big delta plain at about +17—18 m. Apparently this was formed by PTM-5A, i. e. just before the isolation in B 101 (Kattunga Mosse). In BP 300 (von Post † 1968, Fig. 26) the diatom shows a double peak of marine diatoms starting at the zone boundary VII/VIII (AT/SB). The first peak falls between the pollen horizons no. 1 and no. 2 and closer to no. 2, i. e. in time at about 3,000 BC, which exactly agrees with the dates in Torekov. In BP 16 (von Post † 1968, Fig. 25) the sedimentation finished before the zone boundary VII/VIII, and this transgression is not seen in this diagram either. In meander 41 (Wenner 1950) the river now followed the river bed at +16.2—16.4 m (2.0—1.8 m below the shoreline). On the older river bed of PTM-4, alluvial material was deposited containing organic material that Widell (see above) C^{14} dated at 3,105 ±80 BC. Within this date and the date of the isolation in B 101, PTM-5A can be fixed at about 3,000 BC, which exactly agrees with the results found in Torekov (p. 345).

The diatom diagram of BP 300 (above) suggests a small regression at the pollen horizon no. 3. At the same pollen horizon a peat formation starts in the peat bog at Sundholmen (BP 649) at about +14.2 m and in Lönnebo Mosse (BP 650) at +15.4—16.4 m. The pollen horizon no. 3 falls closely after the isolation in B 101 and should be dated at about 2,700—2,750 BC. During this regression the river in meander 41 cut down to the river bed at +13.2 m.

In BP 300 (above) the diatom diagram shows a second Sub-Boreal maximum just after the pollen horizon no. 3. This maximum can thus be dated at about 2,600 BC, i. e. the time of PTM-5B according to the comparisons with Berglund's and Marthinussen's results (see p. 400). During this stage a delta plain was formed at Sundholmen at about +15.0—15.5 m.

Immediately after PTM-5B the Recent Lake Veselången was isolated in the valley. This is shown in the diatom diagram of BP 300 and in Wenner's study of the advance of the delta into this lake (Wenner 1950). Wenner found that the isolation took place about 2,400 BC, which agrees well with this interpretation. During the regression from PTM-5B the river in meander 41 was cut down to the river bed at +12.0 m. At the same time, alluvial material began to be

deposited on the older river bed of PTM-5B containing organic material that Widell (see above) C^{14} dated at 2,455 ±80 BC. This age agrees exactly with this interpretation and with Wenner's dating of the final isolation of the valley lake.

Consequently, it was possible to fix the levels of the following transgression waves in the delta area in the Viskan Valley, viz. PTM-2, PTM-3, PTM-4A, PTM-5A (also dated) and PTM-5B (also dated).

In the outer part of the Viskan Valley, the only information about the PTM shorelines is the shore marks measured by von Post (without exact fixing of the mean sea level). In some areas, von Post mapped the shorelines by following the shore marks along the valley sides. Usually von Post's figures ought to be lowered by some decimetres to get the mean sea level. For example: In a shore cut measured by von Post at +16.7 m, I determined the mean sea level, on the basis of the shape of the shore cut at 0.2—0.3 m lower. The shoreline diagram also says +16.45 m at this point.

At a late stage of this investigation, I tried to put von Post's shore mark into the already established shoreline diagram. The result was striking, and somewhat surprising. The shore marks fall along my PTM shorelines, on or close to these shorelines, but very seldom between them. As the shore marks in this area almost always are shore cuts, the correction needed to get mean sea level is usually small (within some dm). Generally the figures had to be lowered. In the area between Section 23 and Section 39, 130 out of a total of 141 shoremarks (excluding the younger ones and the lacustrine ones) clearly belong to my PTM shorelines. The correction required is usually small according to the following table (p. 310).

This table shows that all eight PTM shorelines from PTM-2 to PTM-7 are clearly registered within this area. The shore marks of PL (PTM-2 and PTM-3) and PTM-5 are especially distinct.

In the outermost part of the Viskan Valley, between Åsbro (Section 6) and Nyebro (Section 43), von Post had the shore marks along the southeastern valley slope mapped. In Fig. 112 I have arranged these shoremarks in the direction of tilting and combined them, as indicated by the map, with dotted lines. The following is seen (Fig. 112):

1. The dotted lines are very fluctuating and give shore zones rather than shorelines.
2. These zones clearly fall at certain levels that fully correspond to all eight PTM shorelines. One more zone may be seen, only between PTM-6 and PTM-7, but this is heterogenic and more of regressional type.
3. A shoreline is often destroyed or reshaped by younger shorelevels (e. g. PTM-6).
4. Below PTM-7 there are four younger shorelines.

Section	PTM-2	PTM-3	PTM-4	PTM-4B	PTM-5	PTM-5B	PTM-6	PTM-7
23			−0.2					
1	−0.3	+0.3			+0.1			
24		−0.5			+0.1	+0.2		
27			−0.2	+0.2	0	±0.2		
101	−0.6				0	−0.4		
5		−0.2		+0.7	+0.3	+0.3		
100	0				0	+0.4		
99		−0.2		−0.1	0	−0.4		
26					+0.3	+0.2		
109	−0.5	0	−0.2	0	−0.1	−0.8	Lake Veselången	
						+0.5		
115	−0.8		0	0	−0.6	−0.1		
94	−1.1	−0.4		−0.3	+0.4			
93	+0.1	−0.6			+0.5			
25	+0.1		0		0		−0.2	
92	−0.7		−0.5	−0.4	−0.7			
97	−0.4		−0.4	−0.5				
91	0	−0.3	−0.1	−0.6			0	
90			+0.3	−0.9	+0.1	−0.2		
89					−0.4	−0.4	−0.1	
88	+0.1	−0.3	+0.7	0	−0.8		−0.6	
87					−0.4	−0.7		−0.4
42	−0.1	−0.1	+0.4	+0.4	−0.4	+0.1		+0.2
86					+0.1	+0.1		+0.3
85	−0.6		−0.1	−0.5	−0.2	−0.5	−0.2	−0.6
84	−0.6		−0.1	−0.5	−0.2	−0.5	+0.1	−0.6
98	0	±0.3	0	−0.6	0	−0.1		
				+0.2				
6	−0.4		−0.5		0	−0.3		−0.2
41	−1.0		−0.4		+0.1	+0.2		
40			−0.4	0	+0.1	+0.1	0	
39	0	0	−0.3	+0.2	−0.2	−0.3	−0.1	0

The shorelines younger that PTM-7 have not yet been closely investigated. However, the four shorelines found here are also observed in some other localities (e.g. in the Falkenberg—Halmstad area). They probably all correspond to minor eustatic fluctuations and are thus termed PTM-8, PTM-9A, PTM-9B and PTM-10. They probably correspond to transgressions found and dated on the northeastern coasts of the North Sea (p. 401), In Fig. 112 (B) the shore-level displacement curve at the O-point (Section 40) shows that the dots form a smooth curve, where the four younger shorelines get the following dates: PTM-8 = about 1,000 BC, PTM-9A = about 500 BC, PTM-9B = about 250 BC and PTM-10 = about 750 AD. These dates agree with the dates from the northeastern coasts of the North Sea (p. 401). At Galtabäck, south of Varberg, two ships of the Vikings were found in the shore sand (Humble and von Post 1937). The ships lie at +0.75 m and +0.45 m, respectively. Von Post postulated a corresponding sea level at +2.0—2.5 m. In my opinion, the sea level was probably lower or about +1.0—1.5 m. Recently the ships have been C^{14} dated at 1,125 ±65 AD. (St-204, Stockholm I). This fits well with the shorelevel desplacement curve. The curve (Fig. 112, B) suggests a present land upheaval at the O-point of about 17 cm per 100 year (i. e. 1.7 mm per year).

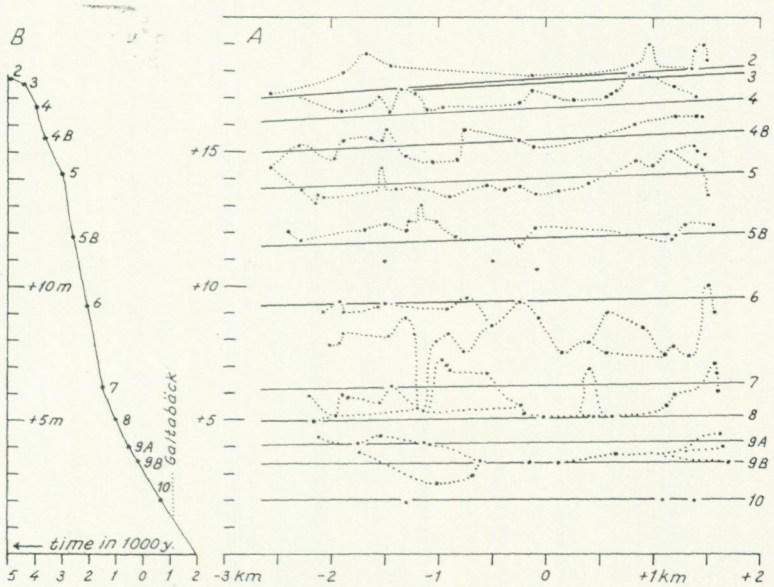


Fig. 112. *A: The shore marks in the valley slope between Åsbro and Åskloster (mapped by von Post) compared with my PTM shorelines. The shore marks form shore zones clearly corresponding to the PTM shorelines. Below PTM-7 four younger shorelines are seen, roughly dated by the shorelevel displacement curve (B).*

2. The Gothenburg area

The Sandarna locality was described by Alin, Niklasson and Thomasson (1934). It offers a very complete picture of the PTM shorelines. It has already been dealt with in connection with the ALV shorelines (p. 245). The interpretation of the stratigraphy there given was made purely on a stratigraphical basis, before the different PTM shorelines were finally fixed. This early interpretation almost exactly agrees with the PTM shorelines found — only PTM-3 has to be added. Sandarna has probably had the following development in PTM time, which is shown in a redrawing of the old section of Sandarna (Fig. 113):

PTM-2 = +25.8 m. Sand and shingle were thrown at least 17 m inland and up to +27.0 m. A shore cut at +25.5 m was formed at Carnegieska Bruken.

Regression (PR-3) to an unfixed level.

PTM-3 = +24.0 m. This level falls just outside a notch in the layer of sand and shingle. The ash layer just above at +24.67—24.72 could belong to this stage.

Regression (PR-4) = about +21.0 m. A beach ridge was formed up to +22.5 m, i. e. 1.5 m above mean sea level. On the top of this ridge there are ash layers from this stage. Inside the ridge there is a thin layer of clay (reaching from +22.5 to +21.4 and +23.8 m), probably a drift clay. It gives the shape of the inner side of the beach ridge. The lowest point inside the ridge is at +21.4 m.

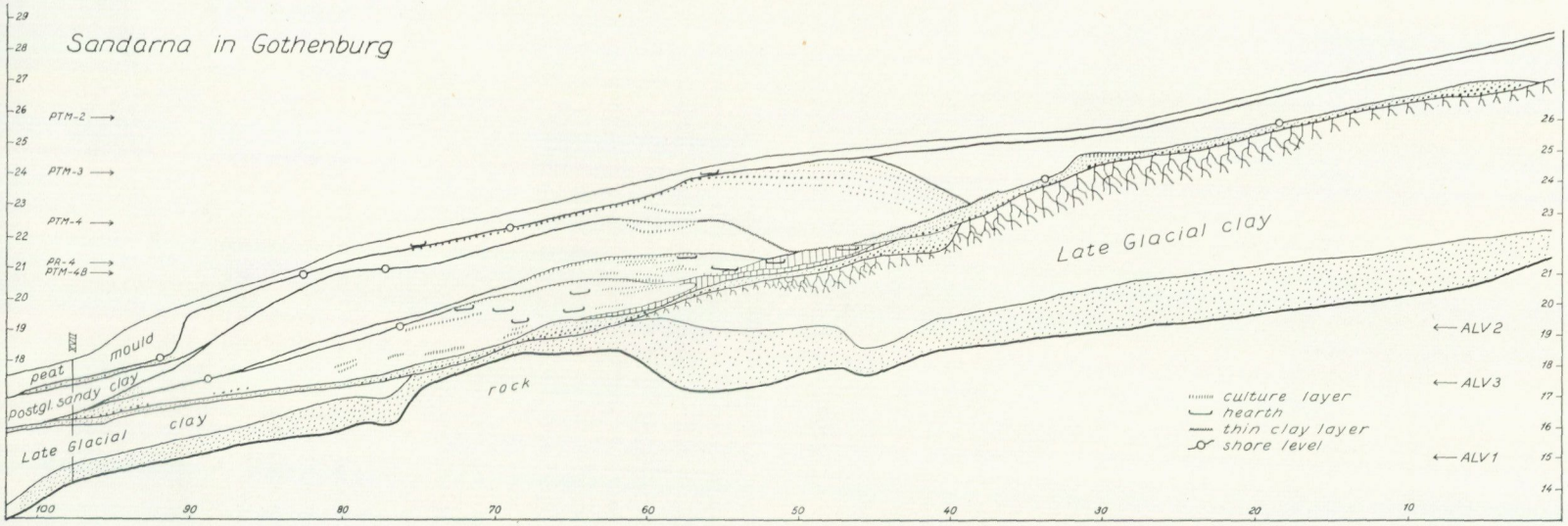


Fig. 113. *Alin's section at Sandarna, redawn and reinterpreted, giving a very complicated picture of the ALV and PTM shorelevel displacement. From a low level (not seen in this section) during ALV-1 the sea rose to ALV-2, burying the old culture layer. A small regression brought the sea level down to ALV-3 and the culture layers and hearths were formed on the beach sand of ALV-2. A distinct transgression brought the sea level up to PTM-2, forming a distinct shore cut at Carnegieska Bruken. PTM-3 is seen below a small notch. PR-4 meant a regression with the formation of a beach ridge above the ALV beach. PTM-4 meant a transgression with the formation of the distinct beach ridge (by Alin interpreted as formed during PL). PTM-5 is seen as a distinct shore cut. The sediments are pollen analysed in point XVII.*

PTM-4 = +22.4 m. The marked beach ridge was now formed, the top of which lies at +24.5 m, i. e. 2.05 m above mean sea level. The steep inner slop shows the transgressional charaeter of this beach ridge. The lowest point inside the ridge lies at +23.1 m. The hearths on the ridge at +23.97 and +24.55 m, respectively, could belong to this stage, but could also be younger.

PTM-4B = +20.8 m. The position of this shoreline cannot be morphologically fixed in this section. The hearth at +21.8 m could belong to this stage or could be younger.

PTM-5 = +18.2 m. A distinct shore mark was formed. This shore mark is a hybrid between a beach ridge and a shore cut. First sand and gravel were accumulated about 2.6 m above mean sea level. Later a "cliff" about 1.6 m high was formed in the outermost part of the beach accumulation. The corresponding gravelly shore material in point XVII has been pollen analysed to the time about the zone boundary VII/VIII (AT-2/SB-1), i. e. to the time of PTM-5.

PTM-5B = +15.2 m. Not found in this area.

PTM-6 = about +12.0 m. Not found in this area.

PTM-7 = +8.2 m. Not found in this section, but in Björkö Mosse (p. 315).

Consequently, the section at Sandarna has given a very complete picture of the PTM shorelines. It has been possible to show that PTM-4 was a very marked event in this area that meant a transgression of about 1.4 m. PTM-3, PTM-4B and PTM-5, on the other hand, seem only to have meant stagnation or at least no distinct transgression.

In order to date the settlement at Sandarna, Thomasson had several pollen and diatom diagrams made from localities in the Gothenburg area (Alin, Niklasson and Thomasson 1934). The localities of interest for this discussion will be described below:

SANDARNA POINT XVII (op. cit., Figs 72 and 74) shows the following stratification:

A: 0.56 m of peat of zone IX (SA) and late VIII (SB).
B: 0.18 m of sand-gravel-stones belonging to the zone boundary VII/VIII (AT-2/SB-1), i. e. PTM-5. This layer here lies at +17.30—17.48 m.
C: 0.96 m of marine clay belonging to the time between ALV-1 and PTM-5.
D: 0.28 m of gravel belonging to ALV-1.
E: 0.12 m of sand belonging to ALV-1.
F: 0.50 m of clay belonging to zone IV (PB).

Pollen statistically there seems to be no hiatus between layer B and layer C, which indicates that PTM-5 did not mean a transgression from a preceding lower position (at least not a transgression of more than 0.5 m). According to the pollen diagram, the zone boundary VII/VIII (AT-2/SB-1) falls in the middle of layer B, i. e. the shore mark at +18.2 m does correspond to PTM-5A.

POPPELMANNAGATAN (op. cit., Fig. 62) has a transgression contact at +23.3 m, according to Thomasson. I made a new boring, B 450, at the same place. Four cores of the transgression contact were taken with a piston corer. The surface at the boring point was levelled by Stadsbyggnadskontoret in Gothenburg. The transgression contact lies in B 450 at +21.32 m, i. e. 2 m lower than Thomasson stated. The altitude was later checked with an aneroid barometer. Two measurements both suggest that +21.32 m is the correct figure. The following stratification was found in B 450:

A: Drift clay.
B: Muddy clay to clayey mud, 25.0 cm thick.
C: Dark coarse detritus mud, 4.8 cm thick. Apparently equivalent to Thomasson's marine drift peat.
D: Black peat, somewhat muddy.

The lowermost 0.4 cm of layer C + the uppermost 0.4 cm of layer D were C^{14} dated at 5,450 ±100 BC, i. e. between the onset of the transgression up to PTM-2 and the time of PTM-2. The second isolation level falls in Thomasson's diagram at analysis no. 20 at +21.6 m (corrected altitude). As PTM-4B falls at +21.8 m, Poppelmannagatan ought to have been isolated about the time of PTM-4B, probably just before. Pollen statistically, analysis no. 20 can be synchronized with analysis no. 20 in Sandarna point XVII, i. e. 17.5 cm of clay were deposited in point XVII after the isolation of Poppelmannagatan.

RUDS NORDGÅRD (op. cit., Figs. 63—64) has its second isolation level at +20.05 m at analysis no. 19. As PTM-4B here falls at +20.2 m, Ruds Nordgård should have been isolated about the time of PTM-4B, probably just before. Analysis no. 19 can pollen statistically be synchronized with analysis no. 20 in Sandarna point XVII and in Poppelmannagatan.

KÅLGÅRDEN (op. cit., Figs. 67—68) has its second isolation level at +17.5 m at analysis no. 5, which pollen statistically can be synchronized with analysis no. 18 in Sandarna point XVII. This means that the isolation took place before PTM-5, while the altitude suggests an isolation just after PTM-5. However, a mere 1.0—1.5 m high threshold is enought to explain the disagreement.

The diatom diagrams of the abovementioned localities show changing floras. However, it is very hard to draw any conclusions about the water depth from the diagrams one by one. When the analysis levels are synchronized pollen statistically, there appear some striking synchronal maxima. (The figures in parenthesis mean cm below the clay surface at the limit layers B/C).

p. XVII	Poppelm.	Ruds N.	Kålg.	
18 (7.5 cm)			5 isol.	= after PTM-4B
20 (17.5 cm)	20 isol.	19 isol.		= about PTM-4B
21 (max.?)		18 max.	6 max.	= max. at PTM-4
22	22	17	7	
23				
24 (max.?)	26 max.			
25	27 max.	15 (max.?)	10 max.	= max. at PTM-2

Consequently this synchronization not only shows the transgression of PTM-2, but also supports the transgression of PTM-4.

Several measurements of PL in the Gothenburg area have been made by Alin, Thomasson and Sandegren. These were listed by Sandegren in the description of the geological maps of Särö and Gothenburg (Lundegårdh and Sandegren 1953 and Sandegren and Johansson 1931). The shore marks, their altitude and their relation to my PTM shorelines are listed below:

Styrsö	shore cut	+22.5	PTM-3	+21.8	(PTM-2)
Örsviken	beach ridge	+22.2	PTM-4	+20.7	(PTM-4B)
Hovås	shore cut	+23.5	PTM-2	+23.8	
Askim	shore cut	+23.5	PTM-3	+23.1	
Hylte	shore cut	+23.5	PTM-3	+23.2	
N. Hästvik	beach ridge	+23.5	PTM-4	+21.8	(PTM-4B)
Mölndal	"beach ridge"	+24.8	PTM-3	+23.7	(PTM-4)
			PTM-2	+25.6	
Carnegieska Br.	shore cut	+25.5	PTM-2	+25.8	
Ardal	beach ridge	+24.7	PTM-4	+22.7	
Bagaregården	shore cut	+25.9	PTM-3	+25.4	
Redbergsparken	shore cut	+26	PTM-3	+25.4	
Kyrkåsen	shore cut	+26	PTM-3	+25.4	
Rörö	beach ridge	+25	PTM-4	+23.8	(PTM-4B)
Lärje station	shore cut	+26.5	PTM-3	+25.8	

Consequently the shore cuts belong to PTM-2 or PTM-3, while the beach ridges belong to PTM-4 (and PTM-4B). The "beach ridge" at Mölndal is a layer (50—35 cm thick) of shingle and gravel that rests upon an old culture layer Alin 1934c). However, it is not sure from Alin's description whether the shingle and gravel represent an offshore formation, washed out from the slope during PTM-2, or a real beach ridge accumulation during PTM-3 or PTM-4. As the culture layer contains shingle in the coastal side and rests upon a thin black layer that seems to be a pitchy soil, it is possible that the culture layer was formed in the sediments of PTM-2 (during the time after PTM-2 when the sea was still in the close proximity) and was later buried by PTM-3 or PTM-4.

On the island Björkö there is a small bog, BJÖRKÖ MOSSE, between the rocks. G. Andersson (1893) described the following stratification from the southern margin of the bog:

A: about 0.2—1.0 m of drift peat showing a surrounding vegetation dominated by *Alnus, Betula* and *Taxus baccata*
B: about 10 cm of clayey mud containing *Ruppia maritima*
C: about 20—30 cm of peat containing a very similar flora to the one in layer A

Andersson thought that layer B corresponded to the "Postglacial transgression". Later Sernander (1902) showed that the whole sequence must belong to the regression after PL. Sernander found the following stratification (7 m from the margin):

A: 30 cm of peat containing mud and clay (= final isolation)
B: 10 cm of clayey mud (= PTM-7)
C: 8 cm of clayey peat mixed with mud (= PR-7)
D: >10 cm of shell gravel

Sandegren (Sandegren and Johansson 1931) described a pollen analysed boring from the middle of the bog. However, the transgressional stratification from the margin of the bog is not seen here in the centre. Sandegren found this stratigraphy:

A: 1.85 m of peat
B: 0.75 m of detritus mud (some marine diatoms at the bottom)
C: 3.35 m of marine clayey mud
D: 0.85 m of Postglacial shell gravel

The isolation level (B/C) seems pollen statistically to correspond roughly to M. Fries' pollen horizon "d". According to Fries (1951) this horizon often corresponds to a recurrence surface. Fries gave this horizon an approximate age of 1,500 BC. This recurrence surface probably corresponds to the one at the zone boundary SB-1/2 which T. Nilsson has dated at 1,650 BC (T.Nilsson 1964b). This means that the isolation of Björkö Mosse seems to have occurred at about 1.650 BC and that the small transgression indicated by the stratigraphy described by Andersson and Sernander occurred at about the same time. This makes a correlation with my PTM-7 obvious (cf. p. 386). According to Sandegren the present threshold lies at +6.7 m. A 1 m contour map (surveying) suggests a threshold at +7—8 m. According to my shoreline diagram, PTM-7 here (at +30.0 km) falls at +8.0 m. At this level Björkö Mosse was a lagoon connected with the sea by one or two narrow openings (about 5 m wide). Thus I find the stratigraphy in Björkö Mosse to be good evidence of the short and weak transgression of PTM-7 at this isobase latitude.

Near Ljungskile about 90 km N of Gothenburg, G. Persson (1968) found a transgression in Vassbosjön at +43.5 m at about T⁰. With the changed direction of tilting in this area (N 16° E) PTM-2 here falls at +43.0 m. This means a fairly good agreement with my PTM-2 shoreline, though the interjacent area has not been investigated and the tilting here has a different, not so well determined, direction giving a changed isobase system. This also means that the assumed direction of tilting, i. e. from N 16° E, is probably quite correct.

3. The Lygnern Valley and the Rya mire

Von Post had seven levelled sections in the Lygnern Valley. These sections contain 12 shore marks (shore cuts) belonging to PTM time. These shore marks have the following relation to my PTM shorelines:

Dal	+18.1	PTM-4B	+18.4	+0.3 m
Gäddevik	+19.1	PTM-4B	+18.8	−0.3 m
	+20.5	PTM-4	+20.1	−0.4 m
Fagered	+19.3	PTM-4B	+19.2	−0.1 m
	+20.7	PTM-4	+20.6	−0.1 m
Ö Öxared	+19.2	PTM-4B	+19.3	+0.1 m
Lönnevik—Sandaryd	+21.5	PTM-5	+21.5	±0.0 m
Flohult	+18.5	PTM-5	+18.3	−0.2 m
	+20.8	PTM-4B	+20.9	+0.1 m
(in A)	+22.2	PTM-4	+22.5	+0.3 m
(in B)	+23.0	PTM-4	+22.5	−0.5 m
Rya	+23.4	PTM-4	+23.0	−0.4 m

This means that there is a strikingly good agreement between von Post's shore marks and my PTM shorelines: six belong to PTM-4, five to PTM-4B and 1 to PTM-5.

At Gåsevadsholm (outside Lygnern) the skeleton of a man "Rolfsåkermannen", killed by a stoneaxe from the time of the passage graves, has been found at about +6.7 m below 2.9 m of marine clay and resting upon a shell bank of *Ostrea edulis* (Erdtman 1921). Erdtman found that the skeleton probably is 4,000—4,400 years old. The pollen analysis from the skeleton itself shows a flora that seems to be slightly younger than the *Ulmus* decline, but clearly older than the onset of the *Picea* and *Fagus* curves, i. e. from about 2,500 BC. The pollen analysis from the middle of the overlying clay gives a somewhat later date, but still clearly older than the onset of the *Picea* and *Fagus* curves, i. e. probably from late SB-1. The content of *Chenopodiaceae* (2.4 %) indicates proximity to the shore. Recently the skeleton was C^{14} dated at 2,580 ±100 BC (St-2488, Lindälv 1968), i. e. the time of PR-6. This is in full agreement with the shorelevel displacement. It means that the man was killed when the sea was at about +12—10 m, i. e. when the depth was 5—3 m.

The Rya mire in the delta area of Lygnern was investigated by von Post (Chapter VIII in the "Viskan investigation", unpublished) and by Smedman (1967, unpublished). The older part of the Rya mire has already been dealt with on p. 247.

The diatom flora in von Posts diagrams of BP 13 and 14 changes at or just before T^0 from a freshwater flora to a marine-brackish one. Apparently this is equivalent to the onset at about 5,800 BC of the transgression up to PTM-2. According to Smedman's results, the diatom flora at the same horizon changes over from a slightly brackish to a freshwater flora. Smedman's freshwater flora is probably a result of the delta. According to Smedman, the brackish stage forms a single peak, C^{14} dated at about 5,095 ±100 BC, i. e. in exact agreement with my dating of PTM-2. Von Post's marine-brackish stage might show a double maximum (this could correspond to PTM-2 and PTM-3, but I find a single maximum more reliable according to the pollen diagrams). The final "isolation", or rather change to the final freshwater flora, occurred according to the pollen diagrams at a synchronal level (in the middle of the Atlantic time) or shortly after 4,325 ±100 BC according to Smedman's date. Consequently, this "isolation" or change to lacustrine environment occurred during the regression down from PTM-3. During the maximum of this regression, great parts of the Rya mire were land and the rest shallow water. The transgression (about 1.4 m according to the results in Gothenburg) up to PTM-4 did not change the lacustrine environment in the Rya mire.

During the fiord stage the threshold of Lygnern was raised at least to its present level at +15.1 m, probably some meters higher. The distinct shore marks

of PTM-4 and PTM-4B indicate that the sea fiord still reached into Lygnern. The shoreline of PTM-5 falls 2 m above the present threshold, but it is not known whether it also reached above the ancient one. PTM-5B did not reach Lygnern.

4. The Onsala peninsula

From the intermarine peat beds in Lunna Mosse and Lunnaled (p. 251, Fig. 86) we know that these localities were reached by the sea shortly after A^0. As mentioned above, it turned out to be a hiatus at the C^{14} dated transgression contact in B 427. However, this area must have been transgressed in close connetion with the onset of the transgression up to PTM-2, i. e. about 5,800 BC. According to Halden, the diatom diagram of Lunna Mosse (Halden 1922) showed only one maximum. According to the shoreline diagram the final isolation ought to have taken place between PTM-5A and PTM-5B, i. e. about 2,700—2,750 BC. The final peat formation started with the beginning of the Sub-Atlantic time, but this is only a minimum age of the isolation. A comparison between Thomasson's pollen diagram of Lunna Mosse (Alin, Niklasson and Thomasson 1934, Fig. 59), Sandegren's diagrams of Vallda Mosse and Krokens Mosse (Lundegårdh and Sandegren 1931, Figs 43—44) and the early Sub-Boreal pollen horizons found in the delta area in the Viskan Valley (p. 306) suggests that the isolation took place at horizon no. 3, i. e. about 2,700—2,750 BC. I find these three horizons very useful, though there are of course local variations which one has to consider.

If we now turn to Thomasson's diatom diagram (op. cit., Fig. 60), this shows that there is an early slatwater maximum of marine-brackish bentonic forms and marine plankton in analyses no. 23—26 and a late maximum of markine-brackish and marine bentonic forms, some marine epiphytes and marine plankton (distinct peak) in the analyses 3—5. Between these maxima marine-brackish epiphytes dominate. The early maximum is equivalent to PTM-2 and the late maximum to PTM-5, as it falls just between my pollen horizons no. 1 and 2.

Sandegren (Alin 1934b, Figs. 16—17) has a pollen and diatom diagram from the point "Grop 7". I divided (ecology according to Miller 1964) Sandegren's 14 diatom species in 4 groups, viz. marine-brackish epiphytes, marine-brackish bentonic forms, marine bentonic forms and marine plankton. The resulting curves show the following:

1. A clear maximum of marine bentonic forms and a minimum of marine-brackish epiphytes at the transition grey sand/green "mud" (=clayey mud) in analyses no. 5—7. This corresponds to PTM-2 and PTM-3.
2. A minimum of marine bentonic forms and a maximum of marine-brackish epiphytes in analysis no. 9. This could correspond to the period between PTM-3 and PTM-4, i. e. PR-4.
3. A maximum of marine plankton and a minimum of marine-brackish epiphytes in analysis no. 15 (the brown "mud"). This could correspond to PTM-4.

4. A maximum of marine-brackish epiphytes and a minimum of marine bentonic forms and marine plankton in analyses no. 19—23 (21). This probably corresponds to the regression between PTM-4 and PTM-5, i. e. PR-5.
5. A maximum of marine bentonic forms, marine plankton and marine-brackish bentonic forms and a minimum of marine-brackish epiphytes in analysis no. 25 (no analyses higher up). Apparently this corresponds to PTM-5.

Now the interesting thing is that my pollen horizons no. 1—3 can be used. Horizon no. 2 falls at analysis no. 27, or just below this, and horizon no. 1 at analysis no. 25, or just below this. This means that the youngest diatomologically found distinct maximum falls just between horizons no. 1 and 2, i. e. this maximum must be equivalent to PTM-5A.

These results show that the PTM-5 meant also in this area a very distinct event — transgression after a regression. Pollen analytically the age of PTM-5 exactly coincides with the results found in the delta area of the Viskan Valley (p. 308).

The stratification of the peat bog Krokens Mosse at +21 m (Lundegårdh and Sandegren 1931, fig. 44) shows that the Postglacial transgression did not reach this altitude. This is important as my PTM-2 here falls at +20.5 m (von Post's "PL 1" falls at +21.5 m).

In this connection it can be worth pointing out that many of Sandegren's pollen diagrams ought to have another Postglacial zonation, e. g. his age 4,500 BC (= T^0 and "LG") seems to be very differently placed, sometimes even at the zone boundary VII/VIII (AT/SB). Apparently T^0 is not a good and synchronal horizon on the Swedish West Coast.

Several measurements of the PL on the Onsala penisula have been made by Alin, Thomasson and Sandegren. These were listed by Sandegreen in description of the Geological maps Särö and Onsala (Lundegårdh and Sandegren 1953 and 1952, respectively). However, these shore marks are often formed by some of the younger PTM shorelines. Sometimes they are polygenous and formed and/or reformed by several PTM shorelines. These shore marks, their altitude and their relation to my PTM shorelines are listed below:

W of Kungsbacka	shore cut	+18	PTM-4B	+18.1 m	
SE of Vallda	shore cut	+18	PTM-4B	+17.8 m	
Brandshult	beach ridge	+18	PTM-5	+15.8 m	(PTM-4B)
Prässe	shore cut	+20.6	PTM-2	+20.0 m	
Meryt	beach ridge	+19.5	PTM-4B	+17.2 m	(PTM-3—4)
Prästgården	beach ridge	+19.5—7	PTM-4B	+16.9 m	(PTM-2—4)
V. Hagen	beach ridge	+20.0	PTM-2	+18.5 m	(PTM-3—4)
Gottskär	shore cut	+19.5	PTM-2	+18.5 m	
Ölmanäs	beach ridge	+19.4	PTM-4	+17.2 m	(PTM-2—3)
	shore cut	+17.1			
Hållsunds udde	beach ridges	+19.5 +19.75	PTM-2—4	+17.6—17.0 m	

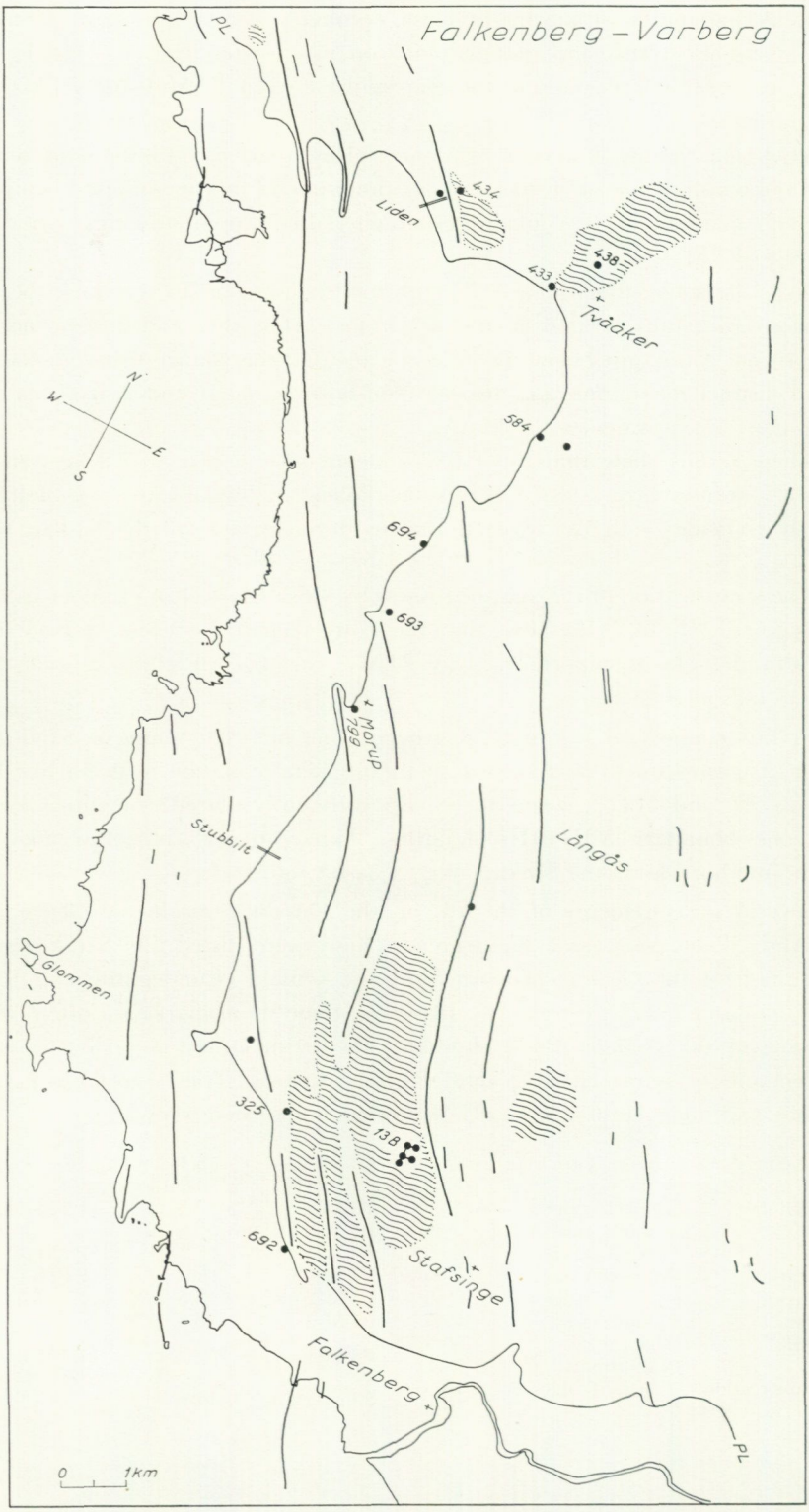


Fig. 114. *Map showing PL between Varberg and Falkenberg, its dependence on the terminal moraines (thicker lines), the lagoonal areas (wavy areas) inside the proper PL beach and some boring points (black dots).*

5. The Varberg—Falkenberg area

NW of Varberg a fiord stretched inland to Gödestad—Rolfstorp. SE of Varberg another fiord extended inland to Hunnestad, where a terminal moraine formed a narrow land ridge between the two fiords. Between Träslövsläge and Falkenberg the PL is very distinct (Fig. 114). It can be followed as a marked beach ridge along the road from Träslövsläge to Tvååker — Morup — Falkenberg. In this area a great number of terminal moraine ridges were mapped (Pl. 3), all running SE—NW. These ridges have to a great extent influenced the position of the shore of the PTM shorelines. This is apparent from Fig. 114 where PL, the terminal moraines and the lagoons inside these are shown. PL is highly polygenous in this area as PTM-2 to PTM-5 here lie very close. Since De Geer (1893) found an intermarine peat bed on the Swedish West Coast, several such localities have been described (Erdtman 1921, Halden 1922, Asklund 1936) in the Varberg—Falkenberg area. Svedmark (1893) described the occurrence of sand and shingle between Late Glacial and Postglacial clay beds as evidence of a Postglacial transgression (e. g. at Varö). Stratifications indicating a Postglacial transgression occur very frequently in this area and are often found in geotechnical borings, ditches, foundations for buildings etc. The more important localities showing this transgression will be described below.

Holmgärde (Erdtman 1921, Fig. 25) in the fiord NW of Varberg shows an onset of a marine transgression in early Atlantic time.

In the fiord SW of Varberg, intermarine peat beds have been described NW and W of the church of Hunnestad (De Geer 1893, Halden 1922, Erdtman 1921). The pollen diagrams show an onset of a marine transgression at the very beginning of the Atlantic time, i. e. about 5,800 BC (or slightly after) at the onset of the transgression up to PTM-2.

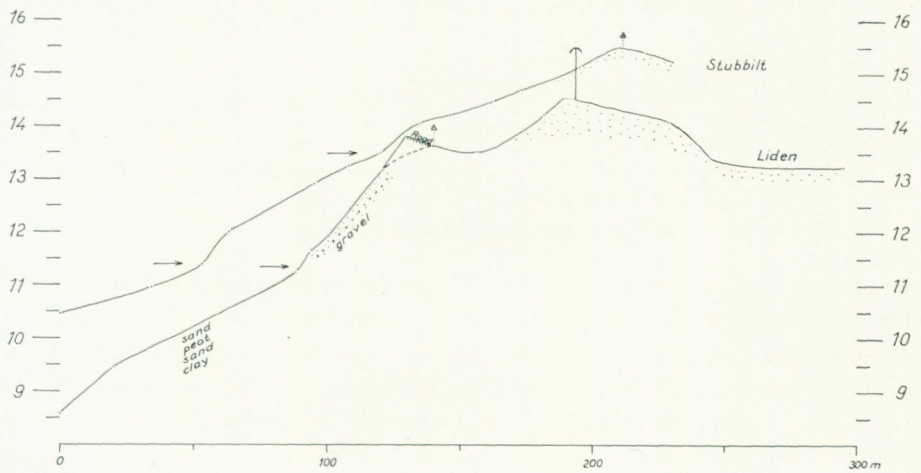


Fig. 115. *Levelled sections across the PL beach. Arrows mark the shorelevels (mean sea level).*

At Liden there is a very marked beach ridge just outside a terminal moraine ridge. A levelled section was made here (Fig. 115). The top of the beach ridge lies at +15.5 m with a depression inside at +13.2 m. A shore cut at about +13.0—13.5 m has been more or less destroyed by the road. This shore must belong to PTM-5, here at +13.0 m. PTM-3, forming PL at +14.8 m, may have reached beyond the beach ridge to the slope of the terminal moraine just inside. At +11.25 m there is a fairly well marked shore cut. It lies, however, 0.9 m above the shoreline of PTM-5B. At +8.6 m there is another shore cut, formed by PTM-6. Inside the terminal moraine there must have been a lagoon during the time of PL (Fig. 114). This is evident from the altitude (about +11 m) and a boring B 431 which showed a layer of peat between Late Glacial clay and Postglacial sand. In another boring B 434 a Postglacial clayey mud was found 0.8 m down below alternating layers of sand and black peaty pitchy soil (three thin layers).

Asklund (1936) stated that the beach ridge of PL in Tvååker reaches up to +16.5 m. PL is here formed by PTM-3 at +14.9 m (PTM-4 falls at +14.2 m). In the ditches east of this beach ridge (and north of Tvååker) Asklund found the following stratification:

A: "Litorinasediment" containing a Postglacial shell fauna. About 100 m east of the railway this layer is 2 m thick.
B: 1.7 m of peat, rich in wood and plant fragments.
C: Lacustrine and marine sediments.

Consequently a lagoon must have occupied the area inside the beach ridge (Fig. 114).

I went back to Asklund's locality and made a boring, B 438, at a suitable point. The following stratigraphy was found:

A: Eolian sand.
B: Sand alternating with layers of mud and humus.
C: Grey sand.
D: Sandy marine clayey mud.
E: 0.77 m of peat (2.65—3.42 m below surface). The uppermost 4.0 cm are muddy, i. e. a peaty coarse detritus mud.
F: Blue-grey sand with increasing clay content downwards.

Samples of the upper and lower limit of the peat were taken with a piston corer. The isolation level was described on p. 160. The uppermost 1.5 cm of layer E was C^{14} dated at 5,615 ±160 BC. The transgression contact seems to lie at about +9.0 m (not levelled) and PTM-2 here falls at +15.1 m. Pollen analyses were made 1.5 cm above and 1.5 cm below the transgression contact, i. e. the limit between layers D and E. The following flora was found (not a complete list):

	Pinus	*Betula*	*Alnus*	*Ulmus*	*Tilia*	*Quercus*	*Salix*	*Corylus*	*NAP*	*Gram.*	*Cyp.*	*Hystrix*
D:	40.6	16.0	13.2	3.8	4.7	18.9	1.9	19.8	27.4	19.8	3.8	13.2
E:	39.5	23.5	20.5	3.5	0.5	10.0	1.5	36.5	73.0	61.5	9.0	—

The flora in layer E shows a lacustrine-telmatic flora of latest zone VI (BO-2). The flora in layer D belongs to earliest zone VII (AT-1) and the content of *Hystrix* shows marine environment.

In geotechnical boring at the bridge in Tvååker (Statens Geotekniska Institut, no. K 1639), the following stratigraphy was found:

A: 3.9 m of stony sand.
B: 1.3 m of muddy fine sand and peaty dy (at +7.3—6.0 m). Apparently it is two different layers, viz. an upper marine and a lower lacustrine-telmatic one.
C: Late Glacial clay, weathered in the top.

A new boring, B 433, was made in the same area, but sand prevented sampling. Below 3.2 m sand at least 0.25 m of (marine) clayey mud was found. The peat was not reached.

By the railway about 1.5 km south of Tvååker the following stratigraphy (the archives of Statens Järnvägar) has been found just inside the PL beach ridge proper (surface at about +13 m):

A: 1 m of sand = transgression, probably PTM-5A.
B: 0.6 m of peat = regression, probably PR-5.
C: 1.1 m of sand = transgression, probably PTM-2 to PTM-4B.
D: >0.8 m of weathered clay (H_3 at the top = 389 and at the bottom = 1,240) containing "mould", i. e. being impregnated with humus to a pitchy soil = the old land surface of ALV time.

This stratigraphy indicates that there was a sandy bay or lagoon in this area (not marked on Fig. 114) during the time from PTM-2 to PTM-4B and that the beach ridge assumed its final shape during PTM-5A.

In the brook just at the road 800 ENE of Hägared the following stratification was found (B 584):

A: 1.8—1.7 m of sand with black layers of humus (= proximity to the shore)
B: 0.25 m of hard oxidized rusty gravel (= a weathered land surface)
C: blue-grey sand (Late Glacial)

Caldenius (1958) mentioned a layer of mould between two layers of shingle at Töllered as evidence that the area had been submerged "by two transgressions, the younger of which probably reached further inland". As I could not find this stratification, I have nothing to add except to point out that several different connections are possible with the Postglacial shorelevel displacement found. PL is here formed by PTM-3 at +14.6 m.

In the same area an organic layer (apparently a pitchy soil) below a dune ridge has been C^{14} dated at 1,020 ±80 BC (Caldenius *et al.* 1960).

In the ditch west of Björkäng a cutting about 250 m long, called B 694, was studied. About 100 m outside the beach ridge of PL the following stratification was found:

A: yellow eolian sand containing thin layers of peat
B1: grey sand containing gravel and pebbles, 0.2—0.5 m thick
B2: grey sand
C: seaweed peat, about 3.5 cm thick
D: grey sand, containing pebbles just below layer C
E: clayey mud with *Ruppia maritima*
F: peat (apparently from ALV time)

Layer E was probably deposited during the period PTM-2 to PTM-4. PL is formed by PTM-3 at +14.2 m. PTM-4A falls at +13.6 m, which fits well with a shore cut at about +13.2—13.7 m just outside the beach ridge itself. Layers D, C and B2 are apparently a shore formation from a regression. Layer C was C^{14} dated to 3,600 ±100 BC. However, this age must be corrected by 305 ±25 years, as the dated material is derived from marine plants (cf. p. 16), i. e. to about 3,295* ±125 BC. Layer C gives the age of the regression between PTM-4B and PTM-5. The maximum of this regression can be fixed at about +10.0—10.5 m (measuring of altitude not quite satisfactory). As PTM-5A here falls at +11.8 m, this suggests that there was a transgression of about 1.5 m up to PTM-5A. Layer B1 must have been formed by PTM-5A and PTM-5B. Layer B1 was followed throughout the whole cutting. It has the form of a thin ridge with a probable shore level at about +10.3 m. This shorelevel corresponds to PTM-5B at +10.0 m.

Consequently this section gave a fairly complete picture of the PTM shorelines, which fits well with the shoreline diagram and shows a regression between PTM-4B and PTM-5, i. e. PR-5.

At the new bridge across Ramsjö Kanal in Morup the following stratification, B 799, was found:

A: 1—2 m of eolian sand
B: 0.1—0.2 m of sand and gravel
C: 0.3 m of marine clayey mud
D: 0.2 m of peat (at about +8—9 m)
E: Late Glacial blue-clay, sandy in the top

At Stubbilt, south of Morup, a section was levelled across the PL (Fig. 115). The top of the beach ridge lies at +15.5 m. The depression inside lies at +14.2 m and does not contain peat or lagoon sediments. A shore cut just outside the beach ridge was fixed at +13.5 m. This fits well with the level of PL, which was here formed by PTM-3 at +13.3 m. Further out there is a marked shore cut at +11.4 m, formed by PTM-5A (at +11.3 m).

In a foundation for a petrol station at Olofsbäck, B 325, I found a buried layer of peat. The locality is situated on the inner part of the beach ridge of PL. The following stratification was found:

A: Sand, at the bottom containing humus. The grain size distribution curve suggests eolian sand.
B: 0.1—0.4 m of peat (thicker in the east). The uppermost 5.0 cm was C^{14} dated at 35 ±70 BC, i. e. the covering sand is eolian.
C: Sand, at the top unstratified and containing humus and at the bottom stratified and sloping from west to east, suggesting the inner margin of the beach ridge.

In B 692 (foundations for houses) just outside the beach ridge of PL the following stratification was found:

A: Mould in eolian sand.
B: Yellow eolian sand, at the bottom containing stones.
C: 2—3 cm of peat, probably a seaweed peat.
D: Beach deposit of sand and stones, between the stones there is peat partly of seaweed and partly of roots of shore grass.

The stones in layer B and the shore grass in layer D could suggest a small osciallation of the sea level. As B 692 lies at about +9—10 m (not quite satisfactorily fixed) and PTM-5B here falls at +9.4 m, this probable oscillation could correspond to PTM-5B.

West of Stafsinge (Fig. 114) the Postglacial sea must have reached in between the terminal moraine ridges creating a big lagoon inside the proper beach ridge of PL. This is evident from marine-brackish layers in the bogs of Lismossen, Ramsjöholmsmossen (or Utmarkamossen) and Arvidstorpsmossen, which have been pollen analysed and described by Erdtman (1921). Probably the inlet to this lagoon was just SE of B 692 (Fig. 114). The lagoon was formed during the transgression up to PTM-2, but different parts of the lagoon were later isolated at different times. The zonation of Erdtman's pollen diagrams is not quite obvious, but I think the following interpretation is the most likely one:

1. Arvidstorpsmossen contains marine-brackish mud corresponding to PTM-2 and PTM-3 and was isolated during the regression between PTM-3 and PTM-4. During PTM-4 there was a freshwater lake, which was finally overgrown in connection with the regression after PTM-4.
2. Lismossen (isolation level at +11.88 m) contains marine-brackish mud corresponding to PTM-2, PTM-3 and PTM-4. The isolation took place during the regression after PTM-4 and Lismossen, after a short lake stage, was overgrown.
3. Ramsjöholmsmossen contains three separate layers of marine-brackish mud which should have the following relation to my PTM shorelines:

A: peat and mud = overgrowth after the final isolation during the regression after PTM-5
B: brackish mud of early Sub-Boreal time = PTM-5
C: brushwood peat of the transition between Atlantic and Sub-Boreal time = regression between PTM-4B and PTM-5, i. e. PR-5
D: brackish mud of middle to late Atlantic time = PTM-4A and PTM-4B

E: lacustrine mud of middle Atlantic time = regression between PTM-3 and PTM-4, i. e. PR-4
F: marine-brackish mud of early to middle Atlantic time = PTM-2 and PTM-3
G: lacustrine mud and peat = the ALV time

The brushwood peat (at about +11.5—11.8 m) indicates a regression followed by a transgression up to PTM-5 (here at +12.4 m) of at least half a metre. The lacustrine mud (at about +11.0 m) between PTM-3 and PTM-4 also suggests a transgression up to PTM-4 (here at +13.8 m).

Consequently, Ransjöholmsmossen seems to show a very complete picture of the shorelevel displacement of my PTM shorelines. As the organic sediments could give very good datings of the PTM shorelines, I have tried to refind Erdtman's stratification. I have made 13 borings at various places in Ramsjöholmsmossen (marked 13 B in Fig. 114). Layers of brackish mud were found, but no stratigraphy that was equivalent to the whole sequence described by Erdtman. Nevertheless, Erdtman's stratigraphy clearly shows the PTM/PR changes here described.

6. The Falkenberg—Halmstad area

Along the greater part of this coast PL lies shortly inside the present coast line, but at River Ätran and River Suseån sea fiords reached far inland (Pl. 9).

In the Falkenberg area intermarine layers of peat and pitchy soil, and buried ground crusts have been found at several places. The more important among these have already been described on p. 253. From the souther shore of the mouth of the Ätran fiord a spit seems to have been built out towards NNW during the time of PL.

The exact shape of the sea fiord at Suseån has not yet been quite fixed. At Heberg station a transgressional stratification was found, viz. the following sequence: eolian sand — Postglacial (silty) sediments — pitchy soil (2—3 cm thick) — Late Glacial weathered clay.

About 3 km SE of Falkenberg ("•12" on the map) there is a distinct shore cut, the mean sea level of which was measured with aneroid barometer to +12—14 m. This shore mark corresponds to PTM-3, PTM-4 and PTM-4B (at +13.1—11.9 m).

Several sections across PL have been levelled in this area by von Post (1948, 1956 † and left sections) and J. Öster (in connection with the mapping of the Halmstad map-sheet, SGU's archives). These sections are dealt with below.

At Ringsegården, von Post has a section showing the following shore marks: shore cut at +13.8—13.9 m (= PTM-3 at +13.0 m), distinct shore cut (cliff) at +7.6—7.4 m (= PTM-6 at +7.5 m), beach ridge at +6.8 m with shore cut at +5.8 m (= PTM-7 at +5.1 m) and younger shore cuts at +4.0 m (= PTM-8 at about +4.0 m) and +2.9 m (= PTM-9B at about +2.9 m).

At Ugglarps Havsbad, Öster found the following shore marks: shore cut at +11.50 m (= PTM-4B at +11.50 m), beach ridge at +11.52 m (= PTM-5 at +10.85 m) and beach ridge at +5.52 m with shore cut at +4.02 m (= PTM-8 at about +3.8 m).

At Stensjö, Öster found the following shore marks: shore cut at +10.66 m (= PTM-5 at +10.6 m), beach ridge at +10.23 m with shore cut at +9.68 m (= PTM-5B at +9.0 m ?), beach ridge at +9.10 m with shore cut at +8.31 m (= ?, PTM-6 at +7.25 m), beach ridge at +8.10 m (= ?) and shore cut at +3.43 m (= PTM-9A at about +3.45 m).

NE of Stensjö there is a large low-laying area inside the PL shoreline proper, This area lies today at about +12 m. As PL here falls at +12.2—12.6 m, this area was presumably occupied by a large "lagoon" with or (more probably) without an open connection to the sea. The stratigraphy has not yet been investigated.

At Steninge Strand, von Post has a section giving the following shore marks: distinct shore level at +12.0 m with a corresponding beach ridge at +13.2 m and a depression inside at +12.3 m (= PL, PTM-3 at +12.0 m), shore cut at +9.3 m (= PTM-5B at +8.8 m), distinct shore cut at +7.6 m (= PTM-6 at +7.2 m), distinct shore cliff at +6.6 m (= PTM-7 at +4.8 m ?) and a shore cut at +5.0 m (= mean sea level of PTM-7 at +4.8 m). Öster found the following shore marks in the same area: shore cut at+7.66 m (= PTM-6 at +7.2 m) and a shore cut at +5.0 m (= PTM-7 at +4.8 m). South of Steninge PL is seen as a distinct shore cut.

At Dungen there is a series of beach ridges. Öster found the following shore marks: beach ridge at +12.83 m with shore cut at +11.60 m (= PTM-3 at +11.5 m), shore cut at +11.12 m (= PTM-4 at +11.0 m), beach ridge at +11.30 m with shore cut at +10.83 m (= PTM-4B at +10.6 m) and a beach ridge at +11.36 m (= PTM-5 at +10.2 m). Consequently the agreement with my PTM shorelines is surprisingly good.

South of the brook Lyngaån (Skintan) Öster has two sections across a series of beach ridges. The following shore marks were found: beach ridge at +11.26 m with shore cut at +11.10 m (= PTM-4 at +10.95 m ?), beach ridge at +11.45 m with shore cut at +11.08 m (= PTM-4B at +10.55 m), beach ridge at +11.69 m with shore cut at +10.08 m (= PTM-5 at+10.05 m), beach ridge at +9.89 m with shore cut at +9.44 m (= PTM-5B at +8.55 m ?), a beach ridge at +7.32 m (= PTM-7 at +4.7 m) and a beach ridge at +4.90 m (= PTM-8 at +3.8 m to PTM-9B at +2.8 m). The so-called "shore cuts" of the beach ridges 1, 2 and 4 are apparently placed too near the top of the beach ridges (the mean sea levels must be placed well below). About 200 m inside the first beach ridge there are three dune ridges according to Öster (undulation between +12.5 and +11.1 m within 30 m). As PTM-2 here falls at +9.8 m and later was submerged, these dunes could belong to the shore of PTM-2.

At Haverdal, von Post has three levelled sections and Öster two. Von Post's sections show the following: limit of shingle at three points at +11.7—12.1 m (= PL, PTM-3 at +11.4 m), an offshore bar at +11.3 m (PTM-3 at +11.4 m), fairly good shore cuts at three points at +10.6—11.0 m (= PTM-4 at +10.9 m), good shore cuts at two points at +9.8 m (= PTM-5 at +10.0 m), indistinct shore marks at two points at +9.3 m (= ?), indistinct shore marks at three points at +7.5—7.8 m (= ?), distinct shore cut at one point at +6.8 m (= PTM-6 at +6.8 m), good shore cut at one point at +6.1 m (= ?), distinct shore cuts at two points at +5.1—5.2 m (= PTM-7 at +4.8 m) and distinct shore cuts at three points at +4.4—4.6 m (= PTM-8 at about +3.8 m). Öster gives a beach ridge at +13.52 m with shore cut at +10.55 m. This shore mark probably corresponds to PTM-3 to PTM-4B, assuming its final shape by PTM-4B at +10.5 m.

At Ringenäs von Post has three levelled sections and Öster two. There are a lot of shore marks. However, these fall at certain levels that correspond to my PTM shorelines. Only a few, indistinct shore marks are seen between the PTM shorelines. An exception is the distinct shoreline at about +5.0 m, i. e. just above PTM-7. It may suggest that PTM-7 in fact is here double. Öster's "shore cuts" outside the beach ridges often lie too near — in altitude and distance — to the top of the beach ridges and apparently do not correspond to a mean sea level. Von Post's section A shows: a distinct shore cliff, the foot of which lies at +12.3 m (= PTM-3 at +11.2 m), distinct shore cut at +9.8 m (= PTM-5 at +9.9 m), shore cut at +7.4 (= ?), shore cut at +7.0 m (= PTM-6 at +6.8 m) and shore cut at +5.2 m (= ?, possibly PTM-7 at +4.6 m). Von Post's section B shows: very distinct shore cliff, the foot of which lies at +12.2 m (= PTM-3 at +11.2 m), shore cut outside the cliff at +10.7 m (= PTM-4 at +10.7 m), good shore cut at +8.9 m (= PTM-5B at +8.4 m), indistinct shore cut at +7.5 m (= ?), indistinct shore mark at +6.9 m (= PTM-6 at +6.8 m), shore cut at +5.1 m (= PTM-7 at +4.6 m), shore cut at +4.3 m (= PTM-8 at +3.7 m) and younger shore marks at +3.7 m (= PTM-9A at about +3.3 m), +2.9 m (= PTM-9B at about +2.8 m), +2.3 m (= PTM-10 at about +1.8 m) and +1.1 m (= ?). Öster's section no. 7 shows: beach ridge of shingle at +13.01—13.47 m with shore cut below +12.05 m (= PTM-3 at +11.2 m), beach ridge or offshore bar at +9.82 m with "shore cut" at (below) +9.41 m (= PTM-5 at +9.9 m or PTM-5B at +8.4 m), beach ridge at +7.87 m with shore cut at +6.74 m (= PTM-6 at +6.8 m) and beach ridge at +6.13 m with shore cut at (below) +5.49 m (= possibly PTM-7 at +4.6 m). Von Post's section C shows: limit of shingle at +13.3 m (= PL, PTM-3 at +11.0 m), fairly distinct shore cut at +11.8 m (= limit of the waves during PTM-3 at +11.0 m), distinct shore cut at +10.1 m (= PTM-5 at +9.8 m), shore cut at +8.2 m (= PTM-5B at +8.3 m), distinct shore cut at +4.9 m (= possibly

PTM-7 at +4.6 m), beach ridge (covered by dune sand up to +5.6 m) damming a fen (bottom at +3.6 m) and with a shore level at about +4.4 m (= PTM-7 at +4.6 m) and a shore mark at +2.6 m outside dunes (= PTM-9). Öster's section no. 8 shows: very distinct beach ridge of shingle at +12.93—13.73 m with shore cut at +11.37 m (= PL, PTM-3 at +11.0 m), very distinct beach ridge of shingle at +12.93 m with shore cut at (below) +11.37 m (and at +10.76 m laterally) and the depression inside at +11.78 m (= PTM-4 at +10.6 m), shore cut at +10.23 m (= PTM-4B at +10.2 m), a double beach ridge at +9.48 and +9.03 m, respectively, with a corresponding sea level at about +8.25 m (= PTM-5B at +8.2 m), shore cut at (below) +7.41 m (= PTM-6 at +6.8 m), flat ridge at +7.21 m (= possibly PTM-6 at +6.8 m), small ridge at +6.75 m with shore cut at (below) +6.05 m (= ?, possibly PTM-7 at +4.6 m) and two beach ridges at +5.15 and +5.18 m, respectively, with a depression between at +4.29 m (one of which = PTM-7 at +4.6 m). East of these sections PL is marked by a very distinct shore cliff, where two different shore levels can be distinguished. The lower shore marks here are indistinct or absent.

7. The Halmstad area

In the Nissan valley a big Postglacial sea fiord reached far inland. A sediment plain and shore cuts mark the extension of this fiord. According to my shoreline diagram PL in Halmstad was formed by PTM-4 at +12.7—13.0 m. After correction to mean sea level, this seems to fit well with the PL described in Halmstad at +13.5 m (Caldenius *et al.* 1960 and 1966).

Between Sannarp and Snöstorp PL is formed by a very distinct shore cliff (about 8—10 m high). This shore continues as a distinct shore cliff or shore cut the whole way down to Påarp. Apparently this shore is highly polygenous and probably contains all the PTM shorelines from PTM-2 to PTM-5B and partly also PTM-6. The youngest shore stage of the cliff between Sannarp and Snöstorp continues from Sannarp towards WNW as a much less distinct shore mark (shore cut + beach ridge and/or dunes), while the cliff itself turns towards NE. According to Caldenius *et al.* (1966) this younger shore was at about +8—9 m and seems thus to have been formed by PTM-5B (at +9.2 m) or (and) by PTM-6 (at +7.4 m).

At Nyhem outside the younger shoreline the following stratigraphy has been found and dated (Mohrén and Larsson 1968):

A: 20 cm of eolian sand.

B: 75 cm of *Phragmites* peat. A sample 28—31 m down was C^{14} dated at 500 ±65 BC. A sample 66—71 cm down was C^{14} dated at 1,040 ±120 BC. The lowermost part contains a marine-brackish diatom flora.

C: >30 cm of medium sand containing a marine-brackish diatom flora.

The surface is at about +7.5 m (not levelled). Consequently, the contact B/C is at about +6.5 m and would have been passed by the sea during PR-7. During PTM-7 at +5.0 m this point was probably exposed to direct wave actions depositing the uppermost part of layer C. During PTM-8 at +4.1 m a fen, at the beginning estuarine, was formed just inside the shore proper.

8. The area of Laholmsbukten

The extension of the Postglacial sea in this area according to my interpretation is shown in Pl. 9. From Påarp a distinct, apparently polygenous, PL (shore cut — shore cliff — beach ridge) can be followed the whole way down to Snapparp at River Lagan. In the Lagan Valley a big sea fiord reached far inland. Sea fiords also reached inland around the brook Vallbergaån and the small rivers Smedjeån and Stensån. The old river channel of Stensån (see p. 255) was buried by sediments containing a marine Postglacial shell fauna.

However, the new and interesting aspect of my interpretation is that the fiords between River Lagan and Båstad did not have an open exposure towards the sea, but lay inside a big spit and flat islands. It was a coast area similar to the West Coast of Jylland with its spits and lagoons. The spit was built out by streams following the coast from Båstad towards River Lagan in the form of a smooth parabola — just as it does today (note the shape of the mouth of River Lagan). Between Skottorp and Skummeslövsstrand there is a flat higher area which was not submerged. The spit was built out from Båstad towards this island. In the Båstad—Malen area the spit is very striking.

The explanation to the formation of this spit must be seen in the fact that PTM-2 in this area only reached +8.5—6.0 m, i. e. far below PL. The formation of the spit must have started during this level, when the sea did not reach so far inland, and later continued during the other PTM shorelines. The spit can be followed right up to the PL shore at Snapparp. This means that the coastal stream (and transportation) made a smooth parabola the whole way between Båstad and Påarp. The presence of this spit explains the difference between the occurrence of indistinct shore marks inside the spit (between Båstad and River Lagan) and a very distinct PL north of the spit (between Spannarp and Påarp).

The theory of this spit or rather coastal barrier, was recently supported by the find of an old peat layer at S. Mellby. The stratigraphy was found and dated by Mohrén (Mohrén and Larsson 1968). The following interpretation is here given:

A: 31.5 cm of medium sand, eolian or littoral. The pollen content shows an Atlantic flora.

B: 7.5 cm of *Phragmites* peat with wood of *Alnus* and *Betula*. A sample from 1.5—2.5 cm down was C^{14} dated at 4,045 ±130 BC, i. e. PR-4.

C: Marine fine sandy medium sand.

The altitude has not yet been measured. However, from the geotechnical data in connection with the mainroad Östra Karup—Halmstad, an altitude of about +9.5 m seems likely. Layer C must correspond to PTM-3 at +9.6 m (PL). Layer B must have been deposited during PR-4, i.e. in a fen formed during this regression (between PTM-3 and PTM-4) on the inland side of the spit to barrier, which consequently must have been built out at least this far to the northeast during PTM-3. Layer C probably corresponds to PTM-4 at +9.4 m (A) and +9.2 m(B).

I think it was this barrier — and no washed terminal moraine, as the geological map says — that forced River Lagan to flow parallel to the coast between Åmot and Snapparp. (This is also suggested by geotechnical borings in the "moraine"). A similar explanation seems to be valid for the courses of Vallbergaån and Smedjeån. (It is also possible that Stensån earlier flowed northwards via Allarp).

Von Post made two levelled sections at Gallared, one containing a shore cut at +12.0 m which must correspond to PTM-4 (at +12.0 m, forming PL) and another with the foot of a distinct shore cliff or shore cut at +11.5 m which is polygenous having assumed its final shape from PTM-5 at +11.2 m.

Along the outer margin of the spit a very distinct shore level is registered in the form of a beach ridge and shore cut. This shore can be followed the whole way from Båstad to Mellby. In Malen the mean sea level was fixed to +4.0 m and it seems only to rise slightly towards Mellby. This shore corresponds to PTM-7 which must consequently represent a distinct event in this area.

Graves from the Iron Age extend at Påarp from +12 m down to +4 m. This fits with the shoreline diagram, where PTM-9B lies at +3.0 m.

9. The section at Eskilstorp

In 1964 I had the luck to find a new ditch at Eskilstorp right up to the PL which here has the form of a big shore cut or a shore cliff. The ditch, now filled, lay 500 m east of Petersberg. The ditch was about 240 m long and contained a very important stratification with a buried beach ridge and several layers of peat and pitchy soil. The stratigraphy was measured and noted down in 63 points. Samples for close soil identification, pollen analysis and C^{14} dating were taken at eight points (marked with an encircled P in Pl. 10). Later the section was levelled and five borings were added in the outer and extended part of the section. The grain size distribution of 15 samples was determined, pollen analyses were made in B 226, B 249, B 268 and B 679, and six samples were C^{14} dated.

The section obtained (Pl. 10) is important. In fact it was this section that cleared up the Postglacial development and made it possible for me to connect up the different PTM shorelines. The following description of the section (Pl. 10) can be given:

1. A limey till slopes downhill. The till is weathered and contains roots in situ between B 216 and B 254.
2. The till is in the outer part covered by a glacial series from sand to clay. The surface of these sediments seems to represent a land surface, as the clay is weathered in B 678 and there is a mould in B 681 and probably also in B 833.
3. In B 680 (in the bank of River Stensån) a typical Late Glacial blue-clay is found at about +4 m. The absence of this layer in the other borings indicates that there must be a buried river channel between B 679 and B 680.
4. Between B 255 and B 678 there is a layer of stratified beach sand (100 m long and max. 1.6 m thick). This sand rests upon an old land surface. The exact genesis of this layer cannot be given. Probably it is an alluvial river sediment deposited in connection with the onset of the transgression up to PTM-2 (but it could also have been formed in connection with a ground water rise at ALV-2 or even a Late Glacial minor transgression). In B 277 and B 275 the sand contains roots in situ.
5. The beach sand is covered by a silt that in the uppermost 2—3 cm is impregnated by humus to form a clear pitchy soil. In B 272 the silt contains roots in situ. The surface of this layer definitely represents an old land surface. The pitchy soil in B 268 was C^{14} dated at 5,270 ±150 BC, which gives the age when the transgression buried the vegetation at +5.1 m with sand.
6. From B 269 a sand layer can be followed up to B 250 where it changes over into a shingly beach ridge between B 250 and B 245—242. Inside the beach ridge there is a sand layer (in B 239 containing two small local layers of pitchy soil). The beach ridge might not look so striking in Pl. 10, it is indeed so in the field. According to the landowner the beach ridge can be followed laterally as a distinct "stone ridge" across his fields along the hill slope. There can be no doubt that this is a real beach ridge. The corresponding mean sea level must lie at about +6.0 m. It was formed by PTM-2. During this sea level the clayey mud in B 679 was deposited. This is apparent from pollen analyses in B 268 and B 679. Probably the brushwood peat between B 237 and B 217 started to be formed at this stage. This is supported by the pollen diagram of B 226, but contradicted by the C^{14} dates. However, the C^{14} dates do not seem to be reliable and the same horizon has given very different results. This is probably due either to water rich in carbonate (from the limey till) or younger roots that follow the till surface.
7. A regression (PR-3 between PTM-2 and PTM-3) brought the sea down to +4—3 m. A layer of peat and pitchy soil was formed between B 258 and

B 278 when a beach sand was deposited in B 678 and B 679. The lowermost 0.5 cm of the peat in B 268 (a somewhat clayey fen peat) was C^{14} dated at 4,905 ±90 BC. Consequently PTM-2 can now be limited between 5,270 ±150 and 4,905 ±90 BC, i. e. PTM-2 occurred about 5,000 BC. The pollen diagram of B 268 shows an early Atlantic flora.

8. The sea started again to rise, now up to PTM-3. The sea reached up to about +8.2 m (= PTM-3A) and buried the brushwood peat with the thin sand layer and the silt between B 216 and B 232. The uppermost 4.0 cm of the peat in B 228 was C^{14} dated at 4,570 ±105 BC. This date gives the age of PTM-3A. However, a small regression of short duration brought the sea level down at least below +7.8 m, allowing a vegetation on the silt bed of PTM-3A. The sea soon started to rise again, reaching up to about +8.2 m (= PTM-3B) and burying the vegetation in the silt — that now turned into a pitchy soil — with sand. The pitchy soil (in the top of the silt) in B 220 was C^{14} dated at 4,480 ±140 BC. This date gives the age of PTM-3B. Consequently, the stratigraphy and C^{14} dates here clearly show that PTM-3 is a double maximum. This was also found in other areas, e. g. the Höganäs area (p. 355). The pollen diagrams suggest that the peat in B 226 corresponds to the sand of PTM-2 in B 268 and that the silt in B 226 corresponds to the time just after the fen peat in B 268. The pitchy soil in B 249 has a pollen flora that corresponds to the one of the silt in B 226, i. e. it was formed by the transgression up to PTM-3.
9. PL is here highly polygenous and formed by PTM-3, PTM-4 and PTM-5. According to the diagram PL is at +8.2 m, though this section suggests a PL at about +8.5—9.5 m. PL is seen as a shore cut or cliff along the hillslope. In B 678 and B 679 erosional material was deposited as a heterogenic mixture of clay, silt and sand. The regressions between PTM-3 and PTM-4 (i. e. PR-4) and between PTM-4 and PTM-5 (i. e. PR-5) are not represented in this section.

The explanation why this stratification was left and not eroded away by the sea is apparently that the above-mentioned spit prevented an open exposure towards the sea.

According to the levelled section (Fig. 117) there is a distinct shore cut or shore cliff at about +13.0 m (or just below). However, this was formed in earliest Alleröd by a shoreline corresponding to the isolation of BP 1248 (p. 166).

10. The Båstad area

The shore cliff/shore cut of PL west of Båstad changes in Båstad into a beach ridge or big spit that crosses the mouth of the Sinarp Valley and curves towards ENE. On the top of this ridge there are often dunes.

From the limestone quarry at Gropamöllan V. Ewald (1926) described an interesting stratification, viz:

A: 0.50 m of mould.
B: 0.70 m of eolian sand.
C: 4—5 cm of black humus — apparently a pitchy soil.
D: 4.20 m of stratified sand and gravel with two thin layers of pebbles 1 and 2 m down respectively.
E: 0.80 m of marine mud (clayey).
F: 0.70 m of black humus (apparently a mould) containing oak stumps in situ and a lot of plant remnants. A stump had several marks of cutting with a stone axe, which shows the presence of man.
G: 61 m of limestone with 2 m deep carst holes in the surface. According to Ewald morainic material is pressed into the upper part of the limestone.

Layer F that must belong to ALV time seems to lie at about ±0 m (the altitude was not given by Ewald). Layer E probably corresponds to a lagoonal stage during PTM-2. Layer D seems to belong to the higher level of PL.

During PL the sea reached in along the brook Örebäcken behind the proper beach ridge (spit further towards ENE). This was apparent from the stratification in three ditches (B 589, B 682 and one unnumbered, marked on Fig. 24).

In a ditch, B 328, just outside the PL shore in Båstad the following stratigraphy was found:

A: 1.5—1.7 m of sand
B: 3 cm of drift peat
C: (below) sand, rusty and oxidized

The drift peat is not a seaweed peat, though it contains 58.8 % of *Hystrix,* but a mixture of mud, coarse detritus of different kind and pieces of branches. The altitude of layer B is about +3.0 m. A pollen analysis of layer B gave: 27.7 % *Betula,* 18.5 % *Pinus,* 9.2 % *Corylus,* 52.9 % *Alnus,* 2.5 % *Quercus,* 0.8 % *Ulmus,* (no *Tilia*), 0.8 % *Fagus* (?), 0.8 % *Carpinus,* 56.3 % NAP with 41.2 % *Chenopodiaceae,* and 58.8 % *Hystrix.* This pollen spectrum belongs to the Sub-Boreal time or more exactly to late SB-1 (cf. the pollen diagram of Fig. 123). The type of soil and the high percentage of *Chenopodiaceae* and *Hystrix* indicate that layer B was formed just at about the mean sea level. This means that layer B was probably deposited during PR-7 and was buried by sand during PTM-7. This agrees well with the altitude of layer B. However, a sample of layer B was C^{14} dated at 275 ±100 BC (i. e. at about the zone boundary SB-2/SA-1), which probably is too young an age due to contamination by roots (few), infiltrated humus (unknown) or small white worms (several removed). If on the other hand, the dated sample is not contaminated, it has an age corresponding to PTM-9B, which here falls at about +2.7 m. Consequently, this alternative is also quite possible, though it does not fit with the pollen content.

Two main sections were levelled in this area (Pl. 9).

Roxmangatan (no. 5, Fig. 116) shows a beach ridge that reaches up to +10.0 m and is covered by (probably) eolian sand that reaches +11.5 m. A distinct shore cut is seen at +5.48 m (mean sea level). This was formed by

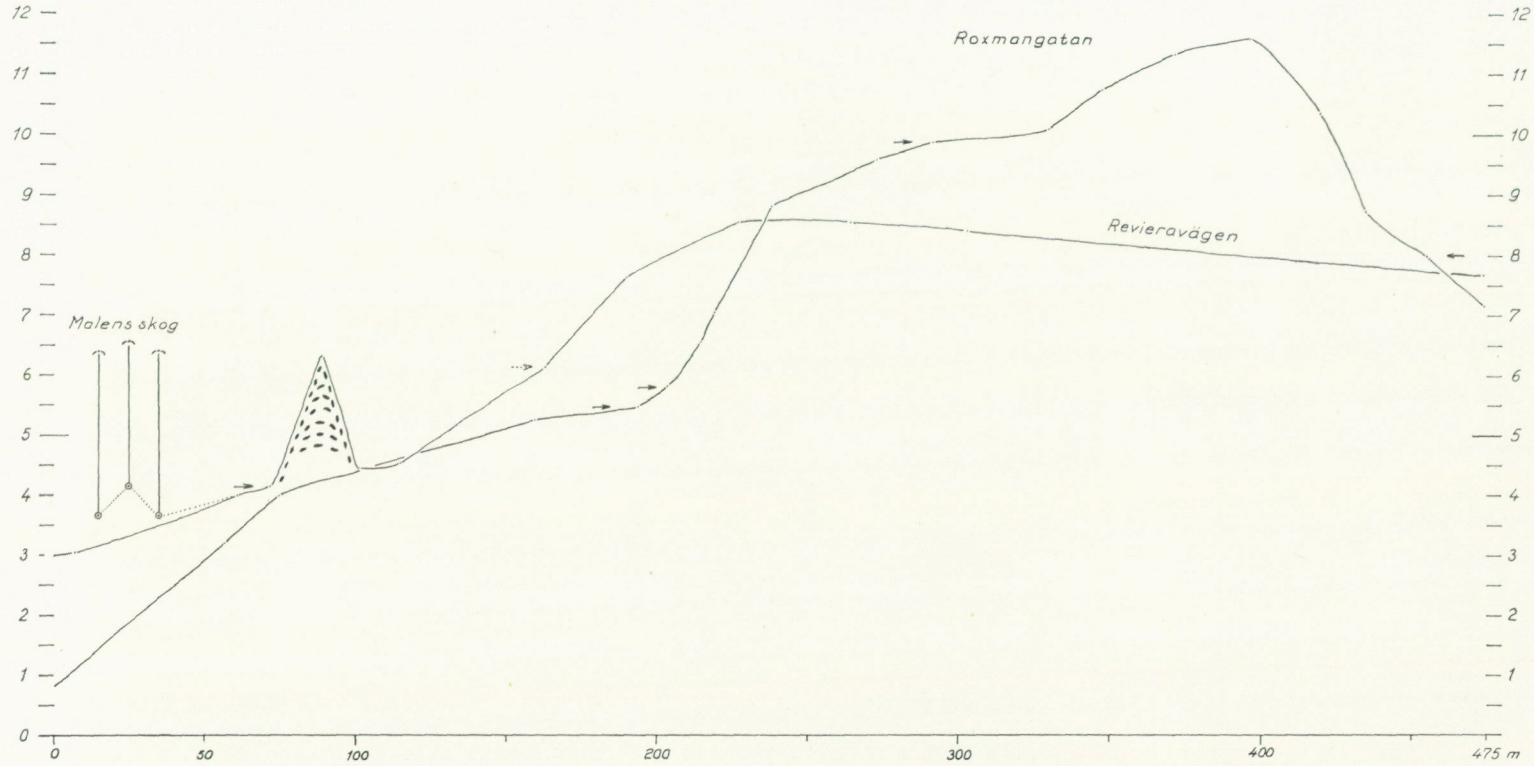


Fig. 116. *Levelled sections across PL in Båstad, formed by a beach ridge that towards NE changes over into a big spit running the whole way up the mouth of River Lagan. PTM-7 is seen as a very distinct beach ridge of shingle.*

PTM-6. Inside the beach ridge there is a shore cut at +7.97 m (mean sea level), which apparently corresponds to PL (here at +8.10 m). The top of the beach ridge is probably formed by eolian sand (if not, there ought to have been a shore level at about +9.87 m).

Malens Skog (no. 4, Fig. 116) represents a very distinct beach ridge of shingle, the top and mean sea level of which were levelled at three different places. The top of the beach ridge lies very horizontally at +6.5 m. The mean sea level was fixed at +3.67 m, +3.72 m and +4.17 m, respectively. The mean sea level of this beach ridge can thus be fixed at about +4.0 m. This beach ridge was obviously formed by PTM-7, which must have meant a distinct event. This ridge has forced the River Stensån to flow parallel to the coast between this ridge and the spit for 400 m.

Rivieravägen (no. 4, Fig 116) shows in the outer part the continuation of the beach ridge in Malens Skog. The ridge is here cut by the road. It consists mainly of shingle. The top lies here at +6.32 m. The mean sea level was fixed at +4.16 m. Another shore level is possibly seen at about +6.14 m (= PTM-5B or PTM-6). The inner part of this section shows the continuation of the beach ridge in Roxmangatan. It has here changed over into a big flat spit built up just above mean sea level. The spit shows a very evenly sloping inland side and a fairly steep coastal side. The highest point lies at +8.56 m, i. e. just above PL which here falls at +8.20 m. In B 667 there is a stratified sand with some pebbles (and in the uppermost part two thin layers of forest peat). This spit as well as the younger beach ridge can be followed towards NE (cf. p. 330).

11. The area between Båstad and Torekov

Several sections were levelled in this area in order to fix PL and other shore marks. The sections will be dealt with in order from Båstad to Torekov. The position of the section is marked on Pl. 9.

Norrviken (no. 6, Fig. 117) shows a till cliff where PL cannot be more closely fixed that to +9.5—7.1 m. A shore mark at +11.9 belongs to the Late Glacial regression (earliest Alleröd).

Kattvik (no. 7, Fig. 117) shows a steep till cliff, where the corresponding mean sea level is very hard to fix. PL here falls at +8.0 m.

Beneath the steep rock cliffs of Hovs Hallar there are big fields of shingle with Postglacial shore marks. This area has been investigated by Junker (1961 unpublished). Junker found shore cuts — which according to my interpretation ought to belong to PL — at +8.79 m and +7.44 m in the eastern part, at +9.60 m (cliff) in the middle part and at +9.89 m in the western part of Hovs Hallar and at +9.60 m (cliff) at Norra Segelstorp. With a correction to mean sea level these shore marks may fit with my PL. In this area PL falls at +7.8—8.0 m.

Ripa (no. 8, Fig. 117) shows a distinct till cliff with gullies. The mouths of the gullies lie above the mean sea level of PL and probably at the high-water level. PL cannot be fixed in this section, but should according to the diagram lie at +7.7 m. Anyhow, this is not contradicted by the section. In a digging in the mouth of a gully (B 726, p. 91) no trace of the Postglacial transgressions was found. A younger shore mark lies somewhere between +5.5 and +6.5 m (= PTM-5B or PTM-6).

Dalen (500 m west of no. 8, Fig. 117) shows a shore cut in till with a large field of shingle outside. The notch in this shore mark was fixed at +10.8 m, i .e. about 3 m above PL. Now the question arises when and how this shore mark was formed. Obviously it is polygenous. In earliest Alleröd a shore cut or shore cliff was eroded in the till. This is equivalent to the shore mark at +13.0 m in



Fig. 117. *Levelled sections of the slopes of Hallandsås.*

Eskilstorp (p. 333). This shorelevel is also seen in other sections on the Bjäre peninsula and probably meant a distinct event — a stagnation or even small transgression. During PL shingle was accumulated up in the old shore mark. Thus the altitude of the present notch can be explained.

Norra Ängalag (no. 9, Fig. 118) lies in a shingly area and shows several Postglacial shore marks. PL is seen as a very distinct beach ridge almost entirely made up by shingle (A). The corresponding mean sea level seems to be at +8.10 m. The top of the beach ridge lies very horizontally at +12.1—12.3 m. Inside the ridge there is a depression reaching down to +10.4 m that does not contain peat or lagoonal deposits. According to the diagram, PL here lies at +7.5 m. This means that the beach ridge was built up 4.5 m above mean sea level. However, this is not at all unlikely as the material in the ridge is shingle, this area is extremely well exposed, ice pushing must have been involved in the shore formation, it was relatively deep outside the shore and the ridge was formed during a long period (PTM-3 to PTM-5). Outside the PL ridge there is a series of younger ridges of shingle (B—E). Ridge B reaches +8.65 m, dams a fen at +7.85 m and seems to correspond to a mean sea level at +7.3—6.5 m. It was probably formed by PTM-5 at +7.5 m (or by PTM-5B at +6.4 m). Ridge C reaches +7.95 m and corresponds to a mean sea level at +6.5—6.3 m. Apparently it was formed by PTM-5B which here falls at +6.4 m. Ridge D (not so well marked) reaches +6.15 m and seems to correspond to a mean sea level at +5.0—5.5 m. It was probably formed by PTM-6 which here falls at +5.2 m. Ridge E is distinct. It reaches +4.97 m and seems to correspond to a mean sea level at +4.0—3.5 m. It was formed by PTM-7 which here falls at +3.75 m. Shell banks of *Mytilus edulis* and other shells occur in the shingle at about +4—5 m.

Perstorp (no. 10, Fig. 118, levelled twice with the same result) shows a series of shore mark. PL here falls at +7.5 m (PTM-5). Apparently PL corresponds to the small ridge A, though this may originally have been larger (may have been partly destroyed by farming). Below A there is a distinct shore cut with the mean sea level fixed at +6.3—7.0 m. It is probably equivalent to ridges C and B in N. Ängalag. Apparently it was formed by PTM-5B at +6.4 m (and earlier PTM-5 at +7.5 m). Ridge B is a broad and flat ridge that reaches +6.6 m and dams a big fen inside at +5.6 m. It is not a typical beach ridge but more like an offshore bar. However, I think ridge B was originally a beach ridge formed by PTM-2 at +4.8 m, which was later transgressed and reshaped to an offshore bar. In the outer part of ridge B there is now a shore mark that is obviously younger than PL. The corresponding mean sea level was fixed at +5.15 m, which means that it apparently belongs to PTM-6 at +5.2 m. The beach ridge C is equivalent to E in N. Ängalag. It reaches +5.0 m and corresponds to a mean sea level at about +4.0—3.6 m (ridge D is small and seems to belong to the same shore). It was formed by PTM-7 which here falls at +3.75 m.

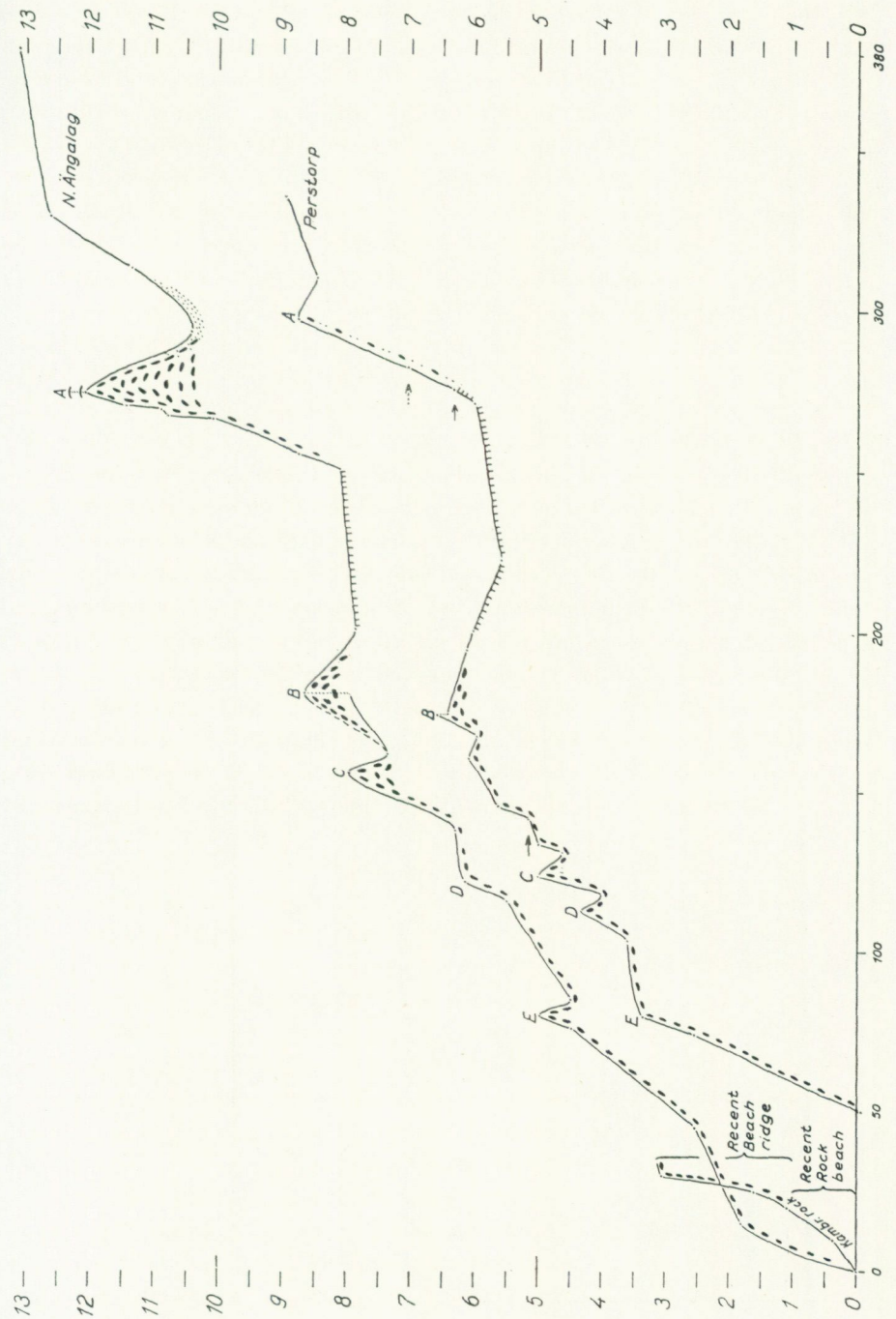


Fig. 118. *Levelled sections in the shingly area NE of Torekov. Several PTM shore marks are seen.*

In the outer part of ridge C a shell bank was found in a pit, B 781, at +4.76 m. The following shells were found: *Litorina litorea* (several), *Mytilus edulis* (several), *Ostrea edulis* (2), *Cardium edule* (1), *Lacuna pallidula* (1) and *Pecten* sp. (a few). The outer and inner fraction of the shells were C^{14} dated at 530 ±100 AD and 590 ±100 AD respectively. However, this must be too young (contamination?). In this part of the Bjäre peninsula, at least, shells are very seldom found in deposits above the ones of PTM-7, while several shells banks (*Mytilus edulis* and *Litorina litorea* most common) are found at and below the level of PTM-7. This indicates a change — an immigration of the molluscs or flourishing in favourable environment (cf. p. 386).

From a point south of Perstrop PL can be followed as a distinct beach ridge the whole way to Torekov and further to Dagshög.

12. The Torekov area

Just off the beach in the small bathing bay at Torekov, a submarine peat is often exposed in the seabed over an area of about 30 x 100 m at about −1.1 —2.5 m. Pieces often drift ashore. The peat is extremely hard and is often worn at the shore to thin discs (10—20 cm wide, but only 1—2 cm thick) without breaking. In the surface of the peat there are a lot of branches and trunks of submerged trees. Several samples were taken from this peat layer (called B 176). It is an alder brushwood peat, about 10 cm thick and underlaid by about 4 cm of silty mud. The lowermost 2.0—2.5 cm peat was C^{14} dated at 5,615 ±100 BC and the uppermost 0.5 cm was C^{14} dated at 6,060 ±100 BC. It is not known why the upper sample is older than the lower one. However, these dates clearly show that the peat — a swamp mainly overgrown with alder — was formed in connection

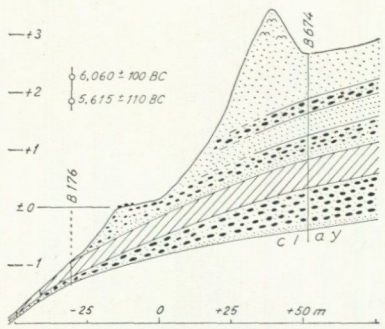


Fig. 119. *The continuation of the submarine peat at Torekov.*

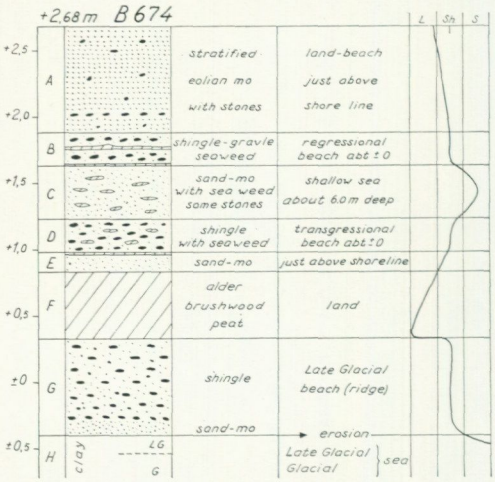


Fig. 120. *Interpretation of the stratigraphy in B 674.*

with the rise of the second Postglacial transgression. By diving the peat was followed over an area of at least 30 x 100 m. The peat sometimes changes over to a peaty coarse detritus mud, especially in the deeper parts (1.7—2.5 m). The alder brushwood peat in B 176 was also found in boring B 674 just inside the beach dunes (Fig. 119). The stratigraphy and its interpretation are given in Fig. 120. The clay surface is quite smooth, indicating erosion (most probably subaquatic erosion), and overlaid by a distinct beach shingle. This must have been accumulated in the earlier part of Alleröd. Layers F to C were formed in connection with the rising sea level, having its maximum in layer C. Layer B shows the subsequent regression and layer A the beach just above sea level.

PL is very distinct in the Torekov area and formed by a beach ridge almost entirely made up of shingle (Fig. 121). De Geer (1893) measured the top at +12.0 m. However, this figure was later used by many authors as PL in shoreline diagrams (e. g. von Post 1933, E. Nilsson 1953), and this must definitely be wrong as the corresponding mean sea level must be placed several metres below the top of such a distinct beach ridge of shingle (cf. p. 304).



Fig. 121. *Pit in the PL beach ridge (= the southern section in Fig. 122), almost entirely made up of shingle.*

At Torekov Strandpark (no. 11, Fig. 122) two sections were levelled across the PL beach ridge. The southern section shows a distinct beach ridge which is entirely made up of shingle, as seen in a big pit (Fig. 121). The top lies at +11.68 m. The corresponding mean sea level was fixed at +8.3—8.8 m. However,

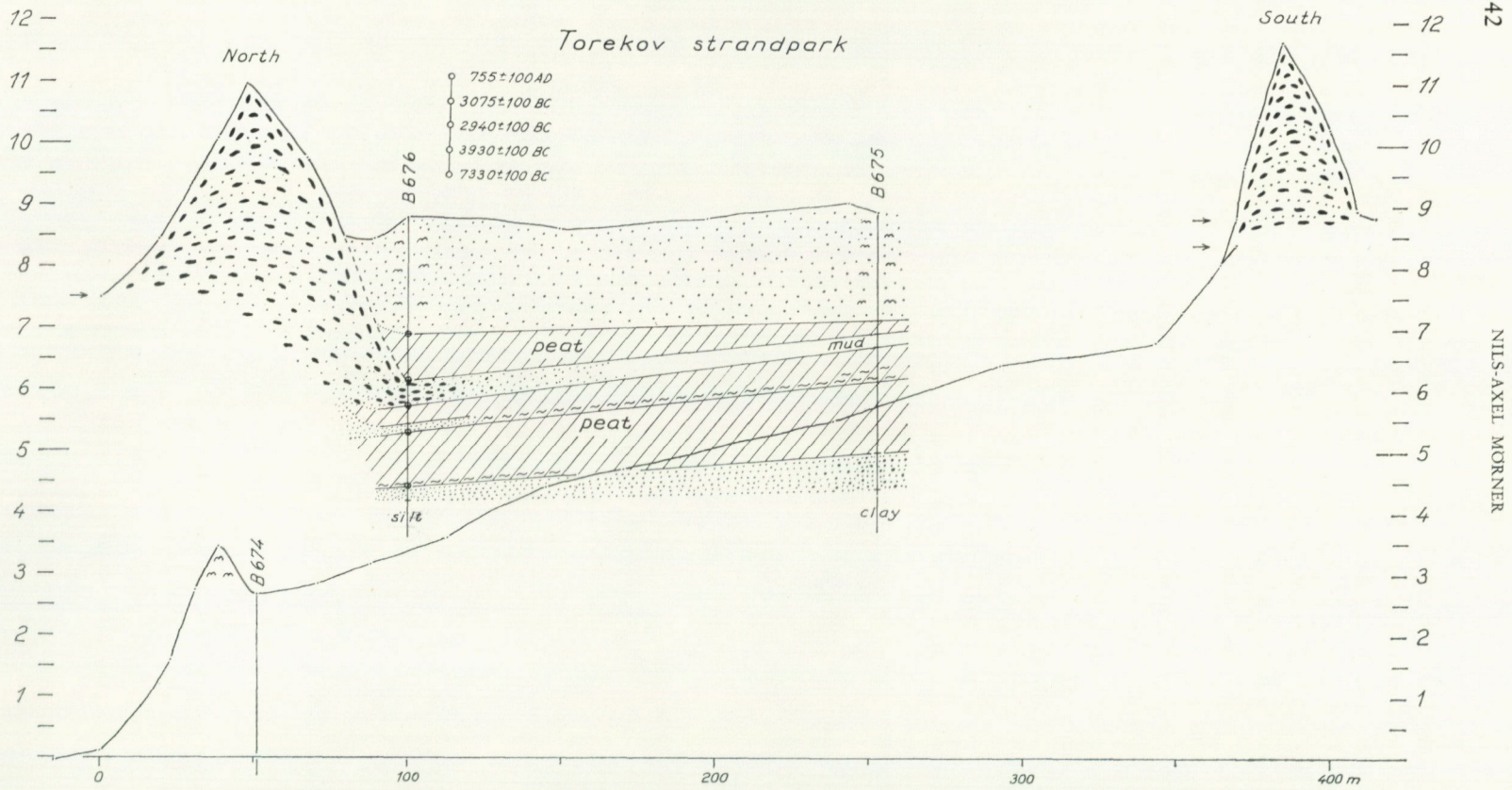


Fig. 122. *Sections of the PL beach ridge. The stratigraphy is closely dated in B 675 and 676.*

this is too high — probably due to covering eolian sand and the unusually large size of the beach ridge. Inside the ridge the surface lies at +8.8 m. No lower shore marks were found — possibly due to the covering eolian sand.

The northern section is very important and contains two borings. Morphologically the mean sea level was here fixed at +7.49 m, which agrees well with PL at +7.4 m according to the diagram. The borings show that the area inside the beach ridge has a thick cover of eolian sand. The following stratigraphy was found in B 676 and B 675:

A: eolian sand
B: peat
C: the innermost part of the beach ridge in B 676 (at +5.64—6.18 m) changing over to lagoonal mud in B 675 (at +6.72—6.92 m)
D: peat
E: sand in B 676 (at +5.79—6.00 m) equivalent to a peaty detritus mud with high content of aquatic pollen in B 675 (at about +6.20—6.30 m)
F: peat
G: sand and gravel from the Late Glacial regression
H: silt in B 676 and hard, probably weathered, glacial clay in B 675

Consequently, there are stratigraphical indications of two transgressions.

B 676 and B 675 were pollen analysed and five samples from B 676 and one from B 675 were C^{14} dated (Figs. 123A and B). The pollen diagrams allow a good zonation. Though there is only 150 m between B 676 and B 675 there are big local variations in the pollen content, but this does not preclude good synchronizations.

The lowermost 3.5 cm in B 676 belongs to pollen zone BO-1 (V) and was C^{14} dated at 7,330 ±100 BC, i. e. the same age as the onset of the transgression up to ALV-2. This indicates a corresponding ground water rise far above the sea level, and probably also a climatic change (cf. p. 279). A similar ground water rise was found in a pollen analysed boring B 670 at Varehög NW of Ängelholm at about +11.0 m. In B 675 the peat formation (sandy muddy peat at the bottom) probably also started in zone BO-1, though no analysis was made here. In the lower peat layer the following horizons were used for synchronization:

1. *Alnus* maximum and *Corylus* minimum in zone BO-2
2. *Corylus* maximum in early zone AT-1
3. NAP maximum in late zone AT-1
4. *Corylus* maximum and NAP minimum in early zone AT-2

Just above horizon 4 in B 676 comes the lower sand layer. The uppermost 2.0 cm of peat just below the sand was C^{14} dated at 3,930 ±100 BC, i. e. the time of PTM-4A. In B 675 there is a distinct and sudden peak of aquatic pollen at and above horizon 4, clearly indicating a ground water rise, which is apparently equivalent to the formation of the sand layer in B 676. Consequently,

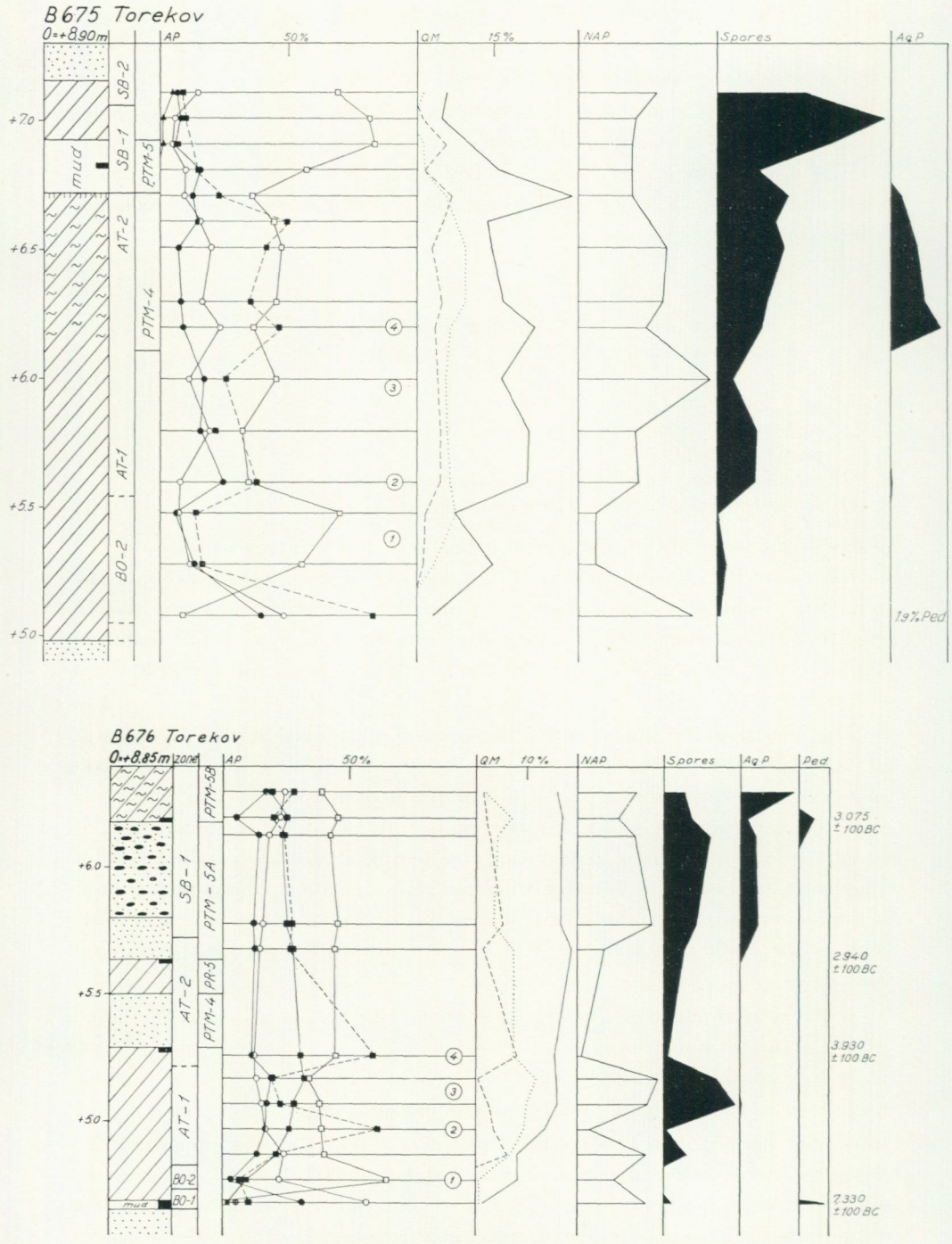


Fig. 123. *The transgressions PTM-4 and PTM-5A are here clearly shown and dated.*

we have here good evidence of the transgression up to PTM-4. According to the diagram PTM-4A here falls at +7.35 m, which means about 1 m of water in B 675 and 1.5 m of water in B 676, i. e. a lagoon inside the beach ridge. The peat layer above this sand layer in B 676 gives evidence of the subsequent regression, i. e. PR-5 (at least down below +6.7 m). Above this peat there is a distinct shore accumulation in B 676. Two 1.5 cm thick samples of peat just below and just above was C^{14} dated at 2,940 ±100 BD and 3,075 ±100 BC, respectively. This means a rapid formation during PTM-5A, which according to the diagram here falls at +7.40 m. In B 675 this transgression is seen as 20 cm of mud (probably brackish) of earliest zone SB-1 and a pitchy soil formation in the uppermost 2.0 cm of the lower peat surface. A C^{14} dating in the middle of the mud gave 415 ±100 AD, but this age is for some unknown reason definitely quite wrong. In B 675 the peat formation went on till early zone SB-2. In B 676 the shore accumulation of PTM-5A is covered by a detritus mud that corresponds to PTM-5B, here falling at +6.4 m. The uppermost 1.0 cm of peat in B 676 was C^{14} dated at 755 ±100 AD. This gives the age of the sand drift, which therefore roughly corresponds the zone boundary SA-1/2.

Consequently, B 676 and B 675 give both evidence and age of PTM-4 and PTM-5A, which are here separated by an obvious regression. It is also clearly shown that these transgressions can never have reached as high up as the morphology of the PL beach ridge often suggests on the Bjäre peninsula. It is surprising that there is no trace of PTM-3, which here must have reached +7.3 m (cf. the Eskilstorp and Höganäs areas). Also there is no trace of PTM-2, which here reached +4.8 m. Apparently this area was effectively separated from the sea by a distinct beach accumulation.

In central Torekov I found a ditch, B 595, just outside the PL beach ridge. The sediments are entirely inorganic, but still give interesting information about the shorelevel displacement (Fig. 124). The grain size distribution was determined in all layers except the very coarse material of layer F. Layers I to G belong to the Late Glacial regression and layers G and H are oxidized. The unconformity between layer G and F marks the long land period. Layer F at +7.50—7.90 m is a beach accumulation of sand, gravel and stones. It was formed by PTM-4. Layer E is a stratified eolian sand which indicates the regression of PR-5. A thin horizon of gravel at +8.0 m can possibly be interpreted as an oscillation (PTM-4B or PTM-4.5). Layers D and C at +8.25—8.50 m give a second beach accumulation formed by PTM-5A. Consequently this inorganic sequence also gives evidence of two transgressions separated by a regression. A similar double beach accumulation separated by eolian sand was also found further south in a big ditch, B 685, just outside the PL beach ridge. Here the eolian sand was followed seawards, where it changed over into a beach accumulation at a lower altitude (= the shore of PR-5).

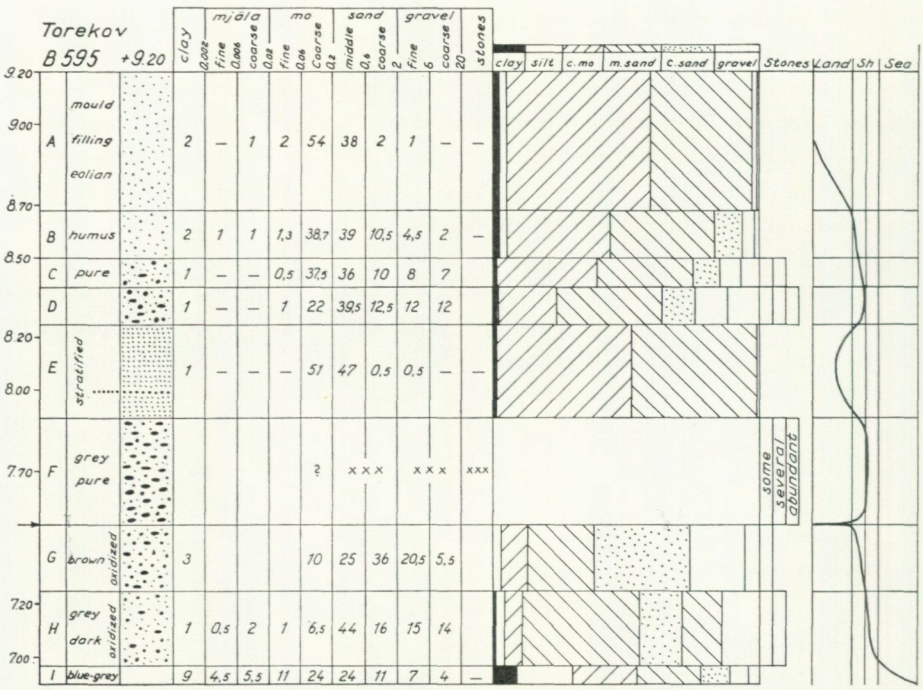


Fig. 124. *An entirely inorganic sequence of strata showing two transgressions separated by a regression. Another stratigraphy (B 849) in Torekov showed three transgressions.*

In southern Torekov the following stratification was found in a ditch, B 849, right in the PL ridge at about +10.5 m:

A: 0.10—0.20 m of eolian sand
B: 0.05 m of land surface in sand
C: 0.50—0.80 m of sand-gravel-stones, beach ridge III (= PTM-5 at +7.4 m)
D: 0.30—0.20 m of eolian sand with precipitation of rust (= PR-5)
E: 0.15—0.50 m of sand-gravel-stones, beach ridge II (= PTM-4 at +7.4 m)
F: 0.30—0.40 m of eolian sand (= PR-4)
G: 0.40—0.50 m of sand-gravel-stones, beach ridge I (= PTM-3 at +7.2 m)
H: 0.40 m of till-like rusty sand with roots, i. e. a land surface

Consequently this stratification shows three transgressions with beach ridge formation separated by two regressions with deposition of eolian sand. This is in full agreement with my shoreline diagram.

In B 713 at about +4—5 m (Fig. 24) 8 cm of peat was found below (from the bottom) 0.75 m of beach accumaulation of sand, gravel and stones, a thin humus layer and 1 m of eolian sand. This peat layer may either belong to the land period before the transgression up to PTM-2 or to the regression prior to the oscillation of PTM-7.

13. The island of Hallands Väderö

The PL on Hallands Väderö is a striking feature in the field, usually formed by a distinct beach ridge. The extension of PL was mapped (Fig. 125). During the time of PL and the shorelevels close to PL (i. e. PTM-3 to PTM-5) Hallands Väderö was restricted to two main islands connected by a spit and a third small island or skerry (Fig. 125). Several bogs and fens were formed in connection with PL and the subsequent regression.

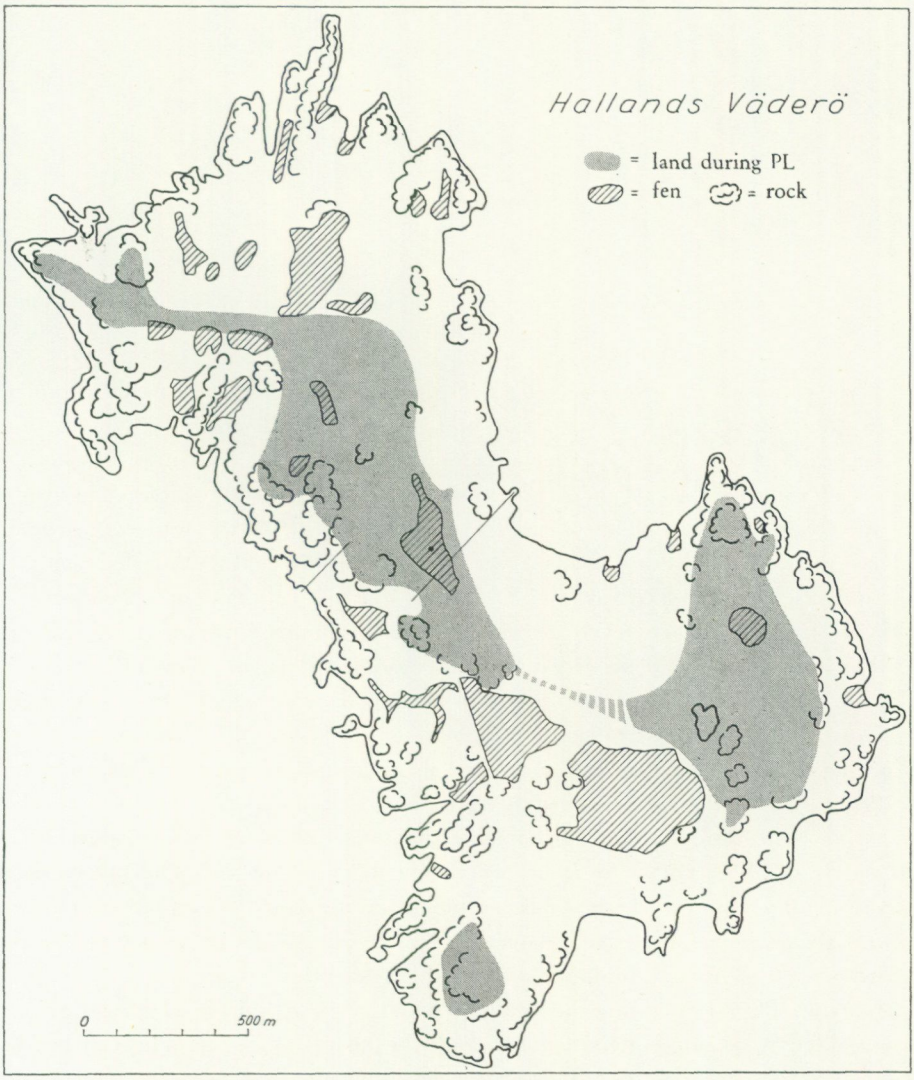


Fig. 125. *During PL time Hallands Väderö was restricted to two main islands and a small island or skerry (= the shaded areas). Except for minor changes the sea kept this position from 4,500 to 2,600 BC.*



Fig. 126. *The main section crosses the beach ridges of PL (mainly of shingle) on each side of the island.*

Two sections were levelled (no. 12, Fig. 126). The section across Oadammen crosses the beach ridges on each side of the island of PL time. In NE the top of the beach ridge (Al) lies quite horizontally at +11.0 m (measured to +11.01 m, +11.05 m and +11.08 m at three points with 50 m between each). The mean sea level was fixed at +8.59 m or +8.16—8.82 m. In SW the top of the beach ridge (A2) lies somewhat lower, viz. at +10.28—10.73 m (three levelled points). The mean sea level in SW was fixed at about +8.61 m. Consequently the morphologically fixed mean sea level on both sides of Hallands Väderö gave identical results, viz. about +8.6 m. However, the shoreline diagram shows PL at only +7.3 m. The disagreement might be ascribed to the unusually large beach ridges here and/or the presence of a younger high-water mark, e. g. of PTM-5B at +6.2 m. A boring B 327 in Oadammen shows 1.0 m of peat resting upon a fine sand at +7.92 m. The pollen diagram of B 327 shows that the peat formation started in earliest Sub-Boreal time. This means that the damming beach ridges were formed by PTM-4 and were later never overriden by the sea. The presence of fine sand and absence of lagoonal sediments in the bottom of Oadammen indicates that the sea was never above this level and PL should consequently lie below +9.7 m. This is in full agreement with the shoreline diagram.

Outside PL there is another ridge (B). However, this is not an obvious beach ridge. It is not horizontal and could be an offshore bar. The top lies at +7.27—6.98 m. A corresponding shore level is possibly seen at about +4.75 m. This could correspond to PTM-6 at +5.0 m.

On the SW coast a short section was made across two minor ridges, which

probably corresponds to younger PTM shorelines. Ridge A is of shingle, reaches +6.75 m and has a corresponding mean sea level at +5.55 m. It may correspond to PTM-6 at +5.0 m. Ridge B reaches +4.45 m and has its mean sea level at +2.71 m. This shore mark corresponds to PTM-8 at about +2.7 m.

14. The area between Torekov and Ängelholm

PL can be followed as a very distinct shoreline, usually a shore cliff or beach ridge, the whole way from Torekov to Ängelholm. Three sections were levelled.

Ramsjöstrand (no. 13, Fig. 127) shows two very distinct beach ridges (A and B) and a series of less distinct ridges (C-H). Beach ridge A is very distinct. The top lies at +9.6—8.6 m (measured at four points in 154 m to +9.12 m, +8.63 m, +9.44 m and +9.63 m). The surface inside the ridge lies at +8.01 m and shows no sign of lagoon or fen. The mean sea level was fixed at +7.20—7.61 m (probably at +7.5 m) in one point and at about +7.50 m in another point. This means that there are good morphological reasons for fixing the mean sea level at +7.50 m. According to the shoreline diagram PL also lies at +7.30 m. It was formed by PTM-5, but PTM-3 and PTM-4 lie just a few dm below. This locality, which does not have such a well exposed position as the NE Bjäre peninsula, shows that the beach ridges at N. Ängalag, Torekov and Hallands Väderö are unusually large and do not correspond to such a high shore level as their shape may suggest. Beach ridge B is also distinct. Its top lies at +7.5—7.0 m (levelled at three points in 164 m to +7.05 m, +7.03 m and +7.56 m). Inside that ridge there is a fen at +5.7 m. The corresponding mean sea level was fixed at +5.98—5.63 m. It should correspond to PTM-6 at +5.2 m (or/and PTM-5B at +6.25 m). Ridge C is small. It reaches +5.12 m. This ridge (or ridge E) should correspond to PTM-7 at +3.6 m.

Glimminge Strand (no. 14, Fig. 127) shows an old till cliff (probably from the shoreline of the Berghem line, cf. Pl. 4), and a distinct beach ridge of shingle (A). This ridge, formed during PL, reaches up to +10.24—10.47 m. The fen inside lies at +9.81 m. The mean sea level was fixed at +7.41 m and +8.04 m, respectively. The sand ridge B is the edge of a spit that was built out from NW towards SE.

Öllöv (no. 15, Fig. 127) shows an old steep till cliff (probably from the shoreline of the Berghem line, cf. Pl. 4) and some beach ridges. Ridge A has not an obvious genesis. It disappears laterally. It may belong to a Late Glacial shoreline. It reaches up to +11.0 m and has a depression inside at +9.5 m. The possible corresponding sea level would have been at about +8.0—8.6 (or even somewhat lower). If it was formed by the Postglacial sea i should correspond to PTM-4 at +7.2 m. The beach ridge B consists of shingle and reaches up to +8.90 m. In the depression inside there is a fen down to +8.26 m. The mean sea level was fixed at +7.45—6.83 m. This means that it corresponds to PTM-5 at +7.30 m, but (depending upon the interpretation of ridge A) probably also to

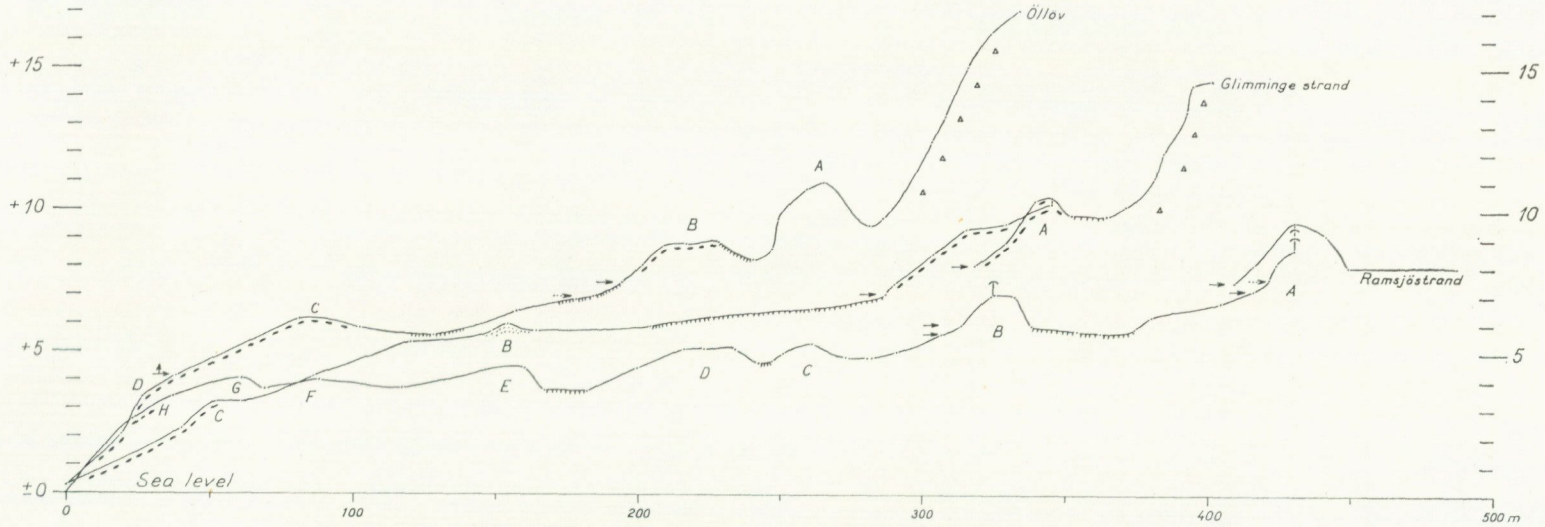


Fig. 127. *Levelled sections on the southern coast of the Bjäre peninsula. The section at Ramsjöstrand clearly shows that the mean sea level of PL can never have reached higher than +7.5 m. The shore cliffs at Glimminge and Öllöv are Late Glacial shore marks (probably belonging to the shoreline of the Berghem line). PL here falls at +7.3 m.*

PTM-4 at +7.20 m and to PTM-3 at +7.05 m. Ridge C is not a clear beach ridge, but looks more like an offshore bar. It reaches +6.15 m and might (at least partly) be related to PTM-6 at +5.0 m and PTM-7 at +3.6 m.

15. The southern coast of Skälderviken

Apparently Postglacial sea fiords extended inland in the river valleys of Rönneå and Vegeå (not marked on Pl. 9). However, the extension of these fiords is not yet determined. South and SW of Ängelholm there are two beach ridges of shingle (Lindström 1880) which belong to the PTM shorelines. The area around Kullen was an island separated from the mainland by a narrow and probably shallow strait. Four sections were levelled in this area.

In the clay pit at Utvälinge ("Vegeholms tegelbruk") an old land surface at +3.0—4.0 m is covered by 1.0 m of sand that contains three 10—12 cm thick layers of peat (B 712).

Utvälinge (no. 16, Fig. 128) does not give a quite clear picture as sand and gravel have been taken away. A ridge of not quite certain genesis reaches +9.57 m. As sand and gravel have been taken in its outer part, the whole ridge should consist of sand and gravel. Thus it is probably a beach deposit. The ridge disappears towards east as a spit. The mean sea level was fixed at +6.22 m outside the ridge and at +6.12 m behind the ridge (spit). This agrees well with PL at +6.65 m formed by PTM-5 (PRM-4 at +6.5 m and PTM-3 at +6.2 m). A younger beach

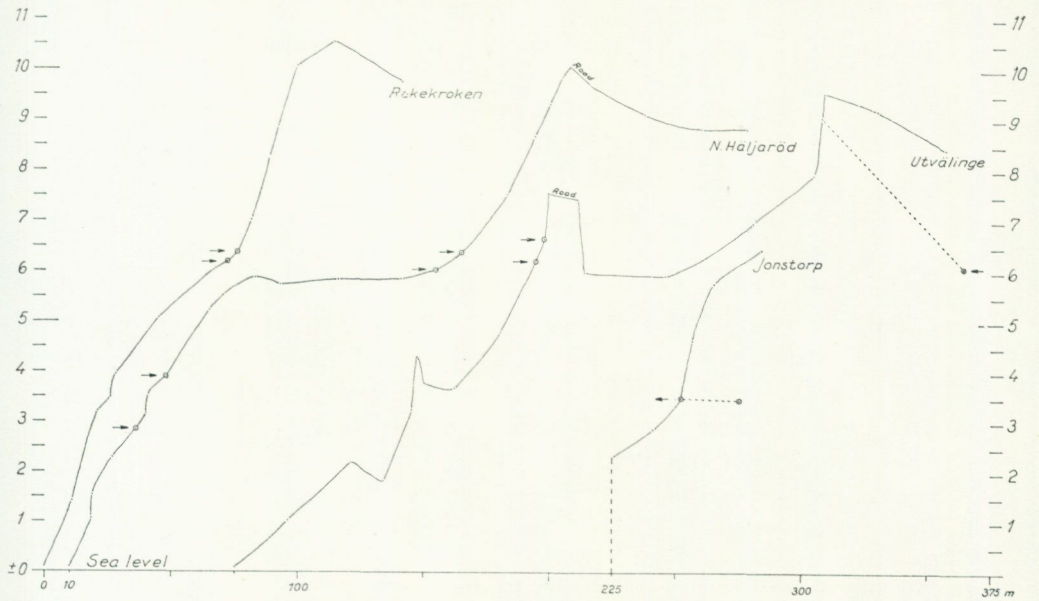


Fig. 128. *Levelled sections on the southern coast of Skälderviken. PL, formed by PTM-5A, here falls at about +6.5 m, agreeing well with the field observations.*

ridge reaches +4,32 m. As much of the ridge is today dug away, it is hard to fix the corresponding mean sea level. Probably it was formed by PTM-7 at +3.4 m.

N. Häljaröd (no. 17, Fig. 128) shows a marked shore cliff with the mean sea level fixed at +6.39—6.05 m. This agrees well with PL according to the diagram. A younger shore level was fixed at +3.91 m or somewhat lower. Apparently it corresponds to PTM-7. A possible, still lower, shorelevel was fixed at +2.85 m. This corresponds to PTM-8.

Rekekroken (no. 18, Fig. 128) shows a distinct shore cliff with its mean sea level fixed at +6.20—6.39 m. PL here falls at +6.55 m.

Jonstorp (no. 19, Fig. 128) shows a very distinct shore mark — a hybrid between shore cut and beach ridge (probably a shore cut in the outer part of an older spit-like ridge of shingle and sand). The mean sea level was fixed at +3.50 (or slightly lower). It was formed by PTM-7, which according to the diagram falls at +3.4 m. The surface above this shore is flat. It lies at about +6.47 m and apparently corresponds to a flat field of shingle that was washed out from the older shingly-gravelly deposits around Jonstorp during PL at +6.50 m.

In a well in Jonstorp a mesolithic fish-trap has been found 6.3 m below surface. It was described by Petersson and Olausson (1952). The following stratigraphy was found:

A: 4.3 m of shingle (at +7.37—3.07 m) — probably belonging to PTM-3 at +5.9 m, PTM-4 at +6.3 m and PTM-5 at +6.5 m.
B: 2.0 m of sandy mud (at +3.07—1.07 m) — probably belonging to the transgression up to PTM-3 and/or (at least partly) PR-3.
C: (below +1.07 m) marine mud — probably belonging to the time about PTM-2 at +3.2 m and the subsequent PR-3.

The fish-trap was found at the limit B/C or in the bottom of layer B. It was probably pinned to the bottom by a pole (and contained remnants of a cod), which suggests a correspondingly shallow sea. According to Olausson three pollen analyses suggest a correlation with von Post's Höganäs diagram (Rydbeck and von Post 1929) that means early AT-2. The stratigraphy suggests that the fish-trap belongs to PTM-2, PR-3 or the transgression up towards PTM-3. The high percent of *Chenopodiaceae* indicates proximity to the sea shore and the presence of big shore meadows. This environment seems only to have occurred during PTM-2 or PR-3 (from PTM-3 the shore was obviously formed by shingle, furthermore the water would have been too deep, at least to pin the fish-trap to the bottom).

16. Northwestern Öresund, especially the Höganäs area

PL follows close inside the present coast line, but at Höganäs it turns inland as a strait separating the island of Kullen from the mainland. It has been stated

(Sundelin 1925, Halden 1929) that PL in this area should lie as high up as at +10.5 m. However, it is really surprising that such a high figure could ever have entered the geological discussions. A mere glance at the recent shore processes and the old shore marks in this area must convince us that the mean sea level of PL was many metres below +10.5 m (viz. at +5.9—6.2 m). This much lower PL agrees with Lindström's statement that the beach ridges reach +5.3—5.9 m (Lindström 1880b). Four sections were levelled in this area in order to fix the real level of PL.

Nyhamnsläge (no. 20, Fig. 129) shows a distinct shore cliff of PL. The top of the cliff lies at +9.65 m. The corresponding mean sea level was fixed at +5.82 m (5.15—6.33 m).

Höganäs S. (no. 21, Fig. 129) shows a (not so well-developed) beach ridge. The top lies at +7.2—7.5 m. The corresponding mean sea level was fixed at about +5.37 m. A lower sea level was fixed at +4.53—3.76 m.

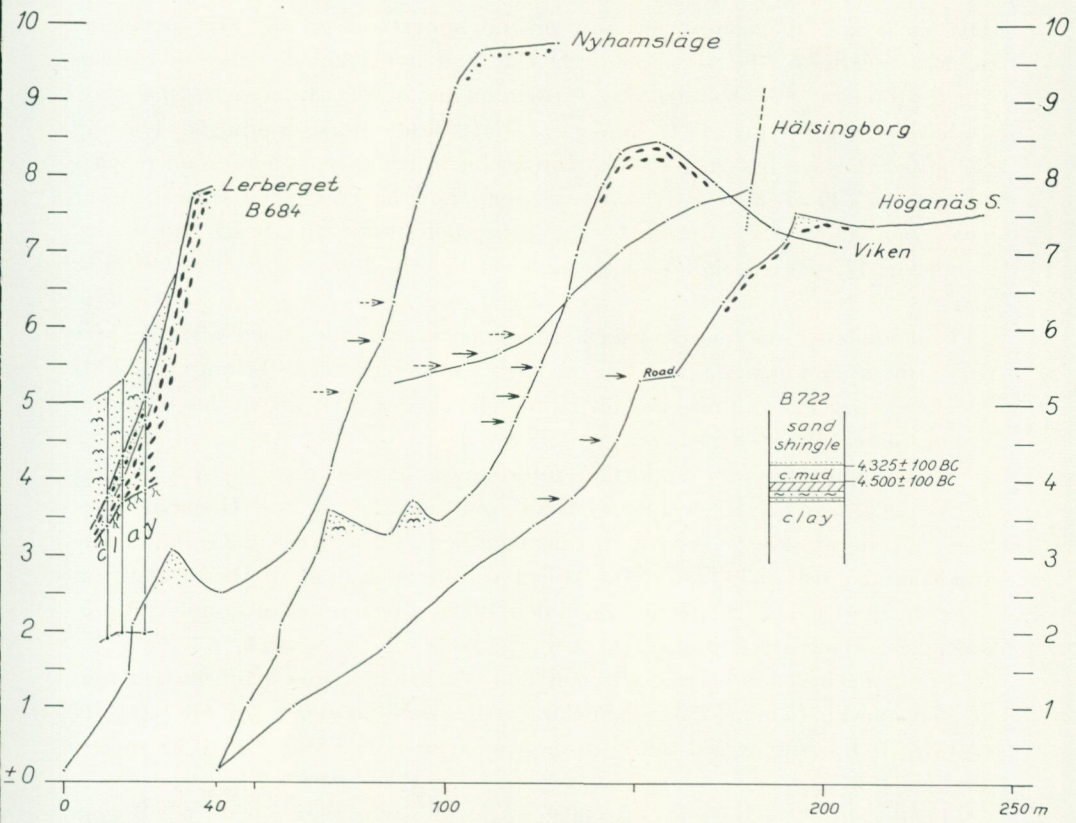


Fig. 129. *Levelled sections in the Höganäs-Hälsingborg area. Earlier PL has been put at +9-10 m. However, such a high level is impossible. PL here falls at +6.2-5.6 m. The section at Lerberget illustrates the importance of stratigraphical observations. In B 722, PTM-3A and PTM-3B are closely dated.*

Lerberget, B 684 (no. 22, Fig. 129) shows a section across a big house foundation in the PL cliff. The top of the shingle lies at +7.75 m, an altitude above which the Postglacial sea can never have reached. In the outer part the old shore deposits are covered by eolian sand that to a great extent changes the shape of the cliff. This is a thing one always has to consider when levelling shore marks in order to fix the mean sea level. This cliff is apparently polygenous and PL can no longer be fixed directly. However, it should lie about +5.5 m. The following stratigraphy was found in the house foundation:

A: Eolian sand
B: Rusty sand and stone = land surface before the sand drift
C: Shore deposits of sand and stones
D: Rusty clayey sand = the old land surface
E: Grey to bluish grey Late Glacial clay containing some fragments of shells = the Late Glacial sea sediment. The clay is hard in the top (weathered) and looser downwards.

The shells and the consistence and general appearance of the clay make me think it is a Late Glacial sedimentary clay and not a boulder clay as Halden (1929) thought. The boulder clay further inland is very different to this clay.

Viken (no. 23, Fig. 129) shows a distinct beach ridge of shingle. The top of the beach ridge lies at +8.44 m. Inside this beach ridge a depression reaches down to +7.09 m. Here it is quite apparent that the Postglacial sea can never have been above the altitude of the depression inside the beach ridge, viz. +7.09 m. The corresponding mean sea level was fixed at +4.77 m (4.09—5.48 m).

Consequently, the morphological shore marks here described all give very nearly the same mean sea level, viz. about +5.05—5.5 m. This belongs to PTM-5B (here at +5.2—5.0 m), though PTM-5 reached a little above this level and is thus the real PL (+6.2—5.9 m).

Stratigraphically very important information has been given by von Post (1928, 1929) and Halden (1929) from four localities in the Höganäs area. Several transgression waves can be distinguished. T. Nilsson (1935) has made important contributions about the pollen statistical datings of these stratifications. In the locality "Lerberget" (Halden 1929) a new series of samples, B 722, was taken, which was C^{14} dated.

From the harbour of Höganäs von Post (1928) describes a brushwood peat at −6.0 m which contains a pollen flora of the zone boundary VI (BO-2)/VII (AT-1). It was submerged by the transgression up to PTM-2, i. e. at or shortly after 5,800 BC.

The locality "Yxprofilen" was pollen analysed by von Post (1929) and diatom analysed by Halden (1929). It shows a peat or forest mould of early Atlantic time at −0.45 m that is covered by marine sediments. Diatomologically the marine sediments show the following changes in salinity:

maximum above +1.1 m = PTM-4 at +5.8 m
minimum at about +0.8 m = PR-4
maximum at about +0.2—0.5 m = PTM-3 at +5.35 m
minimum at about ±0 m = PR-3
maximum at about –0.3—0.2 m = PTM-2 at +2.6 m

The locality "Dräneringsdiket" (Halden 1929) shows a black brushwood peat of early Atlantic time at +1.1 m that is covered by marine sediments which show the following changes in salinity:

maximum = PTM-2
regression = PR-3
maximum = PTM-3
regression = PR-4
maximum (probably with two peaks) = PTM-4 (A and B)

The marine series is covered — probably with a hiatus — by a layer of peat at +2.5 m that contains a pollen flora (e. g. 15 % *Fagus*) that belongs to Sub-Atlantic time, i. e. a time after PTM-7.

The locality "Lerberget" (Halden 1929) shows an old land surface at +3.9 m in the form of a sand rich in charcoal and flints. This is covered by a sandy detritus mud that contains freshwater diatoms with a slight admixture of lagoonal-brackish diatoms. The mud probably corresponds to PTM-2 (though this falls about 1.5 m below). This interpretation seems to be supported by the pollen analyses. The stratigraphy should have the following relations to my PTM shorelines:

A: about 2 m of shore gravel with sand and shingle = PTM-4, PTM-5 and PTM-5B. This layer can be divided into three parts, viz.:
A1: shore gravel containing marine shells = PTM-5 at +5.95 m
A2: pure sand = PR-5
A3: shore gravel = PTM-4 at +5.60 m
B: 0.10—0.16 m of clayey mud with two salinity peaks = PTM-3 (A and B) at +5.2 m
C: peaty dy = PR-3
D: sandy detritus mud = PTM-2
E: sand containing charcoal and flints = the old land surface

Close to B 684 and roughly at the same place as Halden's locality "Lerberget" a series of samples, called B 722, was taken in the cliff. The transgression contact (layer B/C) was measured to +4.10 m. The following stratigraphy was found:

A: sand and shingle (not closely examined) = PTM-4, PTM-5 and PTM-5B
A2: a thin layer of fine sand covered by a hard rusty fine sand = PR-4, possibly
B: 22.5 cm of clayey mud = PTM-3 (A and B)
C: 10.5 cm of black coarse detritus mud with *Phragmites* = PR-3. The blackness is apparently due to a pitchy soil formation in connection with the PTM-3 transgression.
D: 8.8 cm of silty mud = PTM-2
E: 5.8 cm of dark fine sand = the old land surface

F: grey Late Glacial clay, sandy and clearly weathered into a ground crust in the top

The uppermost 0.5 cm of clayey mud was C^{14} dated at 4,325 ±100 BC. A 0.5 cm thick sample just above the transgression contact (here a clayey coarse detritus mud) was C^{14} dated at 4,500 ±100 BC. As layer B in B 722 is identic with layer B in Halden's stratigraphy, the C^{14} dates give the age of PTM-3B and PTM-3A, respectively. These dates closely correspond to those in Eskilstorp (p. 333) and Eastern Blekinge (p. 397).

17. The Hälsingborg area

It has earlier been assumed that PL in Hälsingborg lies at about +9 m (e. g. Sundelin 1925) at the foot of the distinct shore cliff called "Landborgen". When I visited the area, I found it quite obvious that PL definitely cannot be placed at the very foot of the cliff; it must lie further out and below this.

In order to fix the mean sea level of PL a section was levelled in northern Hälsingborg (Pålsjö) where the mean sea level was seen as a small notch just outside the cliff. The section (Fig. 129) shows that the foot of the cliff lies at +7.86 m and the mean sea level was at +5.67 m (or +5.92—5.51 m). This level is the real altitude of PL which was here formed by PTM-5 at +5.60 m (and PTM-4 at +5.20 m).

Some 100 m NW of the section I could study the stratification in a large house foundation (B 721) just outside the cliff. A 1—2 m thick layer of sand and shore gravel rests upon a more or less flat terrace in sedimentary rock. The terrace is obviously much older than the Postglacial transgression as the shore deposits do not contain stones of the substratum. The variations in thickness of the sand and gravel show that the mean sea level was clearly outside the actual foot of the cliff.

Sundelin (1925) stated that there is at Kulla Gunnarstorp a beautiful beach ridge of shingle that reaches +6—7 m. This seems to me to be a serious contradiction to Sundelin's own statement of PL at +9 m and a support to my PL which here falls at +5.75 m. Furthermore Sundelin states that there are at Sofiero a beach ridge reaching about +6 m (PL at +5.75 m) and a shore cut at +4.0—4.5 m (PTM-5B falls at +4.8 m).

In the brickworks at Rudebäck (south of Hälsingborg) Erdmann (1872) describes the following stratification:

A: 0.9—1.0 m of shore gravel containing marine shells
B: 0.15 m of peat
C: 0.45 m of mud containing lacustrine Gastropods
D: 0.30 m of peat containing branches and stumps of oak (in situ)
E: 0.10 m of clayey mud
F: 3.0 m of varved clay

The surface lies at +3.0—4.5 m. As the limit between layers C and D lies at +1.4—2.9 m and the level of PTM-2 here falls at +1.4 m, it is very probable that the mud (C) was formed by a groundwater rise in connection with the marine transgression up to PTM-2. Layer B should in that case correspond to the regression after PTM-2. PL, formed by PTM-5A, here falls at +5.4 m.

South of Råå, Erdmann (1872) stated that there occur three beach ridges with peat containing depressions inside. The two inner ones which are not reached by the sea today lie at +4.5—6.6 m. At Fortuna Erdmann (1872) described shore cut terraces at roughly the same altitude.

Sundelin (1925) gave a more detailed picture of the area between Råå and Rya. He found a system of depressions and ridges of shore deposits outside a shore cliff. The foot of the cliff was stated to lie at +8.0—8.5 m and should mark the PL according to Sundelin (this figure must be lowered to give mean sea level). The genesis of these ridges cannot yet be settled. Sundelin thought that the depressions were the old river beds of River Råån. From Sundelin's map and section the following information about the ridges can be taken (the ridges are numbered from land towards the sea): ridge no. 1 at +4.5 m is distinct, no. 2 at +3.6 m is small, no. 3 at +3.2 m is fairly distinct, no. 4 at +3.0 m is distinct, no. 5 at +1.6 m is fairly small and no. 6—7 at +2.0 m and +1.2 m respectively are probably recent. As PL (PTM-5) here falls at +5.4 m, the ridges must belong to the subsequent regression. Some of the more distinct ridges could correspond to younger oscillations (PTM-6 and PTM-7), while most of this field was probably formed by spits and offshore bars as a normal growing of the coast (cf. the Danish "rimmer og dopper").

From the brickworks at Glumslöv and Hildesborg Erdmann (1881a) described sediments containing lacustrine and terrestial Gastropods below shore gravel.

Sundelin (1925) states that shore deposits containing shells of *Litorina litorea* lie at +6.5 m at Hildesborg. As PL according to my diagram here falls at +5.2 m, this layer should have been thrown up above PL as a beach accumulation.

18. The Landskrona area

The submarine continuation of River Häljarpsån in and outside the harbour of Landskrona and the submarine "forest" (peat and stumps in situ) was observed by Wilche already in 1770 and described as evidence of a lower sea level (cf. p. 274).

Von Post (1928) describes a pollen and diatom analysed series of samples from the harbour of Landskrona. The first impression is that at about −0.90 m there is a marked salinity maximum at the zone boundary VII (AT-2)/VIII (SB-1), i. e. the time of PTM-5 which here forms PL at +5.0 m. However, the picture seems to be more complicated:

A: to 0.30 m sand with *Mya arenaria* = SA-2, historic time
B: to 0.75 m sand with seaweed = middle SB-1
C: to 1.65 m mud of different types and sand = late AT-1 to early AT-2.
D: to 1.90 m sand/mud and lake marl = BO-1
E: (below) older sediments

Consequently, there seem to be three distinct gaps (hiatus). The transgression contact ought to lie 1.65 m down at −1.80 m, i. e. a bit up in von Post's "marine mud and sand" which is apparently lacustrine. A comparison with the diagrams from Höganäs (p. 354) suggests that PTM-2 falls at 1.45—1.60 m down and PTM-3 at 0.95—1.20 m down. These levels seem even to correspond to salinity peaks. In layer B probably the end of PTM-5 and PRM-6 may be distinguished. The important thing is that PTM-2, which here falls at +0.75 m, seems to be represented.

Wood, below marine sediments, from about −5 m in the harbour of Landskrona has recently (Lund I) been C^{14} dated at 6,150 ±100 BC (Lu-19), i. e. the time just before the onset of the second Postglacial transgression. This is in full agreement with the shorelevel displacement found.

At Borstahusen there is a distinct beach ridge. Erdmann (1872) stated that it reaches +3.0—4.5 m and rests upon 1.3 m of peat-like "seaweed" (apparently this is a real peat or a coarse detritus mud). The ridge reaches +5.5 m according to A. Nilsson (1961). I have visited the locality. It is apparent that it is a double beach ridge. A rough "levelling" (mirror + measuring rod) was made. The following values were found:

The depression inside the ridges at +3.7 m.
The top of the inner beach ridge at +5.75 m = PTM-4 at +4.4 m.
The top of the outer beach ridge at +6.55 m = PTM-5 at +5.0 m.
The probable mean sea level mark outside the ridge (hard to fix) at about +3.7 m = PTM-6 at + 3.7 m (PTM-5B at +4.2 m).

In a ditch mud and peat have been found below a coarse shore gravel according to T. Nilsson (verbal information).

The buried culture layer at Västergården (no. 187) in Häljarp (Althin 1954) is the type locality for Althin's Period IIIa of the Mesolithicum in Skåne. A geological description has been made by T. Nilsson (1967a). However, the gap in the section and the disagreements between Althin's stratigraphy and the series of samples described by T. Nilsson makes a full interpretation hard. T. Nilsson found that the "lower peat" (sensu Althin) was of different age in the two series of samples. Consequently the stratigraphy must partly be changed. It was stated that the culture layer lay on a beach ridge that reached +2.5 m but probably did not correspond to PL. The published part of the section suggests that it is not a beach ridge but just a common ridge in the ground that existed before PTM-2. I find the following development:

1. The transgression of PTM-2 brought the sea level up to about +1.0 m. It seems highly probably that a spit, offshore bar or beach ridge just outside prevented this area from the direct wave actions. The area was at this time occupied by man. The alternating layers of sand and *Phragmites* peat (at "y = ±0 to −1") was formed — probably just before the highest level was reached. The pollen diagram dates these layers to AT-1 which agrees well with the transgression of PTM-2. The culture layer is towards the coast at about +1.5—0.8 m split up into 2—5 thin black layers which alternate with sand. This alternation was apparently caused during PTM-2. It seems likely that the sand between the "lower" peat and the thin dark layer in "y = +4" as well as the sand below the black humous continuation of the "upper" peat in "7 = ±0 to +3" belong to PTM-2.
2. Regression = PR-3 at about ±0 m.
3. Transgression of PRM-3 to +3.9 m (or just below). During the earliest part of this transgression the alternating sand and drifted peat in "y = +3—5" was formed. The diatoms show a brackish-marine environment. The pollen diagram does not contradict this dating. The black humous continuation of the "upper" peat is probably a pitchy soil and marks the transgression of an older land surface. The main sand layer belongs to the time when the sea rose over the area. The dark grey sandy continuation of the culture layer was probably washed out from the culture layer by the rising sea. The final gravelly sand belongs to PTM-3 itself and/or PR-4.

This interpretation means that the culture layer entirely belongs to the time about PTM-2. This is archaeologically supported by the relation to Carstensminde on Amager (p. 370) and pollen statistically by the relation to localities showing PTM-2 (Höganäs I, Limhamn, etc.).

The Postglacial sea (PL, formed by PTM-5, at about +5.0 m) reached far inland in the valley or River Saxån (Häljarpsån) and Erdmann (1881b) described a clayey mud containing marine shells and plants at Saxtorp, i. e. 5 km inland.

19. The Barsebäck area

At Barsebäck Erdmann (1872) describes two beach ridges. The outer one reaches +2.0 m and lies upon 1.05 m of peat-like "seaweed" containing thin layers of marine shells (apparently it is a lagoonal coarse detritus mud). The inner beach ridge reaches +3.0—4.5 m. Erdmann gave the following stratigraphy for this ridge:

A: 1.2 m of shore gravel (= PTM-5 at +4.8 m, PL, and PTM-5B)
B: 0.3 m of peat-like "seaweed" (= PR-5)
C: 0.15 m of shore gravel (= PTM-4 at +3.5 m)
D: (below) boulder clay

The outer beach ridge could possibly correspond to PTM-6 (and/or PTM-7), though the stated altitude is a little too low.

In the peat bog Barsebäcks Mosse T. Nilsson (1935) described a pollen analysed section. The following development could be summarized:

1. A big hiatus representing Boreal and early Atlantic time.
2. Brackish sediments at −2.5 to +1.5 m belonging to the period from AT-1/2 to shortly after SB-1c, i. e. PTM-3 to PTM-6.
3. Isolation of the level +1.5—1.0 m shortly after SB-1c, i. e. about 2,000 BC.

According to the given pollen zonation PTM-2 at +0.4 m is not represented though it clearly reached above −2.5 m. However, a change of the zonation is not precluded.

20. The Malmö area

Erdmann (1881b) described an interesting section across a beach ridge 1.6 km SE of Bjerred. The beach ridge reaches +4.8 m, contains layers of seaweed and shells and changes inland over to an alluvial clay. The interesting thing is that the whole beach ridge rests upon Postglacial marine mud which is more than 3.9 m thick in west and 2.4 m thick in east. The mud reaches 594 m inland and has its surface at +0.3—0.6 m. The stratigraphy is not yet dated. However, the marine mud probably corresponds to PTM-3, PTM-4 and PTM-5A (forming PL at +4.7 m) while the beach ridge should have been formed by PTM-6 at +3.6 m and probably also PTM-5B at +4.0 m and PTM-7 at +2.8 m. The layers of "seaweed" in the beach ridge could be pitchy soil and thus show the polygenous nature of the ridge.

At the mouth of River Segeå old dwelling places have been found below Postgalcial marine sediments (Salomonsson 1962). The stratigraphy shows a fen peat (besides the dwelling places) below marine clayey mud and sand. As the Postglacial part is not yet described, it is hard to interpret the stratigraphy. Three C^{14} dates are available (Stockholm VI):

St-1196 wood from peat at −3.7 m = 6,125 ±100 BC (stated to correspond to oldest AT-1).

St-1194 marine clayey mud at −3.20—3.25 m = 5,845 ±100 BC (stated to correspond to AT-1/2).

St-1195 marine clayey mud at −0.75—0.80 m = 5,175 ±90 BC (stated to correspond to AT-2e).

Consequently, there should be a disagreement between the pollen horizons given by Sigling (Stockholm VI) and the C^{14} dates. St-1196 gives the time of the land surface just before the onset of the transgression up to PRM-2. As the age of St-1194 exactly agrees with the age of the onset of the transgression, it apparently corresponds to this event (though the given pollen horizon suggests a younger age). The age of St-1195 agrees with PTM-2 (though the given pollen horizon suggests an age of PTM-4A). This is an important date as PTM-2 here falls at −0.3 m and the clayey mud of St-1195 lay at −0.75—0.80 m.

From Segevången (at the mouth of River Segeå) Welinder (1968) describes the stratigraphy in three pits. The following interpretation is here given:

1. The till surface is covered by a thin layer of muddy (silty) clay at +1.25—1.50 m in point 1 and 3, which was formed during PTM-2 at –0.3 m. This means that the clay was deposited 1.5—1.8 m above PTM-2 — as a flood or high-water sediment —, which seems quite possible, especially at a river mouth.
2. Peat at +1.5—1.7 m in point 3, C^{14} dated at 4,970 ±100 BC = PR-3
3. Mud in point 1 and 3 at +1.45—1.92 m, containing a lagoonal diatom flora = PTM-3 at +2.5 m (totally or just the early part).
4. During PTM-4 and PTM-5 (forming PL at +4.3 m) silty sediments were deposited in point 1—3. The sandy silt with marine molluscs in point 2 inside the beach ridge, shows that the sea once reached further inland and that the beach ridge consequently is younger.
5. The beach ridge at +3.5—4.0 m (according to Welinder) belongs to PTM-6 at +3.3 m and PTM-7 at +2.5 m.

From the harbour of Limhamn G. Persson (1962) has described two pollen and diatom analysed series of samples through a marine clayey mud above a submarine peat at about –8.0 m. However, I am not convinced by Persson's interpretation of the pollen and diatom diagrams and will therefore give a description and reinterpretation of the material.

The peat is a brushwood peat that belongs to the time of ALV-3. Two branches of *Salix* from the uppermost part of the peat have been C^{14} dated at 5,945 ±115 BC (St-720) and 6,040 ±160 BC (St-732), i. e. the time immediately before the onset of the transgression up to PTM-2. The peat is covered by 0.66 m of marine clayey mud in the series of samples called RP3. I think the clayey mud entirely belongs to AT-1. The pollen diagram shows that there is no hiatus in RP3 between the peat and the clayey mud (in RP1 there is a hiatus). The diatoms show a clear maximum at –7.55 m in RP3. This corresponds to PTM-2. At the bottom of the clayey mud there is a diatom flora that could indicate a salinity maximum. However, I think this corresponds to the fiord stage immediately after the onset of the transgression up to PTM-2 before the thresholds in Öresund were submerged and the strait was opened. The changing diatom flora below the maximum of PTM-2 do not correspond to any regression but to a continuous rise towards PTM-2. Just above the maximum of PTM-2 the clayey mud turns sandy, with a diatom flora showing a regression. This apparently corresponds to PR-3. Consequently, I only find one salinity maximum followed by a regression. Pollen statistically the salinity maximum falls shortly after a maximum of *Pinus* and minima of *Alnus* and *Corylus*, i. e. at a level very similar to the one of PTM-2 in Höganäs. The pollen diagrams of RP3 and RP1 show a very similar development and can easily be correlated. The clayey mud

in RP1 is younger (a hiatus and sand) than the earliest part of the transgression and older than the maximum of PTM-2, i. e. the changing diatom flora should not correspond to any changes of the sea level. To sum up, RP3 at −7.29 m shows the following succession:

A: 21 m of sandy clayey mud = PR-3 (i. e. latest AT-1).
B: 45 cm of clayey mud = AT-1. At the uppermost end there is a clear salinity maximum = PTM-2. At the lowermost end the first fiord stage (before the strait was opened) is seen in the absence of brackish-lacustrine diatoms and the presence of a more halophilous flora.
C: 16 cm of brushwood peat = ALV-3. The pollen diagram shows that there is no hiatus between layers A and B.

PTM-2 falls at Limhamn at −1.20 m according to the diagram. It seems very probable that this level corresponds to the artefacts that Rydbeck (1928) described from about −2 m in the harbour of Limhamn (artefacts and shells of *Ostrea* in gravel, dy and pebbles). According to Rydbeck the artefacts are older than the horn axe from Höganäs. According to Althin (1954) it is a mixed mesolithic material.

At Limhamn PL is seen as a very distinct — highly polygenous — beach ridge called Järavallen (as its continuation in southern Skåne). The stratigraphy and archaeological material were described by Kjellmark (1903) and later by Rydbeck (1928). Kjellmark (1903) published the classic section across Järavallen at Soldattorpet. He found that the lower culture layer belongs to an older part of the Older Stone Age, that the upper culture layer belongs to the end of the Older Stone Age and that the artefacts in the ridge at Sibbarp belong to the Younger Stone Age. Kjellmark realized that Järavallen was formed in steps but still did not count on more than one transgression. Rydbeck (1928) found that the upper culture layer at Soldattorpet belongs to the time of the passage graves and the cists.

Rydbeck realized that Järavallen was formed by four separate beach ridges. But he only found two general transgressions for Southern Scandinavia, viz. one at the end of the Older Stone Age and one at the end of the Younger Stone Age. Althin (1954) describes a culture layer in Järavallen at Elinelund. A stratigraphic-archaeologic relation to the section at Soldattorpet was not given. The artefacts lay in a 0.5 m thick black culture layer. Elinelund is the type locality of Althin's Period IIId. A C^{14} date of charcoal gave 3,360 ±210 BC (U-48), i. e. the time of PR-5.

Now the interesting thing is that my PTM shorelines can be transferred almost exactly to the section at Soldattorpet. In Fig. 130 Kjellmark's section has been enlarged, clarified and connected with my PTM shorelines. The following succession can now be given:

PTM-2 at −1.20 m = not represented in Soldattorpet but possibly related to the old artefacts at about −2 m in the harbour of Limhamn.

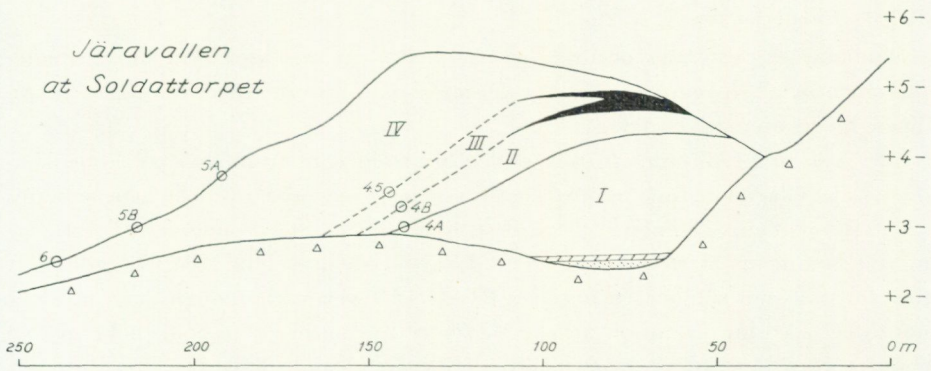


Fig. 130. *The stratigraphy in the classical section of the PL beach ridge at Soldattorpet completely corresponds to the shorelevel displacement here described. Circles = PTM levels. Black layers = culture layers (from the regressional stages).*

PTM-3 at +2.0 m = outside the slightly vaulted till surface in Fig. 130. The peat and sand at about +2.5 m in the depression below beach ridge I are marine-brackish deposits and could have been formed in an estuary of PTM-3 (or belong to an early part of PTM-4 A).

PTM-4A at +3.0 m = beach ridge I of gravel with horizontal stratification and an unconformity to the younger deposits.

Small regression between PTM-4A and PTM-4B = a thin culture layer at the top (+4.3 m) of beach ridge I (Rydbeck 1928).

PTM-4B at about +3.3 m = beach ridge II of sand reaching up to +4.7 m.

PR-5A = culture layer from the transition between the Older and Younger Stone Age. Probably this is equivalent to the culture layer at Elinelund (= Althin's Period IIId), which has been C^{14} dated at 3,360 ±210 BC (U-48).

PTM-4.5 at about +3.5 m = beach ridge III of gravel reaching up to +4.9 m.

PR-5B = the upper culture layer.

PTM-5A at +3.75 = beach ridge IV of gravel reaching up to +5.4—5.5 m.

PTM-5B at +3.2 m = the outer part of beach ridge IV.

PR-6 = not seen.

PTM-6 at +3.0 m = the beach ridge at Sibbarp at +4.41 m that contains Neolitic artefacts (Kjellmark 1903).

PR-7 = not seen.

PTM-7 at +2.5 m = redeposition and accumulation not clearly determined.

Consequently, the section at Soldattorpet (Fig. 130) gives a very complete picture of the PTM shorelines.

21. The Falsterbo area

Submarine peat bogs occur fairly frequently in this area and were already described by S. Nilsson in 1847, e. g. on the shoal Falsterborev and outside Skåre. These layers are not yet dated.

T. Nilsson (1935) describes a pollen analysed core from the bay Foteviken. The Late Glacial sediments are (with a hiatus) covered by a lacustrine series at –0.95—1.05 m belonging to earliest zone AT-2 (and youngest AT-1). The marine sediments start at about AT-2d (at –1.05 m). This could suggest that this area was not submerged until by PTM-4. However, the pollen diagram does not allow a certain zonation and furthermore the former threshold of Foteviken is not known. According to my diagrams the area should have been transgressed by PTM-3 (at +1.2 m). The lacustrine series was probably formed due to groundwater rise in connection with PTM-2 and PTM-3 (if the latter did not enter the area).

From the channel across the Falsterbo peninsula, Mohrén (in Stockholm VI), gave the following stratification:

+3.5 to +2.7 m medium sand, partly eolian partly marine
+2.7 to –5.1 m fine sand with marine shells
–5.1 to –5.4 m telmatic-terrestrial "wood peat"
–5.4 to –5.8 m fine sand, calcareous nonfossiliferous and probably Late Glacial according to Mohrén
–5.8 to –6.5 m sand with flint and chalk
–6.5 to –7.0 m boulders and pebbles
below –10.6 m boulder clay

Three samples of the "wood peat" have been C^{14} dated:

St-1215, muddy "wood peat" = 5,696 ±100 BC
St-1233, terrestrial-telmatic "wood peat" = 5,780 ±100 BC
St-1216, "wood peat" = 5,595 ±100 BC

These dates clearly show that the level –5.1 m was submerged by the transgression up to PTM-2. This agrees well with my shoreline diagrams.

At Skåre Skans T. Nilsson (1935) describes a very important boring through the beach ridge Järavallen. The following succession is seen:

1. Late Glacial clay
2. a big hiatus of the early Postglacial pollen zones
3. a fen peat at –0.42 to ±0.0 m = AT-2f and the time just before this horizon, i.e. the time of PTM-3 (at +1.0 m if the isobases do not change)
4. sand and mud at ±0 to +1.0 m = AT-2f to AT-2b, i. e. the time of PTM-4A and PTM-4B
5. the proper beach ridge = PTM-5 to PTM-6

In the uppermost 2 m of the beach ridge T. Nilsson found a pollen flora that belongs to SB-Ic-d to SB-1b (c), i. e. PTM-6. According to T. Nilsson's C^{14} dated pollen chronology this means about 2,225—1,900 BC (T. Nilsson 1964 a and b). This is very important as PTM-6 here can be given an exact date.

Erdmann (1872), described a stratigraphy in Järavallen and showed two sections across Järavallen west of Trelleborg. The ridge was stated to reach +4.5 m and rest upon peat and "clay" with lacustrine Gastropods. The peat was stated to be up to 1.0 m thick and reach +2.0 m.

22. The Beddinge—Ystad area

PL is seen as the distinct beach ridge called Järavallen. Nathorst (1874) stated that this reaches about +3.0—3.6 m and rests upon peat in several places.

At Skateholm T. Nilsson (1935) had a pollen analysed boring just inside the proper beach ridge. The development can be summarized in the following way:

1. Fen peat at 1.10—1.45 m corresponding to late AT-1 and earliest AT-2 = ground water rise in connection with PTM-2 and PTM-3A.
2. Brackish sediments at −1.1 to +0.45 m beloning to AT-2f to SB-1e, i. e. PTM-3 to PTM-5. According to T. Nilsson the diatoms show salinity maxima at SB-1e to AT-2a (=PTM-5), at AT-2c (roughly = PTM-4A and B) and at AT-2f (=PTM-3B). A more sandy part at AT-2b corresponds to PR-5.
3. Lacustrine sediments belonging to the time around SB-1d, i. e. according to T. Nilsson's (1964a, b) C^{14} dated pollen chronology at about 2,300—2,200 BC = PR-6.
4. The proper beach ridge belonging to the time after SB-1d (cf. the close dating at Skåre Skans, p. 364 = PTM-6.

Consequently, the locality Skateholm gives a very complete picture of the PTM shorelines.

From the harbour of Ystad, Brozelius (1870) described a submarine peat with stumps at −3.0 m. According to T. Nilsson (1935) this layer belongs to Boreal and early Atlantic time.

From Ystad Sandskog, T. Nilsson (1935) described a field with not less than 10 beach ridges. The area has been mapped and is well studied by means of bored sections and pollen analysis. However, the picture is not quite clear. Some of the "beach ridges" were probably formed as offshore bars and spits, more of the type "rimmer og dopper" (cf. p. 390).

From section "a" in the bog Herrestads Mosse, just inside the ridge complex, T. Nilsson gave the following stratigraphy:

A: fen peat, starting at the time just after the horizon SB-1c, i. e. about 2,000 BC (= PR-7)
B: brackish sediments from −2.5 to +2.0 m belonging to AT-2c(?) to SB-1c, i. e. PTM-4 to PTM-6
C: sand

According to this the level −2.5 m was not submerged until PTM-4 (though the diagram suggests PTM-3). It also shows that PTM-6 must have been above +2.0 m and that the sediments at this level immediately after PTM-6 changed over into a fen.

In section "e" the brackish mud at −2.37—3.84 m was stated to belong to AT-2 and to show a salinity maximum in oldest AT-2, i. e. PTM-3 (or PTM-4). This means that PTM-3 seems to be well registered in this section.

Between ridge 5 and 6 there is a deep depression containing peat and mud. The lower peat layer — that is related to the culture layer on ridge 5 — belongs to AT-2 to early SB-1. This suggests that ridge 6 was at least partly formed in late AT-2, probably during PR-5. Althin (1954) described a new investigation of a culture layer between ridge 5 and 6 and gives a section of the stratigraphy. Althin found that it is a mixed mesolithic material that to a great extent must have been redeposited by the sea. The artefacts belong archeologically to early to late Period III, i. e. probably roughly AT-2. According to Althin there are probably two marine sand layers. The stratigraphy has the following probable relations to my shorelines:

layer 7 (probably marine) = PTM-4 (divided into two parts by a "vegetation horizon")
layers 4—5 = PR-4
layer 3 (probably marine) = PTM-5

According to my interpretation the 10 "beach ridges" in Ystad Sandskog are probably not all quite true beach ridges. However, the following relations to my PTM shorelines seem likely:

ridges 1—5 = PTM-3, PTM-4A and PTM-4B
ridge 6 = partly PR-5
ridges 6—8 = PTM-5A, PTM-5B and PTM-6
ridge 9 = PTM-7 and PTM-8 (possibly also PTM-9)
ridge 10 = recent and/or PTM-10

This locality cannot be introduced into my shoreline diagram at right angles to the direction of tilting in the area investigated. It must be compared with a point further out, showing that the isobases have now clearly changed to a more easterly course.

23. The eastern coast of Skåne

There is no reason to deal closely with this area. I only want to point out that some localities here clearly show that the isobases must bend. However, it is also apparent that the intensity of land upheaval was different to the one in the areas studied by me. This means that there is no common mutual relation between the different shorelines and that these localities cannot be introduced into the Kattegatt—West Coast diagram. This also means that the older so-called relation diagrams mixing localities from the Swedish East and West Coast are not true.

At Stenshuvud I have made two rough "levellings" of PL. At Penninggraven there is a beach ridge. Here I found the following altitudes: the depression inside the ridge = +5.8 m, the top of the beach ridge = +6.9 m and the corresponding mean sea level = +4.0 m. Some 3—4 km further south there is a "shore cut" at Hellevik. Above the "shore cut" gravel and shingle are accumulated up to +6.65 m (i. e. it is a hybrid of shore cut and beach ridge). The corresponding mean sea level was fixed at +3.95 m. The agreement between these two measurements shows that PL here lies at +4.0 m. This means the same isobase latitude as the Malmö-Lomma area, i. e. straight westwards.

In Yngsjösjön (T. Nilsson 1935) there is a thin layer of brackish dyey mud at –2.95 m belonging to AT-1d. Apparently this corresponds to the earliest part of the transgression up to PTM-2. The mud is covered by a "very muddy" *Cladium* peat containing brackish diatoms. This probably corresponds to the shallow bay about PTM-2 and/or PR-3. The main Litorina sediments start after AT-1c, i. e. at PTM-3A. In Nosaby-Hammarsjön the Litorina sediments start in late AT-1 at –3.7 m, i.e. at PTM-3A.

From the Lister peninsula Sandegren (in Bagge and Kjellmark 1939) described a very interesting shorelevel displacement at Siretorp. It is really surprising how well his shorelevel displacement curve agrees with my results. The stratigraphy shows four separate maxima. Sandegren's chronology almost exactly agrees with my C^{14} chronology. However, this must be more of a coincidence. Sandegren gave the following development, which makes the following correlations obvious:

1. LG 1 at +4.5 m (4,550 BC) = PTM-3
2. syngression at about +4.5 m = PR-4
3. LG 2 at +6.0 m (4,000 BC) = PTM-4
4. regression to about +5.2 m = PR-5
5. LG 3 at +7.0 m (2,700 BC) = PTM-5
6. regression to about +4.5 m = PR-6
7. LG 4 at +5.5 m (2,100 BC) = PTM-6

The mutual relations between the LG levels are not the same as between the PTM shorelines in my diagram, which shows that the isostasy has been different and relation diagrams thus cannot be used. On the whole the altitudes correspond to the ones in my diagram in the Torekov-Höganäs area.

24. Söborg Sö and NE Sjaelland

Iversen's investigation of Söborg Sö has long been a classic work concerning the Postglacial shorelevel displacement in Scandinavia (Iversen 1937). Söborg Sö is a large depression (in NE Sjaelland) which has a narrow outlet to the sea. The threshold is today at +5 m. During some of the Postglacial transgression waves the threshold was submerged and Söborg Sö turned into a fiord. The mere stratigraphy, which shows four distinct black layers, suggests four fiord periods separated by lake stages. The diatom diagram fully proved that the

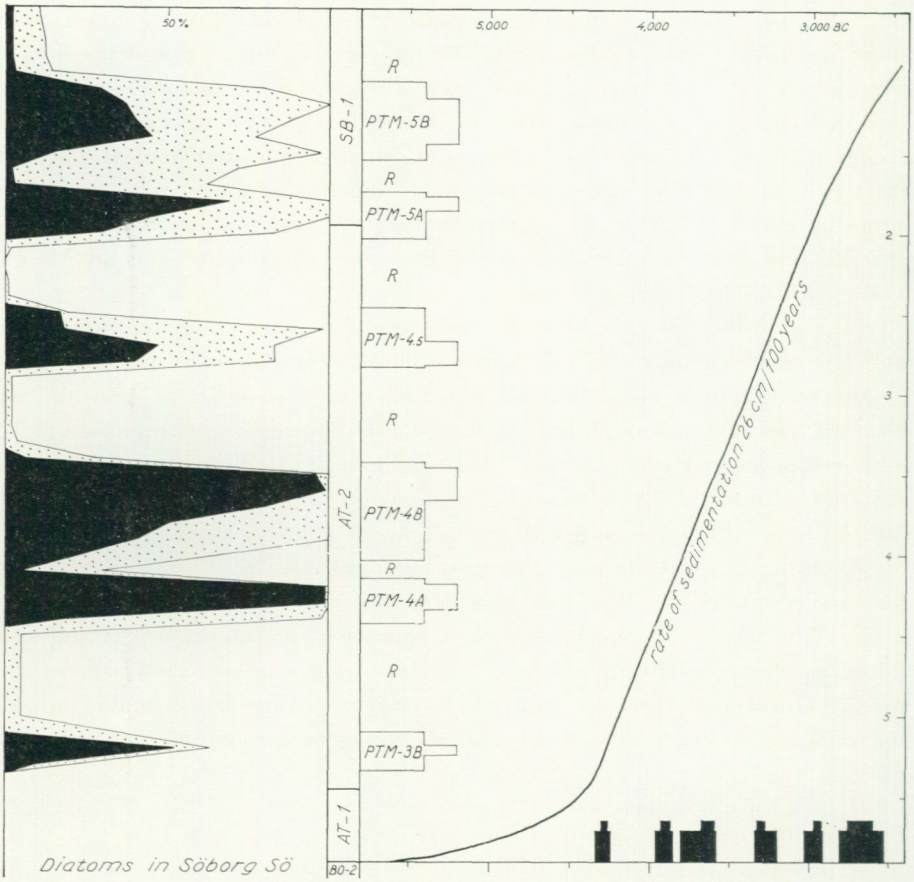


Fig. 131. *The salinity changes (black and dotted areas = marine and brackish diatoms respectively) in Söborg Sö completely correspond to the shorelevel displacement here described. If the known ages of the PTM shorelines are used for the salinity peaks, a quite smooth curve of the rate of sedimentation is obtained.*

black layers correspond to four marine-brackish fiords separated by freshwater stages (Fig. 131). I find the following correlations to my PTM shorelines (well supported by the pollen diagram):

1. Lake stage = PTM-2 at +0.8 m and PTM-3A at about +2.8 m did not reach above the threshold
2. Fiord I = PTM-3B at about +3.8 m, which indicates that the threshold was somewhat lower than today
3. Lake stage = PR-4
4. Fiord IIa = PTM-4A at +4.5 m
5. Fiord IIb = PTM-4B at +4.7 m
6. Lake stage = PR-5 (A)
7. Fiord III = oscillation during PR-5, PTM-4.5 at about +4.2 m

8. Lake stage = PR-5 (B)
9. Fiord IVa = PTM-5A at +5.0 m, i. e. PL
10. Fiord IVb = PTM-5B at +4.2 m
11. Lake stage = final isolation at PR-6. PTM-6 at +3.7 m did not reach into Söborg Sö which indicates that the threshold was raised a little.

Fiord III does not correspond to any of my PTM shorelines. It cannot be found on higher isobase latitudes and apparently corresponds to an oscillation during PR-5 that never forms PL, but lies below this. As it is separated from PTM-4 and PTM-5 by distinct regressions, it should perhaps have been given a separate number. Now I call it PTM-4.5. The age of fiord III may be calculated from the rate of sedimentation. In Fig. 131 the thickness of the sediments has been plotted against the age. If the known ages of PTM-3, PTM-4 and PTM-5 are used, there will be a very smooth curve of the rate of sedimentation (Fig. 131). In early Atlantic time the sedimentation was very slow, which the pollen diagram also suggests. This curve suggests that fiord III occurred 3,350—3,200 BC. However, this is a very rough "date", as the sedimentation rate may have changed and as the radiocarbon method involves several factors of uncertainty.

In NE Sjaelland there are several shore marks. Rördam (1892) found one older shoreline at about +9.7 m, which he thought was Late Glacial, and one younger shoreline at about +4.0 m, which he thought corresponded to PL. In the Hornbaek area Madsen (1943) levelled a series of shore marks. He found seven separate shorelines. He measured the tops of beach ridges and terraces and subtracted 2.65 m (= mean value of two measurements of the limit of the recent shore gravel) to get the corresponding sea level. This was a commendable attempt to get the corresponding sea level. However, the figures obtained still give very approximate values of mean sea level. In my opinion every shore mark must be determined according to its own morphology, position, material, etc. The altitudes of Madsen's shore marks may give the following correlations to my shorelines (the figures here given are not corrected to sea level, and the figures in one section are moved):

1. +9.51—8.69 m (3) = Late Glacial shore cut terraces
2. +8.07—6.94 m (7) = PTM-5A at +5.15 m (PL)
3. +7.03—6.28 m (8) = PTM-5B at +4.45 m
4. +6.45—5.84 m (7) = PTM-6 at +3.80 m
5. +6.31—5.02 m (9) = PTM-7 at +3.00 m
6. +4.46—3.48 m (4) = PTM-8 (and/or PTM-9)
7. +3.36—2.95 m (2) = PTM-9 (and/or PTM-10)

25. The area of Copenhagen

Iversen (1937a) described a pollen and diatom analysed boring in Ordrup Mosse (Klampenborg fiord). Above a submarine peat at −2.60 m there is a thick layer of brackish-marine sediments, where certain salinity maxima are seen. The pollen diagram suggests the following correlations with Söborg Sö:

Söborg I: 4.37—4.62 m down with a corresponding minor peak of marine diatoms = PTM-3 at +2.1 m (PTM-3B as well as PTM-3A).

Söborg II: 2.25—3.62 m down with a distinct maximum of marine epiphytes and *Paralia sulcata* (the maximum could very well be double) = PTM-4 at +3.1 m.

Söborg III: 1.55—1.85 m down with a corresponding minor peak of marine diatoms.

Söborg IVa: 0.80—1.30 m down with a very distinct peak of *Paralia sulcata* that suggests PL = PTM-5A at +3.9 m, i. e. PL.

Consequently, there is an extremely good agreement between the salinity maxima in Söborg Sö and Ordrup Mosse. Söborg III is here also seen as a minor oscillation during the regression of PR-5. The regression of PR-4 is also well established. This interpretation of the stratigraphy gives a very likely curve of the rate of sedimentation.

At Taarbaek V. Milthers (1935) found a section with three layers of marine sand and gravel in freshwater deposits. The lowermost marine layer disappears at about –0.7 m in lacustrine sediments and probably corresponds to PTM-2 at –0.8 m. It was followed by a regression PR-3 (= lacustrine sediment) and then the other layers come with more uncertain correlation to the PTM shorelines.

On Amager, Troels-Smith (1939) found that the culture layers were related to certain shorelevels, viz:

Amager I at +2.0 m = PTM-2

Amager II at +1,75 m = PTM-3

Amager III at +2.50 m = PTM-4

Amager IV at +3.20 m (PL) = PTM-5A (PL)

The culture layer of Carstenmide (= Amager I) corresponds according to Althin (1954) to the culture layer at Häljarp, i.e. Althin's mesolithic Periods IIIa. The culture layer at Häljarp was also found to correspond to PTM-2 and PR-3 (p. 359).

26. NW Sjaelland

My diagram does not exactly apply in this area. The shorelines seem here to lie a little higher. This small change in isostasy is also suggested in the well known map by Mertz (1924).

Tengslemark Mosse was described by K. Jessen (1937). It lies inside a beach ridge that reaches +5.7 m. The section shows two marine layers of *Cardium* mud. According to the pollen diagram the following correlations seem probable:

1. Change from mud to lime mud in possible connection with the onset of the transgression up to PTM-2.
2. The lower thin layer of *Cardium* mud = PTM-4A, at least above +2.0 m (T. Nilsson, 1948a, correlates this layer with Söborg III).
3. Regression (lacustrine lime mud) = PR-5

4. The upper thick layer of *Cardium* mud = PTM-5, at least above +2.5 m.
5. Regression (lacustrine lime mud) = PR-6
6. Beach ridge up to +5.7 m = PTM-6. According to my field observations the corresponding mean sea level seems to lie at about +3.5—4.0 m.

The altitude of the layers of *Cardium* mud shows that the PTM shorelines lie somewhat higher in NW Sjaelland than they do in the diagram, i. e. that this area has had a slightly different isostasy.

The kitchen midden at Klintsö (K. Jessen 1937) shows two high shorelevels separated by a regression. I find the following interpretation:

1. Shore cut in till: mean sea level at +3.5 m (or somewhat lower) with accumulation of sand up to +4.9 m. Probably = PTM-4 (or PTM-5).
2. Regression below +3.30 m, where there is a hearth.
3. Transgression: redeposition of the kitchen midden up to +5.0 m and accumulation of sand and gravel. Mean sea level at +4.0 m (to +3.5 m). Probably = PTM-5 (or PTM-6).

The locality Gislinge Lammefiord has only been given a very brief description (Troels-Smith 1942). The given stratigraphy suggests the following correlations:

A: redeposited kitchen midden = transgression over a dwelling place belonging to Althin's Perion IIIb
B: sand with a hearth at the limit between layers B and C = PR-4 below –1.5 m
C: marine mud (with shells) up to –1.5 m = PTM-3 above –1.5 m
D: *Phragmites* peat = land period

According to Troels-Smith the marine mud has a pollen flora that corresponds to Söborg I, i. e. PTM-3. According to Althin (1954) the artefacts correspond to Ageröd V (Period IIIb), which T. Nilsson (1967b) has dated to zone AT-1 (but younger than Häljarp). As period IIIa at Häljarp belongs to PTM-2 and PR-3, Gislinge Lammefiord ought to correspond to PR-4.This is also indicated by the shoreline diagram, where PTM-3 reaches just above –1.5 m. The regression PR-4 is here well established.

27. Djursland

The maximum extension of the Postglacial sea on Djursland (and the whole of northern Jylland) was mapped by A. Jessen (1920). The Postglacial sea reached with a narrow strait across Djursland from Grenå to Mariager Fiord. In the extremities of two ramifications of this strait lie the localities Korup Sö and Dyrholmen (described below). On the map by Mertz (1924) the isobases of PL were drawn with a correction to obtain mean sea level, which should lie at +5.0—3.0 m on Djursland.

Korup Sö was described by Iversen (1937). He found that the fluctuating curve of *Hystrix* should reflect the same fiord periods as he found in Söborg Sö. However, there seems only to be a rough correlation. PTM-3 (Söborg I),

PTM-4.5 (Söborg III) and PTM-5A (Söborg IVa) seem to correspond to distinct maxima of *Hystrix,* while PTM-4 (Söborg II) and PTM-5B (Söborg IVb) are more indistinct.

At Dyrholmen artefacts of settlement belonging to three different zones (I-III) have been found (Mathiassen 1942). Accroding to Althin (1954) zone I corresponds to his Period IIIc and zone II to Period IIId (i. e. Elinelund). The stratigraphy and pollen statistical datings were described by Troels-Smith (1942)

In section A the pollen analysed (P1) stratigraphy gives the following correlations:

1. the clay at +2.35—2.70 m = PTM-6
2. the sandy mud at –0.05 to +2.35 m = PTM-4 to PTM-5 (Söborg II—IV)
3. the muddy sand below –0.05 m = PTM-3 (Söborg I)

In the other sections the sandy mud splits up into separate layers. The uppermost part, which should be equivalent to Söborg IV, is often absent (at least partly) or represented by sandy layers (probably brought out from land by erosion).

The following development seems likely:

1. the peat at –1.5 m = land period
2. the muddy sand with shells = PTM-3 (Söborg I)
3. regression (PR-4) = settlement of zone I
4. the "lower mud" up to +2.92 m = PTM-4 (Söborg II)
5. regression (PR-5A) = sand above the "lower mud" and settlement of zone II (i. e. the same position as Elinelund in Limhamn)
6. the rest of the mud and the sand above this = PTM-4.5, PTM-5A and PTM-5B (i. e. Söborg III—IV)
7. often a hiatus = PR-6 (and sometimes PTM-5B or even PTM-5A)
8. the clay (up to +3.5 m) containing *Ruppia* and *Hystrix* = PTM-6

The settlement of zone III should correspond with PR-5B to PTM-6. These artefacts often occur redeposited in or below the clay of PTM-6.

The development found in Dyrholmen clearly shows that the PTM shorelines here fall at higher altitudes than my diagram suggests. This means that Djursland must have had a somewhat different isostasy, which is not at all surprising, as northern Jylland has had a different isostasy.

At Brabrand artefacts have been found that should belong to the time about PL ("before, at and after" PL). The stratigraphy was described by Troels-Smith (1937b). Pollen diagram A suggests an ingression of the sea at –3.55 m by PTM-3 (Söborg I). The thin layer of clayey mud in the section clearly correspond to PTM-5A (Söborg IVa), which consequently should form PL. PL here lies at +2.0 m according to A. Jessen (1920) and at +2.5 m according to Mertz (1924). The layers of drifted peat and charcoal could correspond to the

position of the sea during PTM-4. The hearths in the till correspond to a low waterlevel before PTM-5 (PR-5 and/or PTM-4).

On Samsö Troels-Smith (1937a) described three culture layers corresponding to shorelevels. Only a rough pollen dating seems to have been made. Troels-Smith gives the following statement about the age and the corresponding shorelevels:

Samsö (Alstrup A) : older than Söborg II = shorelevel at −1 m

Samsö (Alstrup A) II: simultaneous to the end of Söborg II = shorelevel at +1 m

Samsö (Alstrup A) III: partly simultaneous to, partly younger than Söborg IV = shorelevel at +2.5 m

This would give the following correlations to my PTM shorelines: I = PTM-3, II = PTM-4 and III = PTM-5. However, my diagram suggests the following correlations (which only means a difference in isostasy of about 1 m): I = PTM-4, II = PTM-5 and III = PTM-6. According to the section the mean sea level of PL seems to be a little below +2.5 m.

28. The Praestö Fiord area and Borre Mose

V. Mikkelsen (1949) gave a detailed description of the Praestö Fiord area (SE Sjaelland) and Borre Mose (Mön). He combined his results in a shorelevel displacement curve. However, I do not agree with Mikkelsen's pollen chronology (cf. p. 382). Furthermore it is apparent from the diatom diagrams that there have been fluctuations of the sea level, though Mikkelsen's curve does not show this. Mikkelsen's pollen zone IXa seems usually roughly to correspond to T. Nilsson's zone SB-2. The sedimentation has apparently varied very much and there are a lot of gaps of varying time and duration. I have made a close examination of the material and put all the pollen diagrams in relation to T. Nilsson's pollen chronology and the pollen diagrams of Söborg Sö, Ordrup Mose, etc. My interpretation is given below.

Lake Even east of Dalinge Gård: The diatom diagram of Bp 21 (Fig. 132) is of special interest as it shows several salinity maxima. As a whole this area shows the following:

Earlier land period = peat and lacustrine mud.

PTM-2 = ground water rise and change to lime mud (H), containing a slight admixture of brackish diatoms (i. e. = ingression of the sea). This mud is seen at −8.1—9.1 m, i. e. agreeing well with the marine sea level during PTM-2.

PR-3 = salinity minimum in Bp 21.

PTM-3 = the first small salinity maximum in Bp 21.

PR-4 = salinity minimum in Bp 21.

PTM-4A = distinct increase of marine diatoms in Bp 21 at −7.6 m and deposition of detritus mud (mixed peat and mud) at −3.15—3.45 m in Bp 8.

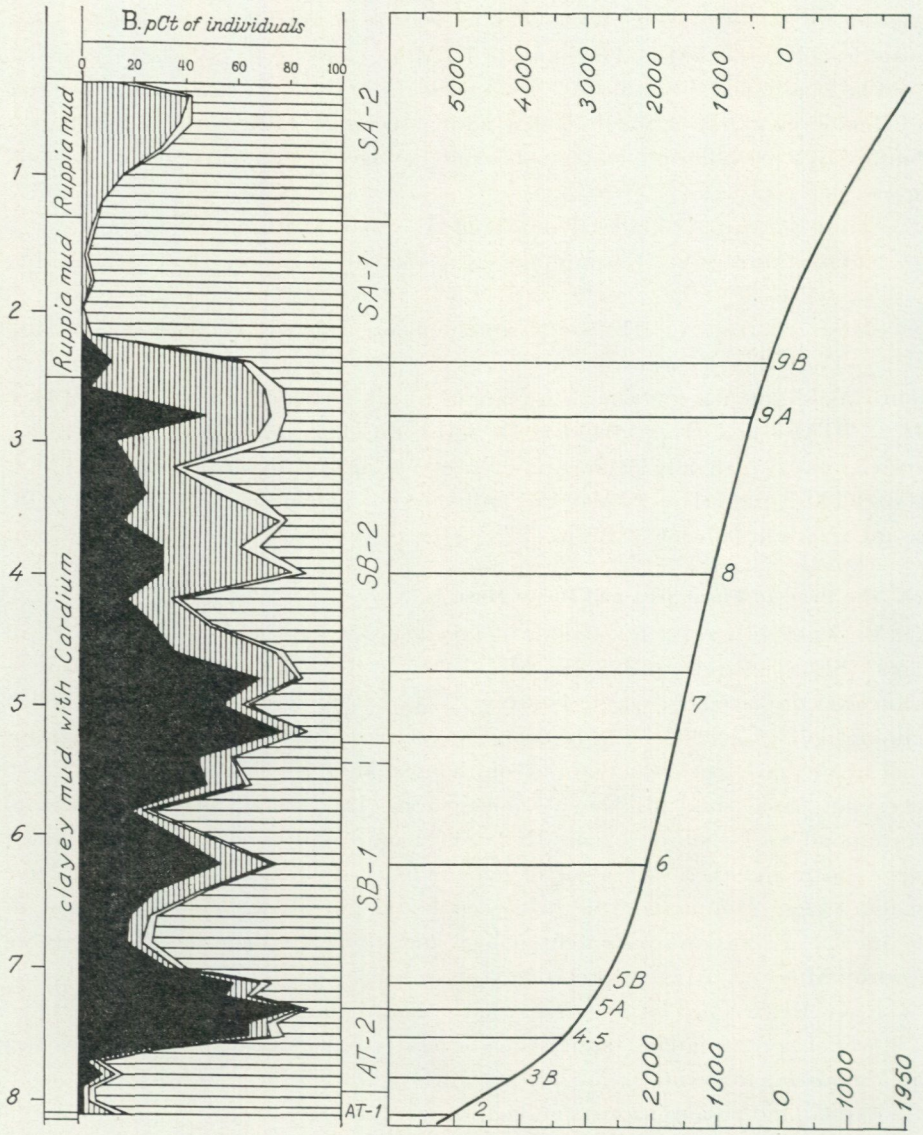


Fig. 132. *Diatom diagram from Praestö Fiord, Lake Even, Dalinge Gård, Bp. 21. The salinity peaks correspond to the PTM shorelines, giving an even curve of the rate of sedimentation.*

PTM-4B = the first salinity maximum in Bp 8, the lowermost part of the first maximum in Bp 13 and the lowermost part of the first distinct and complex maximum in Bp 21.

PR-5A = salinity minimum in Bp 8.

PTM-4.5 = the second salinity maximum in Bp 8.

PR-5B = salinity minimum in Bp 8.

PTM-5A = the peak of the complex maximum in Bp 21, the uppermost part of the first maximum in Bp 13 and the third maximum in Bp 8.

PR = distinct salinity minimum in Bp 13.

PTM-5B = the uppermost part of the complex maximum in Bp 21 and the second maximum in Bp 13 (not quite distinguishable in Bp 8). The sediments of PTM-5 can be followed up to –1.0 m in Bp 7.

PR-6 = distinct salinity minima in Bp 21, Bp 13 and Bp 8.

PTM-6 = distinct salinity maximum in Bp 21, the first peak of the third maximum in Bp 13 and the fourth maximum in Bp 8.

PR-7 = distinct salinity minimum in Bp 21 (pollen statistically dated at about 1,800 BC).

PTM-7 = distinct salinity maximum in Bp 21 (pollen statistically dated at between 1,650 and 1,300 BC), the peak of the last maximum in Bp 13 and the last maximum in Bp 8. *Cardium* mud was deposited up to +0.2 m.

PR-8 = salinity minimum in Bp 21.

PTM-8 = salinity maximum in Bp 21. The curve of the sedimentation rate suggests an age of 1,000 BC, agreeing well with the pollen diagram.

PR-9 = salinity minimum in Bp 21.

PTM-9 = distinct salinity maximum in Bp 21, in late SB-2.

PR-10 = distinct salinity minimum in Bp 21.

PTM-10 = salinity maxima in SA-2 in Bp 21.

LAKE EVEN, SOUTH: The oldest brackish sediments at –2.0 m belongs to PTM-5. In Bp 5 the following is seen:

A: peat above +0.55 m = zone SB-2, PR-8
B: *Ruppia* mud at +0.55 m = SB-1/2, i. e. PTM-7
B/C = hiatus of PR-6, PTM-6 and PR-7
C: sandy peat-mixed mud at +0.30—0.10 = the time of PTM-5

PTM-7 can here be dated to the zone boundary SB-1/2, i. e. to about 1,650 BC.

PL at Lake Even was seen, according to Mikkelsen, in the foot of the shore slope at Dalinge Gård at +1.0 m and in the surface of the marine sediments (*Phragmites* peat) at +0.7 m in the southern part. The Tubaek brook cuts through a stony beach ridge, the top of which lies at +1.4 m.

REVHOLMS MOSE: Bp 12 shows the following:

B: *Ruppia* mud at –0.48—0.74 m = PTM-7 (earliest SB-2)
C: gravelly pebbly sand at –0.74—0.76 m = PR-6 and PTM-6
D: clayey mud at –0.76—1.60 m = PTM-5

THE PROPER PRAESTÖ FIORD BASIN: Bp 12 gives a good picture of the earliest development. The pollen diagram seems to allow the following correlations:

D1: *Cardium* mud above –9.3 m = marine sedimentation starting with the rise to PTM-4.

D2: Brackish mud at –9.3—9.8 m = shallow bay during the time about PTM-3, having its maximum at –9.4—9.5 (9.6) m.

C: Detritus mud with Gastropods and slight admixture of brackish diatoms, at –9.8 —10.0 m = ground water rise and ingression of salt water in connection with the second Postglacial transgression, having its maximum, PTM-2, in the lowermost part of layer D2 (at the pollen index horizons AT-1c-d).

The younger stages are seen in Bp 5, where PTM-5A, PTM-5B, PTM-6 and PTM-7 are seen as minor salinity peaks (separated by salinity minima = regressions) of an unbroken marine stage with rapid sedimentation. PTM-7 falls at the zone boundary SB-1/2 to earliest SB-2.

Orup Mose: Only minor parts of the stratigraphy have been analysed. However, these can be combined to show the following:

PTM-7 = beach sand to +0.1 m in Bp 5 of earliest SB-2.
hiatus = PR-6 and PTM-6.
PTM-5B = *Ruppia* mud (with salinity peak) at –0.3—0.6 m.
hiatus = regression between PTM-5A and PTM-5B.
PTM-5A = clayey mud with *Cardium* (and a weak salinity peak at about the pollen index horizon SB-1h) at –0.6—1.1 m (bottom of Bp 5).
PTM-4.5 = salinity maximum above –1.6 m in Bp 10 at the pollen index horizon AT-2b.
PR-5A = distinct salinity minimum in Bp 10.
PTM-4B = salinity maximum at –1.9—2.4 m in Bp 10 at the pollen index horizon AT-2d(-e).
PTM-4A/4B = very weak or no regression.
PTM-4A = the lowermost clayey mud in Bp 11 at –2.50—2.95 m with a weak salinity peak at the pollen index horizon AT-2e.

The picture obtained is very complete and agrees well with the extrapolated shoreline diagram. The more distinct picture of PTM-4A to PTM-4.5 is probably due to the position of Orup Mose in the outermost part of the old sea fiord.

Borre Mose on northern Mön: The following development is seen in Bp 3 (Fig. 133):

N—O: –8.58—8.72 m algae and lime mud showing a salinity peak at the pollen index horizon AT-1d = PTM-2
K (fiord) = the whole sequence from PTM-3 to PTM-6 (PTM-3 = not distinguishable, PTM-4 = the first salinity peak, PTM-5A and PTM-5B = the double peaks in the middle, PTM-6 = the uppermost part)
I (lake) = PR-7
H (fiord 2) = PTM-7 in early SB-2
G (lake) = PR-8

Above layer G there are two more fiord stages (layers F and D). A correlation with PTM-8 and PTM-9 is likely, though not agreeing with Mikkelsen's pollen zonation. However, the rise of *Fagus* at about layer D probably corresponds to the zone boundary SB-2/SA-1 ant not SA-1/2. The development suggests that there was no threshold during the early part, but that a spit or beach ridge separated the area from the sea after PTM-6. This means that we

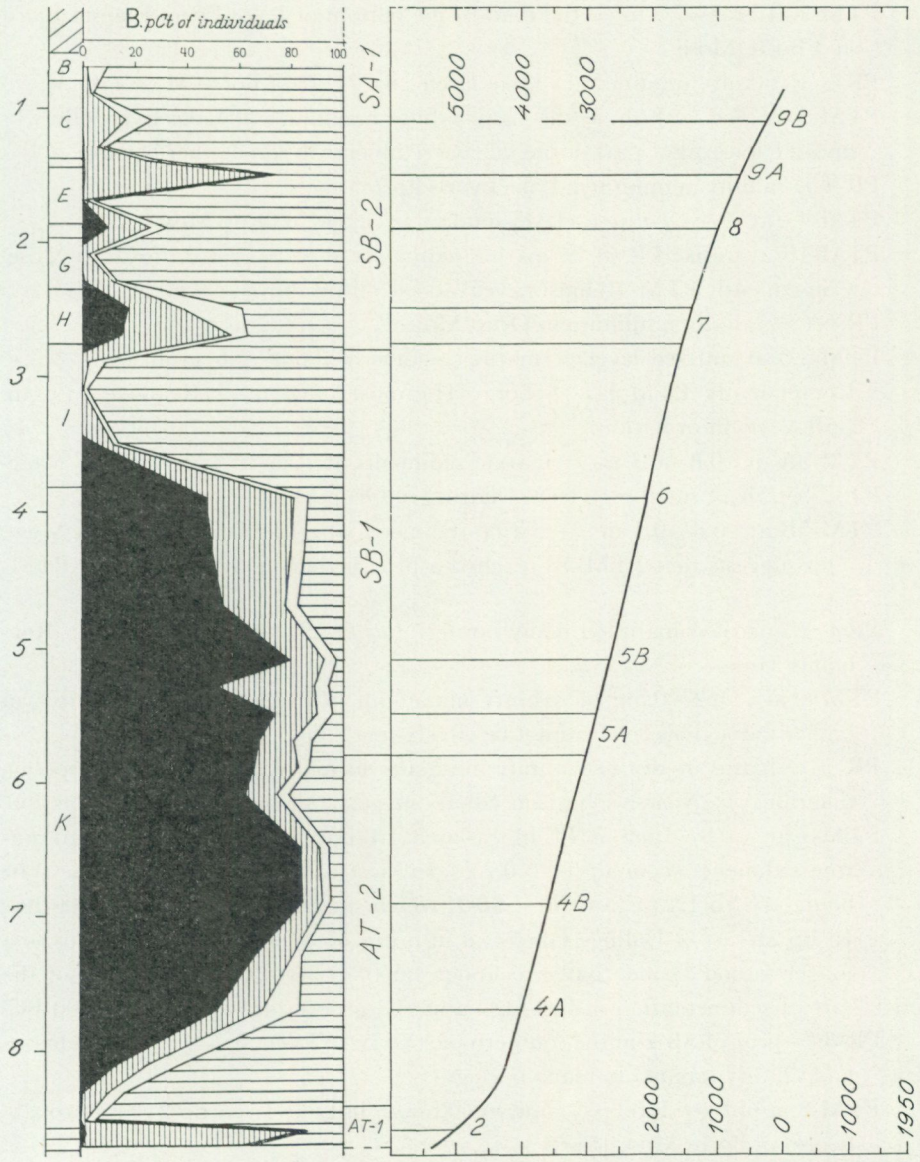


Fig. 133. *Diatom diagram from Borre Mose, Mön. The changes in salinity correspond to the shorelevel displacement here described. The curve of the rate of sedimentation is even, suggesting that the uppermost peaks correspond to PTM-8 and PTM-9.*

cannot be quite sure whether the younger fiord stages correspond to real transgressions or only to breaks through the separating ridge.

The area studied by Mikkelsen lies in my diagram 178—188 km outside the O-point. The shorelevel displacement according to my diagram is compared below with the data found in this area:

PTM-2 at –8.4—7.5 m = the mud in the bottom of Lake Even, Praestö Fiord and Borre Mose.

PR-3 = salinity minimum in Lake Even (Bp 21) and Borre Mose (Bp 3).

PTM-3 at –4.6—3.8 m = the small salinty maximum in Lake Even (Bp 21) and the lowermost part of the marine sediments in some other borings.

PR-4 = salinity minimum in Lake Even (Bp 21).

PTM-4A at –2.4—1.7 m = clayey mud up to –2.5 m in Orup Mose.

PTM-4B at unfixed level = marine sediments at –1.9—2.4 m in Orup Mose. Consequently PTM-4B must have reached a little above –1.9 m.

PR-5A = salinity minimum in Orup Mose.

PTM-4.5 at unfixed level = marine sediments about –1.6 m in Orup Mose. Consequently PTM-4.5 (Söborg III) must have reached above –1.6 m.

PR-5B = no information.

PTM-5A at –0.8—0.3 m = marine sediments at –0.6—1.1 m in Orup Mose.

PTM-5A/5B = small regression (hiatus) in Orup Mose.

PTM-5B at –0.8—0.3 m = marine sediments at –0.3—0.6 m in Orup Mose. This suggests that PTM-5B reached a little higher up (–0.3 m) than PTM-5A.

PR-6 = marked hiatus in many borings and beach sand at –0.75 m in Revholms Mose.

PTM-6 at +0.2—0.5m = salinity maximum in deeper parts and hiatus in higher parts. This level cannot be closely fixed.

PR-7 = hiatus or distinct salinity minimum in many borings. In some pollen diagrams T. Nilsson's horizon SB-1b suggests an age of about 1,800 BC.

PTM-7 at +0.8—1.0m = PL in this area. In southern part of Lake Even marine sediments occur up to +0.7 m. In most cases PTM-7 falls at the zone boundary SB-1/2 or in earliest SB-2, which suggests an age about 1,600 BC. In Bp 21 east of Dalinge Gård and in Borre Mose, PTM-7 corresponds to a longer period (pollen dated at about 1,650—1,300 BC). The curves of the rate of sedimentation in Figs. 132 and 133 give an age of 1,650—1,400 BC.

PR-8 = peat of SB-2 in the southern part of Lake Even at +0.55 m and hiatus and salinity minima in many borings.

PTM-8 at unfixed level = salinity maximum in Lake Even Bp 21 and probably also in Borre Mose (fiord 3).

PR-9 = salinity minimum in Late Even Bp 21 and probably also in Borre Mose.

PTM-9 at unfixed level = salinity maximum in Lake Even Bp 21 and probably also in Borre Mose (fiord 4).

PR-10 = salinity minimum in Lake Even Bp 21 and probably also in Borre Mose.

PTM-10 complex at unfixed levels = salinity maximum in zone SA-2 in Lake Even Bp 21.

Consequently, my shorelines agree extremely well with the development in this area. Furthermore the levels of PTM-4B and PTM-4.5 can now be fixed for this part of the diagram. Also the date of PTM-7 can be given.

29. The SW part of the Baltic Sea

In this area a flattening out of my shorelines and a slight land subsidence are expected.

From the Heiligenhafen and Lübeck Bucht area Schmitz (1953) has given a time-depth graph of pollen-statistically dated submarine transgression contacts (also based upon Tapfer 1940). However, Köster (1960, 1961) has shown that the curve of Heiligenhafen lies higher than the one of Lübecker Bucht. This indicates that the shorelines here are still tilted, which means a serious contradiction to Kolp's (1964, 1965) horizontal shorelines. The curves by Schmitz and Köster are not sufficiently closely fixed in age and position to allow a detailed comparison with my PTM shorelines.

Kolp (1964, 1965) found (morphologically) two horizontal shorelines in the SW Baltic Sea, viz. at −12 mand −6 m. However, there are no grounds to believe in horizontal shorelines within this area, especially not since Köster has shown that the PTM shorelines are tilted between Heiligenhafen and Lübeck. Thus Kolp's shorelines must be of different age in different areas. In Mecklenburger Bucht the −12 m shoreline corresponds to PTM-2. This is in full agreement with the above-mentioned graph by Schmitz (1953). The −6 m shoreline probably corresponds to PTM-3 and PTM-4.

In Bundsö (on the island Als) the transgression is said to have reached the −4.3 m level in earliest Atlantic time (K. Jessen 1938, T. Nilsson 1948). However, this is contradicted by all other information about the position of the shorelevel. Probably the disagreement depends upon local variations in the pollen flora and a rapid sedimantation — and probably the whole marine sequence belongs to Sub-Boreal time.

30. Vendsyssel

PL lies here higher than in other areas perpendicularly to the direction of tilting in my diagrams. This indicates that Vendsyssel has had a different isostasy (cf. p. 429). A shoreline diagram has been constructed (Fig. 11) from the descriptions given by A. Jessen (1918, 1920 and 1936) and S. A. Andersen (1961). This shows that PL is formed by a steeper shoreline (about 2.0 m/10 km) above about +10.5 m and by a less steep shoreline (about 0.9 m/10 km) below about +10.5 m. However, PL may hide still more shorelines (Fig. 11).

At Dybvad, Iversen (1943) found a stratigraphy that clearly shows two transgressions separated by a regression. The pollen diagram indicates that both transgressions belong to zone AT-2, which means that they should correspond to PTM-3 and PTM-4 respectively. Consequently, PTM-2 would lie deeper. However,

it is possible that the thin layer of gravel at about +8.5 m (and the thick sand layer above) is a trace of PTM-2. The following development is seen in Dybvad:

PTM-2 = possible shore at about +8.5 m
PTM-3 = transgression up to +9.5—10.0 m (at least +9.5 m)
PR-4 = distinct regression down to about +9.0 m
PTM-4 = transgression up to +10.0—10.5 m (at least +10.0 m)
PR-5 = the sedimentation of marine mud ends, regression below +9.0 m

S. A. Andersen (1961) stated that there are two beach ridges at Melholt, one older at "just above +9 m" and one younger at +8 m. As the older beach ridge probably belong to PL, it corresponds to PTM-4 (according to the development at Dybvad). The younger beach ridge would then belong to PTM-5. In these ridges there are several gravel pits. Seven C^{14} datings have been made of shells from these gravel pits (Copenhagen VII 1966, Tauber 1966). These dates have not yet been given a close description (the altitude and morphological position were not stated). The C^{14} datings gave the following result:

K-906:1	4,150 ±140 BC	= 3,845* ±165 BC	= PTM-4
:2	4,170 ±140 BC	= 3,865* ±165 BC	
K-890:1	4,100 ±140 BC	= 3,795* ±165 BC	= PTM-4
:2	4,180 ±140 BC	= 3,875* ±165 BC	
K-907	3,990 ±140 BC	= 3,685* ±165 BC	= PTM-4B
K-888	3,670 ±140 BC	= 3,365* ±165 BC	= PR5
K-889	3,610 ±140 BC	= 3,305* ±165 BC	= PR5
K-902	3,600 ±150 BC	= 3,295* ±175 BC	= PR5

The ages fall into two groups, one = PTM-4 and the other = PR-5. As K-902 has been taken in the bottom of a 4 m deep gravel pit, PR-5 must have been followed by a big accumulation of gravel (= PTM-5).

In 1968 I visited Melholt and found the following stratigraphy in the largest gravel pit, B 843:

A: eolian sand (surface at +8—9 m)
B: shore sand + stones
C1: sand + stones + shells
C2: shell bank + stones. The following shells were collected:

Cardium edule	many	*Aporrhais pes pelecani*	single
Litorina litorea	„	*Bittium reticulatum*	„
Nassa reticulata	„	*Cardium echinatum*	„
Ostrea edulis	„	*Lunatia pallida*	„
Litorina obtusata	some	*Macoma baltica*	„
Hydrobia ulva	„	*Natica clausa*	„
Hydrobia ventosa	„	*Tapes edulis*	„
Mytilus edulis	„		

The C^{14} dated shells probably all come from layer C, which consequently was formed during PTM-4 and PR-5. The younger beach ridge at +8 m (S. A. Andersen 1961) was probably formed by PTM-5.

At Kodals Rende in Lönstrup Klint — situated in the extremity of a small Postglacial fiord from SE — A. Jessen (1938, p. 160) describes an interesting stratigraphy. Below 1 m of mould he found 1.0—1.5 m of alternating "shell layers" and peat. According to the altitude the following correlations seem likely:

A: mould = PR-5 and later
B: shell leyer up to +8.3 m = PL, i. e. PTM-4
C: peat = PR-4
D: shell layer = PTM-3
E: peat = ALV and PTM-2 time

In 1968 I visited the locality Kodals Rende and found the following stratigraphy (B 842):

A: Sand.
B: About 0.4 m of brown (peat-like) coarse detritus mud. At the bottom it is a clayey coarse detritus mud containing a marine-brackish diatom flora (*Diploneis didyma, Cocconeis scutellum,* etc.). The lowermost 1.5 cm was C^{14} dated at 3,365 ±100 BC, i. e. PR-5.
C: About 1.5—1.0 m of numerous shells (double shells of *Cardium edule* predominating) + clayey mud. Lenses of coarse detritus mud occur. About a third of the way down a log was found.
D: About 1.0 m of brown to black peat-like organic material of heterogenic genesis. At the top it is a clayey mud mixed with coarse detritus mud, containing a marine-brackish diatom flora (*Paralia sulcata* predominating). At the bottom it is a dyey peat or pitchy soil (without cellular fragments), clearly a terrestrial formation. The uppermost 1.5 cm was C^{14} dated at 5,450 ±120 BC (carbonate not removed) and 5,115 ±135 BC (carbonate removed), i. e. PTM-2 or just before this. The lowermost 1.5 cm was C^{14} dated at 6,125 ±125 BC, i. e. the time (ALV-3) before the onset of the transgression to PTM-2.
E: About 0.8 m of mixed sand and peat. A nut of *Corylus* indicates an age after C^0.
F: About 0.4 m of mud, clay and peat in a heterogenic mixture.
G: Clayey sand.
H: About 0.1—0.2 m of shore gravel.
I: Varved silt-clay/sand.

Layers G—H give the isolation from the Late Galcial sea (= layer I). Layer E probably belongs to the Boreal. Soil identifications under the microscope have shown that A. Jessen's "peat" layers (= D and B) must be reinterpreted. Furthermore only one layer (C) of shells was found (though containing lenses of "peat"). The transgression contact in layer D seems to lie at about +5 m (not levelled). The PTM-2 shoreline (Fig. 11) here falls at +5.4 m, which means full agreement with the stratigraphy and C^{14} dates. Layer C was deposited at about PTM-3 at +7.8 m and PTM-4 at +9.4 m. PR-5 is registered as the change from layer C to layer B. PTM-5 falls at +8.0 m.

Consequently, the C^{14} dates and the stratigraphy of B 842 agree very well with the shoreline diagram for Vendsyssel (Fig. 11) and my PTM/PR succession.

Just north of Fyrreby Aa or Klostergröft (cf. A. Jessen 1936, p. 158) the following stratification was observed (B 841):

A: Eolian sand.
B: About 1 m of marine clayey mud + shells.
B2: 8.5 cm of alternating layers of clayey mud and coarse detritus mud, containing a marine-brackish diatom flora (*Diploneis didyma, Rhopalodia gibberula,* etc.).

C: 8.5 cm of black (peat-like) clayey dyey coarse detritus mud, containing a marine-brackish diatom flora (*Diploneis didyma* predominating). This layer contains logs and stumps. The altitude is approximately +3—4 m.
D: Silt and sand.
E: Clay.

Soil identifications under the microscope show that A. Jessen's "peat" layer is a marine-brackish deposit, continuously changing over to the marine clayey mud with shells. The logs and stumps and the absence of shells in layer C suggest deposition in shallow water over an older land surface overgrown with trees. This area was probably reached by the sea during the transgression up to PTM-2.

The stratigraphy of Lille Vildemose has been described and pollen analysed by V. Mikkelsen (1943). However, T. Nilsson (1948) has shown that Mikkelsen's pollen zonation has to be changed (cf. p. 373). I agree with T. Nilsson. I would give the following interpretation of the pollen analysed point P1 (Fig. 134):

Peat above the isolation level at +2.35 m = land after the isolation in SB-2
Mud to +2.20 m and sandy mud to +2.10 m = PTM-7 starting at the zone boundary SB-1/2)
Fine sand to +1.90 m = PR-7 (latest SB-1)
Clayey mud to about +1.45 m = PTM-6
Sandy clayey mud to about +0.95 m = PR-6
Clayey mud with shells to –0.20 m = PTM-5 (the zone boundary AT-2/SB-1 lies at about –0.25 m)
Sandy sediments with shells to –0.80 m = PR-4

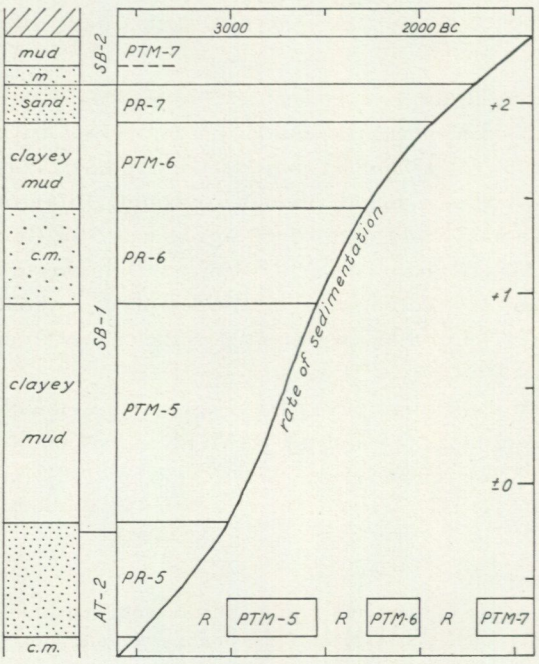


Fig. 134. *Lille Vildmose P1; stratigraphy, pollen zonation, interpretation of the shorelevel displacement and the corresponding curve of the rate of sedimentation.*

If the thickness of the sediments is plotted against the age (Fig. 134), the dots form a quite smooth curve of the rate of the sedimentation.

In early SB-2 a brackish lagoon reached at least above +2.35 m. In P2 and P3 sand layers with very high percentages (90 %) of *Chenopodiaceae* at +2.8 and 4.3 m respectively indicate close proximity to the shore. A sea level at +2.7 m seems very likely. Now the interesting thing is that this level exactly corresponds to PTM-7 in my shoreline diagram. This shows that the disagreement in isostasy only applies to the older shorelines. If this level is connected with the level of the *Dosinia* layers at Strandby (cf. below), the obtained shoreline gets exactly the same gradient as PTM-7 in my diagram.

From this area of Lille Vildmose shells of *Ostrea edulis* in sandy mud 2.0—2.5 m below surface have been C^{14} dated at 3,630 ±150 BC (K-866, Copenhagen VII and Tauber 1966). The exact position of the shells in the stratigraphy is not known. The age suggests that the shells belong to the sandy sediments in the bottom of P1, i. e. PR-5.

Concerning the shorelevel displacement in historical time two dates were obtained from Frederikshavn. Shells of *Litorina litorea* from a shore accumulation at about +1.3 m (B 610) were C^{14} dated at 1,120 ±100 AD, suggesting a present land upheaval of about 1.5 mm per year. Seaweed peat at about +0.5—1.0 m (B 609) was C^{14} dated at < 250 years. See also Fig. 152.

From the description given above and the shoreline diagram (Fig. 11) it is obvious that the "Postglacial transgression" in Vendsyssel can now be split up into several separate transgression waves, corresponding to my PTM shorelines (though with a somewhat different isostatic history). The gradient of the shorelines older than PTM 7 are not sufficiently established yet.

PTM-2 = shoreline 2, the first transgression in Kodals Rende, forming PL in NE but not visable in Dybvad.

PTM-3 = shoreline 3, the first transgression in Dybvad.

PR-4 = distinct regression in Dybvad.

PTM-4 = shoreline 4, the second transgression in Dybvad, where it forms PL as well as at Melholt.

PR-5 = regression in Kodals Rende, and shells in Melholt.

PTM-5 = shoreline 5, gravel and sand above dated shells, and beach ridge at about +8 m in Melholt, but not represented in Dybvad, i. e. falling below +9 m in Dybvad.

PTM-6 = shoreline 6, connecting some shore marks between PL and the Dosinia shoreline only. Not well established yet.

PTM-7 = shoreline 7, the shoreline of the Dosinia sea. This is well established, as will be shown below.

If these shorelines must be more closely fixed as to position and age, the general picture of several separate transgression waves corresponding to my PTM shorelines, is well established. And that is the main question here.

THE DOSINIA LAYERS

Nordmann (1904) found that the shore deposits at about +3 m in the Frederikshavn-Strandby area contained a quite special shell fauna. He called these layers the *Dosinia* layers after the mollusc *Dosinia exoleta*. The shell fauna of the *Dosinia* layers contains a great number of new boreo-lusitanic imigrants, but also many species not found in Kattegatt today. According to Nordmann (1904) the shore deposits studied contained two different zones:

A: the *Mactra* layer = the uppermost 0.6—1.0 m which contained shells of *Mactra subtruncata*
B: the *Dosinia* layer proper = sand and gravel with shells

Laursen (1937) describes a section through "a shell bank from the Dosinia sea". According to Laursen's description the following layers can be distinguished:

A: the *Cardium* layer = the uppermost mouldy sand with shells
B: the *Mactra* layer = a thin layer of sand with shells
C: the *Litorina* layer = a shell deposit in a depression in the clay (F) above (inside) the proper *Dosinia* layer (the stratigraphical position not fixed)
D: the *Dosinia* layer = the proper shell bank; at the top a pebbly sand with lots of shells and at the bottom sand, pebbles and lots of shells between big boulders
E: the "skalgrus II" layer = older pebbly shell sand in a depression in the clay (F)
F: the Older *Yoldia* clay

As layer E only remains in a depression and layer C starts with a layer of big boulders (also directly above layer E), Laursen thought that the *Dosinia* layer was preceded by a transgression from a lower level (PR-7). According to Laursen the *Dosinia* layer was formed as a submarine shell bank and layers A and B belong to the emergence. This agrees well with my interpretation.

Laursen found 56 mollusc species in layers A to E, distributed as follows:

	species, total	peculier to this layer	No. of species also found in: A	B	C	D	E
A	6	0	—	5	5	4	2
B	17	0	5	—	15	12	9
C	27	4	5	15	—	16	15
D	43	18	4	12	16	—	17
E	24	2	2	9	15	17	—

This table shows that layer C is faunistically most related to layer B. The high frequency of *Litorina litorea* in layer C suggests formation close to the sea level.

Laursen states that it is not easy to find the shoreline of the *Dosinia* layers. At Lerbaek Gård, however, he found a long beach ridge reaching up to +6 m. The *Dosinia* layers have been found from Strandby to Saeby and at Hals (Nordmann 1904). North of Hals Mose A. Jessen (1936) has shown that the

series of ridges ("rimmer og dopper") that runs N—S, is here cut of by a distinct shorelevel in E—W. Apparently this is the shoreline of "the Dosina sea", i. e. PTM-7.

Shells of *Dosinia exoleta* from Strandby have been C^{14} dated at 2,520 ±140 BC (K-900, Copenhagen VII, Tauber 1966). If this age is corrected according to the "sea effect" (cf. p. 16), it (2,215* ±165 BC) corresponds to PTM-6 (but not PTM-7 as might have been expected). As PTM-6 here only lies 1.5 m above PTM-7 this does not contradict my interpretation. It only shows that the immigration of the *Dosinia* fauna reached Vendsyssel already during PTM-6. However, the main *Dosinia* layer must still be correlated to PTM-7. From Getterup Bro two C^{14} dates are available (op. cit.), shells of *Ostrea edulis, Mytilus edulis, Cardium edule* and *Tapes aureus* (K-864) gave 2,200 ±140 BC and shells of *Litorina* (K-865) gave 2,060 ±120 BC (mean of two). The corrected dates (1,895* ±165 BC and 1,755* ±165 BC) suggest a deposition during PR-7 (or PTM-6 to PTM-7). The occurrence of *Tapes aureus* (not found in Kattegatt today) indicates an age before the climatic deterioration after the *Dosinia* layer or PTM-7. However, the altitude is not yet known.

Nordmann (1904) gives a list of all shells that had been found in the *Dosinia* layers (111 species). He stated that 27 of these species are new immigrants and do not occur in older deposits. In Table 1 (p. 474) these 27 species are listed and their occurrence in Vendsyssel and in Bohuslän and the Gothenburg area are given.

Nordmann (1904) has already found a correlation of the *Dosinia* fauna between Vendsyssel and Bohuslän. One locality west of Lysekil at about +10 m and two localities at Strömstad (Öddön and Nötholmen) "at a low altitude" contained mollusc faunas that could be correlated with the *Dosinia* fauna in Vendsyssel (Nordmann 1904). In order to give further evidence of this correlation Table 1. was made. In the Gothenburg area Sandegren (in Sandegren and Johansson 1931) has followed the immigration of molluscs by combining the shell banks (their altitude) in percent of PL. Hessland (1943) has studied the immigration of molluscs in Bohuslän. Antevs (1917) has also studied the succession of molluscs in Bohuslän (his abbreviations in Table 1 roughly mean: prt = the time before PL, ptm = PL, sp = the time after PL, during which the climatic optimum should fall, and rec = historical time). Table 1 shows that several of the species that Nordmann stated as only occurring in the *Dosinia* layers occur on the Swedish West Coast in much older layers (e. g. *Kellia suborbicularis, Lucina borealis* and *Nassa incrassata*). Consequently these species are not typical of the *Dosinia* layers (though Nordmann had only found them there). This means that the occurrence of *Lucina borealis* in Kolingsund on Djursland (Nordmann 1904) is not a proof of the presence of the *Dosinia* fauna. From Table 1 it is quite obvious that Hessland's third immigration wave of Sub-Boreal age ("about 2,500—500 BC") corresponds to the immigration of the *Dosinia* fauna in Vendsyssel.

Especially the locality Ejde at +5 m has a fauna that offers a very good correlation with the *Dosinia* layers. In the Gothenburg area several new molluscs have immigrated in shell banks at 30—20 % of PL. This fauna (e. g. *Cardium norvegicum, Dosinia exoleta* and *Dosinia lincta*) offers a very good correlation with the *Dosinia* layers. 30—20 % of PL means about +5.0—7.5 m. As PTM-7 (as a small transgression) has been fixed in Björkö Mosse (p. 316) to +8.0 m, there is a very good correlation between the *Dosinia* layers in Vendsyssel, the fauna in the shell banks at about +5.0—7.5 m in the Gothenburg area and the PTM-7 transgression in Björkö Mosse. Some of Nordmann's molluscs of the *Dosinia* layers occur already at 50—40 % of PL (e. g. four species in the shell bank at +12 m west of V. Holm). As 50—40 % of PL means about +10.0—12.5 m and PTM-6 here falls at +12.0—14.0 m, the shell banks at 50—40 % of PL could show the early phase of the immigration of the *Dosinia* fauna during PTM-6. The distributoin of the *Dosinia* fauna in Laursen's five layers (A-E) at Strandby clearly shows that the *Dosinia* fauna has already disappeared in layer B. (and C), i. e. already in connection with the regression (PR-8) from PTM-7. This indicates a climatic deterioration in early SB-2 (which the eustatic curve also suggests, cf. p. 422).

Consequently, there was a strong immigration of boreo-lusitanic molluscs to Kattegatt (found in Vendsyssel, Bohuslän and the Gothenburg area), starting at about PTM-6 and reaching its optimum at PTM-7. This suggests a climatic optimum at PTM-7. The *Dosinia* fauna rapidly disappeared at the regression down from PTM-7. This suggests a climatic deterioration. The eustatic curve (cf. p. 425) also suggests these climatic changes.

This immigration at PTM-7 may also be seen on the Bjäre peninsula. As stated above (p. 340) the sudden appearence of shells at about the level of PTM-7, indicates a change — an immigration or a flourishing (in favourable environment) of the molluscs.

By Professor Hessland I was kindly permitted to use an unpublished C^{14} date of shells from the *Lutraria elliptica* layer at Ejde (Hessland 1943, p. 255). The shell bank at Ejde is formed as a submarine sand and shell bank in shallow water. The present altitude is +5 m. The mollusc fauna (Table 1) shows an obvious correspondence to the *Dosinia* fauna. The C^{14} date is technically a very good dating, made in three fractions, the outermost of which was not used and the other two giving exactly the same age, viz. 1,735 ±75 BC (St-1167). This age — uncorrected or corrected to the sea effect (1,430* ± 100 BC) — is in full agreement with my date of PTM-7. I think this is the final evidence of the correctness of my date and interpretation of PTM-7.

31. The island Laesö

According to A. Jessen (1897) Laesö was entirely covered by the sea during PL, which he thought was about 3 m higher. This is not proved. Jessen states that the top of highest beach ridge lies at +11 m. The highest point of Laesö,

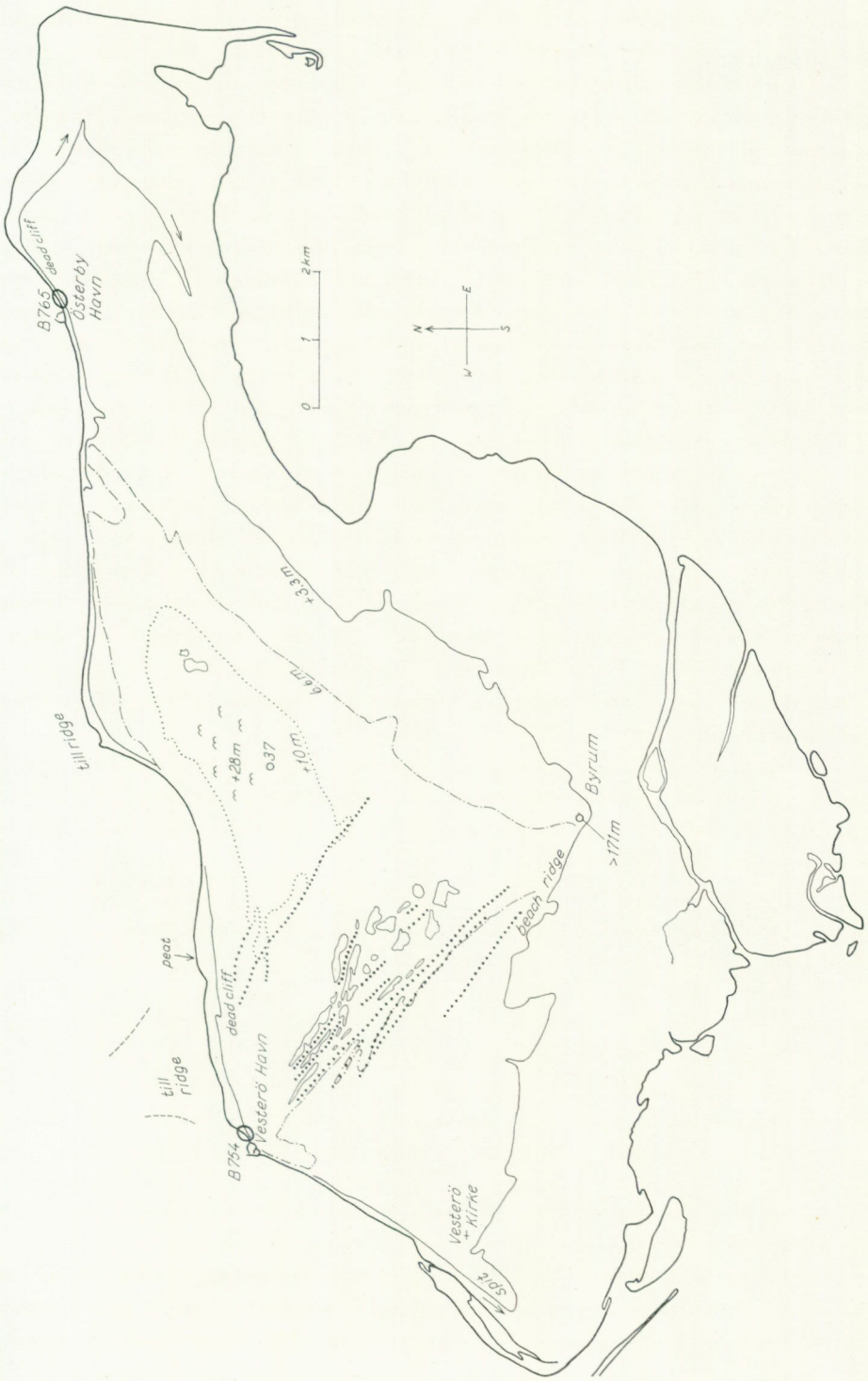


Fig. 135. *Laesö. The +3.3 m contour roughly corresponds to PTM-7. Thick dotted lines = beach (bar) ridges. Circles = borings mentioned in the text.*

+28 m, is a dune area and the "plateau of the Litorina beach-ridge deposits" lies according to O. Mikkelsen (1967) at about +10—13 m.

No doubt the young beach deposits can be followed, at least up to the 10 m contour, and probably up to the top of Laesö (excluding the dunes). However, it is impossible to fix PL and settle whether Laesö was a shingly-sandy skerry or a shoal during PL. On the SW side of the area above +10 m (Fig. 135), there seem to be some beach ridges (not closely studied). If Laesö has had the same isostatic land upheaval as the main area, these ridges may be related to PL, as PL would here fall at about +8.0 m, formed by PTM-3 to PTM-5A. Between the +10 m and +6.6 m contours there is a series of ridges and depressions (fens and ponds), which seem to correspond to "rimmer og dopper", i. e. formed as a normal growing shore. At about the +6.6 m contour between Byrum and Västerby Havn there are some more distinct beach ridges, apparently corresponding to PTM shorelines. PTM-5B here falls at about +6.6 m and PTM-6 at about +5.2 m. The +3.3 m contour is related to a distinct shoreline which apparently belongs to PTM-7 and is equivalent to the *Dosinia* layers in Vendsyssel (it may also, at least partly, be formed by PTM-8 and PTM-9). NW of Byrum there is a real beach ridge. SW of Vesterö K. there is a distinct spit. East of Vesterö Havn and Österby Havn respectively dead cliffs are seen inside the present coast. At the point marked on the map (Fig. 135) peat below sand was said to occur.

In the fresh cliff NW of Vesterö Havn (cf. O. Mikkelsen 1967) I found the following stratification (B 754):

H: About 0.5 m of eolian sand (mould).
G: 1.0 m of shore gravel (the regression).
F: 4.0 m of sea sand.
E: 0.2 m of shore gravel at about +4.0 m.
D: 0.75 m of sea sand (in the upper part possibly eolian) containing a big eroded lump of clayey dy (27.7 % loss on ignition), which was C^{14} dated at 7,750 ±120 BC, i. e. to the time of the low sea level during the transition between ALV-0 and ALV-1.
C: 0.5 m of shore gravel.
B: About 2.0 m of (at the top) eolian sand disappearing towards NW and (the rest) beach sand. In the upper part of this layer there are several structures that (according to common descriptions) should derive from frost activity.
A1: 0.1 m of gravel.
A2: 0.1 m of grey clayey fine sand with shells.
A3: (below +2.0 m) clayey silt (=*Yoldia* clay) with burrows filled with shells and fine sand.

This stratification suggests (but does not prove) that a transgression (= PTM-2) reached above +4.0 m, but that a regression (= PR-3) then brought the sea level down to about +4.0 m (according to the shoreline diagram PTM-2 here falls at +5.0 m). If this is correct it indicates that Laesö has had the same isostasy as the main part of Kattegatt and the Swedish West Coast. But this would

mean that PL should only have reached about +8.0—8.8 m (at the area today above +10 m).

The fresh cliff cast of Österby Havn (B 765) offered a good section across the continuation of the dead cliff:

A: A thick layer of shore gravel, which towards east is accumulated to a beach ridge. Further eastwards this shore changes over into the dead cliff. The altitude of the shore is about +2.5—4.0 m.

B: Thick layers of sea sand (and maybe also eolian sand) divided by a thin layer of gravel.

The beach ridge and the dead cliff are probably formed by "the Dosinia sea", i. e. during PTM-7 (it may also, at least partly, be formed by PTM-8 and PTM-9).

The distinct shore marks of PTM-7 all around Laesö show that this must have been a marked event.

32. The island Anholt

About 1/4 of Anholt is a rough area of drift. The other 3/4 is a flat sand and stone desert (Fig. 136). A. Jessen (1897) found that only the high area of drift emerged above the sea during PL, that the whole desert was made up by

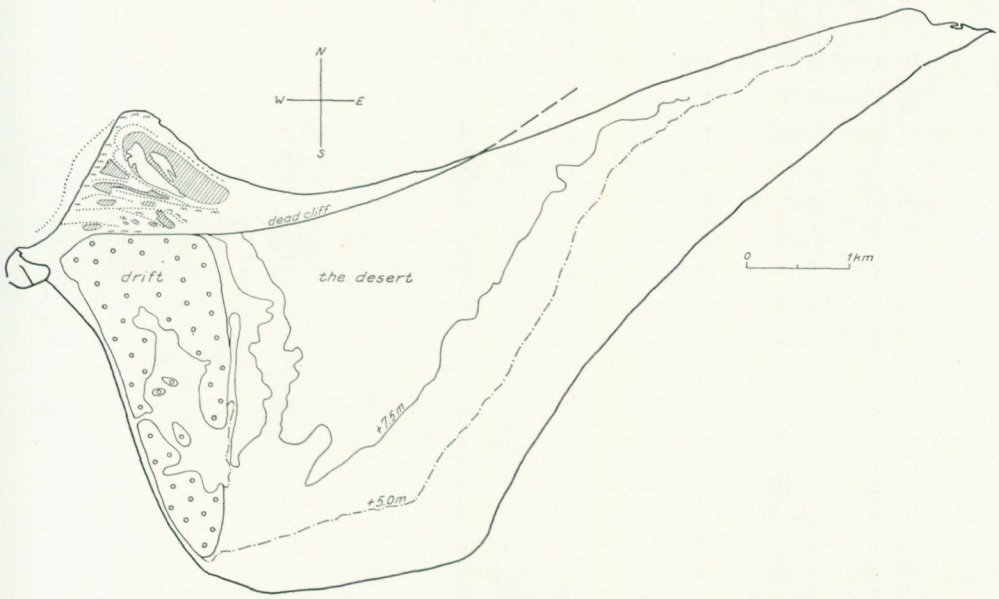


Fig. 136. *Anholt. The rough and steep-sided drift area was formed as an ice marginal deposit of the E4 line. The flat desert area was formed by spits and bars during the time about PTM-3 to PTM-5. The dead cliff corresponds to PTM-7. The NW point of Anholt is young and formed by ridges (dotted lines) and fens (hatched).*

a system of beach ridges and that the depression in the middle of the high area was occupied by a lagoon during PL. At the channel dug from the PL lagoon to the west coast peat has been found at +0.2 m below 0.8 m of marine clay.

I tried to fix the highest shore level in the "lagoon" (by six borings and 14 measurements with aneroid barometer). B 778b at +2.5 m showed the following stratigraphy:

A: 0.3 m of mould (peaty)
B: 0.15 m of kiselgur
C: 0.30 m of grey sea sand
D: 0.50 m of grey silty clay with marine shells (e. g. *Mytilus*)
E: 0.50 m of grey sea sand

My efforts only showed the presence of a shore level at about +3.5 m. However, this level corresponds to PTM-7, which is very well registered as a distinct dead cliff along the northern side of Anholt, (Fig. 136). This means a good agreement with the shoreline diagram that here says PTM-7 = +3.4 m.

According to the shoreline diagram PL would fall at +6.4 m. As all the shorelines from PTM-3 to PTM-5B lie within 0.9 m below PL, there is a long time available for the formation of the desert, which consists of a system of sand and stone ridges (probably as "rimmer og dopper"). The NW part of Anholt is today rapidly growing out in the same way, i. e. one spit is added to the other with a fen or lagoon between (Fig. 136).

33. Dates of the PTM shorelines in some Baltic areas

At Ramsås (near Mönsterås) Munthe (Munthe and Hedström 1904) found peaty dy below 2 m of shingly sand of the Litorina beach ridge. The uppermost part of the peaty dy was C^{14} dated by G. Lundqvist (1957) at 5,075 ±110 BC, i e. in full agreement with my date of PTM-2.

On the island of Gotland G. Lundqvist (1965) has made several C^{14} datings in order to date the Litorina transgressions. The dates vary very much, but Lundqvist thought that two main transgressions can be distinguished, viz. LG 1 = 4,500 BC and LG 2 = 4,000 BC. Von Post's (1903) very important section across the Litorina beach ridge at Snoder complimented with Lundqvist's C^{14} dates offer a very good and interesting picture. The following stratigraphy is taken from the inner side of the section, where the datings were made:

A: Peat = PR-6 and younger.
B: Sand, the innermost part of von Post's beach ridge no. 2 that contains some marine shells = PTM-5 (at about +16.0 m).
C: Peat = PR-5. The uppermost part was C^{14} dated at 3,290 ±85 BC (St-1585), i. e. the time just before PTM-5. In the outer part of the section PR-5 is represented by eolian sand (possibly with stubs in situ).
D: Brackish mud containing shells of *Cardium edule*, *Mytilus edulis* and *Hydrobia ulvae* = PTM-4 (at about +14.0 m).
E: Quite lacustrine lake marl C^{14} dated at 4,045 ±85 BC (St-1584) = PR-4.

F: Slightly brackish (or lacustrine) mud = the end of PTM-3 or beginning of PR-4.
G: The proper beach ridge containing several marine shells = PTM-3 (the outer part = PTM-4).
H: Peat, the uppermost part was C^{14} dated at 4,680 ±80 BC (St-1582), i. e. the time just before PTM-3, and the lowermost part was C^{14} dated at 5,800 ±90 BC (St-1583), i. e. the time of the onset of the PTM-2 transgression.

The agreement with my PTM shorelines is almost exact. However, this interpretation also gives many interesting aspect upon the shorelevel displacement on Gotland:

The onset of the PTM-2 transgression caused peat formation at about +11 m.
PTM-2 did not reach above +11.5 m.
PTM-3 reached up to about +14.0 m and deposited the gravelly beach ridge (at least the inner part).
PR-4 meant quite lacustrine environment in Mästermyr.
PTM-4 meant brackish environment in Mästermyr; probably it deposited the outer part of the gravelly beach ridge.
PR-5 meant a distinct regression with peat formation inside and dune formation outside the old beach ridge.
PTM-5 meant a distinct transgression and deposition of the sandy beach ridge. The corresponding sea level was about +16.0 m.

This seems to be a good base and beginning of the reinterpretation of the Postglacial shorelevel displacement in the Baltic area, which this description has shown to be necessary.

In Södermanland (eastern Middle Sweden) S. Florin (1959) has C^{14} dated the maximum of the first Litorina transgression (L I), viz. in Bygdslättens Mosse = 4,870 ±120 BC to 5,020 ±120 BC and in Källtorpsmossen = 4,990 ± 130 BC. This means full agreement with my PTM-2.

According to the C^{14} dated curve of land upheaval in Hälsingland by G. Lundqvist (1962, 1963), a lake at +103.5 m was at 4,800 ±140 BC isolated from the brackish Litorina Sea, while a lake at +108 m was at 5,210 ±140 BC isolated from the Ancylus Lake. This means that the saltwater reached Hälsingland at about 5,000 BC, i. e. at PTM-2 (the very maximum of the second Postglacial maximum). Lundqvist's curve of land upheaval also shows the following:

"Knee" at about 4,000—3,700 BC before a rapid regression = PTM-4
Very rapid regression about 3,700—3,500 BC = PR-5
Flattening out to slow regression = PTM-5 at 3,000 BC
"Knee" before rapid regression at about 2,000 BC (or somewhat later = PTM-6
Rapid regression before 1,530 ±80 BC = PR-7
Flattening out to slow regression at 1,530 ±80 BC = PTM-7
A weak "knee" at about 360 ±140 BC = PTM-9

Consequently, stagnations and regressions in the eustatic curve are here seen as rapid regressions, while transgressions are seen as retardations in the land upheaval.

The first appearance of brackish diatoms of the Litorina Sea in the Postglacial varved sediments in Ångermanland (northern Sweden) that Lidén (1913) had dated geochronologically, was by Fromm (1938) found to occur at 5,000—5,100 BC. A comparison with G. Lundqvist's C^{14} datings shows partly that the first appearance of brackish diatoms here occurred at PTM-2 and partly that there consequently seems to be little (+ 100 years) or no difference between the radiocarbon method and the geochronology at ages about 5,000 BC. (cf. p. 179). At about 4,600 BC the diatom flora suggests a salinity maximum. This could correspond to PTM-3 (A at 4,500 BC or B at 4,300 BC).

Consequently, the results by Fromm and G. Lundqvist have shown that the so-called *Clypeus* limit in northern Sweden does not correspond to the ingression of saltwater in Öresund but to the maximum of the second Postglacial transgression, i. e. PTM-2.

34. Dates of the PTM shorelines in Southern Norway

On Jaeren, Faegri (1940) found two Tapes transgressions separated by a regression. According to Faergri the younger transgression, dated to the zone boundary AT/SB, corresponds to Söborg IV in Denmark (i. e. my PTM-5), while the older transgression, not closely dated, could correspond to Söborg II (i. e. my PTM-4).

On Bömlo Faegri (1944) also found two Tapes transgressions separated by a regression (in Eidetjönn at +8.0 m). Faegri parallels these transgressions with Söborg II and Söborg III—IV, which means my PTM-4 and PTM-5 separated by the distinct regression of PR-5.

C^{14} datings and pollen analyses in some localities in Southern Norway show the presence of several transgression waves, viz. the following:

1. Localities submerged by the PTM-1 (ALV-2) transgression:
   Dostad +2 m (Gabrielsen 1959), intermarine peat and mud at +0.5 to −1.2 (roughly corresponding to ALV-1): The transgression contact was C^{14} dated at 6,820 ±100 BC.
2. Localities submerged by the PTM-2 transgression:
   Sigersvoll (Sollersnes † and Faegri 1951), submarine peat at −0.75 m below clay and shore deposits: The peat belongs to zone V-VI and thus seems to have been transgressed by PTM-2.
   Oddernes +5 m (Hafsten 1958), peat of zone V below marine clayey mud of zone VI—VIII: The transgression contact corresponds to the zone boundary V/VI (A^0). Probably the transgression corresponds to the onset of the PTM-2 transgression, This means that the onset of the *Alnus* curve is here somewhat younger than in Sweden.

Oftenes +5 m (Trondheim III), intermarine peat: The uppermost part of the peat was C^{14} dated at 6,350 ±250 BC (T-273).

Vaage +0.5 m (Trondheim III), peat below marine sediments: The uppermost part of the peat was C^{14} dated at 6,000 ±170 BC (T-208).

Aa +0—2.5 m (B. G. Andersen 1960), 2 m marine-brackish mud above sand and gravel: The lowermost 5 cm was C^{14} dated at 5,830 ±190 BC, i. e. the onset of the PTM-2 transgression.

Ravnemyr +4 m (Trondheim III), marine sediments between peat: The transgression contact was C^{14} dated at 5,450 ±250 BC (T-209), i. e. the time of the transgression up to PTM-2, and the isolation level was C^{14} date at 1,100 ±100 BC (T-281), i. e. PR-8.

3. Localities submerged by the PTM-3 transgression:

Lannesmyra +8 m (Trondheim III); shell fragments below peat were C^{14} dated at 4,850 ±170 BC (T-292). With "sea correction" this means PTM-3

4. Localities submerged by the PTM-4 transgression:

Nesheim (B. G. Andersen 1960), a beach ridge at +7.8 m resting upon stumps and mud above an *Ostrea* bank at about +1 m: The shells have been C^{14} dated at 4,470 ±160 BC. With "sea correction" this means PTM -3 to PTM-4. Then the mud and stumps belong to the regression of PR-5 and the beach ridge — the Tapes limit on Lista — was formed by PTM-5.

35. The sequences of ingression at the coasts of the Netherlands, Niedersachen and Schleswig—Holstein

These areas have been investigated by several scientists. However, I will here only deal (briefly) with some of the latest and concluding papers based upon a lot of C^{14} dates (e. g. Jelgersma 1961, Müller 1962 and Brand *et al.* 1965).

The ingression of the sea at the Dutch coasts has been given a thorough description by Jelgersma (1961) based upon pollen analyses and a great number of C^{14} dates. However, all the C^{14} dates have to be corrected to the Suess effect (see Gronningen IV). Of course, this is not my territory, but still a brief outline of the development — as suggested by the corrected C^{14} dates — will here be given:

1. Transgression at −22.5 m C^{14} dated at 5,830 ±85 BC (GrN-1057) = the very onset of the transgression up to PTM-2.
2. The Early Atlantic Tidal Flat deposits from 5,800 to about 4,400 BC = PTM-2, PR-3 and early PTM-3. This sequence seems recently to have been documented by a diatom analysed boring at Ooltgensplaat, Weipolderse-Gors 410/83 (Hageman 1968, Fig. 3c); PTM-2 = clay with brackish diatom flora at −12.7—13.8 m, PR-3 = peat at −12.1—12.7 m and PTM-3 = peak of marine diatoms at −11.5 m at the bottom of the Calais deposits (= PTM-3 to PTM-6).

3. Peat formation at –9.0—10.3 m at about 4,400 BC; viz. 4,370 ±80 BC (GrN-1620), 4,380 ±170 BC (GrN-639) and 4,440 ±95 BC (GrN-1621) = late PTM-3 (B) and PR-4.
4. The Late Atlantic Tidal Flat deposits ending 3,470 ±70 BC (GrN-1143) in Zuidland at –6.9 m = PTM-4.
5. Peat formation about 3,500—3,000 BC = PR-5.
6. In Profile XII between Lodderland and Zuidland the peat (C^{14} dated at 3,470 ±70 to 2,830 ±90 BC) between the Early Sub-Boreal Tidal Flat deposits and the Late Atlantic Tidal Flat deposits is split up into two separate peat layers. The Tidal Flat deposits between these peat layers might perhaps be equivalent to PTM-4.5.
7. The Early Sub-Boreal Tidal Flat deposits about 3,000—2,400 BC. The lower ingression contact has been C^{14} dated at 3,045 ±110 BC at –6.75 m (GrN-655), 3,025 ±190 BC at –5.9 m (GrN-601) and 3,010 ±90 BC at –3.9 m (GrN-1060). The onset of the upper peat formation has been C^{14} dated at 2,430 ±85 BC at –4.1 m (GrN-1098), 2,450 ±140 BC at –6.0 m (GrN-1142), 2,350 ±150 BC at –4.3 m (GrN-499), 2,310 ±110 BC at –5.0 m (GrN-656), 2,400 ±150 BC at –4.25 m (GrN-633) and 2,370 ±75 BC at –4.35 m (GrN-1135) = PTM-5.
8. Peat formation starting at about 2,400 BC = PR-6.
9. Continuation of the Early Sub-Boreal Tidal Flat deposits in Koegras at –3.55 m to 2,015 ±130 BC (GrN-460) and in Uigeest at –3.65 m to 2,190 ±80 BC (GrN-1649) = PTM-6.
10. Peat older than 1,890 ±85 BC at –3.75 m (GrN-1096) in Lodderland = PR-7.
11. Late Sub-Boreal Tidal Flat deposits C^{14} dated in Lodderland at 1,890 ±85 BC at –3.75 m to 950 ±70 BC at –2.15 m (GrN-1095) = PTM-7, PR-8 PTM-8.
12. Peat formation about 950—700 BC = PR-9.
13. The Early Sub-Atlantic Tidal Flat deposits starting at 695 ±75 BC at –1.9 m (GrN-1094), 585 ±130 BC at –2.5 m (GrN-463) and 450 ±150 BC at –4.0 m (GrN-619) = PTM-9.
14. Peat formation ending 245 ±75 AD at –1.3 m (GrN-1093) and habitation layer dated at about 200 BC to 200 AD = PR-10.
15. The Late Sub-Atlantic Tidal Flat deposits = PTM-10 complex, recently subdivided as described on p. 422.

Consequently, there seems to be a good agreement between the ingression of the North Sea at the Dutch coasts and the shorelevel displacement found by me (cf. Fig. 138).

The ingression of the sea at the coast of Niedersachsen has been thoroughly described by W. Müller (1962). His results are based upon a great

number of C^{14} dates. Müller found nine separate ingression (transgression) waves. However, the C^{14} dated sections at Elsfleth and Nordenham give a somewhat different picture. Thus a brief outline will be made.

If the C^{14} dated stratigraphy of Elsfleth (A), Nordenham (B) and Stade (C) are compared the following development seems likely:

1. ingression of the sea at about −10.5 m 4,710 ±120 BC (in B) = shortly after PTM-2.
2. ingressivum *m 1* 4,700—4,300 BC = PTM-3
3. peat formation 4,300—4,000 BC (in A and B) = PR-4
4. ingressivum *m 2a* 4,000—3,400 BC (in B) = PTM-4
5. peat formation 3,400—3,200 (in B) = PR-5
6. ingressivum *m 2b* 3,200 (in B) to 2,900 (in A and C) = PTM-5A
7. peat formation 2,900—2,750 BC (in A and C) = regression PTM-5A/B
8. ingressivum *m 3a* 2,750—2,450 BC = PTM-5B
9. onset of peat formation at 2,450 BC (in B) = PR-6
10. ingressivum *m 3b*, continuation of m 3 to 2,000 BC (in A) = PTM-6
11. peat formation 2,000—1,650 BC (in A) = PR-7
12. ingressivum *ju 1* 1,650—1,300 BC (in A, starting somewhat earlier in B and C) = PTM-7
13. peat formation 1,300—1,100 BC (in A and C) = PR-8
14. ingressivum *ju 2* 1,100—950 BC = PTM-8
15. regression = PR-9 (+ younger stages)

Consequently, there seems to be a strikingly good agreement between the devlopment in Niedersachsen and my PTM shorelines (cf. Fig. 138).

The ingression of the sea at the coasts of Schleswig-Holstein has been described by Brand *et al.* (1965). However, the C^{14} dates (Hannover V) suggests a more complicated picture:

1. Forest peat below silty clay of the Barlet bed in Meldorf has been C^{14} dated at 7,280 ±130 BC (Hv-184), i. e. the Barlet bed seems here to be equivalent to PTM-1.
2. Forest peat below silty clay of the Eesch bed in Meldorf has been C^{14} at 5,875 ±100 BC (Hv-183), i. e. the time of onset of the PTM-2 transgression.
3. Ingression at Wallen at 4,995 ±90 BC (Hv-628), i. e. at about PTM-2.
4. Ingression at Husum at 4,400 ±80 BC (Hv-224) = at PTM-3.
5. Peat formation ending in Delve at 4,180 ±85 (Hv-629) and in Husum at 4,100 ±170 BC (Hv-232) = PR-4.
6. Ingression at Delve and Husum (see 5) by the Fiel bed about 4,150 BC and at Husum by the IIb flooding about 3,980 ±90 BC (Hv-226) = PTM-4.
7. Peat formation in Meldorf at 3,530 ±135 BC (Hv-181) = PR-5.

8. The second transgression in Delve ending at 2,445 ±100 BC (Hv-631) and the later part of the Fiel bed in Husum ending at 2,500 ±80 BC (Hv-219) = PTM-5.
9. Peat formation starting at about 2,500 BC in Delve and Husum (see 8) = PR-6.
10. In Meldorf the Husum bed ends at 2,210 ±125 BC (Hv-179). The final part may correspond to PTM-6.
11. Peat formation ending at about 1,700 BC = PR-7.
12. The Meldorf bed starting at 1,670 ±115 BC (Hv-241), 1,720 ±100 BC (Hv-215), 2,050 ±80 BC (Hv-299) and 1,690 ±85 BC (Hv-764) and ending at 1,160 ±80 BC (Hv-242) = PTM-7.
13. Peat formation starting at about 1,150 BC (see 12) and ending at about 700—500 BC (see 14) = PR-8, PTM-8 and PR-9.
14. The Schwabstedt bed starting at 740 ±105 BC (Hv-176), 570 ±90 BC (Hv-237) and 455 ±80 BC (Hv-766) and ending at 125 ±50 AD (Hv-243) = PTM-9.
15. Peat formation at about 125—850 AD = PR-10.
16. The "first post Christian transgression" starting at 860 ±90 AD (Hv-231) = PTM-10 (complex).

Consequently, there seems to be a good agreement between the development in Schleswig-Holstein and my PTM shorelines (cf. Fig. 138). The date of the Barlet bed to PTM-1 is important for a comparison with my ALV-2 (PTM-1) shoreline. However, the altitude is not known.

36. The shorelevel displacement in Northern Norway according to Marthinussen

With a careful investigation over a big area Marthinussen (1960) worked out an isobase system and a shoreline diagram over Northern Norway. In this area, with less resistant rocks, less vegetation and arctic climate, the shorelines are unusually distinct. Marthinussen found four Tapes shorelines (Tapes I—IV) and five younger shorelines (N5—N1). With C^{14} datings of driftwood from the different shorelines and peat below shore deposits Marthinussen (1962) succeeded in working out a good chronology. The following dates are available for the younger portion:

5,800 ±150 BC (T-182), Tomaselv; peat below shore gravel = onset of the PTM-2 transgression.

5,450 ±150 BC (T-270), Ramsås I; peat below shore deposits of Tapes I = transgressed during the PTM-2 transgression.

4,400 ±150 BC (T-185), Djupdalen; driftwood on Tapes IV = (the time of PTM-3).

4,300 ±200 BC (T-267), Nord-Mjele; driftwood on Tapes II = PTM-3.

4,150 ±150 BC (T-296), Ramsås II; peat between shore deposits of Tapes

II and Tapes III = PR-4 (distinct regression).

3,750 ±150 BC (T-184), Börfjordbotn; driftwood on Tapes III = PTM -4.

3,550 ±150 BC (T-183), Börfjordbotn; driftwood on Tapes III = PTM-4B.

2,870 ±160 BC (T-126), Oldervik; driftwood on Tapes IV = PTM-5.

2,550 ±150 BC (T-266), Nöss; driftwood on Tapes IV = PTM-5B.

2,150 ±100 BC (T-186), Saraberget; driftwood on N 4 = PTM-6.

2,150 ±150 BC (T-244), Lyngpollen; driftwood on N 4 = PTM-6.

550 ±100 BC (T-243), Austbotn; driftwood on N 2 = PTM-9 just before the beginning of the Sub-Atlantic time, which meant a climatic deterioration reflected in the eustatic curve (p. 425).

The shorelevel displacement and isostatic land upheaval are closely dealt with on p. 427 (cf. Fig. 150).

37. The shorelevel displacement in Eastern Bleking (SE Sweden) according to Berglund

With pollen analysis, diatom analysis, C^{14} datings and studies of some shore marks Berglund (1964) has worked out a detailed and well dated shorelevel displacement curve. Berglund thought that some of the C^{14} dates of Litorina sediments should be corrected ("sea correction") by 200—400 years to get agreement with the pollen diagram. However, a comparison with my dates shows that there is full agreement with the C^{14} dates. This suggests that the zone boundary AT-2/SB-1 should be raised. A position of this zone boundary in Hallarums Mosse BP I at analysis no. 89—88 (*Pinus* and *Corylus* fall, *Betula* and *Alnus* rise) seems likely (no distinct *Ulmus* decline is present). Also minor reinterpretations of the diatom diagrams concerning the PTM-2 and PTM-3 equivalents seem necessary. Thus Berglund's results from Hallarums Mosse show the following (Fig. 137):

1. Maximum of diatoms of shallow Litorina bay C^{14} dated at 5,000 ±90 BC (lower part of his AT-1 transgression) = PTM-2.
2. Minimum of diatoms of shallow Litorina bay and maximum of diatoms of Litorina lagoon = PR-3.
3. Maximum of diatoms of shallow Litorina bay C^{14} dated at 4,445 ±150 BC (upper part of his AT-1 transgression) = PTM-3A.
4. Maximum of diatoms of Litorina lagoon = regression during PTM-3, between PTM-3A and PTM-3B (cf. Lerberget at Höganäs, p. 356, and Eskilstorps p. 333).
5. Maximum of diatoms of deep Litorina bay C^{14} dated at 4,270 ±85 BC (his 1 AT-2 transgression) = PTM-3B.
6. Maximum of diatoms of shallow Litorina bay = PR-4.
7. Maximum of diatoms of deep Litorina bay C^{14} dated at 3,995 ±75 BC (his 2 AT-2 transgression) = PTM-4A.

8. A slight maximum of diatoms of deep Litorina bay (no distinct minimum between 7 and 8) C^{14} dated at 3,715 ±85 BC (his 1 SB-1 transgression) = PTM-4B or PTM-4.5 (if the date is a little too old).
9. Maximum of diatoms of shallow Litorina bay = PR-5
10. Maximum of diatoms of deep Litorina bay C^{14} dated at 3,090 ±85 BC (his 2 SB-1 transgression) = PTM-5A.
    The diatoms of deep Litorina bay continue from PTM-5A with three maxima about 40 cm up to a distinct gap overlaid by peat.
11. Maximum of diatoms of deep Litorina bay just below the gap C^{14} dated at 2,635 ±70 BC (after his 2 SB-1 transgression) = PTM-5B.

In BP I there is a gap at +1.8 m starting in connection with PR-6. In the central part (BP II) the marine sedimentation continued until the beginning of PR-8. PTM-7 is probably distinguishable in the pollen diagram of BP II as the peaks of *Chenopodiaceae* and *Hystrix* just above the zone boundary SB-1/2.

In the fen Inlängans Mosse (threshold at +4.5—5.0 m) the following succession was found:

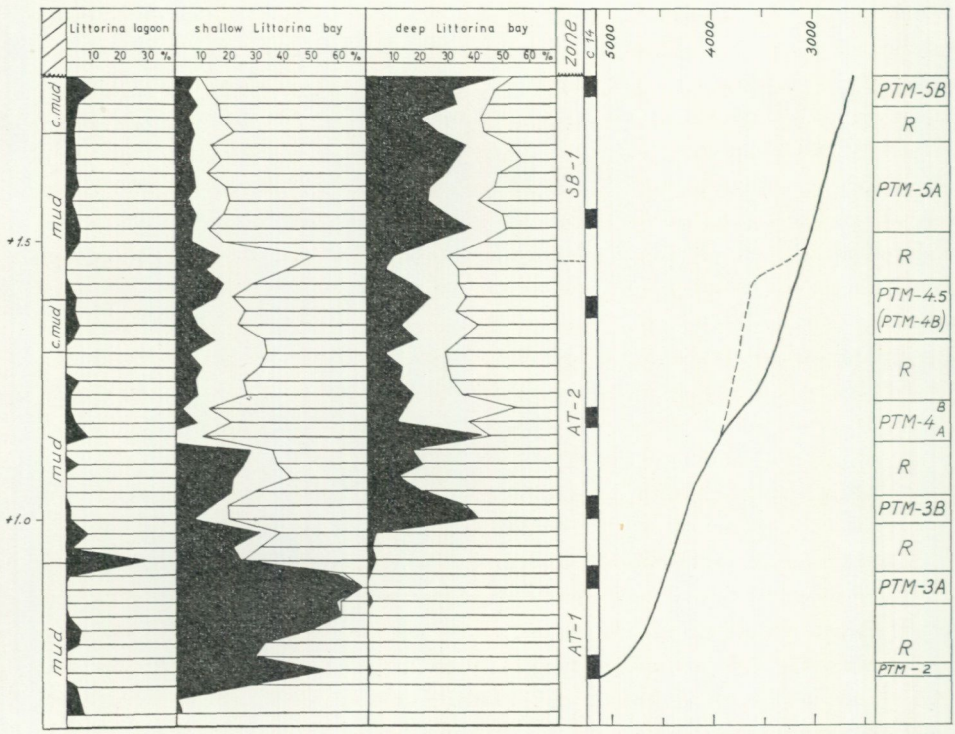


Fig. 137. *Diatom diagram from Hallarums Mosse BP 1, Eastern Blekinge. The changes in salinity and C^{14} dates closely correspond to the shorelevel displacement here described, indicating a necessary reinterpretation of Berglund's original shorelevel displacement curve.*

1. Sand = PR-6 (regression before 3 SB-1 transgression according to Berglund).
2. Lower part of brackish sediments C^{14} dated at 2,220 ±75 BC = PTM-6.
3. Lacustrine mud just above the brackish mud C^{14} dated at 1,195 ±65 BC = PR-8.

Consequently, the brackish mud contains both PTM-6 and PTM-7. The zone boundary SB-1/2, in the middel of the brackish mud, was C^{14} dated at 1,595 ±65 BC.

The section across the Litorina beach ridge at Björkärr shows the following succession according to my interpretation:

1. Ridge I (probably double) reaching +6.3 m = PTM-4A, PTM-4B and PTM-4.5.
2. "Humus rich sand" (probably pitchy soil) = PR-5.
3. Ridge II (double) reaching +7.0 m = PTM-5A, forming PL.
4. Ridge III reaching +6.3 m = PTM-5B.
5. Habitation, pitted-ware (Säter III) culture, recently (Lund I) C^{14} dated at 2,210 ±100 BC (Lu-28), 2,300 ±100 BC (Lu-36) and 2,490 ±100 BC (Lu-38) = PR-6.

Berglund measured the altitude of several Litorina beach ridges in Eastern Blekinge. According to my interpretation they shall be dated as follows:

1. The highest beach ridges = PTM-5A, forming PL at about +7.0 m.
2. The second highest beach ridges = PTM-5B.
3. The third highest beach ridges = PTM-6, and often also PTM-7.

At Ekenäs, Late Neolithic cists reach down to +5.5—6.0 m, which means that PTM-7 must lie below this level.

On the island Öppenskär a fen with its pass threshold at +2.2 m was isolated at the zone boundary SB-2/SA-1, i. e. during PR-10.

Consequently, there is after certain reinterpretation an almost exact agreement between Berglund's and my results (Figs. 137 and 138). The shorelevel displacement curve obtained after these reinterpretations is given in Fig. 149.

Final remarks on the PTM shorelines

Morphologically (shorelines), stratigraphically (transgressions/regressions) and with pollen analyses and a lot of C^{14} datings it has been possible to give a very detailed picture of the Postglacial shorelevel displacement over a very big area (about 350 km in the direction of tilting). The picture obtained has also been shown to apply to many other areas. The shorelevel displacement after 5,800 BC is summarized below:

5,800 BC = onset of the PTM-2 transgression (continuous up to PTM-2).

This onset is very well determined in the Viskan Valley, but the same

age has been obtained in several other areas, e. g. Gotland, Northern Norway, Southern Norway, the Netherlands and Schleswig-Holstein.

5,100—4,950 BC = PTM-2. This maximum is well dated in the section at Eskilstorp, but the same result has been found in other areas, as Eastern Blekinge, Södermanland and Northern Sweden.

PR-3 after 4,950 BC. This regression is well determined and dated in the section at Eskilstorp.

4,500—4,300 BC = PTM-3. This maximum was dated at Eskilstorp and Höganäs. It is also dated in Gotland, Northern Norway and Eastern Blekinge. At Eskilstorp, Höganäs and Eastern Blekinge it is seen as two maxima, viz. PTM-3A at about 4,500 BC and PTM-3B at about 4,300 BC. However, only one shoreline was observed. In Söborg Sö only PTM-3B reached above the threshold, indicating a difference in altitude at this isobase latitude between PTM-3A and PTM-3B.

PR-4 at about 4,300—3,950 BC. This regression was found in many places. It is also seen in other areas as Gotland, Eastern Blekinge, Northern Norway, Niedersachsen and Schleswig-Holstein.

3,950—3,600 BC = PTM-4A and PTM-4B. The onset of this transgression was dated in Torekov. The transgressivity is still large at the isobase latitude of Gothenburg. It is a clear double maximum (two shorelines, double maximum in Söborg Sö, etc.). It is also seen in other areas as Gotland, Eastern Blekinge, Northern Norway and at the northeastern coasts of the North Sea.

PR-5 about 3,600—3,025 BC. This regression is well determined. It seems to have been interrupted by the oscillation of PTM-4.5 (= Söborg III) at about 3,250 BC. It is also seen in other areas, as Eastern Blekinge, Gotland, Northern Norway and the northeastern coasts of the North Sea.

3,025—2,600 BC = PTM-5A and PTM-5B. PTM-5A was dated in Torekov (also in Eastern Blekinge). The continuation to PTM-5B is dated in Northern Norway and Eastern Blekinge. Between PTM-5A and PTM-5B is a clear regression (e. g. Torekov, Söborg Sö and Niedersachsen). It is also seen in other areas as Gotland, Eastern Blekinge, Northern Norway, Southern Norway and the northeastern coasts of the North Sea.

PR-6 about 2,600—2,300 BC. This regression is seen in several localities. It is also seen in other areas as Gotland, Eastern Blekinge, Northern Norway and the northeastern coasts of the North Sea.

2,300—2,000 BC = PTM-6. This maximum is dated pollen statistically by T. Nilsson, but with C^{14} in Eastern Blekinge and Northern Norway. It may also be seen at the northeastern coasts of the North Sea.

PR-7 about 2,000—1,650 BC. This regression is via pollen analysis indirectly C^{14} dated. It is well determined also at the northeastern coasts of the North Sea (but not seen in Eastern Blekinge).

1,650—1,300 BC = PTM-7. The shoreline is very distinct and the transgression is seen in Björkö Mosse. PTM-7 is connected to the immigration of a new boreo-lusitanic mollusc fauna. Probably the eustatic curve now reached just above the present sea level. Thus PTM-7 seems to correspond to the climatic optimum. PTM-7 is very well determined along the northeastern coasts of the North Sea. It corresponds to Fairbridge's Younger Peron Submergence.

PR-8 about 1,300—1,100 BC. This regression is well determined. At the beginning of PR-8 most of the boreo-lusitanic molluscs that immigrated during PTM-7 (and PTM-6) had already disappeared. Probably there is also a fall in the eustatic curve (p. 422). Thus PR-8 seems to correspond to a climatic deterioration. PR-8 is also seen in Eastern Blekinge, Niedersachsen and Schleswig-Holstein. It corresponds to Fairbridge's Crane Key Emergence.

1,100—950 BC = PTM-8. This maximum is represented by a shoreline at the mouth of River Viskan, the continuation of which is not yet closely investigated, however. PTM-8 is seen in Praestö Fiord, the Netherlands, Niedersachsen and Northern Norway.

PR-9 about 950—700 BC. This regression is seen in Praestö Fiord, the Netherlands, Niedersachsen and Schleswig-Holstein. It corresponds to Fairbrige's Pelham Bay Emergence.

PTM-9 about 700 (500) to 250 BC. This is a distinct maximum. It is seen as 1—2 shorelines at the mouth of River Viskan and as maxima in Praestö Fiord, the Netherlands, Schleswig-Holstein and Northern Norway (the N2 line). It corresponds to Fairbridge's Abrolhos Submergence. This maximum has two peaks, viz. PTM-9A at about 500 BC and PTM-9B at about 250 BC.

PR-10 after 250 BC (i. e. = the early Sub-Atlantic time). Regression in Praestö Fiord and the Netherlands. It corresponds to Fairbridge's Florida Emergence.

PTM-10 complex. Several minor maxima can probably be distinguished in Sub-Atlantic time. In the Netherlands the rise of sea level starts at about 250 AD and in Schleswig-Holstein at about 850 AD. Fairbidge's Rottnest Submergence was dated at about 350—950 AD. The shoreline at the mouth of River Viskan was estimated at about 750 AD. The maxima in Praestö Fiord seem to be younger.

In Fig. 138 transgressions/regressions found by this investigation on the Swedish West Coast, in Kattegatt and in Denmark have been compared with Marthinussen's results in Northern Norway (Tapes I dated with PTM-2), Berglund's results in Eastern Blekinge (somewhat reinterpreted), Jergersma's results in the Netherlands (corrected dates), Müller's results in Niedersachsen and Brand's results in Schleswig-Holstein (recent dates added). This comparison clearly

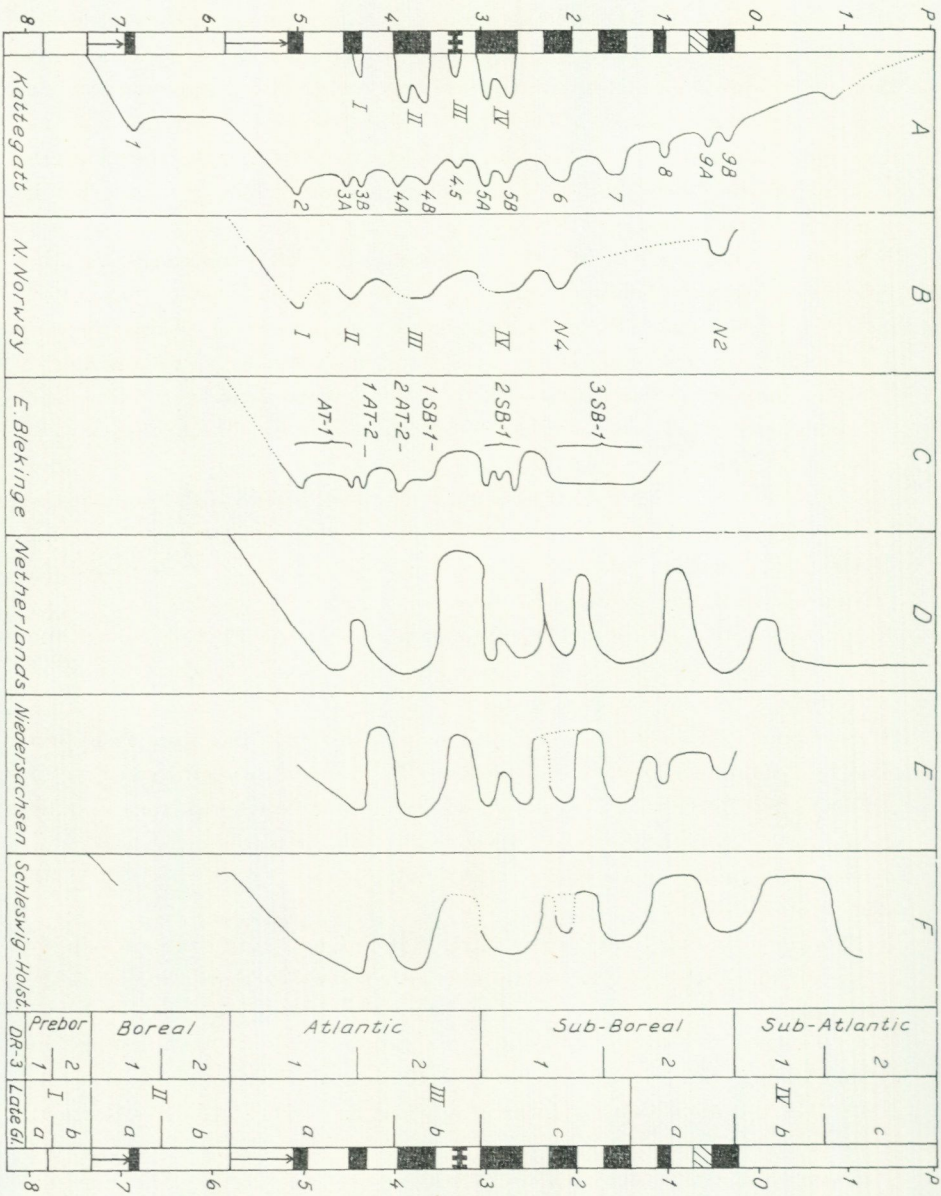


Fig. 138. *Postglacial transgressions, PTM (= black areas), and regressions, PR, from different North European areas. Scale does not represent amplitude of the fluctuations. A = the results here presented (I-IV correspond to Söborg Sö). The amplitude and age of these fluctuations are closely fixed in Figs. 147 and 145. B = Marthinussen's cure, not altered. The altered curve (Fig. 150) gives a much more detailed picture. C = Berglund's curve, altered (cf. Fig. 149). D-F = approximate curves from C^{14} dated peat layers on the NE coasts of the North Sea. Recent results from the Netherlands indicate a further detailed picture, though the amplitude cannot yet be established in these areas. The second last column gives the pollen zones. The last column gives the division here proposed according to climatic-eustatic reasons.*

shows that my picture of transgression/regressions also applies to other areas.

The onset of the distinct transgressions of PTM-1 and PTM-2 must mean worldwide climatic ameliorations and thus ought to give the beginning of the Boreal (7,330 BC) and Atlantic (5,800 BC) time respectively. The Preboreal time ought to be divided into PB-1 and PB-2 at about 7,750 BC, where the *Corylus* curve (C^0) starts on the Swedish West Coast (at about 7,330 BC the *Corylus* curve makes a distinct increase). Sea also p. 17 and 424.

In the last column of Fig. 138 a subdivision of the Holocen (or the Holocen Kattegatt formation) is proposed (cf., e. g. Dechend 1961, Lüttig 1960, 1967, Müller 1962, Brand *et al.* 1965). Zones I—IV correspond to the Postglacial and zones II—IV to the Holocene (cf. p. 424). This division is more closely dealt with in a special paper (Mörner 1969).

Isostasy and eustasy

The shorelevel displacement is the result of crustal movements (= isostasy) and changes in the ocean level (= eustasy).

As mentioned introductorily my intention has been to work out a very detailed, well fixed and closely dated shoreline diagram over a large area, giving shorelevel displacement curves from several different isobase latitudes, from which the isostatic and eustatic causes could later be calculated.

The crustal movements may be of different types. In this area it is a restoration of the equilibrium in the earth's crust before the glaciation, which meant a corresponding downward pressing of the earth's crust. When I started this investigation I thought that the isostatic land upheaval should form a smooth curve — at least in its earlier more intensive part. However, the present investigation has shown a more complicated isostasy.

The position of the ocean level is related to the glaciation in the world — the glacial-eustatic theory. It has often been stated that only a "stable area" can give information about the eustatic sea level. However, submarine studies can only give approximative curves. The details must be studied in a suitably uplifted area. But this requires a well fixed and closely dated shoreline diagram, where shorelevel displacement curves from different isobase latitudes can be used.

Introductory discussion about the land upheaval

All the shorelines found are tilted from NE towards SW, having the direction of tilting in N 40° E.

Tilted shorelines may be of the following appearence (Fig. 139 A no. 1—3):

1. straight lines if the land upheaval decreased evenly towards the periphery
2. curved lines if the upheaval decreased continuously towards the periphery
3. undulated lines if the upheaval was disturbed by local variations

The shorelines found are all straight lines bent at one point (Fig. 139 A, no. 4).

An important question is how a tilted shoreline reaches the corresponding eustatic depth. The following alternatives are possible (Fig. 139 B, no 1—4):

1. The shoreline intersects the eustatic level as a straight line without changes in tilting. Of course, somewhere the shorelines must bend and return to the eustatic depth. And this probably does not occur far below the eustatic depth. Thus this type seems very unlikely, though it is presupposed in many shoreline diagram, e. g. by E.Nilsson (1953, 1968) and Hyyppä (1963, 1966).

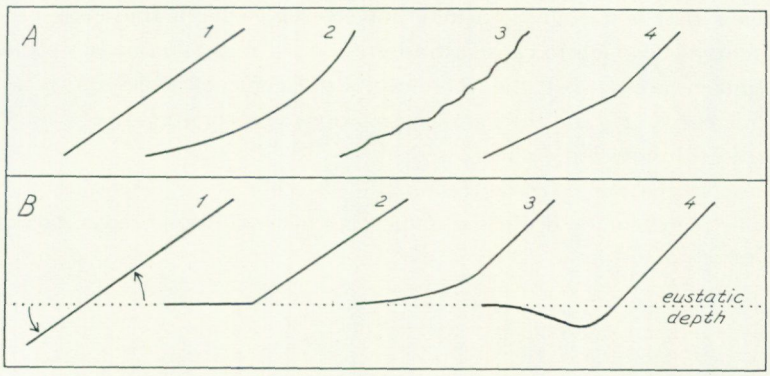


Fig. 139. *A. Different types of tilted shorelines. No. 4 applies in this area. B. Various models of how the tilted shorelines reach the corresponding eustatic depth.*

2. The tilted shorelines turn over into the eustatic depth with a hinge.
3. The tilted shorelines curve smoothly over into the eustatic depth.
4. The tilted shorelines just pass (as slightly curved or straight lines) the eustatic depth and then curve up to the eustatic depth.

Only shorelines of types 3 and 4 seem likely. The shorelines within this area are — totally of partly — of type 4.

Concerning the position of the margin of land upheaval the following alternatives are possible:

1. The margin of land upheaval remains stationary the whole time. In this area this type seems unlikely.
2. The margin of land upheaval is moved inland. The moving inland may occur in the following ways:

2a. An equal movement giving rise to bent shorelines (in the marginal parts).
2b. An unequal movement giving rise to straight shorelines with certain bending points.
2c. A "jumping" inland between certain tectonical lines (e. g. the hinge lines of Sauramo 1942).

As will be shown further on, the land upheaval on the Swedish West Coast is found to be a complicated combination of forces of different types and with changing geographical positions of the margin as well as the centre of land upheaval.

Finally the relation between the eustatic curve and the shorelines in uplifted and sunken areas respectively must be considered (Fig. 140).

In uplifted areas ($I+$) the shorelevel displacement curves ($S+$) lie above the eustatic curve (E) and the following relations apply:

eustatic transgression = decreased, sometimes to syngression or even regression
eustatic stagnation = regression
eustatic regression = increased

This means that a transgression may not be seen, while a flattening out of the eustatic curve is enough to cause a transgression + regression in an uplifted area.

In sunken areas ($I-$) the shorelevel displacement curves ($S-$) lie below the eustitic curve (E) and the following relations apply:

eustatic transgression = increased
eustatic stagnation = transgression
eustatic regression = decreased, sometimes to syngression or even transgression

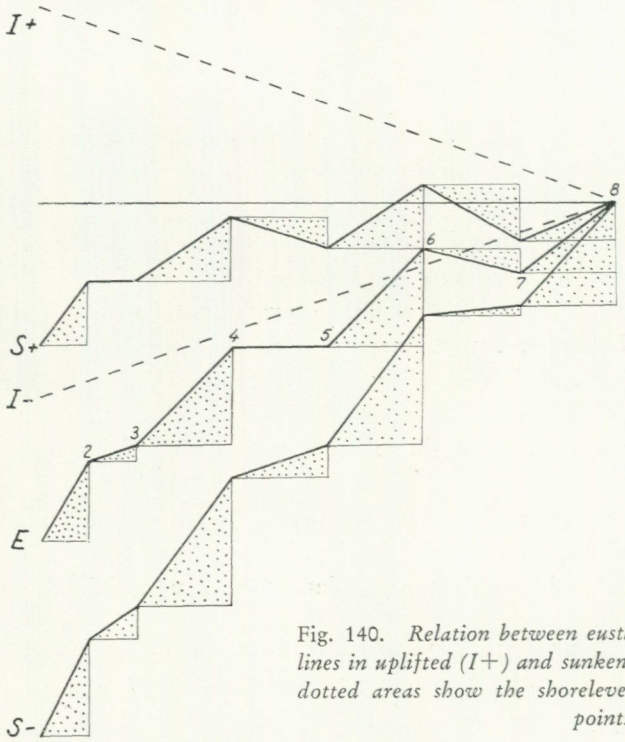


Fig. 140. *Relation between eustatic curve (E) and the shorelines in uplifted (I+) and sunken (I-) areas. The height of the dotted areas show the shorelevel displacement between two points.*

The isobases and direction of tilting

The isobases run very uniformly over most of the area investigated. The direction of tilting is from N 40° E. This fact makes this area very suitable for investigation of shorelevel displacement and isostasy and eustasy.

Along a line 35 km NW of and parallel to the direction of tilting (= the profile line) in the Viskan Valley, the isobases bend and turn towards ENE, having the direction of tilting from N 16° E. Consequently this area is more uplifted, but with a less steep gradient. Apparently this change corresponds to the geographical change from highland above ML to lower areas more or less entirely below ML (Fig. 146). This means that we may here have an indication of a hydro-isostatic component (cf. p. 9 and 420).

In Northern Jylland there was a somewhat different isostasy, as PL lies some metres higher than my diagram suggests (cf. p. 429).

In the area of Djursland—Samsö Belt—NW Sjaelland, PL lies a few metres higher than my diagram suggests, indicating a minor disagreement in isostasy. This disagreement is not found for the older shorelines (too small), which means that it does not grow bigger backwards in time. It probably derives from the time 5,800—5,000 BC, when the bend at –43.4 km was created.

In Eastern Skåne and Blekinge the isobases have changed. Also the proportions between the shorelines are different, showing that relation diagrams cannot be used — at least not in this area.

The shoreline diagrams

The shoreline diagrams (Pls. 4—6) give the shorelevel displacement from the oldest ML in Sweden at about 11,750 BC up to PTM-7 at about 1,500 BC, i. e. over a period of more than 10,000 years. In my opinion the shorelines are well fixed (morphologically) and closely dated (C^{14} and pollen). The diagrams cover an area corresponding to 250—350 km in the direction of tilting.

The shoreline diagrams show straight shorelines that are bent along a line lying 43.4 km outside the O-point at the mouth of River Viskan.

The shoreline diagrams show that this bend was caused by an increased land upheaval, where the outer area did not follow this upheaval, but even sunk a little.

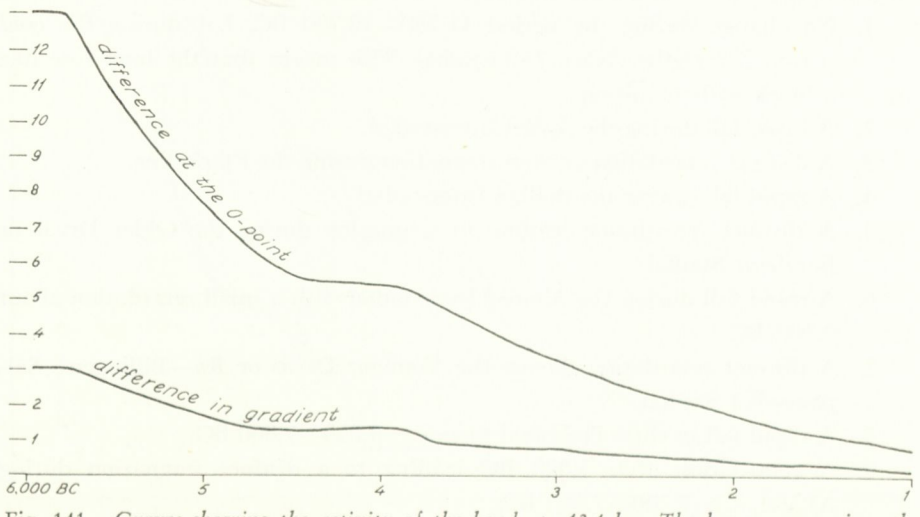


Fig. 141. *Curves showing the activity of the bend at -43.4 km. The lower curve gives the difference of the gradients outside and inside the bend. The upper curve gives the difference at the 0-point between the extrapolations of the shorelines from outside the bend and real shorelines.*

This started between ALV-3 and PTM-2, i. e. 5,800—5,000 BC, as all shorelines older than 5,800 BC are equally bent. The younger shorelines are less and less bent.

If the shorelines outside and inside the bend are compared, either at a certain point or concerning the gradient, the bending activity can be reconstructed (Fig. 141). This shows:

1. no difference before 5,800 BC
2. a rapid bending 5,800—4,400 BC (ALV-3 to PTM-3)
3. almost no bending 4,400—3,800 BC (PTM-3 to PTM-4)
4. a rapid bending (evenly decreasing with time) from 3,800 BC, and on

This suggests a corresponding activity in the land upheaval, i. e. with a retardation at about PTM-3 to PTM-4.

The gradients

The changes of gradient of the shorelines give a good picture of the intensity of the tilting.

In Fig. 142 the gradients of the shorelines inside and outside the bend respectively have been combined into two curves of the changes in gradient.

First of all these curves are not even, but very uneven. This shows a tilting with changed intensity. This is an important fact in the interpretation of isostasy. In detail, the curves show the following:

1. No change during the period 11,750—10,700 BC, i. e. during the cold period before the Ågård Interstadial. This means that the land rose like a block without tilting.
2. A rapid fall during the Ågård Interstadial.
3. A distinct retardation or even stagnation during the Fjärås line.
4. A rapid fall during the Bölling Interstadial.
5. A distinct retardation leading to stagnation during the Older Dryas or Berghem Stadial.
6. A rapid fall during the Alleröd Interstadial with a small retardation about 9,300 BC.
7. A distinct retardation during the Younger Dryas or Ra—Billingen—Salpausselkä Stadial.
8. A rapid fall in early Preboreal time, i. e. 8,050—7,800 BC.
9. A retardation after 7,800 BC leading to a distinct stagnation during ALV-1, i. e. 7,700—7,330 BC.
10. A rapid fall during the transgression from ALV-1 up to ALV-2 (= PTM-1), i. e. 7,330—6,900 BC.
11. A distinct stagnation from ALV-2 to ALV-3, i. e. 6,900—5,800 BC.

12. A rapid fall inside and a rise outside the bend between ALV-3 and PTM-2, i. e. 5,800—5,000 BC. This means that the land rapidly rose in NE, creating the bend at –43.4 km, where the land sunk in relation to the area still further out.
13. A more or less continuous fall from PTM-3 on, i. e. 4,300 BC. A retardation is seen at PTM-4, i. e. 3,900 BC. This corresponds to the retardation or stagnation in the bending activity (Fig. 141).

This means that the following obvious connections can be seen:

Late Glacial cold period = retarded land upheaval

Late Glacial warm period = accelerated land upheaval

Early Postglacial eustatic transgression = accelerated land upheaval and even land subsidence

Early Postglacial eustatic stagnation = stagnation in land upheaval

Consequently, the isostatic land upheaval was influenced by:

1. fluctuations in the Late Glacial recession of land ice (= glacio-isostasy)
2. fluctuations in the eustatic rise of sea level (= hydro-isostasy)

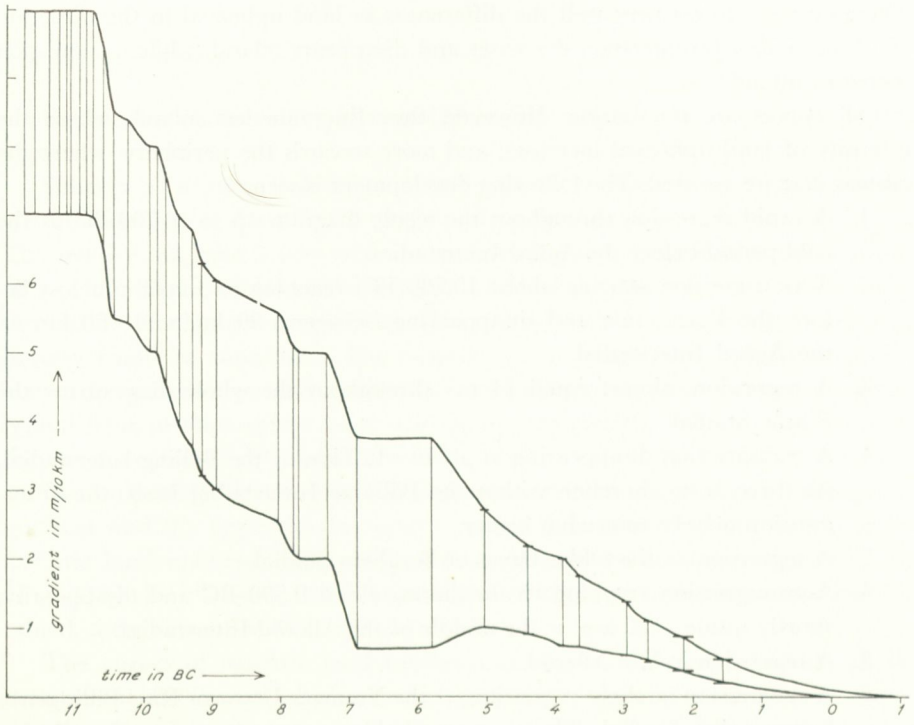


Fig. 142. *Curves of the changes in gradient outside and inside the bend. The vertical lines give the shorelines here identified. The two curves are parallel up to 5,800 BC, i.e. to the time when the bend was created. Time scale in thousands of years.*

Furthermore the land initially rose as a block, while it later rose with a centre further inland giving rise to tilted shorelines. However, it is also shown that the activity of this centre has changed very much (as will be shown further on, not only in intensity but also geographically).

On the whole the curves of changes in gradient have given very important information about the isostasy.

As far as I know this type of curve has not earlier been used to express the land upheaval. However, I find a curve of this type necessary if one wants to make deductions about isostasy. A shorelevel displacement curve is not enough. But this type of curve requires a closely determined direction of tilting and a detailed and well dated shoreline diagram.

The shorelevel displacement curves

In Fig. 143 eight shorelevel displacement curves have been drawn for every 30 km in the direction of tilting between +60 km and −150 km, i. e. four curves from the area inside and four from the area outside the bend at −43.4 km. These curves express very well the differences in land upheaval in the direction of tilting, i. e. a transgression decreases and disappears inland, while a regression increases inland.

All curves are fluctuating. However, they fluctuate less inland, where the intensity of land upheaval increases, and more towards the periphery, where the eustasy is more asserted. The following development is seen:

1. A rapid regression throughout the whole diagram up to 10,700 BC = the cold period before the Ågård Interstadial.
2. A transgression starting about 10,700 BC, reaching its maximum just before the Fjärås line and disappearing between −90 km and −60 km = the Ågård Interstadial.
3. A regression, almost equal (4 m) throughout the whole diagram = the Fjärås Stadial.
4. A transgression disappearing at about −120 km = the Bölling Interstadial. As there is no shoreline within the Böllinge Interstadial itself, this transgression may be somewhat bigger.
5. A regression = the Older Dryas or Berghem Stadial.
6. A transgression reaching its maximum about 9,500 BC and disappearing shortly inside −120 km = the middle of the Alleröd Interstadial.
7. A regression in late Alleröd.
8. A syngression or slight regression = the Younger Dryas or Ra—Billingen—Salpausselkä Stadial. There was probably a very slow regression during the Taberg and Skövde Phases, while there was a more rapid regression during the final part of Younger Dryas.

9. A transgression in early Preboreal time reaching its maximum about 7,800 BC and disappearing shortly inside −120 km.
10. A regression of almost equal magnitude (4 m) throughout the whole diagram from ALV-0 down to ALV-1, i. e. 7,800—7,700 BC.
11. A syngression during ALV-1, i. e. 7,700—7,330 BC.
12. A rapid transgression reaching its maximum at ALV-2 (= PTM-1), i. e. about 6,900—6,800 BC, and disappearing shortly inside +60 km.
13. A regression of equal magnitude (1.5—2.0 m) throughout the whole diagram from ALV-2 down to ALV-3, i. e. 6,850—6,550 BC.
14. A syngression during ALV-3, i. e. 6,550—5,800 BC.
15. A rapid transgression from ALV-3 up to PTM-2, i. e. 5,800—5,000 BC, and not disappearing within this diagram.
16. A series of younger transgressions (PTM) and regressions (PR) up to the last transgression maximum studied, viz. PTM-7 at 1,650—1,400 BC.

This means that there is an obvious connection between a transgression (Fig. 143 and an acceleration of the land upheaval (Fig. 142), which indicates the presence of a hydro-isostatic factor.

The isostatic curves

For relative sea level (S), eustasy (E) and isostasy (I) the following equation applies:

Position of relative sealevel + eustatic depth = isostatic land upheaval (or subsidence); i.e. $S + E = I$ (or $I - S = E$)

The relative sea level is very well known from the shorelevel displacement curves (Fig. 143). The intensity of the isostatic land upheaval is fairly well known from the curves of changes in gradient (Fig. 142). With a true eustatic curve the isostasy could be calculated. The eustatic curves might to a certain degree be known from earlier published eustatic curves. However, these curves vary greatly and none of them offers more than an approximation. With a known isostasy the eustasy could be calculated.

By comparing the shorelevel displacement curves, the curves of changes in gradient and the approximate eustatic curves, I have worked out curves of the isostatic land upheaval (Fig. 144) and a curve of the eustatic rise of sea level (Fig. 145). By changing and comparing until the most reliable picture was obtained, these curves have been constructed.

The curves of isostatic land upheaval in this way obtained include all the details that the curves of changes in gradient, shorelevel displacement curves and shoreline diagram suggested.

These curves (Fig. 144) show the following isostatic land upheaval:

1. A rapid fall 11,400—10,700 BC throughout the whole diagram.

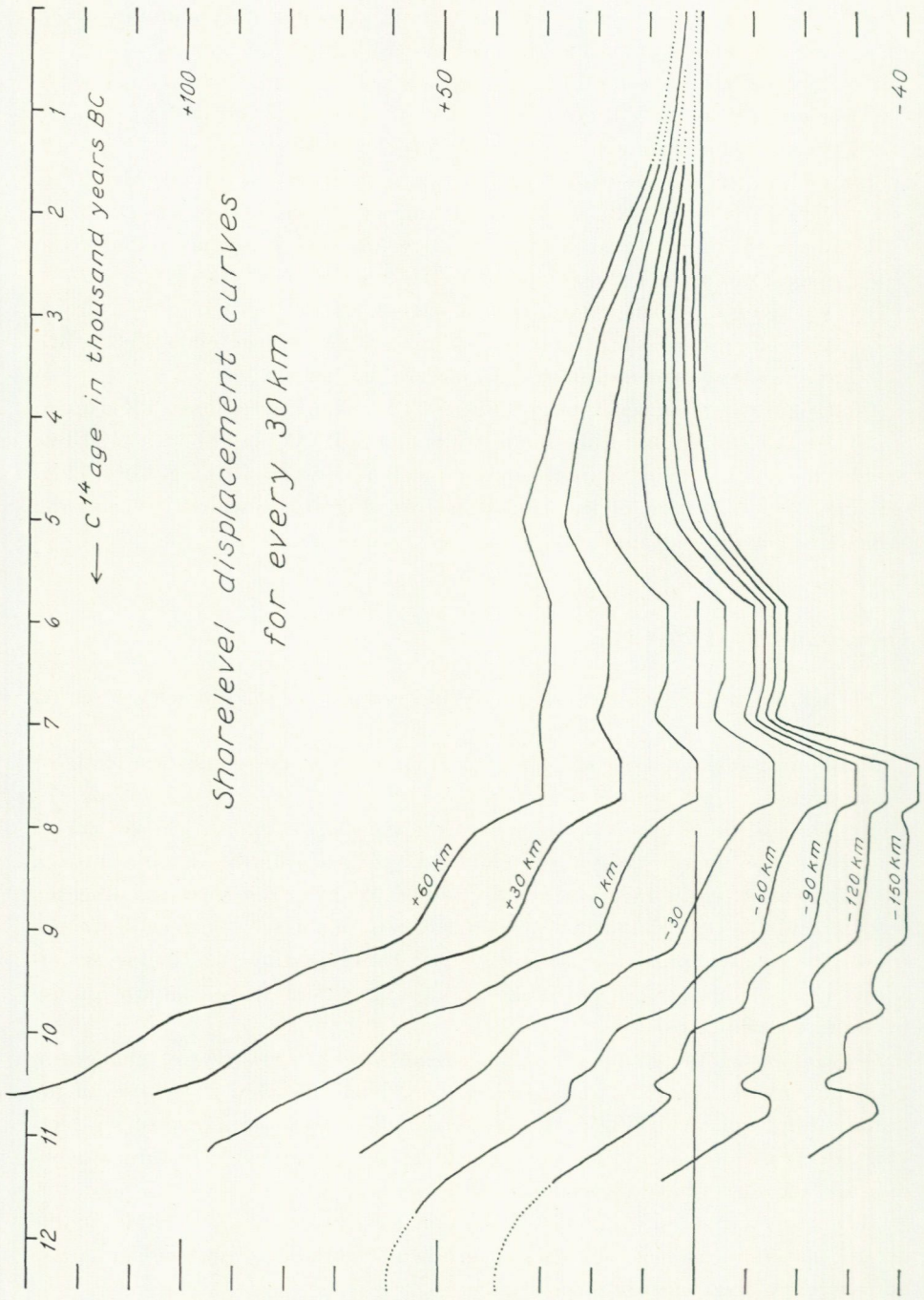


Fig. 143. *These curves (S) should be compared with the ones in Fig. 144 (I) and Fig. 145 (E) as* $S + E = I$.

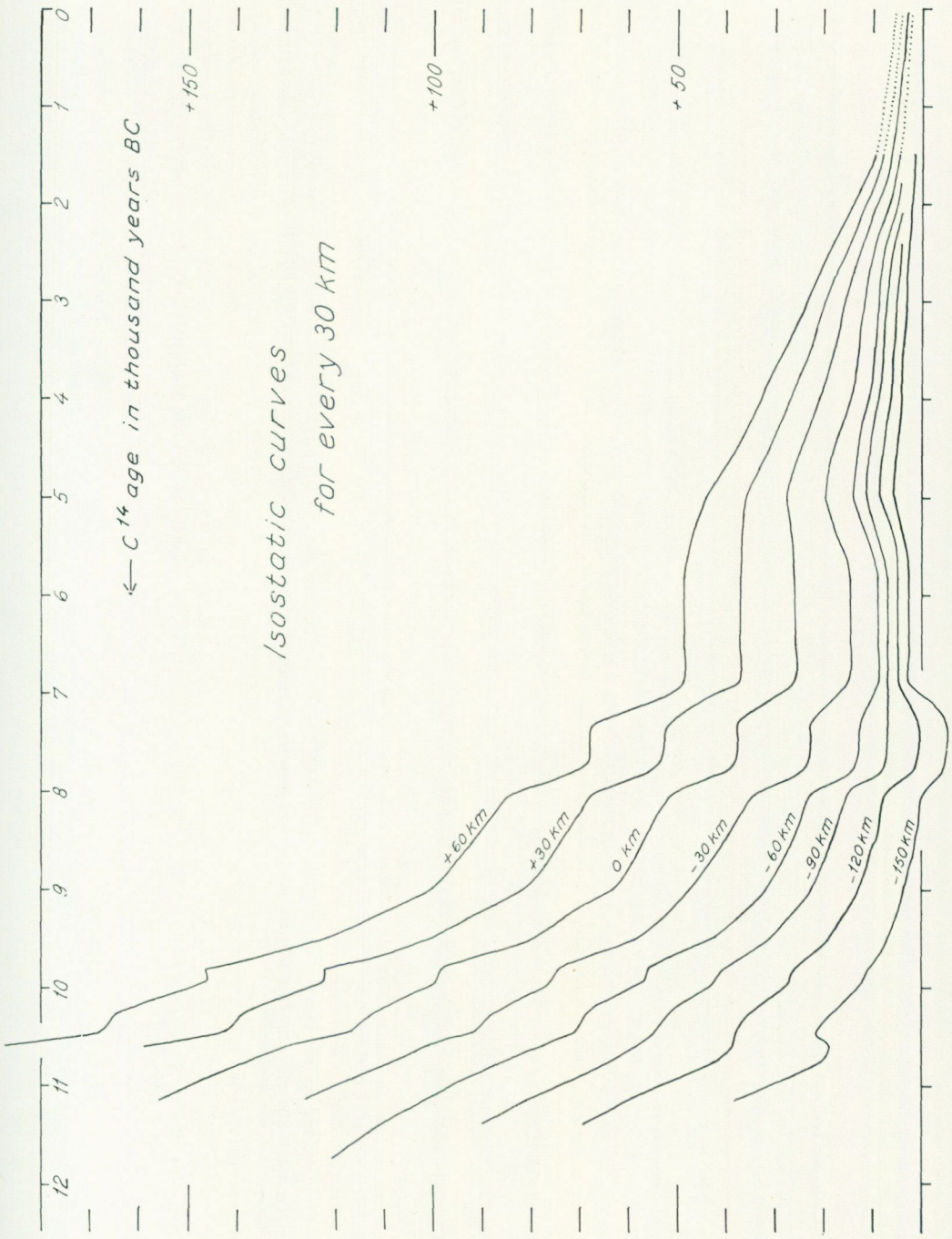


Fig. 144. *The fluctuations in these curves correspond to the ones in the curves of changes in gradient (Fig. 142).*

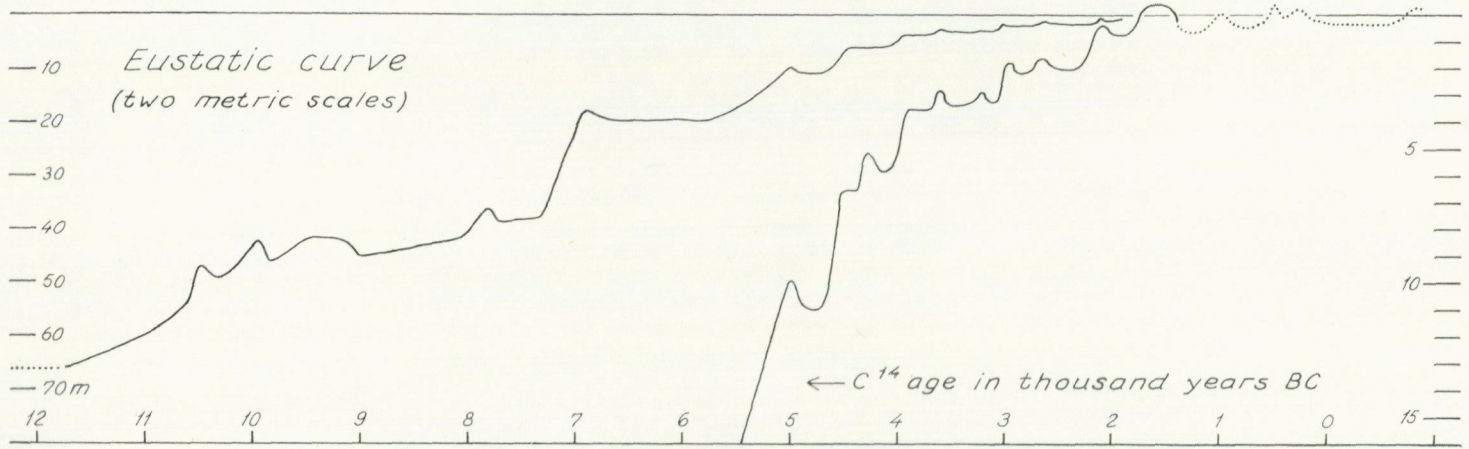


Fig. 145. *The eustatic curve here presented. The vertical scale of the younger part is enlarged in order to show the fluctuations. Compared with the shorelevel displacement curves (Figs. 143 and 147) this curve gives quite reliable isostatic curves (Figs. 144 and 148), including all the details indicated by the changes in gradients (Fig. 142). The Late Glacial and early Postglacial fluctuations correspond to distinct climatic changes, while the climatic counterpart to the younger fluctuations are not yet fully established. This eustatic curve rises with fluctuations up to PTM-7 at +0.4 m at 1,650—1,400 BC, suggesting that this corresponds to a climatic optimum. The marine shell fauna in Kattegatt also indicates a temperature optimum at PTM-6 to PTM-7, followed by a distinct deterioration. It seems highly probably that, due to the variations in the atmospheric ^{14}C activity (Figs. 40 and 41), the duration of the transgression from −38.0 m to −18.5 m (7,330—6,900 BC) should in reality be longer and the duration of the syngression 6,550—5,800 BC should be shorter, thus giving a more likely picture.*

2. A rapid fall inland with land subsidence in the periphery 10,700—10,350 BC, i. e. during the Ågård Interstadial.
3. A retardation about 10,300, i. e. during the Fjärås Stadial.
4. An accelaration 10,300—9,950 BC, i. e. during the Bölling Interstadial.
5. A stagnation (increasing inland) with a slight upheaval towards the periphery 9,950—9,800 BC, i. e. during the Older Dryas or Berghem Stadial.
6. A rapid, continuously decreasing fall during the Alleröd Interstadial.
7. A slight retardation (increasing inland) during the Younger Dryas Stadial (probably especially during the Taberg and Skövde Phases).
8. A distinct acceleration in the earliest Preboreal.
9. A retardation and stagnation 7,800—7,330 BC.
10. A distinct acceleration with land subsidence in the periphery 7,330—6,900 BC, i. e. during the big first Postglacial transgression from ALV-1 up to ALV-2 (= PTM-1).
11. A stagnation during ALV-2 and ALV-3.
12. An acceleration in 5,800—5,000 BC leading to the creation of the bend at –43,4 km, where the land sunk. The land subsidence was greatest at the point –43.4 km, which is also shown by these curves.
13. An almost continuous decrease from PTM-2 up to the present time.

This means that the periphery of the land upheaval has changed position several times and that there are obvious connections between eustatic transgressions and peripheric land subsidences and between Late Glacial cold periods and retardations or stagnations in the land upheaval. Consequently, the land upheaval has here turned out to be very sensitive to fluctuations in the ice recession (= glacio-isostasy) as well as to fluctuations in the eustatic sea level (= hydro-isostasy).

Conclusions about the isostatic land upheaval

With the results obtained it is now possible to reconstruct the land upheaval from about 11,750 BC (i. e. the time of the oldest Swedish ML) in a very detailed way. The following development is seen (illustrated in Fig. 146):

A: From 11,750 BC to 10,700 BC the outer part, i. e. at least the area between –20 km and –120 km, fairly rapidly rose as a block, where no tilting can be seen. Still further out there must have been a tilting.

B: After 10,700 BC the centre of land upheaval moved to the highland of Småland, which meant that the shorelines were now tilted.

B1: During the Ågård Interstadial the land rose rapidly with the periphery of land upheaval just outside –120 km, and consequent land subsidence at –150 km. This was caused by the recession of ice inland (glacio-

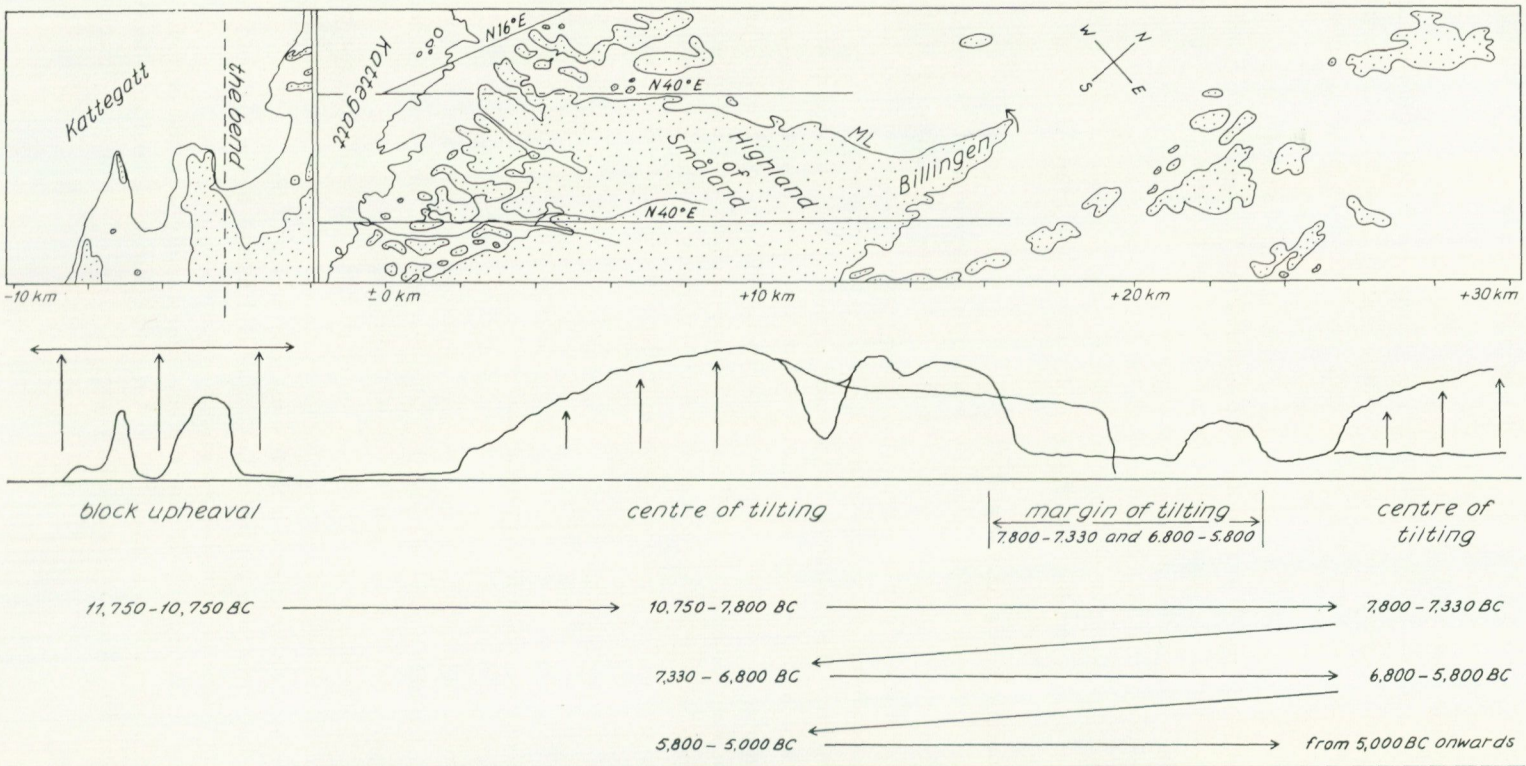


Fig. 146. *Reconstruction of the isostatic land upheaval of SW Sweden. The map and section are drawn in the direction of tilting (from N 40° E). Dotted area in the map shows land above ML. The section shows corresponding changes in elevation (approximately). The distance scale should be corrected with one more zero. The lowermost part shows the geographic changes of the centre and margin of tilting and upheval.*

isostasy) and the transgression of the sea at the periphery (hydro-isostasy).

B2: During the Fjärås Stadial the land upheaval was retarded (glacio-isostasy).

B3: During the Bölling Interstadial the land rose rapidly (glacio-isostasy).

B4: During the Older Dryas or Berghem Stadial the land upheaval ceased inland, and continued very slowly further out (glacio-isostasy).

B5: During the Alleröd Interstadial the land rose rapidly (glacio-isostasy).

B6: During the Younger Dryas or Ra—Billingen—Salpausselkä Stadial the land upheaval slowed down, at least inland (glacio-isostasy).

B7: At 8,050 BC two things happened that influenced the land upheaval, viz. 1) the ice began rapidly to recede (glacio-isostasy) and 2) the whole Baltic Ice Lake was drained about 26 m down to the sea level (hydro-isostasy). This caused — glacio-isostatically and hydro-isostatically respectively — a very rapid land upheaval in early Preboreal time (about 8,050—7,800 BC).

C: In early Preboreal time (about 7,800 BC) the centre of land upheaval was moved from the highland of Småland still further inland to the highlands of Central Sweden.

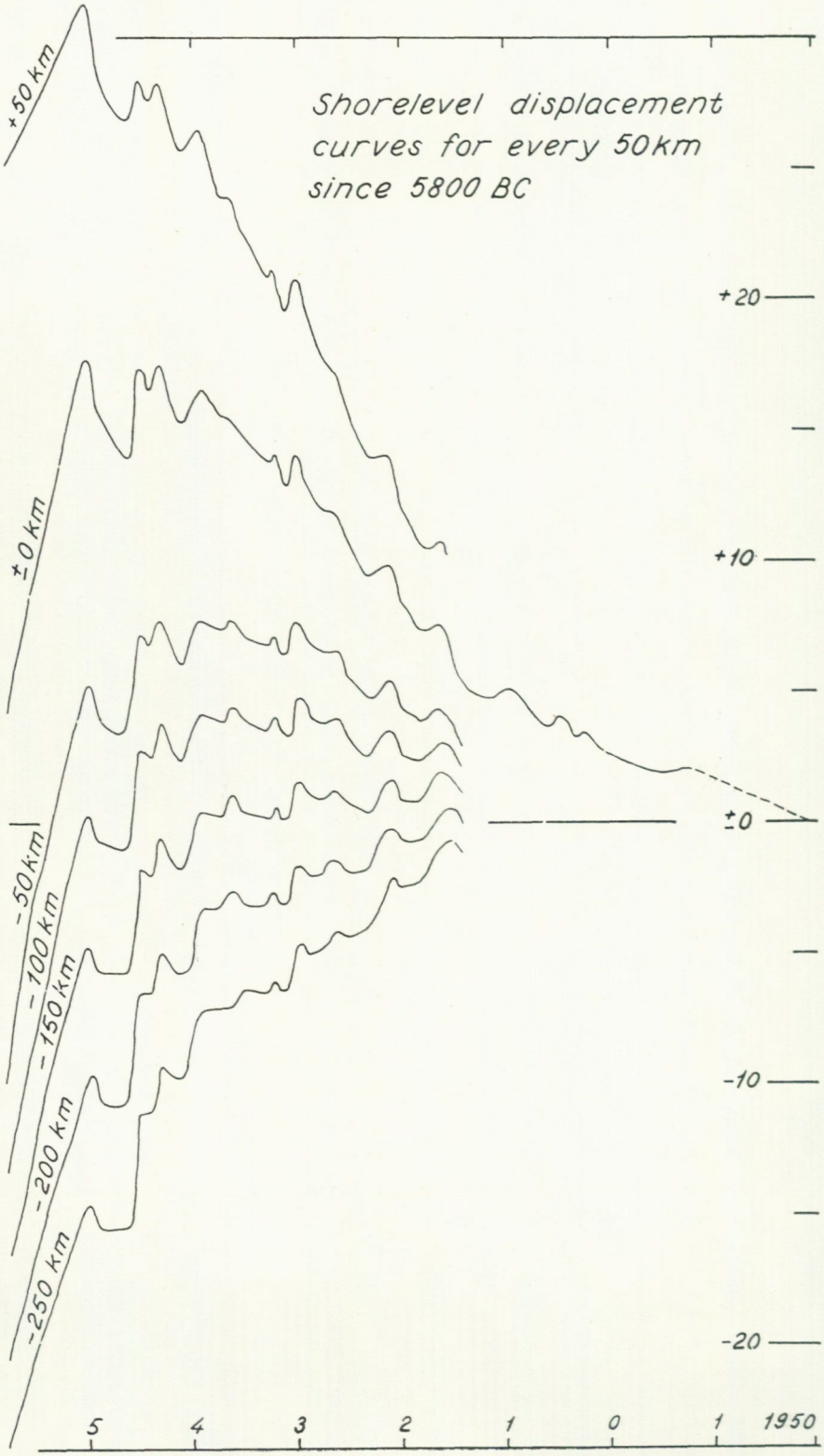
C1: During the time of ALV-1, when the eustatic sea level was almost stable, the periphery (or margin) of land upheaval was on the other side of the highland of Småland, i. e. somewhere NE of Billingen. This meant no shorelevel displacement in the area investigated.

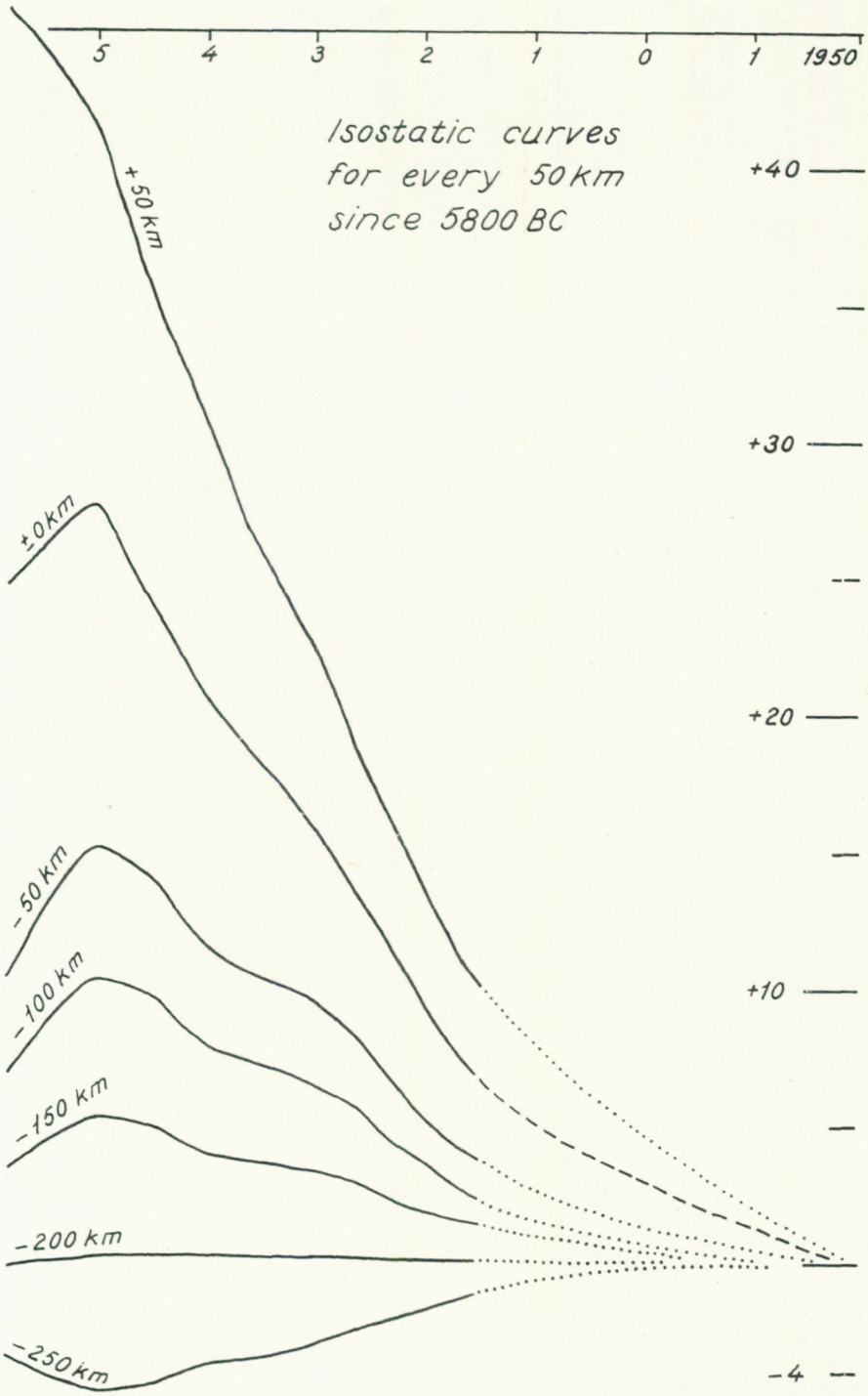
C2: At 7,330 BC the sea eustatically started to rise rapidly and large areas of Kattegatt were submerged. This caused a hydro-isostatic land subsidence outside –90 km and a rapid land upheaval further inland. Apparently this was a reactivation of the centre in the highland of Småland.

C3: When the transgression had reached its maximum, the centre of land upheaval was again moved to Central Sweden, with the periphery (margin) of land upheaval inside the highland of Småland (NE of Billingen). During this period the eustatic sea level was stable except for a small regression.

C4: At 5,800 BC the sea eustatically started to rise rapidly. This had a great influence upon the isostasy. The land started again to rise with the centre once again in the highland of Småland. However, the area outside a line at –43.4 km did not follow this land upheaval, which meant the creation of the bend at –43.4 km. At the bend the land sank in relation to the areas inside as well as outside. This caused the increase of the gradient of PTM-2 outside the bend.

D: From PTM-2 at 5,000 BC there was an almost continuous land upheaval up to the present time. The centre of land upheaval was in Central Sweden and the periphery outside –150 km.


Shorelevel displacement
curves for every 50km
since 5800 BC
+50 km
±0 km
-50km
-100 km
-150 km
-200 km
-250 km
+20
+10
±0
-10
-20
5
4
3
2
1
0
1
1950



Figs. 147 and 148. *The eustatic depth added to the shorelevel displacement curves gives quite reliable isostatic curves. 5,800 BC marks a distinct limit eustatically as well as isostatically. Along a line at -43.4 km a bend was created and the land sunk in relation to the areas inside as well as outside. The shorelevel displacement at -200 km almost exactly corresponds to the eustatic curve. After PTM-2 the land upheaval continuously decreases to -200 km, where it changes over to subsidence.*

Consequently, we have here seen an isostasy that is highly sensitive to minor fluctuations in the load of ice (glacio-isostasy) and water (hydro-isostasy) and where the position of the centre and periphery of land upheaval have changed.

In general the land upheaval decreased with time and with distance towards the periphery, and the centre of land upheaval moved inland in three steps; viz. 1) the block upheaval of the area around NW Skåne, 2) the tilting from the highland of Småland and 3) the tilting from the highlands of Central Sweden. This means in general a fairly simple picture of land upheaval, to which, however, the very high glacio-isostatic and hydro-isostatic sensitivity were added.

The eustatic curve

The eustatic curve here presented (Fig. 145) is the only one that can in a reliable way express the shorelevel displacement and isostasy in the area investigated. However, this does of course not preclude further details (expected for the Younger Dryas) or minor changes.

It has been shown above that the hydro-isostasy is a fact, which must now be taken into consideration. This means that the transgressed shelf areas most probably have sunk hydro-isostatically. Thus it must be very hard to find a real "stable area". This actualizes some words written by Newman and Munsart (1968, p. 95): "... we suspect that coastal stability is a myth and curves depicting land-sea relationships probably are valid only locally. We doubt that any coast has remained stable during the Pleistocene Epoch ...".

The shorelevel displacement during the period after PTM-2 is known in detail and is characterized by a more or less continuously decreasing land upheaval. Thus this part was used for the first calculation of isostasy and eustasy. In Fig. 147 shorelevel displacement curves for every 50 km in the direction of tilting between +50 km and −250 km have been drawn. The curve of −200 km has turned out almost exactly to correspond to the eustatic curve (Fig. 145). The corresponding isostatic curves give a very reliable picture of land upheaval (Fig. 148), with decreasing land upheaval (after PTM-2) from +50 to −200 km and land subsidence outside −200 km. If the eustatic curve is changed the isostatic curves become unlikely. This eustatic curve (Fig. 145) lies above the one by Jergersma (1961, 1965), which is just what one would expect as the Dutch coast is slowly sinking (cf. p. 433).

As a whole the eustatic curve (Fig. 145) shows the following:

1. During the cold period 11,750—10,700 BC the sea level rose from about −63 to −56 m.
2. During the Ågård Interstadial (10,700—10,350 BC) the sea level rapidly rose to about −47 m, i. e. 9 m.

3. During the Fjärås Stadial (10,350—10,300 BC) the sea level fell to about –49 m, i. e. 2 m.
4. During the Bölling Interstadial (10,300—9,950 BC) the sea rapidly rose to about –42 m, i. e. 7 m.
5. During the Older Dryas Stadial (9,950—9,800 BC) the sea level fell to about –46 m, i. e. 4 m.
6. During the early part of the Alleröd Interstadial the sea level rapidly rose to about –42 m (reached at about 9,500 BC). Later the sea level was stationary. As the gradients of the shorelines during this period are not quite certain minor changes are possible.
7. At the transition between the Alleröd Interstadial and the Younger Dryas Stadial the sea level fell to about –45 m, i. e. 3 m.
8. During the Younger Dryas Stadial (9,000—8,050 BC) the sea level slowly rose to about –42 m.
9. In early Postglacial time the sea level rapidly rose to about –36 m at 7,800 BC, i. e. a rise of 6 m.
10. Between 7,800 BC and 7,700 BC the sea level fell to about –38.5 m, i. e. 2.5 m, indicating a global cold period.
11. During ALV-1 (7,700—7,330 BC) the sea level was almost stationary (rising to about –38 m).
12. Between 7,330 BC and 6,900—6,800 BC the sea level very rapidly rose to about –18.5 m, i. e. 19.5 m. This would mean a rise of sea level of about 4 cm per year, which seems quite impossible. However, the explanation seems to be that due to the variations in the ^{14}C content of the atmosphere (cf. p. 180, Figs. 40—41), the short time obtained for the transgression is wrong. The end of ALV-1 should be older and the top of the transgression at ALV-2 younger. If the real date of the transgression is about 7,500—6,500 BC the rise of sea level would be about 2 cm per year.
13. Between ALV-2 (6,900—6,800 BC) and ALV-3 (6,550 to 5,800 BC) the sea level fell about 1.8 m to 20.3 m, indicating a global colder period.
14. During ALV-3 (6,550—5,800 BC) the sea level was quite stationary. According to the variations of ^{14}C in the atmosphere ALV-3 may in reality be shorter (the onset younger).
15. Between 5,800 BC and 5,000 BC (= PTM-2) the sea level rose very rapidly to –10.0 m, i. e. a rise of about 10 m. This means a rise of 1.25 cm per year. PTM-2 was reached at 5,000 BC.
16. PTM-2 at –10.0 m was followed by a regression of about 1 m to –11.0 m (= PR-3).
17. After PR-3 the sea level rose rapidly by about 4.5 m to –6.6 m at PTM-3A. This level was reached at 4,500 BC, i. e. at the very end of zone AT-1.

18. The sea level remained stationary at this level until about 4,350—4,300 BC. In uplifted areas this corresponds to a regression (PR-3.5) between PTM-3A and PTM-3B.
19. The sea level rose about 1.4 m to −5.2 m at PTM-3B, which was reached at 4,300 BC (or 4,300–4,200 BC).
20. The sea level fell about 0.8 m to −6.0 m at PR-4 (4,200—3,950 BC).
21. After PR-4 the sea level rapidly rose about 2.45 m to −3.55 m at PTM-4A (3,900 BC).
22. The sea level remained stationary at this level until 3,800—3,700 BC. In uplifted areas this corresponds to a regression (PR-4.5) between PTM-4A and PTM-4B.
23. The sea level rose about 0.65 to −2.9 m at PTM-4B (3,700—3,550 BC).
24. The sea level fell about 0.4 m to −3.3 m (= PR-5). This level was kept from about 3,550 to 3,100 BC — except for a small oscillation of about 0.4 m which corresponds to PTM-4.5 at −2.9 m.
25. The sea level rose about 1.2 m to −1.8 m at PTM-5A (3,000 BC).
26. The sea level fell about 0.3 m to −2.1 m at 2,900—2,800 BC (= the regression, PR-5.5, between PTM-5A and PTM-5B).
27. The sea level rose about 0.4 m to −1.7 m at PTM-5B (about 3.650 BC).
28. The sea level fell about 0.3 m to −2.0 m at PR-6 (2,600—2,300 BC).
29. The sea level rose about 1.6 m to −0.4 m at PTM-6 (about 2,100 BC).
30. The sea level fell about 0.4 m to −0.75 m at PR-7 (2,000—1,700 BC).
31. The sea level rose about 1.15 m to +0.4 m at PTM-7 (1,650—1,400 BC).
32. At about 1,400 BC the sea level rapidly fell below the present sea level (probably to about −0.7 m). This is PR-8.
33. The sea level rose to about the present sea level at PTM-8 at about 1.000 BC (1,100—950 BC).
34. At about 950 BC the sea level fell below the present sea level (probably to about −0.7 m). This is PR-9.
35. The sea level rose to about the present sea level at PTM-9A at about 500 BC.
36. The sea level fell below the present sea level (probably to about −0.6 m). This is the regression (PR-9.5) between PTM-9A and PTM-9B.
37. The sea level rose to about the present sea level at PTM-9B at about 250 BC, i. e. at the very end of zone SA-1.
38. The sea level fell below the present sea level (probably to about −0.7 m). This is PR-10. In Holland this regression corresponds to a habitation layer dated at about 200 BC to 200 AD.
39. The younger fluctuations — the PTM-10 complex — are not yet investigated. From Holland the following Sub-Atlantic PTM are indicated; Duinkerke II about 200—700 AD (PTM-10A), Duinkerke IIIa about

900—1,100 AD (PTM-10B) and Duinkerke IIIb after about 1,350 AD (PTM-10C), divided into minor oscillations (e. g. Waalewijn 1966 Fig. 2 and Köster 1968 Fig. 2).

Consequently, the eustatic curve here presented (followed from about −63 m at about 11,750 BC) fluctuates, but with a fairly small aplitude.

Concerning the Late Glacial part there is an obvious connection between the changes in climate and the fluctuations of the eustatic sea level. The Ågård, Bölling and Alleröd Interstadials all correspond to transgressions, while the Fjärås, Older Dryas (or Berghem) and Younger Dryas (or Ra—Billingen—Salpausselkä) Stadials correspond to regressions of about 2—4 m. This also gives evidence of the correctness of the Ågård Interstadial and Fjärås Stadial here introduced, as well as for the general picture of the climatic development during the Late Glacial. The fluctuations during the Postglacial or Holocene are harder to explain.

The regression at 7,800—7,700 BC and the following stagnation during ALV-1 must correspond to a general worldwide cold period. However, no such general cold period has yet been established, though there are indications in different parts of the world, e. g. Alaska (Goldthwait 1960), North Ontario (Zoltai 1967), Norway (Liestöl 1962, Sollid 1964, Anundsen and Simonsen 1967), Switzerland (Zoller 1960), Italy (Beug 1964), NW Germany (Behre 1966 and 1967) and England (Simmons 1964). The Piottino Oscillation in the Swiss Alps (Zoller 1960) could be taken as evidence of this climatic deterioration. However, I think Zoller's Late Galcial pollen zones need a thorough reinterpretation.[1] The Piottino Oscillation is C^{14} dated at about 8,000 BC and probably corresponds to the latest part of Younger Dryas, i. e. the Billingen Phase or Salpausselkä III Phase (cf. Fig. 42). On the other hand Behre's division of pollen zone IV in three subzones clearly shows a climatic deterioration in Preboreal time. Obviously this corresponds to the one reflected in the eustatic curve. From SW Norway, Anundsen (Anundsen and Simonsen 1967) has shown that the readvance forming the Eidfjord—Osa ice marginal line occurred at about a C^{14} date 7,770 ±330 BC, i. e. at the same time as the eustatic sea level falls, indicating a worldwide climatic deterioration. For this Preboreal climatic deterioration I propose the local name

[1]) The following zonation seems possible. The diagram from Origliosee (Prof. Ia): cold stage at the bottom below 765 cm = stadials prior to 10,700 BC (less certain), interstadial 765—595 cm = Ågård Interstadial 10,700—10,350 BC (possibly only the upper part corresponds to the Ågård Interstadial), stadial 595—545 cm = Fjärås Stadial 10,350—10,300 BC, interstadial 545—505 cm = Bölling (Ib) 10,300—9,950 BC, stadial 505—460 cm = Older Dryas (Ic) 9,950—9,800 BC (two phases separated by an interval), interstadial 460—410 cm = Alleröd Interstadial (II) 9,800—9,000 BC, and stadial 410—385 cm = Younger Dryas (III) 9,000—8,050 BC. The diagram from Bedrina (Prof. IIIa): increasing vegetation 560—430 (435) cm = Alleröd Interstadial (II) 9,800—9,000 BC, colder period 430 (435) to 270 cm showing several fluctuations, the last of which is the Piottion Oscillation = Younger Dryas (III) 9,000—8,050 BC divided into three phases and two intervals, and the final climatic amelioration above 270 cm = the Preboreal (IV) starting at 8,050—8,000 BC.

Eidfjord Stadial (or Preboreal Stadial). In this connection it must also be remembered that the North American cold period — Valders (e. g. Leighton 1960), Mankato (e. g. Flint 1955) and Sumas (e. g. Easterbrook 1966) — equivalent to the North European Yonger Dryas is usually dated at about 9,000 BC to 6,500—7,000 BC (op. cit.), i. e. it continued during the Preboeral of North Europe. The Preboreal division is shown in the table below.

The very distinct eustatic transgression starting at 7,330 BC probably gives the most logical boundary between the Würm (Weichselian, Wisconsin) Glacial Age and the Flandrian Interglacial Age and between the Pleistocene Epoch and the Holocene Epoch (Mörner 1969).

The regression from ALV-2 to ALV-3 (and the syngression during ALV-3) must also correspond to a general worldwide cold climate. This most probably corresponds to the well known Cochrane readvance in North America (e. g. Karlstrom 1956, Zoltai 1967) This climatic deterioration seems also to be reflected in some North European pollen diagrams, e. g. in Behre's diagram from Westrhauderfehn (1966, Abb. 2, or 1967, Fig. 2) as a *Betula* peak + *Pinus* fall (spectrum 40) or in Königsson's diagram from Skede Mosse S 50 (1968a, Fig. 6, or 1968b, Fig. 90) or Stormaren (1968b, Plate) as the *Betula* peak + *Pinus* fall, dated at about 6,785 ±110 BC (at the upper part of his local pollen zone D). As a local, North European, name for this Boreal climatic deterioration I propose Viskan Stadial (or Boreal Stadial), as the corresponding eustatic regression was first (and easily) established within the Viskan Valley (p. 241). The Boreal division is shown by the table below.

pollen	C^{14}	eustatic s.l.	climatic division
VII	5,800	very rapid rise	distinct amelioration
VI	6,550	syngression	(stagnation)
V b	6,850	regression	Cochrane or Viskan Stadial
V a	7,330	very rapid rise	very distinct amelioration
IV c	7,700	syngression	(stagnation)
IV b	7,800	regression	Eidfjord (or Preboreal) Stadial
IV a	8,050	transgression	Friesland Interstadial
III		very slow rise	Younger Dryas Stadial

The climatic background of the still younger eustatic fluctuations are not yet sufficiently known. It may here suffice to show the existence of eustatic fluctuations that must correspond to climatic changes. PTM corresponds to climatic ameliorations and PR to deteriorations. My eustatic curve shows that the maximum level at about +0.4 m was reached at PTM-7 at 1,650—1,400 BC. Consequently, PTM-7 would correspond to the (or at least one) climatic optimum during Holocene. However, this is not at all certain as the melting of the ice cover may have been retarded, so that the real climatic optimum does not

necessarily correspond to the highest eustatic position, but can be older. Nevertheless, PTM-7 corresponds to a distinct climatic peak, here called the Dosinia Optimum after the characteristic shell fauna in Kattegatt (p. 384). The regression down to PR-8 at about 1,300—1,100 BC shows a climatic deterioration, in full agreement with the changes in mollusc fauna in Kattegatt (p. 386). This is a distinct climatic deterioration, here called the Strandby Deterioration (after the locality in Vendsyssel, p. 386), which marks the end of the Postglacial, Flandrian Interglacial and Holocene Epoch climatic optimum. The well known climatic deterioration at the zone boundary between the Sub-Boreal and Sub-Atlantic, i. e. at about 250—200 BC, corresponds to a distinct eustatic regression. The recurrence surfaces in peat bogs are generally thought to reflect climatic changes (though local features must not be ignored). T.Nilsson (1964b) discussed 10—13 North European recurrence surfaces of supposed regional importance. The ages of these recurrence surfaces, though not yet fully established and fixed in age, correspond to my PR stages or changes between PTM and PR stages, i. e. the beginning, the middle and the end of PR stages (climatic deteriorations). Several so-called "Little Ice Ages" (see e. g. Schove 1966 or Fairbridge 1961) have also been described during the Postglacial, viz. at about 2,500 BC corresponding to PR-6, at about 1,250 BC corresponding to PR-8, at about 850 BC corresponding to PR-9 and at about 350 BC corresponding to PR-9.5 or PR-10. From pollen analysis there are numerous indications of Postglacial climatic fluctuations, e. g. Zoller's (1960) pollen diagram from the Swiss Alps. Zoller's diagram from Pian di Signano (Prof. IV) shows three sand layers with NAP maxima and *Abies* minima, indicating climatic deteriorations; the first possibly corresponding to the Cochrane Stadial, the second, the Misoxer Oscillation dated at about 5,000—4,900 BC, corresponding to PR-3, and the third probably corresponding to PR-4. Zoller's diagram from Cadagno Fuori 5 (Prof. V) shows: a cold phase at the bottom, possibly corresponding to the Cochrane Stadial (or Piottino Phase), three colder stages in the sequence 125—90 cm below surface probably corresponding to PR-3 (the Misoxer Oscillation), PR-3.5 and PR-4, and finally a climatic deterioration, the Piora Oscillation, corresponding to a readvence of the ice, which is dated at younger than 3,150 ± 100 BC. The Piora osciallation probably corresponds to PR-5B (the *Ulmus* decline), PR-5.5 or PR-6. The NAP minimum and *Abies* maximum in the sand at the bottom of Zoller's diagram from Cadagno Fuori 6 (Prof. VI) may indicate a climatic amelioration corresponding to PTM-7, while the mud above, C^{14} dated at 1,300 BC, with NAP maximum and *Abies* minimum may indicate a deterioration corresponding to PR-8. Seen as a whole, the global Postglacial climatic fluctuations are as yet fairly incompletely known, though there are, as shown above, several indications from the studies of glaciers, the peat bogs and the vegetational history of climatic deteriorations corresponding to the PR stages of the eustatic curve here presented.

Comparisons with other investigations

If the eustatic curve here given is true, it must in comparison with every true shorelevel displacement curve also give a true isostatic curve. However, very few well fixed and closely dated shorelevel displacement curves exist. Below, comparisons are made to some shorelevel displacement curves and supposed eustatic curves.

1. Eastern Blekinge, Sweden

From this area Berglund (1964, 1966) has a fairly well established shorelevel displacement curve. However, some changes seem necessary (Fig. 32, cf. p. 397). As this area lies in the Baltic basin, it has been dammed above sea level during certain periods. In Fig. 149 an isostatic curve has been calculated from a comparison between the eustatic curve and the altered shorelevel displacement curve. This curve shows the damming of the Baltic Ice Lake and the Ancylus

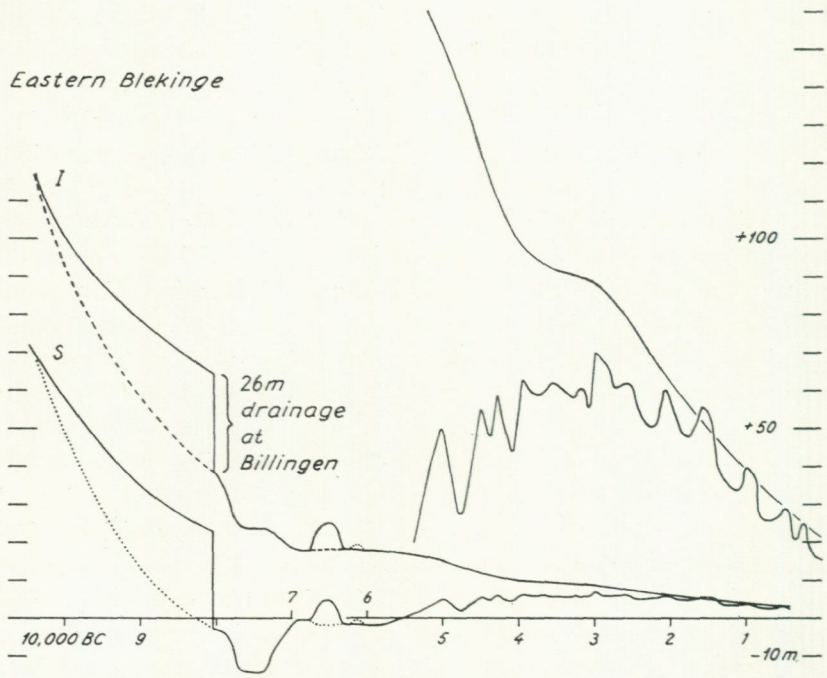


Fig. 149. *S = shorelevel displacement curves for Eastern Blekinge. Dotted line below full line gives approximate damming above sea level of the Baltic Ice Lake and the Ancylus Lake respectively. I = isostatic curve calculated from the S curve. The drainage of the Baltic Ice Lake is well registered as well as the damming and drainage of the Ancylus Lake. To the right the S and I curves for the period after 5,500 BC are enlarged ten times (i.e. +50 m = +5 m) showing the PTM/PR changes.*

Lake. The damming of the Ancylus Lake is of special interest as it has often been discussed. The damming indicated by this curve agrees exactly with my interpretation (p. 298) based on the shorelevel displacement in Kattegatt. The first and main transgression is equivalent to the marine eustatic transgression up to ALV-2 (= PTM-1). The level just below the onset of this transgression has been C^{14} dated at 7,430 ±110 BC, i. e. in complete agreement with my dates. Shortly after the ALV-2 level was reached, and probably in connection with the onset of the regression from ALV-2 to ALV-3, the Ancylus Lake proper was dammed and started to rise, searching for a SW outlet. The curve shows a damming of 7 m at about 6,500 BC (6,750—6,350 BC), and also clearly shows that the Ancylus Lake was drained at about 6,500—6,350 BC down to the sea level (by erosion in the thresholds). This interpretation fits well with dates from Öland (Königsson 1968a and 1968b) and Gotland (G.Lundqvist 1965). Berglund thinks that the water level fell to about –40 m in early the Postglacial time (= my ALV-1). However, such a low level is unlikely, as it requires too rapid an isostatic land upheaval (Fig. 149). My calculations assume a regression maximum at about –14 m. On the whole my eustatic curve and Berglund's curve reinterpreted give a very likely isostatic curve. This is a good indication of the correctness of my eustatic curve.

2. Northern Norway

This area has been thoroughly investigated by Marthinussen (see p. 396). He has worked out a very detailed shoreline diagram for an area of about 125 km in the direction of tilting (Marthinussen 1960). In my opinion this is hitherto the best shoreline diagram ever published, at least concerning Scandinavia. However, as the shorelines (P11—P1) from the period between Younger Dryas and the Tapes I shoreline are not yet sufficiently fixed and dated, the calculation of isostasy must here be restricted to the younger shorelines (the N shorelines).

For Skjaerafossen in the innermost part, Kvalvika in the middle and Ingöj in the outermost part of Marthinussen's diagram, shorelevel displacement curves have been drawn for the period after 5,000 BC (Fig. 150). On the bases of these curves (slightly changed) and my eustatic curve (Fig. 145), isostatic curves have been drawn (Fig. 150). With minor changes in the courses of the shorelines, quite smooth isostatic curves are obtained (Fig. 150).

The changes required are small and probably within the margin of error for the determination of the shorelines. Marthinussen (1960) says "some revision of the diagram is still needed". Marthinussen's shorelines have been given the following interpretation (cf. p. 396):

Tapes I is quite equivalent to PTM-2.

Tapes II is quite equivalent to PTM-3.

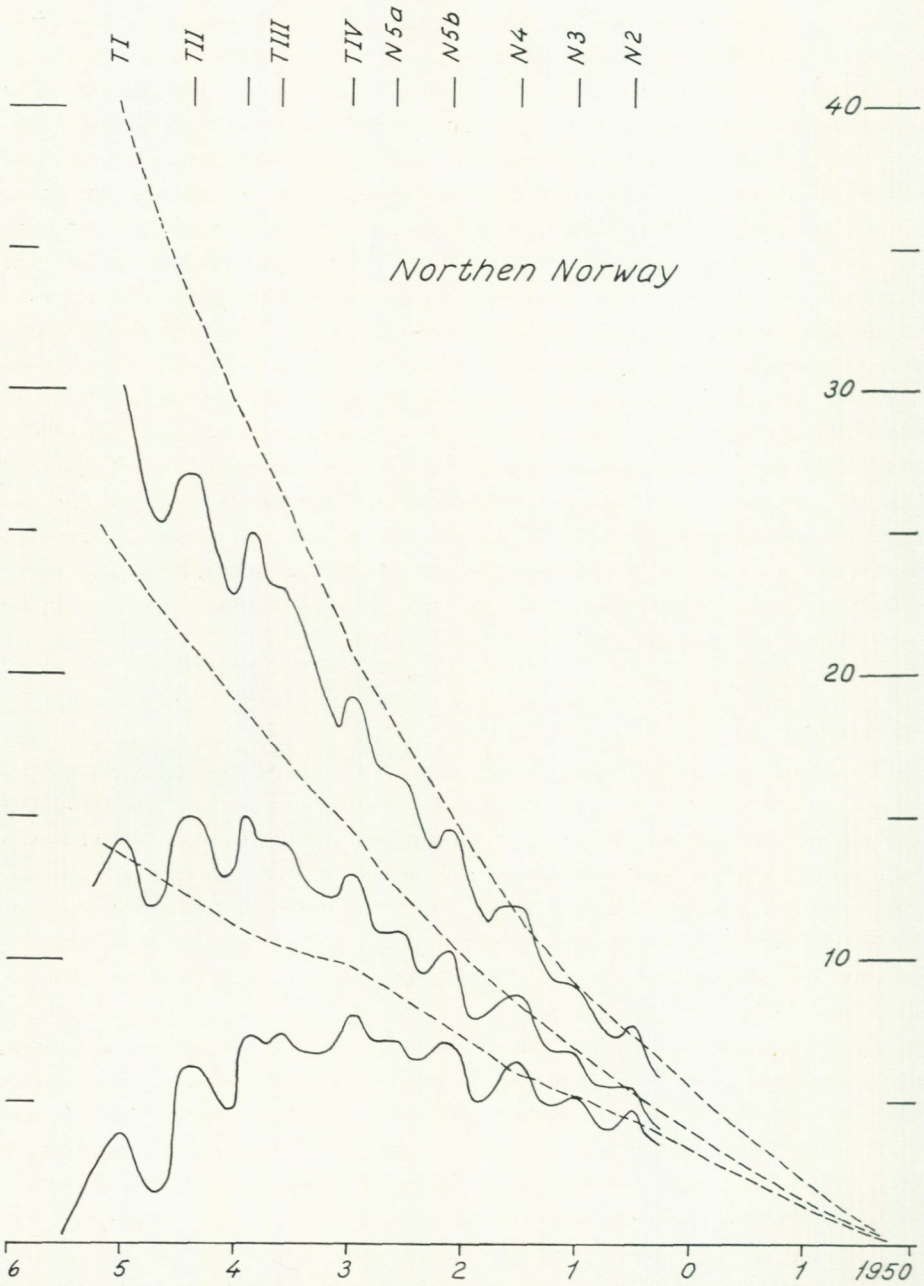


Fig. 150. *Shorelevel displacement curves (full lines) and isostatic curves (dashed lines) for three points in Marthinussen's shorelines diagram. The PTM levels (TI to N2) gave the isostatic curves, from which the PR levels were then calculated. (The final part of the middle curve is not quite correctly drawn). Note the smoothness of the isostatic curves.*

Tapes III is double. Marthinussen's Tapes III shoreline is quite equivalent to PTM-4B, while an older shoreline equivalent to PTM-4A lies somewhat higher.

Tapes IV is quite equivalent to PTM-5A.

N 5 is double. An older shoreline equivalent to PTM-5B lies in the inner part above N 5, while a younger shoreline equivalent to PTM-6 lies somewhat below N 5. Two C^{14} dates of driftwood from altitudes that were said to correspond to the N 4 shoreline gave ages that correspond to PTM-6 (see p. 397), but as the younger N 5 shoreline and the N 4 shoreline lie very close in these areas, the C^{14} dates do not contradict this interpretation.

N 4 is quite equivalent to PTM-7.

N 3 seems to correspond to a maximum at about 1,100—950 BC (PTM-8) and to have a somewhat steeper gradient. The corresponding position of the eustatic curve seems to have been at or just below the present sea level.

N 2 corresponds to a maximum (PTM-9A) at about 500 BC and seems to lie some decimetres lower. The position of the eustatic curve seems to have been at or rather just above the present sea level.

N 1 seems to have a somewhat steeper gradient. The curves suggest a date of about 300 to 0 BC (i. e. probably PTM-9B).

Some distinct shore marks about 1 m above the seaweed boundary fall in the the curves somewhere about 1,000 AD.

Summing up, the very smooth isostatic curves are good evidence of the correctness of the eustatic curve here presented.

3. Southern Norway

The available shorelevel displacement curves are still too incomplete to be used for a calculation of isostasy.

4. Vendsyssel, Denmark

If the shorelines in Vendsyssel (Fig. 11) — though not yet finally established — are compared (perpendicularly to the direction of tilting) with the ones in my shoreline diagrams (Pls. 4—6), the disagreement is obvious. Consequently, Vendsyssel has (at least mainly) had its own isostatic history. The first problem concerns ML (cf. p. 51); either there is a metachronous ML (as on the Swedish West Coast) or a synchronous transgressive ML (dot-dashed line in Fig. 11). This problem is not yet solved. However, Danish geologists believe that the recession of ice was connected with a transgression. This transgression must have reached its maximum at the onset of the East Jylland Stadial (the D line), i. e. about 13,000 BC.

As the Late Glacial shorelines are few and not yet sufficiently closely fixed in gradient and age and as the position of the ALV shorelines is not yet determined, only a preliminary discription can here be given.

The curve of changes in gradient shows: a slight land subsidence during the East Jylland Stadial, a more or less continuous Late Glacial tilting (probably an irrigularity during Older Dryas), a strong land subsidence (much stronger than in the main area) during 5,800—5,000 BC, a strong tilting (much stronger than in the main area) 5,000 BC to about 3,000 BC (compare the gradient of PTM-2 in Vendsyssel and the main area 3 m/10 km and 1 m/10 km, respectively), and finally a tilting from about 3,000 BC onwards of the same intensity as in the main area.

The Late Glacial shorelevel displacement curves (Fig. 151) indicate a rapid fall during the East Jylland Stadial (i. e. about 13,000—12,800 BC) and a more or less continuous Late Glacial regression onwards. The corresponding isostatic curves (Fig. 151) give a slight subsidence during the East Jylland Stadial (cf. the curves of changes in gradient) and a continuous Late Glacial land upheaval (probably with an irrigularity during Older Dryas) onwards. Prior to the East Jylland Stadial, Vendsyssel was probably more or less isostatically stable, giving place for a transgression of the sea. Concerning the Late Glacial part the following results are obtained from Fig. 151:

1. The eustatic sea level changes can be calculated, at least back to 13,000 BC. At 13,000 BC the eustatic sea level would have been at −60 m and at 12,750 BC at −70 m, indicating a eustatic fall of 10 m during the East Jylland Stadial, the distinct and worldwide climatic deterioration of which is consequently here demonstrated. These eustatic positions form a quite reliable continuation of my eustatic curve and agree very well with

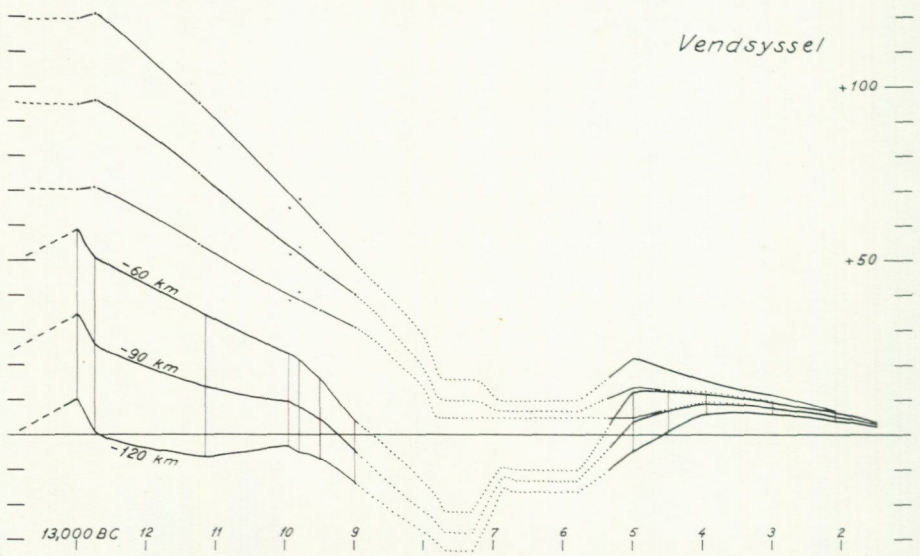


Fig. 151. *Shorelevel displacement curves for the points -60, -90 and -120 km in the shoreline diagram for Vendsyssel (Fig. 11) and the corresponding isostatic curves.*

Curray's data from the NW Gulf of Mexico (Fig. 157). Between 12,750 BC and 11,750 BC (where my curve starts, Fig. 145) the eustatic changes are not yet determined; a rise from –70 m to –66 m is known, but there may have been minor fluctuations corresponding to the climatic changes during this period (cf. Fig. 42).

2. The intensity of the land upheaval was much lower than in the main area (at least concerning the period 12,750—9,500 BC).
3. The isostatic land upheaval since 13,000 BC is 70 m, 95 m 120 m for –120 km, –90 km and –60 km respectively. Assuming that the thickness of the ice cover was about three times the isostatic depression (Tanner 1930, p. 413), this indicates that the Late Weichselian ice cover in Vendsyssel was at least 210—360 m thick.

The PTM shorelines form shorelevel displacement curves that give quite likely isostatic curves (Figs. 151 and 152). In NE there was a very strong land upheaval from 5,000 BC to about 4,000—3,000 BC, which towards SW changed over into a land subsidence. From PTM-5A onwards the land upheaval fairly closely follows the one of the main area. The altitude and gradient of PTM-7

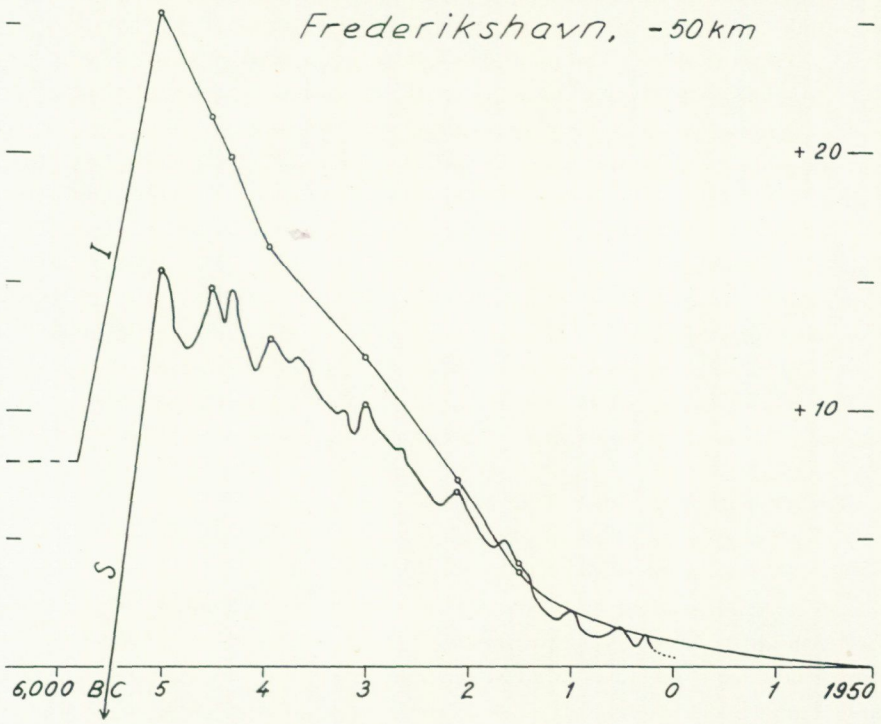


Fig. 152. *Shorelevel displacement curve (S) and isostatic curve (I) for Frederikshavn at -50 km. Circles indicate fixed levels. The shorelevel displacement between the fixed levels is calculated from the isostatic curve obtained.*

are the same in Vendsyssel as in the main area. The isostatic curve for Frederikshavn, i. e. –50 km, (Fig. 152) indicates a present upheaval of 0.4—0.5 mm per year.

5. Central Sweden

From this area S.Florin (1944) has given a shorelevel displacement curve. However, the amplitude of the fluctuations stated by Florin is definitely too great to apply to a normal isostasy, and probably also to a true shorelevel displacement. Florin interpreted the fluctuations as due to undulations of the earth's crust — a theory that was fashonable at that time (cf. von Post 1947, Cleve-Euler 1923). Though isostatic irregularities can be expected in an area between the Highland of Småland and Central Sweden, the given curves still require too big and too rapid changes in the earth's crust to be likely. The curve cannot — unless radically simplified — be used for calculations of isostasy.

6. The Baltic area (Southern Sweden and Finland)

E.Nilsson (1953, 1968) and Hyyppä (1963, 1966) think they have found a more or less identical shoreline system in southern Sweden and Finland respectively that would apply to the whole Baltic area. While Florin's (1944) and von Post's (1947, 1952) hypotheses about the land upheaval postulate rapid isostatic changes, E.Nilsson's and Hyyppä's hypotheses (the diagrams) represent the opposite extreme, assuming a completely undisturbed isostasy that would apply over an immense area, which my results contradict. Thus there are no grounds for dealing more closely with these results. However, these shoreline diagrams are not only theoretically unlikely, but in several respects demonstrably wrong, e. g. the areas studied by me, the plain "Kristanstadslätten" (cf. p. 110), the area studied by Berglund, the bottom of SW Baltic Sea, etc.

Concerning Finland itself, numerous more or less reliable shoreline diagrams and shorelevel displacement curves have been published. However, the information is so copious and controversial that I find it wiser not to discuss these results yet, awaiting further C^{14} dates which may clarify the picture.

7. The SW part of the Baltic Sea

From this area shorelevel displacement curves have been published by Schmitz (1953), Köster (1961) and Kolp (1964). However, none of these curves are sufficiently closely dated and fixed to allow a detailed calculation of isostasy.

If Schmitz's curve is used, an isostatic curve is obtained that shows stagnation and a slight land upheaval to PTM-7 where a land subsidence starts. If Köster's curve from Lübecker Bucht is used, the isostatic curve obtained slowly falls to PTM-7 where it turns and rises towards the present. A true shore level displacement curve would probably have given a more or less continuous land subsidence. Although the extrapolated PTM shorelines cannot be regarded as exact

in this area, they do give steadily rising isostatic curves, i. e. an unbroken land subsidence. If the isostasy is expressed hypothetically as a quite straight line from ±0 at present via –2 m at 250 BC, this would require a shorelevel displacement curve that still lies within the margin of error of the pollen datings.

Within this area a continuous land subsidence is most likely, at least where the PTM shorelines are concerned.

8. The northeastern coasts of the North Sea

In connection with the discussion about the PTM shorelines (p. 393) it was shown how very well the sequence of ingressions in this area correspond to my PTM shorelines. However, Jelgersma's closely dated time-depth graph (Jelgersma 1961) does not show these fluctuations, which makes a detailed calculation of isostasy impossible. If Jelgersma's curve (1961) is used for calculation of isostasy, the following fairly unlikely picture is obtained: a land upheaval before 4,000 BC, a stagnation about 4,000—3,000 BC, a slight land subsidence about 3,000—1,500 BC and an increased subsidence after about 1,500 BC. However, it seems more likely that the isostatic land subsidence continues back in time. In Fig. 153 two more or less hypothetical isostatic curves are drawn (one straight and one curved line) and the corresponding — also more or less hypothetical — shorelevel displacement curves are calculated. As is shown by this figure the only great difference to Jelgersma's curve is about 6,500—4,000 BC. In my opinion this

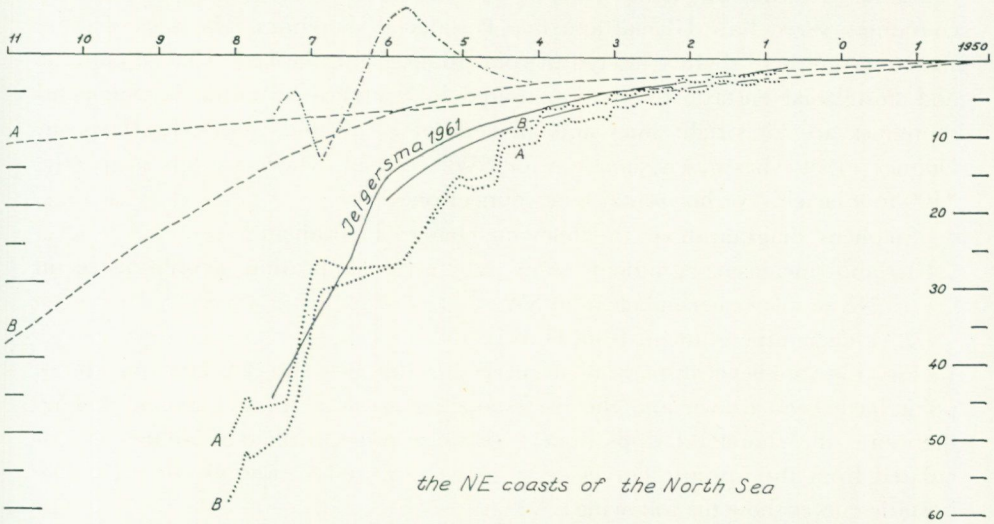


Fig. 153. *Jelgersma's curve gives a quite unlikely isostatic curve (dot-dashed) for the period 7,500-4,000 BC. Two hypothetical isostatic curves (dashed) are drawn and the corresponding shorelevel displacement calculated (dotted). The most reliable shorelevel displacement curve seems to be obtained if the isostatic B curve from its position at 4,000 BC is connected with the A curve at about 7,800 BC (or extended back as a straight line). The isostatic B curve suggests a present subsidence of about 0.5 mm per year. Time scale in 1000 years BC.*

shows that the eustatic curve here presented is at least not contradicted by the results within this area, but rather supported. It also suggests that Jelgersma's curve requires a still closer determination, though the tides in that area prevent as close a determination as is possible in the Kattegatt area.

A high position of PTM-7 is also indicated by pollen analysis in the bogs at the Dutch and German coast (T.Nilsson 1948 b). A similar peak in the shorelevel displacement curve was obtained by Godwin (1940) for the Fenland of England.

Outside the coast of Brittany in France, Pinot (1965) has found a very distinct submarine shorline at −37 m. Though Pinot thinks this shoreline is much older and followed by a regression at least down to −60 m, it is tempting to correlate it with ALV-1, as the shore features are said to be "excelently" preserved and as the level almost exactly corresponds to the eustatic depth of −38 m (Fig. 145) at about 7,350 BC or just before the onset of the transgression up to ALV-2 (= PTM-1). However, an "excellent", i. e. unusually good, preservation could hardly agree with a subsequent regression; probably only with a rapid transgression. Pinot also gives a shoreline at −21 m. This level almost exactly corresponds to ALV-3.

9. Ireland—Scotland

Stephens (1968) has published a shoreline diagram for NE Ireland and SW Scotland, covering an area of about 360 km in the direction of tilting and containing seven Late Glacial and five Postglacial shorelines. The ages of these shorelines are here slightly altered in concordance with the Late Glacial climatic and Postglacial eustatic fluctuations found in Southern Scandinavia. Stephens' shorelines are all stright lines and all (except L4) tilted from NE. However, Donner (1959) has given shoreline for SW Scotland, which are less steep (the "100-foot beach") or horizontal (the younger ones).

Stephens' diagram shows the following changes in gradient:

1. and increasing gradient from A2 to D, indicating a subsidence in NE or a stronger upheaval in SW
2. a decreasing gradient from D to L

In Fig. 154 shorelevel displacement curves for 100, 200 and 300 km from the 0-point have been drawn and the corresponding isostatic curves calculated. Furthermore, the shorelevel displacement between the identified shorelines is calculated from the isostatic curves (e. g. between F and G, and G and L1). The isostatic curves show the following:

1. A strong peripheral land upheaval from A to D, which decreases inland. Consequently, the centre of upheaval was situated in Ireland. The upheaval of the Irish side between C and D changes towards Scotland into stagnation and subsidence, corresponding to the Perth Readvance (= Older Dryas).

2. A strong central land upheaval from D to E (i. e. during early Alleröd), which decreases towards the periphery. Consequently, the centre of upheaval was now moved from Ireland to Scotland.
3. A retarded land upheaval from E to F leading to a distinct subsidence of the peripheral area. The centre of upheaval was still in Scotland, but was influenced by the Highland Readvance (= Younger Dryas).
4. An almost equally decreasing — in time and in distance towards the periphery — land upheaval from shoreline F onwards (the centre in Scotland).

Consequently, the curious change in gradient at shoreline D is here shown to depend upon an early isostatic balance between the upheaval of Ireland and Scotland, similar to the one between the Highland of Småland and Central Sweden (p. 415, Fig. 146). This is in full agreement with the bedrock morphology and the recession of land ice.

An important stratigraphy is described from Garscadden Mains (Mitchell 1952). The regressional sequence (= zone II and younger) fits well with this shorelevel displacements (the 300 km curve). The transgressional sequence (= zone I) as supposed by Mitchell (1952) and Donner (1957) has for good reasons been given a quite different interpretation by Anderson and Simpson (1952)

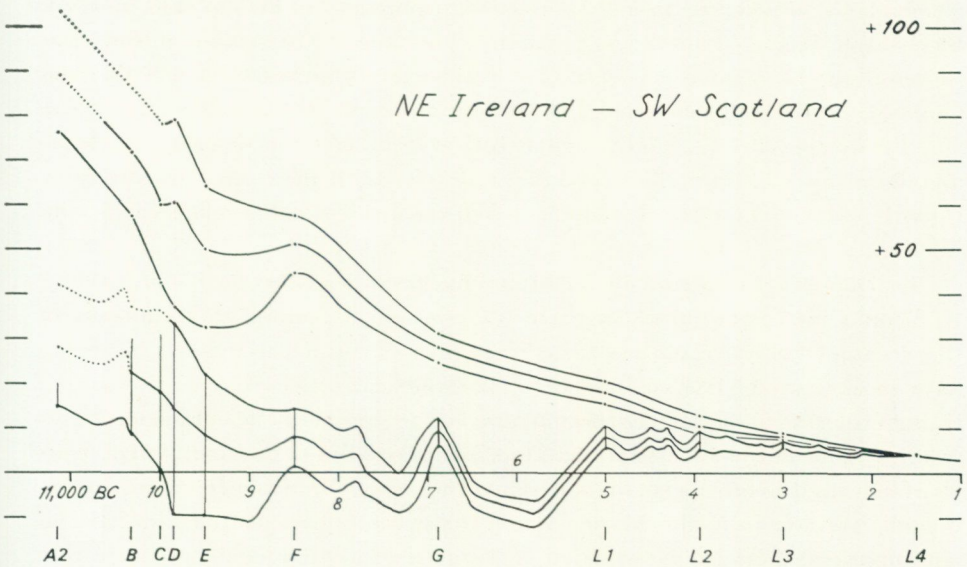


Fig. 154. *Three shorelevel displacement curves (below) and corresponding isostatic curves (above) for the area between NE Ireland and SW Scotland. Vertical lines = identified shorelines. The shorelevel displacement between the identified shorelines is calculated from the isostatic curves. The centre of upheaval changed from Ireland to Scotland (after the D line). The G shoreline apparently corresponds to PTM-1. This transgression seems to be registered in Robbans Port.*

which means that no transgression is registered (at about Ib/Ic) at Garscadden Mains. However, a transgression is not incompatible with this shorelevel displacement curve. It only means that shoreline B (and/or C) bends to a gentler gradient over Scotland.

The shorelevel displacement here given (Fig. 154) fits well with the stratigraphy at Roddans Port (Morrison and Stephens 1965, Stephens 1968). Shoreline G is apparently equivalent to PTM-1. This transgression did not reach into the Roddans Port basin due to the separating drumlin (Morrison and Stephens 1965, Fig. 2), but the sedimentation changed. The PTM-1 transgression is obviously registered as the 3.4 cm thick clay layer (of zone VI) in the peat. A peak of *Chenopodiaceae* in this clay layer indicates proximity to the shore. The peat above and detritus mud below this clay layer reflect the low position of the sea level before and after the G shoreline.

Seen as a whole, my eustatic curve fits very well with Stephens' shoreline diagram (though not yet fully established) for NE Ireland and SW Scotland.

10. The American NE coast

The shorelevel displacement of southeastern New England has been expressed in an approximate time-depth graph by Redfield and Rubin (1962). A rough comparison with my eustatic curve gives a Late Glacial land upheaval and a Postglacial land subsidence. From the coast of Connecticut, Bloom (Bloom 1964, Bloom and Stuiver 1963) gives a curve (based on C^{14} dated submarine peat samples) of the relative rise of sea level during the last 7,000 years. Also this curve suggests a land subsidence.

The shorelevel displacement in the Boston area has been described by Kaye and Barghoorn (1964). A calculation of isostasy with their data gives a fairly rapid Late Glacial land upheaval changing over into a slow Postglacial land subsidence.

The shorelevel displacement in Maine has been described by Bloom (1963). If Bloom's interpretation of an early transgression depositing the sediments of the Presumscot Formation is correct, there must according to my eustatic curve have been a strong land subsidence in Late Glacial time. However, no such a transgression is found in the Boston area or in southern New England. This seems to indicate that the stratified sand and gravel below the marine sediments in Maine need another explanation. There may have been a more or less continuous regression from the Marine Limit. This would give a rapid Late Glacial land upheaval that changes over into a Postglacial land subsidence, i. e. a picture similar to the ones obtained from the Boston area and southern New England.

On the shelf off the NE coast of America (Emery 1965) shells of estuarine or shallow sea molluscs have been found down to about –150 m (Emery and Garrison 1967) with the greatest number found between –38 and –59 m (Merrill *et al.* 1965). A number of these shells have been C^{14} dated (e. g. Emery

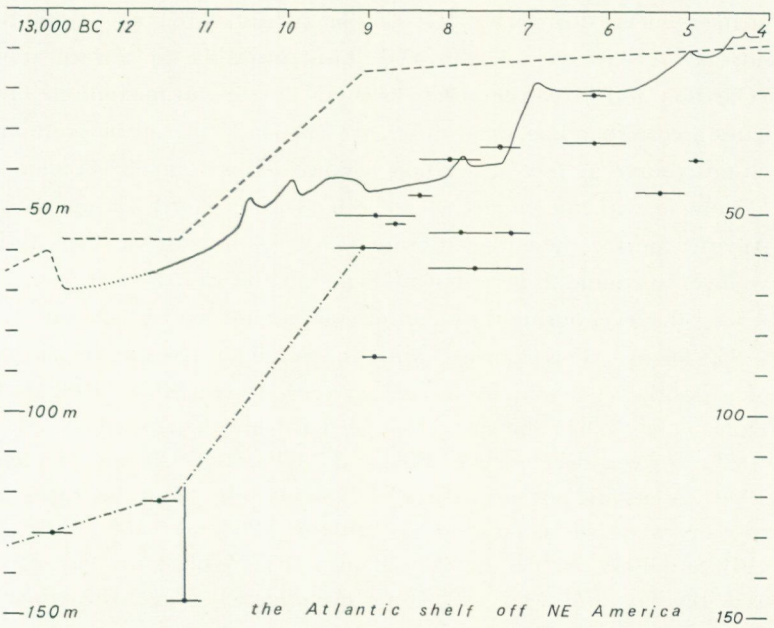


Fig. 155. *Time-depth indications from the shelf compared to my eustatic curve. Dot-dashed line gives shorelevel displacement, while dashed line gives approximate isostatic changes. The strong subsidence between 11,400 and 9,000 BC corresponds to the deglaciation and rapid upheavel of the New England area. The -130 m date indicate a small difference (about 15 m) to the level during the glaciation maximum at about 18,000-16,000 BC (at about -145 m). This would give a corresponding eustatic sea level at -85 m.*

and Garrison 1967). From Georges Bank, Emery *et al.* (1965) report a C^{14} dated peat at –59 m containing salt-marsh grass. The age is 9,050 ±350 BC. This peat falls about 15 m below my eustatic curve (Fig. 155), indicating a subsidence of this area, which was the marginal area of the last glaciation maximum (Emery *et al.* 1965, Fig. 5). In Fig. 155 the available time-depth indications from the shelf are compared to my eustatic curve. The following is shown:

1. The shelf has clearly subsided since the last glaciation maximum at about 13,000—12,800 BC.
2. The shelf has subsided unequally. In general the marginal areas of the shelf are strongly subsided, while the costal areas (the sampling points M 27, AEV 1 and D 45) are only a little or even not at all subsided.
3. From about 11,400 BC (or later) to about 9,000 BC the shelf (at least the marginal areas) rapidly subsided. This subsidence corresponds to the deglaciation and corresponding rapid land upheaval of the New England area.
4. The oldest data (–130 m at 12,900 ±250 BC) corresponds to the maximum extension of the last glaciation in the New England area. The position

of the sea level during the glaciation maximum at 18,000—16,000 BC cannot have been far below this level. Most probably the terrace at −145 m (Garrison and McMaster 1966) was cut during this maximum. This indicates a corresponding small difference (about 15 m) in the position of the eustatic curve at these glaciation maxima. This is, in my opinion, in full agreement with the extension of the land ice in North Europe and North America during these glaciation maxima. As the eustatic level during the younger maximum is here shown (Figs. 155 and 157) to have been at about −70 m, the level during the older maximum must have been at about −85 m (−85—90 m). This contrasts with the common (North American) view of a position at about −118—125 m (e. g. Curray 1960, 1961 and 1965, Donn *et al.* 1962, Shepard 1963, Shepard and Curray 1967 and Emery 1967) or even deeper (e. g. Fisk and McFarlan 1955 and Heezen *et al.* 1959). A eustatic position at about −85 m fits better with the (especially European) view of a position at between −80 and −100 m (e. g. Daly 1910 and 1934, Antevs 1928b, Valentin 1952, Woldstedt 1954, Flint 1957 and Bonifay and Mars 1959) or even higher (e. g. McFarlan 1961). Furthermore, as shown by this work, we must from now on also consider the posibility of a hydro-isostatic subsidence of shelf areas (p. 420).

5. Garrison and McMaster (1966) have shown the occurrence of four shore cut terraces, viz. at −145 m, −118 m, −81.5 m and −23.5 m, and a zone of "beach ridges" at about −63.5 m. The −145 m terrace corresponds to the Nicholls Shore (Veatch and Smith 1939) and a distinct sub-bottom erosion surface (Ewing *et al.* 1963). According to the description here given (Fig. 155) the following datings seem probable: −145 = 18,000—16,000 BC, i. e. the first Late Wisconsin glaciation maximum, −118 m = 11,500—11,000 BC, i. e. the low Baltic Stadial in Southern Scandinavia, −81,5 m = 10,000—9,800 BC, i. e. the Older Dryas of Northern Europe, −63.5 m = 9,500—9,000 BC, i. e. the end of Alleröd, and −23.5 m = 6,900—5,800 BC, i. e. ALV-2 and ALV-3 in my investigation area. According to the profiles by Ewing *et al.* (1963) the sub-surface corresponding to the −145 m terrace is double (their *A* and *A'* sub-surfaces). It is here suggested that the *A'* sub-surface corresponds to the sea level (at about −145 m) during the first Late Wisconsin glaciation maximum at about 18,000—16,000 BC and the *A* sub-surface (in profiles where both are recorded) corresponds to the sea level (about −130 m) during the second Late Wisconsin glaciation maximum at about 13,000—12,800 BC.

Consequently, the shelf along the NE coast of the United States seems to have subsided from the Late Glacial time onwards, while the coastal areas show a Late Glacial land upheaval that increses in intensity northwards (Barnstable—Boston—Portland) and a Postglacial land subsidence (cf. the table on p. 442).

11. The Gulf of Mexico and the American East Coast as a whole

From SW Florida Scholl (1964) and Scholl and Stuiver (1967) have given a well dated curve (more than 30 time-depth indications) of the rise of relative sea level during the last 4,000 years. According to Scholl, his curve "must principally reflect a eustatic submergence of the southwestern Florida coast" as this area in his opinion has been stable. Scholl drew an even curve, though the time-depth indications allow minor fluctuations. At about 1,700—1,500 BC there is a distinct flattening out of the rise of sea level. This corresponds to my PTM-7. Scholl and Stuiver (1967, p. 446) write that the Florida submergence curve is "only a record of average sea-level position during the last 4 millennia. This is because sea-level oscillations of an amplitude of less than 0.5 m over periods of a few hundred years might be virtually unrecorded in southern Florida or if recorded, easily lost or confused with possible hurricane deposits. The smooth nature of the submergence curve (Fig. 6), therefore, should not be construed to indicate the lack of possible high-frequency low-amplitude oscillations in sea level during the last 4 000 years."

In Fig 156 I have tried to reconstruct the isostatic changes (*I*) of SW Florida starting from PTM-7, the eustatic level of which is closely fixed at +0.4 m, and the knowledge that the eustatic levels of PTM-8, PTM-9A and PTM-9B roughly correspond to the present sea level (± a few decimeters). The oldest part of the isostatic curve can be drawn in two ways: either there had been a continuous subsidence at least since 3,000 BC (*I* 1) or the subsidence started (or accelerated) in connection with the transgression from PR-6 to PTM-6 (*I* 2). From these isostatic curves and my eustatic curve the shorelevel displacement (*S*) is calculated (Fig. 156). These curves (*S* 1 and *S* 2) seem to fit nicely with the Florida data, in some respects even better than Scholl's smooth curve. The oldest data may indicate that the isostatic curve *I* 2 is more correct than *I* 1. In that case the subsidence started in connection with the transgression from PR-6 to PTM-6, i. e. when the fairly large shallow coastal area was submerged. This would show the hydro-isostatic nature of the subsidence. Summing up, Fig. 156 shows two very important things about the data from SW Florida:

1. This area is subsiding (1.7 m since 1,500 BC). Consequently, it is not correct to regard the Florida curve a eustatic curve and use it for calculations of the subsidence of other areas as done by Redfield (1967) and Bloom (1968).
2. My fluctuating eustatic curve is not at all contradicted by these data, rather supported.

From the NW part of the Gulf of Mexico, Curray (1960) and Shepard (1960) have given time-depth graphs for the last 20,000 years based upon C^{14} dated shells, the distribution and character of sediments, and the morphology (channels bordered by ridges). Curray (1960) gave 12 C^{14} dates (rejecting eight other dates) of shells of types now found in brackish shallow water. But

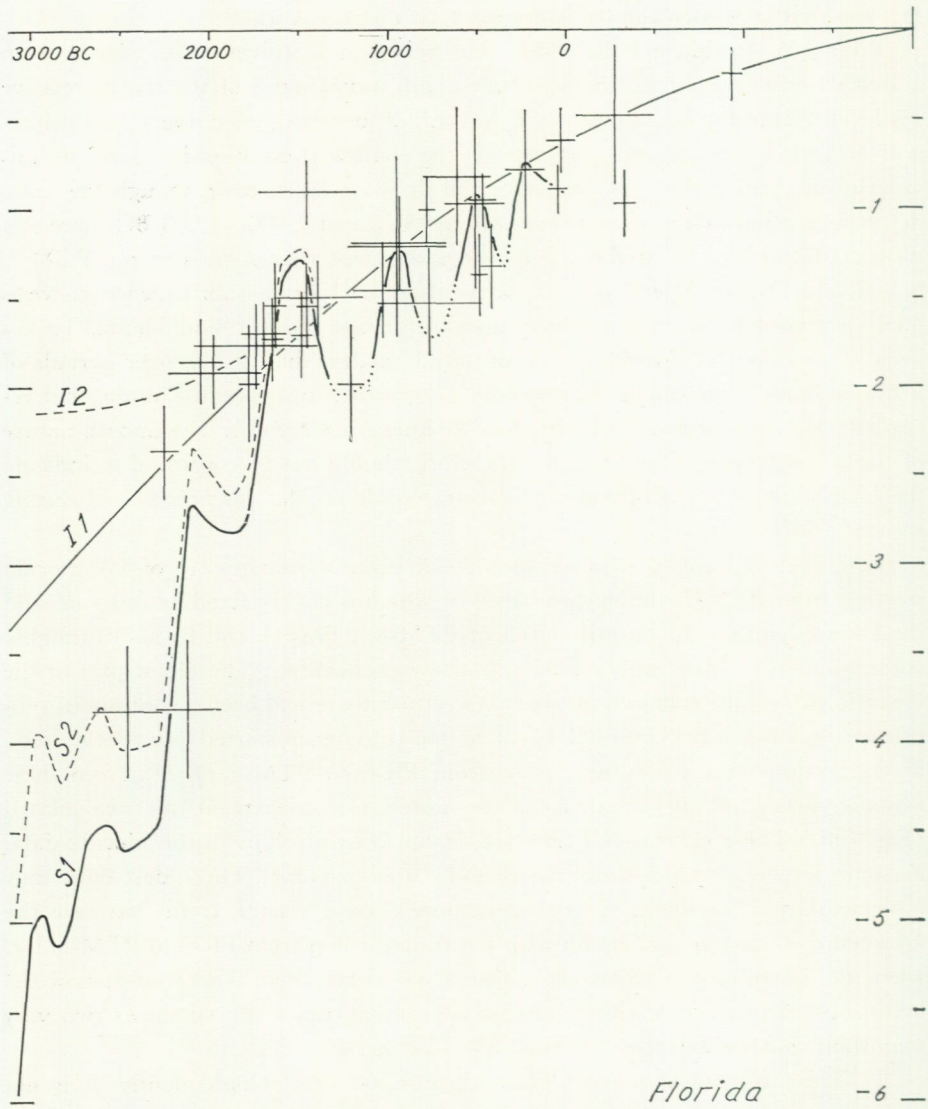


Fig. 156. *My eustatic curve gives a shorelevel displacement curve (S) that fits very well with the available time-depth indications (crosses) from the Florida area, if this area has slowly subsided as shown by the isostatic curve (I). The isostatic curve before PTM-7 can be drawn in two ways (I1 and I2).*

he added (Curray 1960, p. 254): "There is always the possibility, however, that the shells were transported either up or down the shelf after the death of the organisms". These dates, ranging between 15,000 BC and 6,000 BC, all fall fairly close to — above or below — my eustatic curve (Fig. 157). Consequently, there is no indication of any subsidence. Shepard (1960) also thinks that this

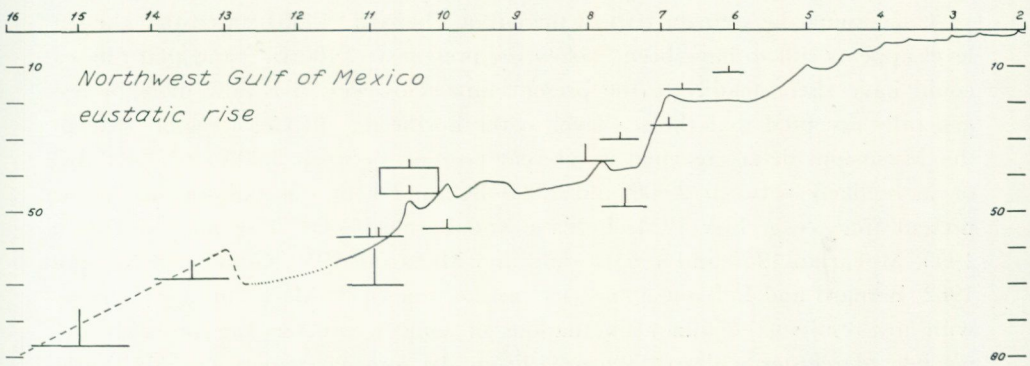


Fig. 157. *Carray's time-depth indications from the NW Gulf of Mexico compared to my eustatic curve. Time scale in 1000 years BC. The figure shows that this area has not subsided and has probably been stable during the last 18,000 years. The two oldest dates consequently give the continuation of my eustatic curve (dashed line), agreeing well with the information from Vendsyssel.*

area has probably been stable. Thus the two oldest dates give an idea of the continuation of my eustatic curve back in time. They also fit well (Fig. 157) with my eustatic curve and the indication from Vendsyssel (p. 430) of a regression from –60 m to –70 m during the East Jylland Stadial at about 13,000—12,800 BC. Curray (1960) thought he found morphological and sedimentological indications of very distinct regressions to about –63 m and –38 m, respectively. However, such big and rapid oscillations are quite incompatible with my results. It also requires much too rapid eustatic changes (4—5 cm per year). Probably the submarine features in question must be given some other explanation. The maximum Late Wisconsin lowering of sea level was according to Bernard and LeBlanc (1965) "at least 91 m and possibly 136 m," according to McFarlan (1961) about 76 m (76 m or 91 m) and according to Curray (1960) about 118 m. A sea level at –91 m fits fairly well with the continuation of my eustatic curve (p. 438), while a sea level at –118 m is here supposed either to be wrong or to correspond to an earlier glaciation maximum, probably Riss and/or Mindel (lying 38.8 % below the Late Wisconsin level –85 m). The distinct terrace at –81.5 m and concentration of tops of submarine banks at –81,5 to –87.0 m (Parker and Curray 1956) correspond in depth with the supposed eustatic position during the glaciation maximum at about 18,000—16,000 BC. However, there is as yet no information about the age of this terrace and these banks. Curray (1961) reported that shells (of a type with a present living depth range of 2—18 m) found at about –113 m were C^{14} dated at 17,350 ±300 BC, i. e. the time of the glaciation maximum. As the relation to the former (living depth range) as well as to the present (postmortal transportation) sea level is fairly uncertain, this time-depth indication does not contradict a eustatic position at –85 m — nevertheless the disagreement with –85 m (above) is as big as with –118 m (below).

Concerning the younger part of the curve, Shepard (1960) stated that the sea level appears still to have been "below the present at 2,100 BP" and that the sea could have risen steadily to the present time. However, it is now more or less generally accepted that the sea level in the northern Gulf Coast region (except the Mississippi delta) reached its present position between 3,000 and 1,000 BC or more likely between 2,000 and 1,000 BC, and kept this position up to the present time (e. g. Fisk 1951, LeBlanc and Bernard 1954, Fisk and McFarlan 1955, McFarlan 1955 and 1961, Gould and McFarlan 1959, Gould and Morgan 1962, Bernard and LeBlanc 1965), i. e. at the time of PTM-7. This agrees nicely with my results (the minor fluctuations of some decimeters are probably impossible to register within this area). From the somewhat more easterly south-central Louisiana, Coleman and Smith (1964) have given a section showing five peat horizons, from which 13 C^{14} datings have been made. The age of the peat horizons suggests that they correspond to transgression maxima (my PTM levels). The data indicate a subsidence, at least since 3,500 BC, of the following magnitude: 2.5 m since 1,000 BC, 3.4 m since 2,000 BC, 4.0 m since 3,000 BC, 4.2 m since 4,000 BC and 3.4 m since 5,000 BC. As the data are too few these figures are not well founded.

Taken as a whole, there seems to be a good correspondence between my eustatic curve and the time-depth indications from the northern Gulf Coast region (except for the Mississippi delta, which obviously is subsiding) for the older as well as the younger part of the curve. Consequently, this region seems to have been more or less stable during the last 17,000 years (Fig. 157).

If the North American East Coast is considered in its entirety (Newman and Rusnak 1965, Fig. 3; Scholl and Stuiver 1967, Fig. 7; Redfield 1967, Fig. 3) it is apparent that the rate of subsidence varies along the coast. Scholl (1964, also Scholl and Stuiver 1967) assumes that the Florida curve gives the eustatic rise of sea level. Redfield (1967) stated that the time-depth indications from Florida, North Carolina, Bermuda and Louisiana roughly correspond and give the eustatic rise of sea level. He used the Florida curve as a base for a calculation of the rate of subsidence of other areas. Bloom (1968) did the same. However, it was shown above that the Florida area is also subsiding. Below I have listed the areas on the North American East Coast from north to south (the Netherlands added for comparison) and calculated the approximate degree of subsidence since PTM-7, i. e. about 1,500 BC (or 3,500 BP). The corresponding shorelevel lies 0.4 m higher.

Maine	1.0—2.5 m	Bloom 1963
NE Massachusetts	3.8 m	McIntire and Morgan 1963
Boston	1.0—5.0 m	Kaye and Barghoorn 1964
Cape Cod	7.0—7.5 m	Redfield and Rubin 1962

Connecticut	4.3 m	Bloom 1964, Bloom and Stuiver 1963
New Jersey	7.0 m	Stuiver and Daddario 1963
Virginia	4.0—4.5 m	Newman and Rusnak 1965
North Carolina	3.0—4.0 m	Redfield 1967
Florida	1.7 m	Fig. 156, Scholl 1964, Scholl
Bermuda	3.0—4.0 m	Redfield 1967
Louisiana	3.0 m	Coleman and Smith 1964
the Netherlands	2.0—3.5 m	Fig. 153, Jelgersma 1961 and 1965

This list shows that we have a land subsidence that (from north) increases towards the periphery of the last glaciation with a maximum subsidence in Cape Cod and New Jersey and that we have a land subsidence that decreases from New Jersey in the north to Florida in the south. Furthermore it was shown above that the subsidence also increased towards the margin of the continental shelf.

12. New Zealand

Schofield (1960a and 1960b) has given a curve of the relative sea level for the Firth of Tames (the northern part of North Island) during the last 4,000 years. The curve starts at +2.3 m at about 1,950 BC and falls with several fluctuations to the present position. The curve is based upon two sections across "stranded beach ridges called cheniers", from which seven shell samples had been C^{14} dated. However, Schofield's curve must be altered as two C^{14} dates were interchanged (Schofield 1964, p. 365). Furthermore the C^{14} datings were made of marine shells and must thus be corrected (p. 16). The "sea correction" for this area is not yet known (probably between −250 and −500 years; cf. p. 16). Here, the correction −305 ±25 years, found for the Kattegatt area, is used.

The Mirandea traverse (Schofield 1960b, Fig 6b) contains three higher cheniers, M13, M12 and M11, which correspond to PTM-7, PTM-9A and PTM-9B respectively. The Whakatiwai traverse (Schofield 1960b, Fig. 5) contains four higher cheniers, W10, W8, W6 and W4, which seem to correspond to PTM-7, PTM-8, PTM-9A and PTM-9B respectively. (The C^{14} date of W2 is apparently too old). This means that Schofield's results interpreted in this way give shorelevel displacement curves (Fig. 158) agreeing well with my eustatic curve (Fig. 145).

If the isostatic position at PTM-7 (= M13 and W10, respectively), 0.4 m below the position of the relative sea level, is connected with ±0 m in 1950 AD, it gives approximate isostatic curves (Fig. 158). The Miranda area is slightly more uplifted than the Whakatiwai area. The difference between the isostatic curves and the shorelevel displacement curves gives information about the corresponding eustatic changes. However, the curves are not yet sufficiently closely fixed in position and age to allow a detailed interpretation. The isostatic curve from the Miranda area is in Fig. 158 extrapolated back in time and the corresponding

shorelevel displacement curve is calculated. This curve clearly shows that the highest Postglacial sea level corresponds to PTM-7, which buried and destroyed the older shore features in the Miranda and Whakatiwai areas.

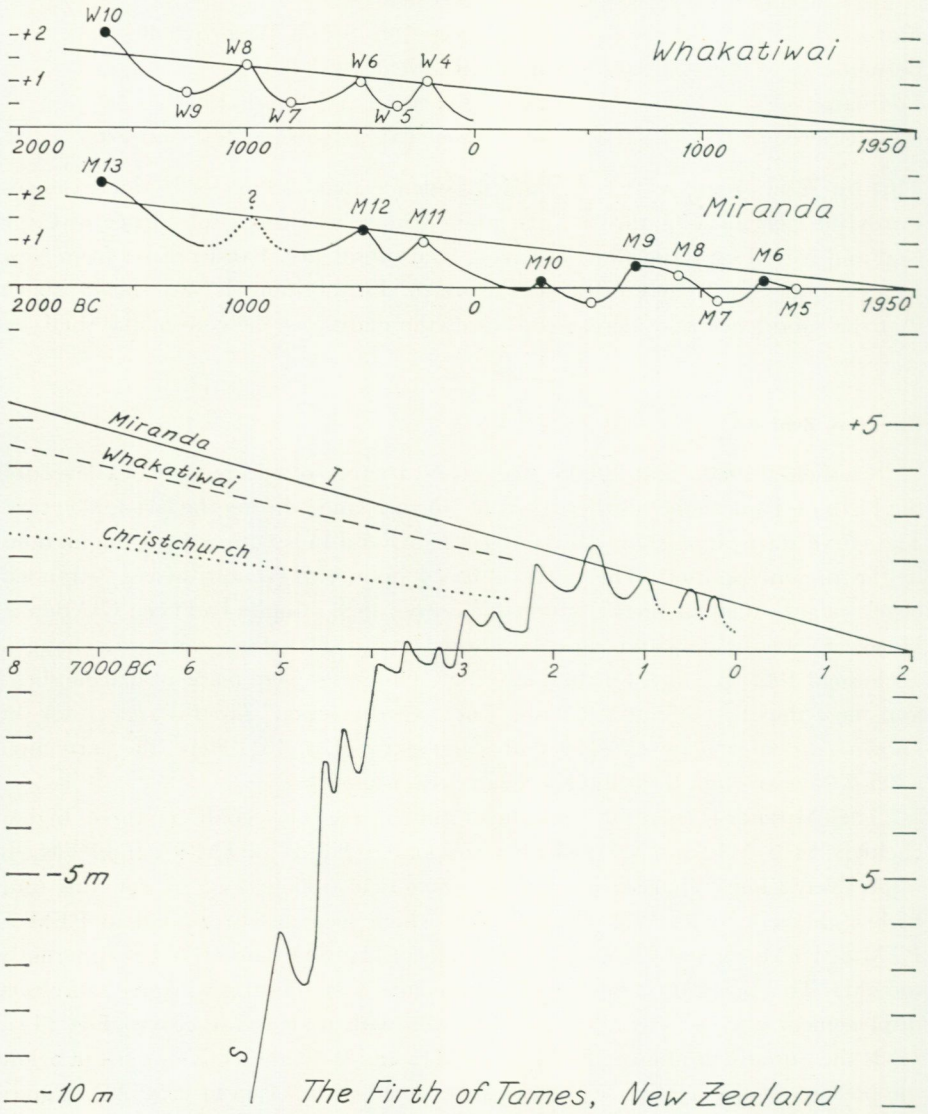


Fig. 158. *The upper two graphs give the shorelevel displacement as indicated by Schofield's data (black dots = C^{14} dated shorelevel, white dots = undated shorelevel). The W 10 and M 13 levels apparently correspond to PTM-7. The isostatic upheaval is expressed as straight lines between PTM-7 and the present. The difference between these lines and the shorelevel displacement curves would give the corresponding eustatic changes. The lower graph gives the shorelevel displacement from 5,500 BC as calculated from the extrapolated isostatic curve of the Miranda area. PTM-7 forms the highest Postglacial sea level.*

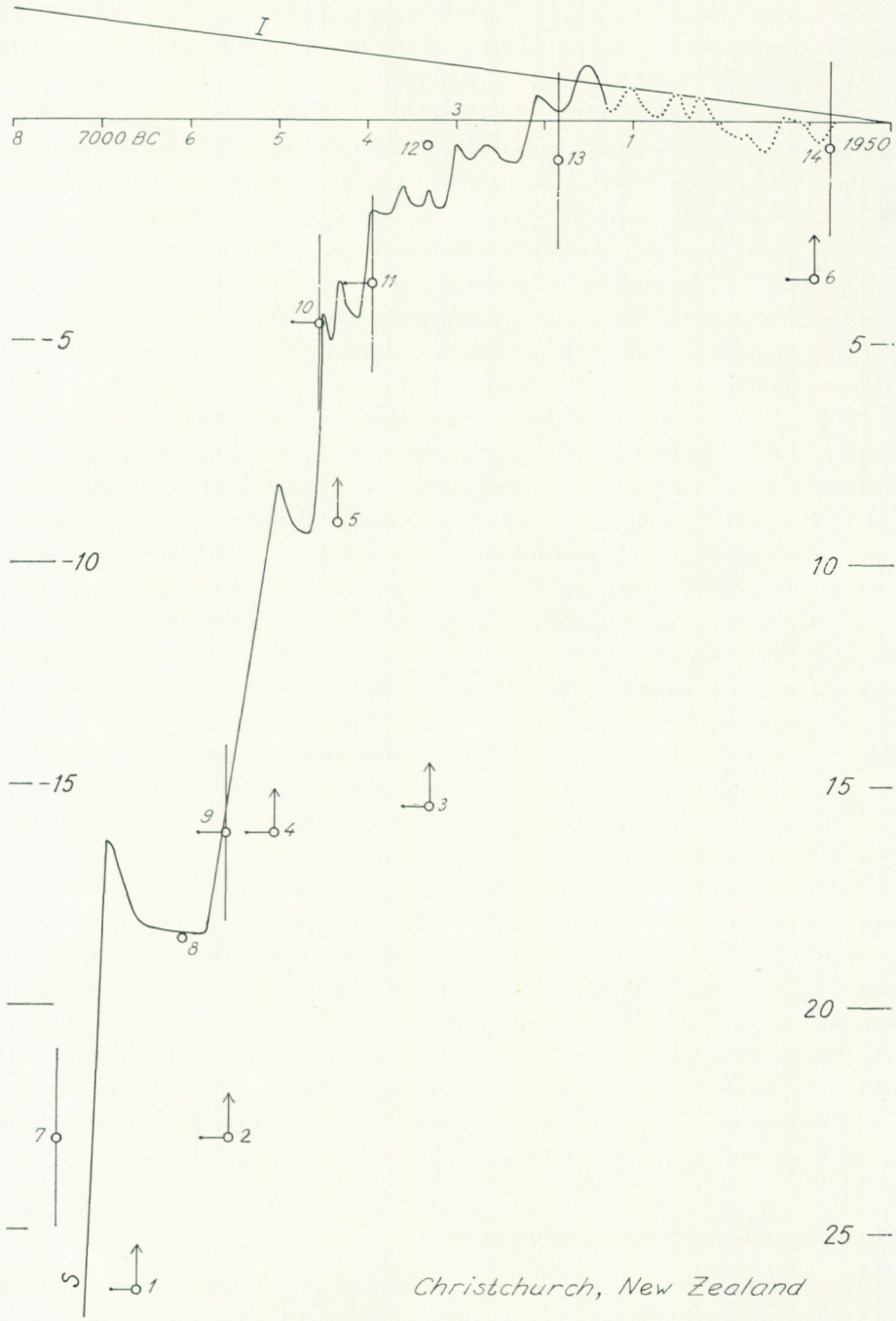


Fig. 159. *Suggate's 14 time-depth indications (circles) very closely correspond to my eustatic curve, if this area has been slightly uplifted (2 m in 8,000 years). Symbols: circle with vertical line = tidal range of dated wood or shells in estuarine deposits (e.g. 7 and 9), circle with arrow = dated sample in off shore position (e.g. 1 and 5), circle with horizontal line to the left = "sea correction" of dated shells (e.g. 4 and 9) and circle only = dated estuarine peat (8 and 12).*

In Foxton (the southern part of North Island) Te Punga (1958) found wood at –46 m that was C^{14} dated at 7,950 ±150 BC. This falls below my eustatic curve, suggesting a land subsidence of this area.

From the Christchurch area (the middle of South Island) Suggate (1968) has given a very interesting curve of the Postglacial rise of sea level. According to this curve the sea rapidly rose from –18.5 m at 6,000 BC to –4.5 m at 4,500 BC. This rapid rise corresponds to the one from ALV-3 to PTM-2. Suggate's curve is based upon 14 time-depth indications. Compared to my eustatic curve the Christchurch area seems to be slightly uplifted (2.0 m in 8,000 years). The approximate isostatic curve gives a shorelevel displacement curve as shown in Fig. 159. Suggate's time-depth indications closely agree with this curve. Some of the time-depth indications (data 1—14) require a closer description. Data 1, 2, 3 and 6 derive from shells in off-shore deposits. Data 7 is a date of wood (7,450 ±120 BC) found in peat at the base of sandy (probably marine) sediments. It falls 13 m above the corresponding point in the shorelevel displacement curve. However, it would fall right on the curve if the age was reduced by 400 years. The statistical error and the age of the wood (cf. Schofield 1964, p. 363) may justify such a correction. On the other hand, the estuarine environment is not fully proved and Suggate (1968, p. 295) writes "lacking clear evidence of estuarine conditions ... this sample must remain unsatisfactory as an indication of sea level at the recorded date". Data 4 is a date of shells containing a majority of open water species, from close above estuarine deposits. Consequently, the curve must lie above this data. Data 5 is a date of probably waterlogged drift wood from the top of a sand bed, resting upon the estuarine silt from which data 9 is derived. Data 12 is a date of a thin peat layer within a "presumably estuarine" silt. The peat seems to have been formed at high tide level.

From the southernmost part of New Zealand (Stewart Island) Cullen (1967) reports a peat at –14 m of supposed tidal marsh origin that was C^{14} dated at 7,350 ±80 BC. If it really is a tidal marsh peat, this clearly indicates a land upheaval. Cullen also reports a submarine shoreline at –64 m. However, the age of the shoreline is quite unknown. Cullen (1967) combined dated samples from Foxton (Te Punga 1958), Christchurch (Suggate 1958) and Stewart Island (i. e. areas with very different isostatic history according to this description) and the undated submarine shoreline to give a curve of relative sea level. Consequently, this curve is not true, and gives a quite misleading picture.

13. Combination of data from different areas

Shepard and Suess (1956) presented a graph of data from Australia, Holland and different parts of the Gulf Coast. The graph suggests a more or less continuous rise of sea level to the present. The data younger than 6,000 BC fall below my eustatic curve, while those older than 6,000 BC mainly fall above.

Godwin, Suggate and Willis (1958) gave a graph of data from several areas. According to this graph the present position of the sea level was reached already at about 3,500 BC.

Shepard (1960) gave a graph of data from Texas, Holland, Argentina, Louisiana, Australia and Florida, i. e. according to Shepard from "various stable coasts of the world". Shepard found that "it would seem rather unlikely that the present sea level was reached . . . as far back as 5,000 BP".

Fairbridge (1961) made an extensive synthesis of different data from all over the world, giving a highly fluctuating curve. However, much of the information, at least from Scandinavia, is now fundamentaly reinterpreted, which means that Fairbridge's curve must also be reconstructed. If Fairbridge's curve is compared to my eustatic curve the general correspondence is striking, though the amplitude of Fairbridge's fluctuations is much bigger, and several peaks lie far above mine (Fig. 160). As a whole Fairbridge's curve is very interesting and important, though it apparently does not give a true picture of the eustatic rise of sea level (it would give quite impossible isostatic curves in uplifted Scandinavian areas).

Shepard (1963) gave a graph of 77 data from nine "relatively stable areas", and an average curve from these data of the rise of sea level. This average curve gives a steady rise to the present. However, a smooth line can in my opinion never express the fluctuating eustatic rise of sea level correctly. Concerning the question of when the present sea level was reached Shepard says, after having discussed a shell found 2—3 feet above the present low tide in Ceylon that had been C^{14} da-

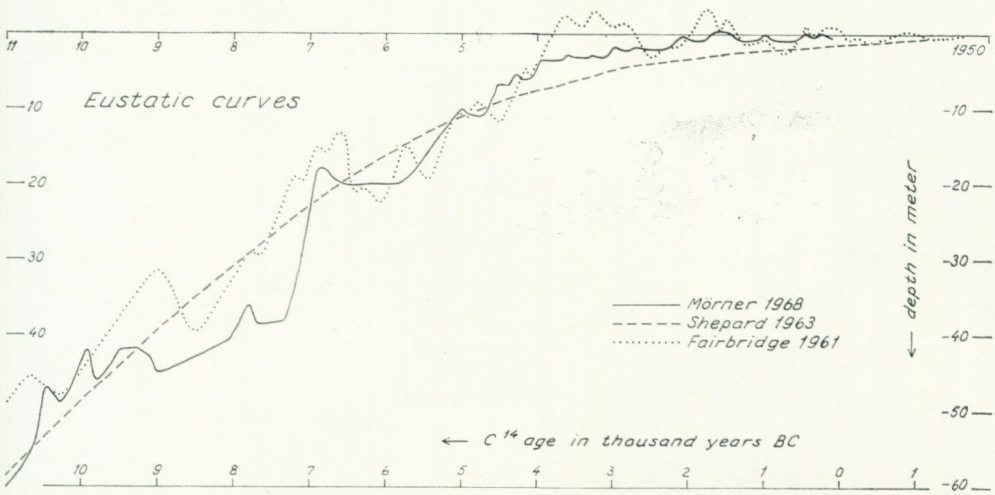


Fig. 160. *My eustatic curve compared to those of Fairbridge and Shepard. Though differing in many respects the general agreement is striking. However, an even curve as Shepard's can never express the fluctuating eustatic rise correctly. Fairbridge's curve, on the other hand, shows too big and rapid changes and shall be reinterpreted, as indicated from several different parts of the world.*

ted at 1,045 ±220 BC: "The writer has also found various other evidences of such a minor high stand in New Caledonia, the Cook Island, and Hawaii, and there appears to be a rather good possibility that the sea stood this much higher in postglacial times. Such a small change in sea level would be hard to evaluate from either the shell records of the Gulf Coast or the peat of Holland so it cannot be ruled out at the present time."

Shepard and Curray (1967) have given a "proposed eustatic curve" for the last 7,000 years based upon so-called "evidence from stable areas". (The correctness of the words "evidence" and "stable" is here questioned). This curve is quite smooth and rises at a continuously decreasing rate from –10 m at 5,000 BC till the present position is reached some hundred years AD. However, this curve is only an avarage curve for some slightly subsided areas.

In Fig. 160 my eustatic curve is compared with the curves by Fairbridge (1961) and Shepard (1963). Though differing in many respects the general agreement is striking.

Summary

All the results here given lead to conclusions about the isostasy and eustasy. The way may have been long and tiring — though necessary. Thus a brief chapter-by-chapter summary is appropriate.

INTRODUCTION: I here discuss why this investigation area is so uniquely suitable for a detailed investigation of shorelevel displacement.

MATERIAL AND METHODS: Pitchy soil is an important deposit, the formation of which is here discussed (p. 13). *Hystrix* is identified in the pollen analysis. It is supposed to have lived in Kattegatt at least up to pollen zone VII—VIII. In order to estimate the C^{14} dates of marine shells, the retarded carbonate cycle in the sea is discussed (p. 16). A correction ("sea correction") of −305 ±25 years is here used. The pollen zones and the dates of the pollen zones are given in a table (p. 17).

THE INVESTIGATION OF THE SEABED OF KATTEGATT: The submarine shore features and ice marginal lines in Kattegatt were investigated and a geological map of the seabed could be drawn (Pl. 1). The geology, sediments and bottom topography are briefly discussed.

THE WEICHSELIAN GLACIATION BEFORE 20,000 BP: Much information about the fluctuations during the Weichselian glaciation prior to the last maximum was obtained in connection with this investigation. Many earlier described localities were now reinterpreted. The results are seen in Figs. 8, 9 and 10. The Old Baltic ice stream across Skåne is supposed to correspond to the Post-Brörup readvance of the ice. The ice margin during the glaciation maximum about 54,000—55,000 BP seems now fairly well established (Fig. 9).

THE LATE WEICHSELIAN DEGLACIATION OF THE KATTEGATT AREA: The ice marginal lines are given in Pls. 1—3. The picture of deglaciation is very detailed. The recession of ice from the C line in Jylland, is characterized in Kattegatt, Denmark, Northern Germany and Southern Sweden by a recession towards NE-N of the main Swedish ice cover, separating one Baltic ice lobe after the other in Lille Belt, Store Belt, Öresund and Hanöbukten. The angles between these lobes — especially the angle between the main Swedish ice and the main Baltic ice — was rapidly displaced inwards. These angles are here termed "ice marginal forks". They are a characteristic feature of the deglaciation within this area. The distinct ice marginal fork of the F5 line in NW Skåne (Fig. 19) is very important. It occupies a key position of the understanding of the deglaciation of Skåne. The recession is summarized on p. 107.

THE DEGLACIATION OF THE SWEDISH WEST COAST AND THE LATE GLACIAL SHORELEVEL DISPLACEMENT: Two very distinct ice marginal lines — the Fjärås line and the complex Moslätt/Berghem line — were morphologically followed along the whole Swedish West Coast. The Marine Limit (ML) was mea-

sured along these synchronal ice marginal lines. In the shoreline diagram these ML observations form two quite straight, tilted shorelines. The correctness of these shorelines is proved by C^{14} dated isolation contacts in bogs situated far outside the corresponding ice margin (e. g. Höghults Mosse, p. 133 and Klinehögkärret p. 139). The Fjärås line was formed during a cold stadial between the Ågård and Bölling Interstadials. It corresponds to the very end of the classical Oldest Dryas. The Moslätt/Berghem line was formed during Older Dryas. The shorelevel displacement during Alleröd and Younger Dryas is based upon pollen and C^{14} dated isolation contacts. The Late Glacial shorelevel displacement is summarized on p. 166.

THE LATE GLACIAL CHRONOLOGY: From the changes and the C^{14} dates of the Late Glacial marine shell bearing faunas, a new interstadial period was established, viz. the Ågård Interstadial at about 10,700–10,350 BC. It is separated from the classical Bölling Interstadial (10,300—9,950 BC) by the Fjärås Stadial at about 10,350—10,300 BC. From the number of varves and the changes in shell fauna in the clay pit at Agnesberg, it was established that the Older Dryas was 150 years long and can be divided into three stages, viz. the Moslätt Phase (9,950—9,925 BC), the Agnesberg Interval (9,925—9,850 BC) and the Berghem Phase (9,850—9,800 BC). By comparing a large number of North European C^{14} dates, the Late Glacial pollen zone boundaries were fixed as follows: Ia/Ib = 10,300—10,350 BC, Ib/Ic = 9,950 BC, Ic/II = 9,800 BC, II/III = 9,000—8,950 BC and III/IV = 8,050—8,000 BC. The Younger Dryas was 950 years long. It is here shown that in the area of the Middle Swedish end moraines it begins with the Taberg readvance. The Finnish and Swedish varve chronologies and the C^{14} chronology of Younger Dryas are compared in a table on p. 179. The Swedish varve chronology is in my opinion extended to the very onset of Alleröd. The C^{14} chronology was compared to the varve chronology. It was shown that C^{14} dates from 9,800—8,000 BC were 150—200 years too young, from about 7,300—5,800 BC were too old (probably up to 400 years) and from 5,000—4,500 BC were about 100 years too young (Fig. 40). These data from a continuation of Damon's and Suess' curves of the variation of ^{14}C in the atmosphere (Fig. 41). The Late Glacial chronology and climatic development are summarized on p. 183 and in the glaciation curve, Fig. 42.

THE ALV SHORELINES: This chapter deals with the fundamental part of the investigation. The shorelines from the transition period between Late Glacial regression and Postglacial transgression were very closely fixed and dated within the Viskan Valley, forming an ideal base for amplified investigations. The submarine continuation of these shorelines was followed across Kattegatt (Pls. 5 and 7). Submarine dunes, shore marks, peat and lacustrine layers in situ, ground crusts and shallow sea deposits were found. The first Postglacial transgression started at 7,330 BC (between 8,050 and 7,800 BC there was also a small eustatic

transgression). The second or classical Postglacial transgression, which rose above the thresholds in the southwestern Baltic Sea, started at 5,800 BC. The "Ancylus transgression" in the Baltic is here reinterpreted as follows: a eustatic transgression (the main part) + an isostatic transgression (about 8 m) + a regression caused by erosion in the thresholds (about 7—8 m). The description of the ALV shorelines is summarized on p. 239 and p. 301.

THE PTM SHORELINES: Thanks to the suitable intensity of land upheaval, the closely fixed isobase system, numerous new localities and, above all, the C^{14} dates, which allow reliable correlations, a very detailed picture of the Postglacial flucatuations of the sea level was obtained. (Figs. 138, 147, 145; Pl. 6). The transgression maxima are termed PTM. The following ones were found: 2 = 5,000 BC, 3A = 4.500 BC, 3B = 4,300 BC, 4A = 3,900 BC, 4B = 3,600 BC, 4.5 = 3,250 BC, 5A = 3,000 BC, 5B = 2,600 BC, 6 = 2,100 BC, 7 = 1,600 BC, 8 = 1,000 BC, 9A = 500 BC, 9B = 250 BC and 10 = a complex of younger maxima, not suffieciently studied. The description of the PTM shorelines is summarized on p. 399.

ISOSTASY AND EUSTASY: This is the concluding chapter. Pages 404—425 should rather be read in their entirety than summarized here. As the shorelines in my diagrams (Pls. 4—6) are closely fixed in age and position, they can be used for calculations of the isostatic land upheaval and the eustatic rise of sea level in detail. The shoreline diagrams show the presence of a bend at –43.4 km, created 5,800 BC, all older shorelines being bent equally. The activity of the bend is reconstructed in Fig. 141. The changes in gradient of the shorelines (Fig. 142) inside and outside the bend give very important information about the isostatic land upheaval. These curves, in themselves, show that the land upheaval was influenced by fluctuations in the ice recession (glacio-isostasy) and fluctuations in the eustatic rise of sea level (hydro-isostasy). From the shoreline diagrams, shorelevel displacement curves were drawn for different points in the direction of tilting. (Figs. 143 and 147). For relative sea level (S), eustasy (E) and isostasy (I) the following equations apply: $S + E = I$ or $I - S = E$. S is here very exactly known (Fig. 143). I is fairly well known from the curves of changes in gradient (Fig. 142). E was only approximately known. By these premises isostatic curves for every shorelevel displacement curve (Figs. 144 and 148) and a eustatic curve (Fig. 145) were constructed. The large number of shorelevel displacement curves from different points in the direction of tilting make possible a necessary check of the eustatic curve. The isostatic curves include all the details that the shorelevel displacement curves and the curves of changes in gradient indicate. The results allowed a detailed reconstruction of the land upheaval. (Fig. 146). It was found that the intensity of land upheaval in general decreased with time and with distance towards the periphery, that the centre and periphery of the land upheaval had changed position, and that the glacio-isostatic and hydro-isostatic

sensivity were high. This eustatic curve (Fig. 145) is the only one that can express the shorelevel displacement and the isostatic land upheaval in a reliable way. It is highly fluctuating. The Late Glacial and early Postglacial changes between colder and warmer periods are all reflected in this eustatic curve — also the Ågård Interstadial, Fjärås Stadial, Friesland Interstadial, Eidfjord Stadial and Cochrane Stadial, which consequently are not only local but worldwide events. The younger eustatic fluctuations are not yet explained. The eustatic curve rises to PTM-7 at +0.4 m at 1,650—1,400 BC, indicating a corresponding climatic optimum, the Dosinia Optimum. This is also indicated by the immigration and variations of molluscs in Kattegatt (p. 386). PR-8 corresponds to a climatic deterioration — the Strandby Deterioration — during which the most temperate molluscs became extinct in Kattegatt (p. 386).

In the final part of this chapter the eustatic curve is compared with the results from other areas in the world. The PTM/PR changes correspond in detail to the fluctuations in Eastern Blekinge (Berglund's curve altered) and a very reliable isostatic curve was obtained (Fig. 149). This isostatic curve also supports my reinterpretation of the Ancylus Lake. Shorelevel displacement curves taken from Marthinussen's shoreline diagram from Northern Norway fit, with small changes, exactly with my eustatic curve, giving smooth isostatic curves (Fig. 150). This is indeed good evidence of the correctness of the eustatic curve here presented. The fluctuations found on the NE coasts of the North Sea fit in age very well with my eustatic curve, but as the amplitude of these fluctuations cannot yet be fixed, only hypothetical isostatic curves can as yet be drawn. Stephens' shoreline diagram for NE Ireland to SW Scotland fits well with my eustatic curve (Fig. 154). The North American East Coast was shown to have subsided differently. Time-depth indications from the shelf suggest a small difference in the position of the eustatic curve between the two glaciation maxima at 18,000—16,000 BC (–85—90 m) and 13,000—12,800 BC (–70 m), which is regarded as agreeing with the extension of the land ice, at least in North America and North Europe during these maxima. Scholl's time-depth indications from Florida were shown (Fig. 156) to reflect a slight subsidence and not at all to contradict (maybe even to support) the fluctuations of my eustatic curve. Curray's data of the rise of sea level in the NW part of the Gulf of Mexico fall close to my eustatic curve (Fig. 157), suggesting that this area has been stable. The sea level fluctuations described by Schofield from northern New Zealand agree well with my eustatic curve (Fig. 158). Suggate's time-depth indications from Christchurch, New Zealand, fit very well with my eustatic curve (Fig. 159), indicating a very slow land upheaval.

The results here presented show a striking agreement between the changes in ice recession, climate as recorded by pollen and molluscs, shorelevel displacement, isostasy and eustasy.

In my opinion these results must be considered as more reliable than older ones for the following reasons: the uniquely suitable conditions in this area for the reliable determination of the shorelines, the large area in the direction of tilting over which the shorelines were followed and the isostatic and eustatic curves checked, and the great number of good datings (radiocarbon and pollen).

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Последний Четвериичный Период Истории моря в Каттегате и Шведского Западного Побережья

Разледенение, перемещение берегового уровня, хронология, изостазия и эвстазия

Нильс-Аксель Мёрнер

Резюмэ

Введение

Я здесь рассматриваю почему именно эта область исследования так исключительно подходяща для подробного исследования перемещения берегового уровня.

Материалы и методы

Смолистый грунт является значительным наслоением, формация которого здесь рассматривается (стр. 13). *Hystrix* определяется при помощи спорово-пыльцового анализа. Предположено, что он существовал в Каттегате по крайней мере до пыльцовой зоны VII—VIII. Для вычисления радиоуглеродных датировок морских ракушек, рассмотрим замедленный углеродный цикл моря (стр. 16). Здесь применяется «морская поправка» («sea correction») на -305 ± 25 л. Пыльцовые зоны и их датировка даны таблицей (стр. 17).

Исследование морского дна в Каттегате

Особенности подводных берегов и маргинальные линии льда в Каттегате были исследованы и геологическая карта морского дна была начерчена (Табл. 1). Геология, осадки и топография глубин рассмотрены вкратце.

Оледенение Вюрма за *20,000* л. до наш. вр.

Много сведений, касающихся колебаний в течении оледенения Вюрма перед последним максимумом, было почерпнуто в связи с этим исследованием. Многие, ранее описанные районы, были растолкованы заново. Результаты показаны диаграммами 8,9 и 10. Предполагается, что Старый Балтийский ледяной поток через Сконе (Skåne) соответствует новому нашествию льда После-Брёрупа (Post-Brörup). Граница льда, во время максимального оледенения приблизительно за 54,000—50,000 л. до наш. вр., теперь уже достаточно точно определена. (Рис. 9).

Позднейшее разледенение Вюрма в области Каттегата

Маргинальные линии льда даются Табл. 1—3. Картина разледенения очень подробно разработана. Отступание льда от линии С в Юилланде (Jylland) характеризуется в Каттегате, Дании, Северной Германии и Южной Швеции отступанием на Северо-Восток главного Шведского ледника, отделившего одну за другой Балтийские ледяные доли (lobe) в Малом Белте, Большом Белте, Эресунде и Ханёбухте. Углы, образованные этими долями, — особенно угол, образованный главным Шведским ледником и главным Балтийским ледником, — быстро передвигался внутрь. Эти углы названы здесь «ледяными маргинальными вилками». Они являются характерной чертой разледенения этой области. Особая маргинальная ледяная вилка линии F5 на Сев.-Зап. Сконе (Skåne) имеет большое значение. Она дает ключ к пониманию разледенения Сконе. Отступание ее резюмировано на стр. 107.

Разледенение Шведского Западного побережья и позднее Ледниковое перемещение берега

Две совершенно различные маргинальные линии льда — линия Фьерос (Fjärås) и сложная линия Муслетт/Бергхем (Moslätt/Berghem) — морфологически были прослежены вдоль всего Шведского побережья. Морской Предел (ML) был вымерен вдоль этих, совпадающих по времени, ледяных маргинальных линий. На диаграмме береговой линии эти наблюдения ML образуют две совершенно правильные наклонные линии берега. Точность измерений этих береговых линий подтверждается радиоуглеродными датировками изолированных уровней в болотах, находящихся далеко вне соответствующей границы льда (Höghults Mosse стр. 133, Klinehögkärret стр. 139); Линия Фьерос образовалась во время ледникового периода в течении Промежуточных Периодов Огорда и Бёллинга (Ågård, Bölling). Она принадлежит к самому концу классического периода Древнейшего Dryas Линия Муслетт/Бергхем образовалась во время Древнего Dryas. Перемещение берегового уровня во время периода Аллерёд (Alleröd) и Молодого Dryas основывается на радиоуглеродных датировках изолированных уровней. Позднее Ледниковое перемещение берегового уровня изложено вкратце на стр. 166.

Поздняя Ледниковая хронология

Исходя из изменений и радиоуглеродных датировок Поздней Ледниковой фауны в области морских раковин был установлен новый промежуточный период, так называемый Промежуточный Период Огорд (Ågård) приблизительно за 10,750—10,350 л. до наш. эры (BC). Он отделен от классического Промежуточного Периода Бёллинга (10,300—9,950 л. до наш. эры) периодом Фьерос приблизительно за 10,350—10,300 л. до наш. эры (BC). Исходя из количества ленточных слоев и перемен в фауне ра-

ковин в глинистой шахте в Агнесберге, было установлено, что Древний Dryas длился 150 лет и что он может быть разделен на 3 периода: Фазу Муслетт (9,950—9,925 л. до наш. э.), Интервал Агнесберга (9,925—9,850 л. до наш. э.) и Фазу Бергхем (9,850—9,800 л. до наш. э.). Сравнивая большое количество северо-европейс радиоуглеродных датировок, Поздние-Ледниковые пыльцовые граничные зоны были установлены следующим образом: 1a/1в = 10,300—10,350 л. до н. э.; 1в/1с = 9,950 л. до н. э.; 1с/11 = 9,800 л. до н. э.; 11/111 = 9,000—8,950 л. до н. э.; 111/1y = 8,050—8,000 л. до н. э. Молодой Dryas длился 950 лет. Здесь показывается, что в области Средне-Шведских морен он начался с нового продвижения Таберга. (Taberg readvance) Финские и Шведские хронологии ленточных слоев и радиоуглеродные хронологии Молодого Dryas сравниваются на таблице на стр. 179. Шведская хронология ленточных слоев, по моему мнению, продлилась до самого нашествия Аллерёда. Радиоуглеродная хронология была сравнена с хронологией ленточных слоев. Было показано, что радиоуглеродные датировки от 9,800—8,000 л. до н. э. были на 150—200 л. слишком молоды, от 7,300—5,800 л. до н. э. были слишком стары (вероятно на 400 л.) и от 5,000—4,500 л. до н. э. были приблизительно на 100 лет слишком молоды (дигр. 40). Эти данные образовывают продолжение кривых Дамона и Сюсса (Damon's and Suess' curves) на вариации радиоуглеродных датировок в атмосфере (диагр. 41). Поздняя Ледниковая хронология и климатическое развитие резюмированы на стр. 183 и кривой обледенения (Рис. 42).

Береговая Линия ALV

Эта глава касается основной части исследования. Береговые линии переходного периода между Поздним-Ледниковым отступлением и После-Ледниковой трансгрессией очень точно определены и датированы в пределах долины Вискан (Viskan); они дают идеальную базу для более широких исследований. Подводное морское продолжение этих берегов было прослежено через Каттегат (Табл. 5 и 7). Были найдены подводные дюны, береговые метки, торфяные и озерные слои находившиеся на месте, земляная кора и мелкие морские отложения. Первая После-Ледниковая трансгрессия началась в 7,330 л. до н. э. (между 8,050 и. 7,800 л. до н. э. также произошла маленькая эвстатическая трансгрессия). Вторая или классическая После-Ледниковая трансгрессия, поднявшаяся выше порогов стока в Юго-Западной части Балтийского моря, началась в 5,800 г. до н. э. Анциловая трансгрессия (Ancylus transgression) в Балтийском море объясняется здесь следующим образом: как эвстатическая трансгрессия (главным образом) + изостатическая трансгрессия (около 8 м.) + регрессия, вызванная эрозией на порогах стока (около 7—8 м.). Описание береговых линий ALV резюмировано на стр. 239 и стр. 301.

Береговые линии РТМ

Благодаря подходящей интенсивности вздымания земли, точно установленной изобазной системе (isobase system), многочисленным новым районам и, главным образом, благодаря радиоуглеродным датировкам, позволяющим достоверные соотношения, была получена подробная картина После-Ледниковых колебаний уровня моря (диагр. 139, 143, 145, Табл. 6). Максимумы трансгрессии названы РТМ. Следующие были найдены: 2 = 5,000 г. до н. э.; 3A = 4,500 г. до н. э.; 3B = 4,300 г. до н. э.; 4A = 3,900 г. до н. э.; 4B = 3,600 г. до н. э.; 4.5 = 3,250 г. до н. э.; 5A = 3,000 г. до н. э.; 5B = 2,600 г. до н. э.; 6 = 2,100 г. до н. э.; 7 = 1,600 г. до н. э.; 8= 1,000 г. до н. э.; 9A = 500 г. до н. э.; 9B = 250 г. до н. э. и 10 = составному комплексу более молодых максимумов недостаточно изученных. Описание береговых линий РТМ резюмировано на стр. 399.

Изостазия и эвстазия

Это — заключительная глава. Стр. 404—425 должны скорее быть прочитанными целиком, чем быть здесь резюмированными. В виду того, что береговые линии на моих диаграммах (Табл. 4—6) установлены точно, в отношении возраста и положения, то они могут быть использованы для вычисления изостатичного вздымания земли и детального эвстатического подъема уровня моря. Диаграммы береговых линий указывают на присутствие уклона в —43,4 км., создавшегося в 5,800 г. до н. э. все же более старые береговые линии имеют одинаковый изгиб Активность уклона восстановлена на диагр. 141. Изменения наклона береговых линий (диагр. 142) внутри и вне сгиба дают очень важное сведение, касающееся изостатического вздымания земли. Эти кривые, сами по себе, показывают, что вздымание земли происходило под влиянием колебаний ледникового отступания (глацио-изостазии) и колебаний в эвстатическом поднятии уровня моря (гидро-изостазии). Исходя из диаграмм береговой линии, кривые перемещений уровня берегов чертились для разных точек в направлении к наклону (диагр. 143 и 147). Для сравнительного уровня моря (S), эвстазии (E) и изостазии (I) применимы следующие уравнения: $S + E = I$ или $I - S = E$.S в данном случае точно известен (диагр. 143). I достаточно точно определен кривыми перемен наклона (диагр. 142). E был только приблизительно известен. С этими данными, изостатические кривые для каждой из кривых перемещения берегового уровня (диагр. 144 и 148) и эвстатическая кривая (диагр. 145) были начерчены. Большое количество кривых перемещения уровня берега в различных точках по направлению к наклону позволяют произвести необходимый контроль эвстатической кривой. В изостатические кривые включены все детали, указываемые кривыми перемещения береговой линии и кривыми изменений наклона. Эти результаты позволили подробное восстановление вздымания земли (диагр. 146). Было найдено,

что интенсивность вздымания земли в общем уменьшалась со временем и по мере удаления к периферии, и что центр и периферия вздымания земли переменили положение, и также что глацио-изостатическая и гидро-изостатическая чувствительность были повышены. Эта эвстатическая кривая (диагр. 145) является единственной, которая может достоверно выразить перемещение уровня берега и изостатическое вздымание земли. Она в высшей степени колеблющаяся. Поздне-Ледниковые и ранние После-ледниковые изменения между более холодными и теплыми периодами отражены в этой эвстатической кривой, а также и Промежуточный Период Огорд, Период Фьерос, Промежуточный период Фрисланда, Период Эйдфиорда и Период Кохрана, являющиеся следовательно не только местными, но и мировыми событиями. Более молодые эвстатические изменения еще не объяснены. Эвстатическая кривая поднимается к PTM-7 на + 0,4 м. в 1,650—1,400 г. до н. э., указывая на соответственный климатический оптимум (the Dosinia Optimum). Это также указывается иммиграцией и вариациями моллюсков в Каттегате (стр. 386). PR-8 соответствует климатическому ухудшению (the Strandby Deterioration) во время которого более термофильные моллюски вымерли в Каттегате (стр. 386).

В заключении этой главы эвстатическая кривая сравнивается с результатами других областей мира. Изменения PTM/PR соответствуют, во всех подробностях, колебаниям в Восточном Блекинге (изменяя кривую Берглунда) и очень достоверная изостатическая кривая была получена (диагр. 149). Эта изостатическая кривая также подтверждает мое объяснение Анцилового озера (Ancylus Lake). Кривые перемещений берегового уровня, взятые из диаграммы линии берега Северной Норвегии Мартинюссена, совпадают с небольшими изменениями с моей эвстатической кривой, давая плавные изостатические кривые. Это — наилучшее доказательство правильности приведенной здесь эвстатической кривой. Колебания, найденные на Сев.-Вост. берегах Северного моря, по возрасту очень схожи с моей эвстатической кривой, но так как широта этих колебаний не может еще быть установлена, то только предполагаемые изостатические кривые могут быть начерчены. Диаграмма Стефенса береговой линии от СВ Ирландии до ЮЗ Шотландии хорошо подходит к моей эвстатической кривой (диагр. 154). Восточное Побережье Северной Америки, как указываю, улеглось иначе. Указания времени — глубины уступа наводят на мысль что была незначительная разница в положении эвстатической кривой между двумя максимальными оледенениями 18,000—16,000 (BC) до нашей эры (−85—90 м) и 13,000—12,800 до нашей эры (−70 м) и можно сказать, что это соответствует с распространением льда (по крайней мере в Северной Америке и Северной Европе) в течении этих стадий. Указания Шолла о времени-глубине из Флориды отражают,

как указываю (диагр. 156), незначительное упадение и совсем не противоречат (даже может быть подтверждают) колебания моей эвстатической кривой. Дата Каррейа (Carray's data) для подъема уровня моря в Сев.-Зап. части Мексиканского залива точно совпадает с моей эвстатической кривой (диагр. 157), наводя на мысль, что эта область оставалась устойчивой. Колебания уровня моря от севера Новой Зеландии, описанные Ш офильдом, вполне соответствуют с моей эвстатической кривой (диагр. 158). Указания Суггата времени — глубины из Кристчерч в Новой Зеландии хорошо походят к моей эвстатической кривой (диагр. 159) доказывая очень медленное повышение этой области.

Представленные здесь результаты показывают поразительное сходство в изменениях ледникового отступания, в климате, как это отмечено пыльцой и моллюсками, перемещением берегового уровня, изостазией и эвстазией.

Согласно моему мнению, эти результаты должны считаться более достоверными, чем старые, по следующим причинам: исключительно подходяшим условиям этой области для достоверного определения береговых линий, большой поверхности в направлении наклона по которой были прослежены береговые линии и проверены изостатические и эвстатические кривые, а также и наличие большого количества отличных датировок (радиоуглеродных и спорово-пыльцовых).

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DGF = Medd. Dansk Geol. Fören.
DGU = Danmarks Geol. Undersögelse
GFF = Geol. Fören. i Stockholm Förhandl.
NGU = Norges Geol. Undersökelse
SGU = Sveriges Geol. Undersökning

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— III. — Amer. Jour. Sci. Radiocarbon Suppl., 2 (also in DGF, 14).
— IV. — *Ibid.*, 2 (also in DGF, 14).
— V. — *Ibid.*, 4 (also in DGF, 16).
— VI. — *Ibid.*, 6 (also in DGF, 16).
— VII. — *Ibid.*, 8 (also in DGF, 16).
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Tables

Table 1. DISTRIBUTION OF MOLLUSCS ENTIRELY BELONGING TO THE DOSINIA LAYERS ACCORDING TO NORDMANN (1904)

	Strandby	Hals	Laursen 1937					the Gothenburg area							Nordmann			Hessland 1943			Antevs 1917			
			A	B	C	D	E	88 %	70—60 %	60—50 %	50—40 %	40—30 %	30—20 %	20—10 %	Lysekil	Öddön	Nötholm	7000—6000 BC	6000—5500 BC	2500—500 BC	Ejde	prt	ptm	spr	rec
Abra prismatica			.		.	.	.	.	.	.	.	.	.	.					.	.		.	.	x	.	x
Arcinella plicata	x	x	.		.	.	.	.	.	.	.	.	x	.					x	.		.	.	x	.	x
Bela turricula		x	.		.	.	.	.	.	.	.	.	.	.					.	.		.	.	.	.	.
Cardium norvegicum	x		.		.	x	.	.	.	.	.	.	x	.					.	.		.	.	.	.	.
Cylichna cylindracea		x	.		.	.	.	.	.	.	.	.	x	.					.	.		.	.	.	.	.
Cypraea eropaea	x		.		.	.	.	.	.	.	.	.	.	.					.	.		.	.	.	.	.
Dosinia exoleta	x		.		.	x	.	.	.	.	.	.	x	.					.	.		.	.	.	.	.
Dosinia lincta	x		.		.	.	.	.	.	.	.	.	x	.			x		.	.	x	x	.	.	x	x
Eulima distorata	x		.		.	x	.	.	.	.	.	.	.	.		x			.	.			x	.	x	x
Eulimella sp.	x		.		.	.	.	.	.	.	.	.	x	.					x	.			.	(x)	.	(x)
Fusus antiquus	x		.		.	.	.	.	.	.	.	.	.	.					.	.			.	.	.	.
Kellia suborbicularis	x		.		.	.	.	.	.	.	x	.	.	.			x		x	.			x	x	x	x
Lucina borealis	x	x	x	.	.	x	x	.	x	.	.	.	.	.		x	x		.	.	x		x	x	x	x
Lucinopsis undata		x	.		.	.	.	.	.	.	x	.	.	.			x		x	.	x		.	.	x	x
Lutraria elliptica	x	x	.		.	.	.	.	.	.	.	.	.	.					.	.	x	x	.	.	.	.
Mytilus adriaticus		x	.		.	.	.	.	.	.	.	.	.	.					.	.			.	.	.	.
Nacella pellucida	x		.		.	.	.	.	.	.	x	.	.	.			x		x	.			x	x	x	x
Nassa incrassata	x		.	x	.	x	.	.	x	.	.	.	.	.			x		x	.		x	x	x	x	x
Pecten maximus	x		.		.	x	.	.	.	.	.	.	.	.					.	.	x	x	.	.	.	.
Pecten opercularis	x	x	.		.	x	.	.	.	.	.	.	.	x					.	.		x	.	.	.	.
Pholas dactylus		x	.		.	.	.	.	.	.	.	.	.	.					.	.			.	.	.	.
Psammobia faeröensis		x	.		.	.	.	.	.	.	.	.	x	.					.	x	.	x	.	.	x	x
Psammobia vespertina	x		.		.	x	.	.	.	.	.	.	.	.	x	x			.	.	x	x	x	.	x	.
Rissoa cimicoides	x		.		.	.	.	.	.	.	.	.	.	.			x		.	.			.	.	.	.
Scalaria Turtonis	x	x	.		.	.	.	.	.	.	.	.	.	.		x			.	.			.	.	.	.
Tapes edulis (vigineus)	x		.		.	x	.	.	.	.	.	.	x	.					.	x	.		x	x	x	x
Turritella tenebra	x	x	.		x	.	.	.	.	.	.	.	.	.			x		.	.			x	.	x	x

Table 2. GRAIN SIZE DISTRIBUTION OF SUBMARINE SAMPLES

The fractions smaller than 16.0 mm are expressed as a percentage of the total weight of the particles smaller than 16.0 mm. The stone frequency is expressed as a ratio between the weights of the particles smaller and greater than 16.0 mm respectively.

Boring	clay	0.002	silt	0.06	fine sand	0.2	medium sand	0.6	coarse sand	2.0	fine gravel	6.0	coarse gravel	20.0 (16.0)	stones
B 140:E	1.5		1.5		96.0		1.0		—		—		—		—
B 144:K	1.0		0.5		1.5		55.0		41.2		1.8		—		—
B 151:Y			(1.5)		2.0		20.5		37.5		14.5		24.0		4:1
B 153:Ä	3.0		3.0		15.0		43.0		33.2		0.8		2.0		—
B 153:Ä	1.5		1.0		14.0		72.0		10.5		0.7		0.3		—
B 384			(1.0)		2.5		7.0		56.5		31.0		2.0		6:1
B 390			(1.5)		2.5		16.5		44.0		12.5		24.0		30:1
B 399	1.2		1.8		3.5		52.0		35.0		1.5		4.0		33:1
B 401	0.8		0.5		1.2		34.5		61.0		2.0		—		—
B 406	0.5		0.5		9.5		62.5		20.5		3.5		3.0		—
B 503	1.2		3.2		89.0		6.0		—		—		—		—
B 507	2.5		6.5		65.0		26.0		—		—		—		—
B 517:a	1.5		1.0		5.0		40.0		41.5		11.0		—		—
B 517:x			(2.0)		6.0		28.0		16.5		31.5		16.0		—
B 522	3.0		6.5		34.0		49.5		5.0		1.0		1.0		—
B 523	1.0		0.5		5.5		69.5		21.0		2.0		0.5		—
B 529	1.5		1.0		4.5		48.0		32.2		11.5		1.3		—
B 603	1.5		—		18.0		68.5		1.7		0.3		—		—
B 604	0.7		0.3		19.0		67.0		6.0		2.5		4.5		32:1
B 605			(1.8)		40.0		51.0		7.0		0.2		—		—
B 606	1.0		—		34.6		61.8		2.2		0.4		—		—
B 622	1.5		0.5		46.6		49.0		1.5		0.9		—		—
B 637			(1.5)		38.5		53.0		7.0		—		—		—
B 638	2.5		11.5		71.0		13.3		1.5		0.2		—		—
B 737	0.8		1.2		68.5		29.0		0.5		—		—		1.1:1
B 740	1.2		1.8		18.0		24.0		30.0		18.0		7.0		50:1
B 742	0.8		0.4		12.3		50.5		7.0		4.0		25.0		0.27:1
B 751	1.0		0.5		53.5		44.2		0.8		—		—		—
B 762	1.0		1.5		8.5		63.5		13.0		4.9		7.6		4:1
B 763	3.3		6.5		29.0		57.0		4.2		—		—		+
B 764	2.0		5.0		20.5		66.3		2.7		—		3.5		+
B 767	1.2		2.0		12.8		54.0		10.0		5.5		4.5		15:1
B 769	2.5		7.0		22.0		48.5		6.0		5.0		9.0		1.75:1
B 772	2.5		5.0		26.0		38.5		5.0		15.0		8.0		13:1
B 773	1.0		1.0		2.0		49.5		30.0		11.5		6.0		—

Table 3. RADIOCARBON DATES

Half-life of radiocarbon 5,568 ±30 years. "Sea correction" (305 ±25) not subtracted.

Lab. no.	Designation of sample	Material and strat. thickness	Age in BP	Age in BC ± stat.err.	"Sea corr."
St-1208	B 1 (BP 1196)	pitchy soil, 4.0 cm	7,795	5,845 ±150	
St-1207	B 4 (BP 1233)	peaty Phragmites mud, 10 cm	9,305	7,355 ±110	
St-1206	B 5 (BP 22)	Phragmites mud, 5—10 cm	7,750	5,800 ±110	
St-1464	B 34	clayey mud, 0.5+1.5 cm	7,800	5,850 ±330	
St-1531	B 95:1	detritus mud, 2.0 cm	7,730	5,780 ±165	
St-1532	B 95:2	sedge peat, 2.0 cm	7,545	5,595 ±150	
St-1533	B 95:3	peat, 2.0 cm	7,585	5,635 ±190	
St-1534	B 95:4	detritus mud, 2.0 cm	12,165	10,215 ±230	
St-1528	B 99:1	peat, 2.0 cm	7,985	6,035 ±155	
St-1529	B 99:2	coarse detritus mud, 2.0 cm	8,980	7,030 ±170	
St-1530	B 99:3	clayey mud, 3.0 cm	8,620	6,670 ±170	
St-1280	B 100	brushwood peat, 1.0 cm	7,795	5,845 ±90	
St-1291	B 101:A	mud, 1.5 cm	4,890	2,940 ±90	
St-1292	B 101:B	peat, 1.5 cm	7,605	5,655 ±90	
St-1463	B 104	pitchy soil, 1.0 cm	7,775	5,825 ±100	
St-1290	B 107	pitchy soil, (1—2 cm)	9,280	7,330 ±110	
St-1491	B 114—115 = BP 300:1	muddy clay, 8.0 cm	15,190	13,240 ±260	
St-1498	B = BP 300:2	muddy clay to clayey mud, 5.0 cm	9,810	7,860 ±100	
St-1492	B = BP 300:3	clayey mud, 5.0 cm	7,650	5,700 ±100	
St-1500	B = BP 300:4	mud, 10.0 cm	6,970	5,020 ±90	
St-1502	B 116—117 = BP 629:1	muddy clay, 8.0 cm	12,240	10,290 ±240	
St-1503	B = BP 629:3	muddy clay, 5.0 cm	10,550	8,600 ±145	
St-1496	B = BP 629:2	muddy clay, 5.0 cm	9,510	7,560 ±135	
St-1505	B = BP 629:4	mud, 8.0 cm	7,065	5,115 ±145	
St-1510	B 118—119 = BP 1540:1	coarse detritus mud, 1.5 cm	9,330	7,380 ±200	
St-1511	B = BP 1540:2	mud, 2.0 cm	10,400	8,450 ±170	
St-1497	B 120—121 = BP 1561:1	peaty coarse detritus mud, 2.5 cm	9,155	7,205 ±110	
St-1707	B = BP 1561:2	mud, 2.5 cm	9,400	7,450 ±450	
St-1710	B 124 (BP 1232)	Phragmites mud, 2.6—0.5 cm	9,700	7,750 ±120	
St-1817	B 143:H	pitchy soil + mud, 2.5 + 2.0 cm	9,130	7,180 ±120	
St-1813	B 143:H (R)	clayey mud, 2.5 cm	9,230	7,280 ±500	
St-1816	B 145:N+L	pitchy soil, 2.6 cm	9,435	7,485 ±180	
St-1814	B 145:N (R)	pitchy soil, 2.0 cm	9,280	7,330 ±300	
St-1698	B 171	peat, about 10 cm	9,155	7,205 ±120	
St-1820	B 176:I	peat, lowermost 2.0—2.5 cm	7,565	5,615 ±110	
St-2172	B 176:II	peat, uppermost 0.5 cm	8,010	6,060 ±100	
St-1819	B 220	pitchy soil, 1—2 cm	6,430	4,480 ±140	
St-1711	B 228:I	peat, 4.0 cm	6,520	4,570 ±105	
St-1815	B 228:II	peat, 3.0 cm	3,005	1,055 ±80	
St-2214	B 228:III	peat, 0.5 cm	5,780	3,830 ±95	
St-2177	B 268:II	peat, 0.5 cm	6,855	4,905 ±90	
St-1818	B 268:I	pitchy soil, 2—3 cm	7,720	5,270 ±150	

Lab. no.	Designation of sample	Material and strat. thickness	Age in BP	Age in BC ± stat.err.	"Sea corr."
St-2211	B 286	dy + shells	3,255	1,305 ±80	×
St-2206	B 287	shells	8,735	6,785 ±105	×
St-2158	B 325:3	peat, 5.0 cm	1,985	35 ±70	
St-2764	B 328	drift peat, 3.0 cm	2,225	275 ±100	
St-2012	B 427:I	peat, 0.5 cm	8,595	6,645 ±100	
St-2010	B 427:II	mud, 3.0 cm	10,000	8,050 ±330	
St-2003	B 432	coarse detritus mud, 1.5 cm	10,400	8,450 ±220	
St-2006	B 437	detritus mud, 1.5 cm	8,120	6,170 ±210	
St-2011	B 438:I	peat, 1.5 cm	7,565	5,615 ±160	
St-2005	B 438:II	dyey detritus mud,	10,285	8,335 ±120	
St-2004	B 441:I	detritus mud + pitchy soil, 1.0 cm	9,280	7,330 ±130	
St-2170	B 441:II	detritus mud, 2.0 cm	9,780	7,830 ±200	
St-2007	B 450	muds, 0.4 + 0.4 cm	7,400	5,450 ±100	
St-2169	B 501	dy, 5.0 cm	9,280	7,330 ±125	
St-2171	B 502	wood + dyey peat, 4.0 cm	10,820	8,870 ±200	
St-2174	B 504	peat + wood, 3.5 cm	9,725	7,775 ±200	
St-2167	B 551	mud, 2.0 cm	7,525	5,575 ±180	
St-2173	B 552	mould in sand	2,100	150 ±75	
St-2175	B 557	clayey mud, 3.0 cm	9,725	7,775 ±115	
St-2166	B 566	muddy clay, 5.0 cm	4,210	2,260 ±130	
St-2165	B 574:III	mud, 1.5 cm	9,970	8,020 ±160	
St-2164	B 574:II	clayey mud, 1.5 cm	10,225	8,275 ±120	
St-2163	B 574:I	clayey mud + muddy clay, 1.5 + 0.5 cm	11,170	9,220 ±240	
St-2168	B 579	muddy clay, 3.0 cm	11,235	9,285 ±235	
St-2203	B 583:I	shells	7,200	5,250 ±130	×
St-2204	B 583:II	shells	11,565	9,615 ±150	×
St-2176	B 583:III	silty mud with humus, lump	1,985	35 ±115	
St-2340	B 609	seaweed peat, 0.5 cm	<250		(×)
St-2347	B 610	shells	830	±100	×
St-2375	B 647	peat, 4.0 cm	9,230	7,280 ±260	
St-2289	B 655:III	silty clayey mud, 5.0 cm	10,195	8,245 ±185	
St-2288	B 655:II	detritus mud + pitchy soil, 1.0 + 1.0 cm	8,930	6,980 ±160	
St-2682	B 672	silty dy	>40,000		
St-2433	B 675	mud, 2.0 cm	1,535	±100	
St-2285	B 676:I	peat, 1.0 cm	1,195	±100	
St-2336	B 676:IV	peat, 1.5 cm	5,025	3,075 ±100	
St-2286	B 676:II	peat, 1.5 cm	4,890	2,940 ±100	
St-2345	B 676:V	peat, 2.0 cm	5,880	3,930 ±100	
St-2287	B 676:III	mud, 3.5 cm	9,280	7,330 ±140	
St-2331	B 694	seaweed peat, 3.5 cm	5,550	3,600 ±100	(×)
St-2335	B 701:I	peaty detritus mud, 0.5 cm	8,860	6,910 ±105	
St-2337	B 701:II	mud, 1.0 cm	9,355	7,405 ±185	
St-2344	B 703	peat, 0.5 cm	9,945	7,995 ±120	
St-2346	B 711	dy, 2.0 cm	10,000	8,050 ±120	
St-2508	B 715	clayey silty mud, 1.9 cm	11,770	9,820 ±215	
St-2450	B 716	shells	12,460	10,510 ±140	×
St-2525	B 717:IV	mud, 1.4 cm	9,915	7,965 ±185	
St-2528	B 717:II	clayey mud, 2.4 cm	10,915	8,965 ±225	
St-2509	B 717:I	muddy clay, 6.0 cm	12,200	10,250 ±270	
St-2524	B 719	clayey mud, 3.0 cm	11,700	9,750 ±320	
St-2527	B 722:I	clayey mud, 0.5 cm	6,275	4,325 ±100	

Lab. no.	Designation of sample	Material and strat. thickness	Age in BP	Age in BC ± stat.err.	"Sea corr."
St-2510	B 722:II	coarse detritus mud, 0.5 cm	6,450	4,500 ±100	
St-2753	B 754	clayey dy, lump	9,700	7,750 ±120	
St-2728	B 781	shells, fraction A	1,420	±100	×
		shells, fraction B	1,360	±100	×
St-2726	B 838:I	clayey coarse detritus mud, 4.0 cm	11,070	9,120 ±135	
St-2763	B 838:II	silty clayey mud + dy, 19.0 cm (—5.0 cm)	11,735	9,785 ±110	
St-2893	B 842:I	clayey detritus mud, 1.5 cm	5,315	3,365 ±100	
St-2894	B 842:IV	clayey mud + coarse detritus, 1.5 cm, carbonate not removed	7,400	5,450 ±120	
St-2894	B 842:IV	clayey mud + coarse detritus, 1.5 cm, carbonate removed	7,065	5,115 ±135	
St-2895	B 842:V	dyey peat or pitchy soil, 1.5 cm	8,075	6,125 ±125	
St-2328	Ågård A	shells	12,575	10,625 ±235	×
St-2332	Ågård B	shells	12,930	10,980 ±270	×
St-2333	Fajans A	shells	12,930	10,980 ±280	×
St-2334	Fajans B	shells	12,970	10,020 ±280	×
St-2447	Torsgården II	shells	13,050	11,100 ±140	×
St-2470	Edared	bone (reindeer)	12,265	9,315 ±100	
St-2352	Huveröd	bone (whale)	7,690	5,740 ±180	(×)
St-1167	125 Ejde	shells, fraction B	3,685	1,735 ±75	×
		shells, fraction C	3,685	1,735 ±75	×

Table 4. SAMPLES OF THE SEABED OF KATTEGATT

In the column "soil at bottom surface" the following abbreviations are used: Cl (c.) = clay (clayey), M (m.) = mud (muddy), Si (si.) = silt (silty), S (s.) = sand (sandy), FS = fine sand, G (g.) = gravel (gravelly), St (st.) = stones (stony), AR = Archaean rock, SR = sedimentary rock, Sh = shell bank, Ti = till, H = hard bottom, P = peat. In the column "core length in cm" the figures in parenthesis indicate that the sample is a result of sucking. In the column "sampler" the following abbreviations are used: 0.6, 3, 5 and 7 = the length of the piston corer, PD = pipe dredger, D = ordinary dredgers, T = trawl, Div. = diving.

locality	N. Lat.	E. Long.	depth in m	soil at bottom surface	core length in cm	sampler	ref.
B 136	57° 13.3′	11° 47.5′	15	S		0.6	
B 137	57° 13.1′	11° 47.9′	10-11	S		0.6	
B 138	57° 12.7′	11° 48.8′	15	S		0.6	
B 139	57° 12.12′	11° 49.8′	27	S		0.6	
B 140 : a	57° 12.2′	12° 09.2′	8	G		0.6	
: b	57° 12.2′	12° 09.2′	8	FS		3	Tab. 2
: c	57° 12.2′	12° 09.2′	8	G	193.5	3	p. 188
B 141	57° 12.1′	12° 08.0′	13	S	244.5	3	p. 189
B 142	57° 11.85′	12° 06.35′	17	FS	237.5	3	p. 189
B 143 : H	56° 31.0′	12° 49.8′	15	S	150	3	p. 259
B 144 : J	56° 31.13′	12° 47.5′	16	S	33	3	
: K	56° 31.13′	12° 47.5′	16	S	23	3	Tab. 2
B 145 : L	56° 31.0′	12° 49.8′	15-16	S	101	3	
: M	56° 31.0′	12° 49.8′	15-16	S	10.5	7	
: N	56° 31.0′	12° 49.8′	15-16	S	275	7	p. 258
B 146	56° 31.0′	12° 47.8′	17	Si	61	3	
B 147	56° 31.15′	12° 47.35′	17.5	s.G	28	3	
B 148 : S	56° 31.6′	12° 44.4′	19	FS	191	3	p. 263
: R	56° 31.6′	12° 44.4′	19	FS	92.5	3	
B 149 :	56° 31.9′	12° 46.7′	21.5	c.M	268.3	3	p. 263
B 150	56° 31.45′	12° 45.45′	19	m.Cl	243.5	3	
B 151	56° 31.35′	12° 46.45′	18	st.g.S	20	3	p. 255
B 152	56° 31.30′	12° 47.50′	17	g.S	14	3	
B 153 : Ä	56° 31.0′	12° 48.65′	16	S		3	Tab. 2
: Ä	56° 31.0′	12° 48.65′	16	S	83.5	3	
B 176	56° 25.7′	12° 37.95′	1.7-2.5	P	10-20	Div.	p. 340
B 279	56° 51.1′	11° 41.2′	22	FS	61	3	p. 286
B 280	56° 51.0′	11° 38.0′	17	S		3	
B 281	56° 38.2′	11° 18.5′	20	S		3	
B 282	56° 37.7′	11° 20.5′	25	sh.FS	47	3	
B 283	57° 36.0′	11° 24.7′	16			3	p. 288
B 284	56° 17.7′	12° 38.5′	18	m.Cl-c.M	206.5	3	p. 273
B 285	56° 17.8′	12° 37.5′	18	Cl	273	3	p. 272
B 286	56° 17.9′	12° 36.5′	21	Cl	23.5	3	p. 272
B 287	56° 17.9′	12° 36.5′	21	c.M	120	3	p. 272
B 288	56° 21.3′	12° 42.0′	12	Cl	25	3	
B 289	56° 21.4′	12° 41.1′	12	Cl(S)	40	3	
B 290	56° 21.46′	12° 40.13′	15	S	55	3	
B 291	56° 21.53′	12° 39.35′	17	c.M	160	3	p. 269
B 292	56° 21.61′	12° 38.45′	19	c.M	256	3	p. 269
B 293	56° 21.7′	12° 37.5′	19	m.Cl	257.5	3	p. 270
B 294	56° 26.0′	12° 37.2′	10	S		3	
B 295	56° 26.6′	12° 36.9′	15	S	40	3	
B 296	56° 27.05′	12° 36.7′	17	Cl	280	3	
B 297	56° 27.6′	12° 36,4′	18	c. Si-FS	225	3	
B 298	56° 28.05′	12° 36,1′	20	Cl	230	3	
B 299	56° 30.3′	12° 49.0′	13	G-S	36.5	3	

locality	N. Lat.	E. Long.	depth in m	soil at bottom surface	core length in cm	sam-pler	ref.
B 300	56° 39.85′	12° 48.5′	13	s.G	26.5	3	
B 301	56° 29.45′	12° 47.8′	13	g.S	26.0	3	
B 302	56° 29.0′	12° 47.2′	13	S	64	3	
B 303	56° 29.5′	12° 37.6′	20	FS	91	3	
B 304	56° 29.4′	12° 39.5′	19	Cl(S)	180	3	p. 265
B 305	56° 29.3′	12° 41.4′	19	Cl(S)	270	3	p. 265
B 306	56° 29.2′	12° 43.3′	18	m.Cl	137	3	p. 265
B 307	56° 29.1′	12° 45.3′	14	S	28	3	
B 308	56° 37.8′	12° 50.5′	11	FS	40	3	
B 309	56° 37.8′	12° 49.6′	8	FS	(140)	3	
B 310	56° 37.35′	12° 49.35′	11	FS	(70)	3	
B 311	56° 36.9′	12° 49.1′	11	FS	(70)	3	
B 312	56° 36.4′	12° 48.9′	12	M-FS	(65)	3	
B 313	56° 33.6′	12° 52.4′	12	FS	20	3	
B 314	56° 33.62′	12° 51.35′	13	S	80	3	
B 315	56° 33.65′	12° 50.2′	13	Cl	55	3	p. 257
B 316	56° 33.72′	12° 49.2′	13	FS	133.8	3	p. 257
B 317	56° 33.75′	12° 48.1′	14	FS	241.5	3	p. 257
B 318	56° 33.8′	12° 47.3′	15	FS	249.8	3	p. 257
B 329	57° 09.33′	12° 11.35′	6	s. Cl		3	
B 330	57° 09.18′	12° 11.4′	6	S-Cl		3	
B 331	57° 09.14′	12° 11.7′	6.5	FS	187	3	p. 187
B 332	57° 08.77′	12° 12.0′	5	S	66	3	
B 333	57° 06.98′	12° 14.4′	3	S		3	
B 334	57° 06.52′	12° 12.98′	7.5	S		3	
B 335	57° 06.58′	12° 13.12′	7.5-7.0	S	(100)	3	
B 336	57° 03.52′	12° 15.9′	10	S	(100)	3	
B 337	57° 03.25′	12° 15.22′	11.5	H		3	
B 338	57° 02.72′	12° 15.03′	13	H		0.6	
B 339	57° 02.72′	12° 15.03′	13.0-13.5	S		0.6	
B 340	57° 02.72′	12° 15.03′	13	G		3	
B 341	57° 01.76′	12° 17.51′	9	St		0.6	
B 342	57° 01.76′	12° 17.51′	8.5-9.0	S	11	0.6	
B 343	57° 01.76′	12° 17.51′	9.5	H		0.6	
B 344	57° 00.95′	12° 19.03′	5	H		0.6	
B 345	57° 00.95′	12° 19.03′	5	S		3	
B 346	57° 00.95′	12° 19.03′	5	S	(80)	3	
B 347	56° 58.52′	12° 20.6′	5	H		0.6	
B 348	56° 58.52′	12° 20.6′	5	G		0.6	
B 349	56° 57.76′	12° 19.9′	12.5	H		0.6	
B 350	56° 57.76′	12° 19.9′	12	H		0.6	
B 351	56° 57.76′	12° 19.9′	12.5	Cl	7	3	
B 352	56° 57.76′	12° 19.9′	12.5	g.S	10	3	
B 353	56° 57.45′	12° 19.9′	12.5	H		0.6	
B 354	56° 57.45′	12° 19.9′	12	G		3	
B 355	56° 56.28′	12° 20.15′	11	St		0.6	
B 356	56° 56.28′	12° 20.15′	11	H		0.6	
B 357	56° 56.28′	12° 20.15′	12	H		0.6	
B 358	56° 56.28′	12° 20.15′	11.5	St		0.6	
B 359	56° 56.28′	12° 20.15′	11.5	St		0.6	
B 360	56° 54.02′	12° 22.36′	12	St		0.6	
B 361	56° 53.92′	12° 22.36′	12	St		0.6	
B 362	56° 53.92′	12° 22.7′	11	St (AR)		0.6	
B 363	56° 53.94′	12° 23.0′	10	St (AR)		0.6	
B 364	56° 53.97′	12° 24.0′	8-10	St (AR)		0.6	
B 365	56° 53.85′	12° 22.85′	8.5	St (AR)		0.6	
B 366	56° 53.85′	12° 24.4′	8.5	St-Cl		3	

locality	N. Lat.	E. Long.	depth in m	soil at bottom surface	core length in cm	sam-pler	ref.
B 367	56° 52.57′	12° 29.36′	8	G		0.6	
B 368	56° 52.57′	12° 29.36′	8	G		0.6	
B 369	56° 52.57′	12° 29.36′	8	St-S		3	
B 370	56° 52.72′	12° 29.0′	6-6.5	FS		0.6	
B 371	56° 52.72′	12° 29.0′	6-6.5	FS		3	
B 372	56° 51.3′	12° 30.75′	10	FS		3	
B 373	56° 51.55′	12° 31.41′	7	St		3	
B 374	56° 50.23′	12° 32.10′	9	H		0.6	
B 375	56° 50.23′	12° 32.10′	11	G-S	50	3	p. 254
B 376	56° 49.25′	12° 34.34′	10	FS		3	
B 377	56° 49.45′	12° 34.63′	7.5	FS		3	
B 378	56° 49.72′	12° 35.0′	5	FS		3	
B 379	56° 47.52′	12° 36.72′	7.5	FS		3	
B 380	56° 45.77′	12° 36.21′	11.5	FS		3	
B 381	56° 45.77′	12° 36.83′	9.5	FS		3	
B 382	56° 45.77′	12° 37.3′	7	FS		3	
B 383	56° 43.53′	12° 38.1′	6-6.5	S		0.6	
B 384	56° 43.53′	12° 38.1′	6-6.5	st. g. S	18	3	Tab. 2
B 385	56° 43.37′	12° 37.8′	10.5-11.0	FS		0.6	
B 386	56° 43.37′	12° 37.8′	10.5	Si		3	
B 387	56° 43.22′	12° 37.55′	12.5	S	128	3	p. 254
B 388	56° 43.3′	12° 37.55′	10.5	Si		3	
B 389	56° 41.98′	12° 37.7′	10	S		3	
B 390	56° 25.83′	12° 39.92′	6.5	g.S	130	3	Tab. 2
B 391	56° 27.73′	12° 37.6′	13	FS	72	3	
B 392	56° 30.85′	12° 50.6′	16	S		3	
B 393	56° 30.87′	12° 50.6′	16	S	34.5	3	
B 394	56° 37.15′	12° 49.95′	14-13.7	c.Si	25	3	
B 395	56° 37.76′	12° 50.8′	11.5-12.0	c.Si-Cl	31	3	
B 396	56° 37.97′	12° 51.7′	10	S		3	
B 397	56° 37.05′	12° 53.9′	4-5	FS	(75)	3	
B 398 : a	56° 27.0′	12° 34.65′	14	FS	(100)	3	
B 398 : b	56° 26.8′	12° 34.26′	5	H		3	
B 399	56° 20.3′	12° 43.34′	11.5	S	77	3	Tab. 2
B 400	56° 20.3′	12° 43.34′	11.5	H		3	
B 401	56° 20.45′	12° 42.5′	13	S	(130)	3	Tab. 2
B 402	56° 20.55′	12° 41.55′	15.5	H		3	
B 403	56° 20.73′	12° 40.55′	18.5	S	28	3	p. 272
B 404	56° 20.47′	12° 43.04′	11.5	Cl	15	3	
B 405	56° 21.04′	12° 43.28′	13-13.5	S	15	3	
B 406	56° 20.15′	12° 42.95′	13	S	(130)	3	Tab. 2
B 407	56° 19.67′	12° 48.8′	15	S	33	3	
B 408	56° 15.17′	12° 44.53′	13.5	S	20.5	3	
B 409	56° 16.02′	12° 44.53′	14	FS	22	3	
B 410	56° 16.82′	12° 44.53′	16	Cl	37	3	
B 411	56° 17.04′	12° 42.2′	17.5	c.Si	145	3	
B 412	56° 17.23′	12° 39.8′	20	Cl	160	3	
B 413	56° 17.58′	12° 35.9′	22.5	Cl-Si	152.5	3	
B 414	56° 17.10′	12° 35.3′	24	Cl	5	3	
B 415	56° 18.05′	12° 34.65′	24.8	Cl	198	3	
B 500	56° 33.6′	12° 49.3′	14	S	82	5	p. 258
B 501	56° 31.1′	12° 49.4′	14	S	133	5	p. 259
B 502	56° 11.5′	11° 57.0′	25	FS	250.5	3	p. 280
B 503	56° 09.2′	11° 35.0′	20	FS	(200)	3	Tab. 2
B 504	56° 12.5′	11° 28.0′	21	m.c. Si	222	3	p. 283
B 505	56° 16.0′	11° 22.1′	19	FS	(129)	3	
B 506	56° 17.0′	11° 20.6′	19	m.c. Si-FS	30	3	

locality	N. Lat.	E. Long.	depth in m	soil at bottom surface	core length in cm	sam-pler	ref.
B 507	56° 19.0′	11° 15.7′	21	si. S	(177)	3	Tab. 2
B 508	56° 20.7′	11° 12.5′	20	m.c. Si-S	(150)	3	
B 509	56° 21.8′	11° 11.0′	19	c. Si-S	(130)	3	
B 510	56° 22.2′	11° 09.8′	18	si. FS	(50)	3	
B 511	56° 25.4′	11° 09.7′	17	FS	(130)	3	
B 512	56° 28.5′	11° 17.0′	17	FS	(50)	3	
B 513	56° 29.3′	11° 20.0′	18	FS	(70)	3	
B 514	56° 31.7′	11° 24.5′	23	Si-FS	(70)	3	
B 515	56° 34.6′	11° 27.0′	20	s.G-St	(70)	3	
B 516	56° 37.0′	11° 21.0′	18	S	(60)	3	
B 517	56° 39.3′	11° 18.0′	18	g.S	(150)	3	p. 288
B 518	56° 46.5′	10° 59.5′	8	FS	(150)	3	p. 55
B 519	56° 47.5′	10° 56.0′	9.5	H		3	
B 520	56° 54.3′	10° 50.3′	10	Si-FS		3	
B 521	57° 08.3′	10° 46.15′	18	c. Si	(128)	3	
B 522	57° 10.0′	10° 45.6′	15	si. S	(185)	3	Tab. 2
B 523	57° 14.2′	10° 43.3′	16	S	(130)	3	Tab. 2
B 524	57° 16.3′	10° 41.7′	18.75	si m. Cl	200	3	
B 525	57° 18.3′	10° 40.0′	15	FS	(15)	3	
B 526	57° 25.9′	10° 43.4′	26	m.Cl	284	3	
B 527	57° 27.5′	10° 52.0′	40	c. M	476	5	
B 528	57° 28.3′	10° 57.5′	37	c. M	437	5	
B 529	57° 28.1′	11° 24.0′	26	g. S	(150)	3+PD	p. 99
B 530	57° 24.5′	11° 33.5′	38	c. Si		D	
B 531	57° 23.7′	11° 32.5′	55	Cl		D	
B 532	57° 24.2′	11° 34.5′	50	Cl		D	
B 533	57° 23.5′	11° 33.6′	45	si. Cl		D	
B 534	57° 20.9′	11° 33.5′	60	Cl		D	
B 535	57° 18.10′	11° 33.5′	65	Cl		D	
B 536	57° 17.3′	11° 42.3′	56	si. FS		D	
B 537	57° 16.1′	11° 42.8′	37	si. FS		D	
B 538	57° 15.4′	11° 44.2′	44	si. FS		D	
B 539	57° 14.8′	11° 47.3′	37	S		D	
B 540	57° 13.5′	11° 49.4′	60-52	St		3+D	
B 541	57° 13.25′	11° 48.2′	17	St		D	
B 542	57° 12.0′	11° 49.8′	45	Sh-S		D	
B 543	57° 16.0′	11° 36.35′	75	Cl		D	
B 544	57° 12.7′	11° 38.6′	77	Cl		D	
B 545	57° 11.7′	11° 37.3′	25	St		D	
B 546	57° 09.0′	11° 39.0′	45	FS		D	p. 83
B 547	57° 05.0′	11° 41.0′	30	S		D	p. 83
B 600	57° 27,3′	11° 15.7′	22	S	(157)	3	
B 601	57° 24.8′	11° 14.0′	19.8	H		3	
B 602	57° 21.5′	11° 05.75′	10.3	s. Cl		3	p. 290
B 603	57° 24.15′	11° 05.50′	14	S	(157)	3	p. 290
B 604	57° 23.4′	11° 00.65′	13	Ti	(75)	3	p. 61
B 605	57° 24.8′	11° 00.12′	7.3	S	(147)	3	p. 290
B 606	57° 26.15′	10° 59.8′	10.5	S	(217)	3	Tab. 2
B 607	57° 27.3′	10° 59.6′	27.5	Cl		3	
B 608	57° 23.45′	10° 56.82′	12.5-13	FS	(145)	3	
B 611	57° 25.9′	10° 40.50′	21	c. Si	286.5	3	
B 612	57° 26.03′	10° 37.10′	15.3	c. Si	267.0	3	p. 291
B 613	57° 21.12′	10° 49.75′	10	FS	(195)	3	
B 614	57° 15.15′	10° 46.7′	16	FS	(240)	3	
B 615	57° 02.25′	10° 55.0′	11	FS	(210)	3	
B 616	56° 55.4′	11° 08.25′	13.8	H		3	
B 619	56° 44.55′	11° 05.35′	16.2	FS	(150)	3	

locality	N. Lat.	E. Long.	depth in m	soil at bottom surface	core length in cm	sam-pler	ref.
B 620	56° 44.48′	11° 05.35′	16.2	FS	(50)	3	
B 621	56° 44.50′	11° 05.35′	16.2	st. S		D	
	56° 44.53′	11° 05.05′	15.5				
B 622	56° 44.53′	11° 05.05′	15.5	S		PD	Tab. 2
	56° 44.58′	11° 05.65′	16.2				
B 623	56° 44.58′	11° 05.35′	16.2	H		3	
B 624	56° 47.25′	11° 05.05′	14.5	FS		3	
B 625	56° 47.2′	11° 05.0′	14.5	FS		3	
B 626	56° 48.9′	11° 01.15′	15.0	FS		3	
B 627	56° 44.35′	11° 05.45′	16.2	H		3	
B 628	56° 44.35′	11° 05.35′	16.2	st. FS		PD	
	56° 44.55′	11° 04.8′	16.2				
B 629	56° 44.6′	11° 06.1′	16	FS	(150)	3	
B 630	56° 48.6′	11° 11.9′	18.0	FS	20	3	p. 287
B 631	56° 48.6′	11° 11.9′	18.0	st. FS		PD	
	56° 48.6′	11° 12.2′					
B 632	56° 48.6′	11° 11.9′	18.0	FS	(50)	3	
B 633	56° 48.68′	11° 15.25′	18.5	FS	44	3	p. 287
B 634	56° 46.6′	11° 15.20′	19.5	FS	35(+70)	3	p. 287
B 635	56° 45.4′	11° 15.15′	20.0	FS	30(+70)	3	p. 287
B 636	56° 39.55′	11° 31.25′	9.0	H		3	
B 637	56° 39.65′	11° 31.2′	8.0	S	(200)	3	Tab. 2
B 638	56° 46.2′	11° 37.7′	19.4	si. FS	(200)	3	Tab. 2
B 639	56° 46.34′	11° 39.8′	22.0	FS	(200)	3	
B 640	56° 47.4′	11° 40.0′	22.5	H		3	
B 641	56° 47.2′	11° 37.4′	19.8	FS		3	
B 642	56° 48.27′	11° 36.5′	19.0	FS	(200)	3	
B 643	56° 48.48′	11° 39.7′	22.1	H		3	
B 644	55° 41.1′	12° 38.9′	13.8	FS	(100)	3	
B 645	55° 41.0′	12° 38.6′	14	FS	(100)	3	
B 646	55° 42.0′	12° 38.1′	13.2	si. M	141	3	p. 277
B 647	55° 42.0′	12° 38.1′	13.0	si.c. M	98	3	p. 277
B 648	56° 07.8′	11° 59.3′	18.0	Si	105	3	p. 282
B 649	56° 09.9′	11° 58.2′	24.0	c.m. Si	96.5	3	p. 280
B 650	56° 11.4′	11° 57.3′	26	c. Si	123	3	p. 280
B 651	55° 59.4′	11° 23.05′	15.8	Si	65	3	p. 284
B 652	55° 59.25′	11° 23.15′	14.5	Si	35	3	p. 284
B 653	55° 59.05′	11° 24.0′	15.0	Si	111.8	3	p. 284
B 654	55° 59.05′	11° 24.0′	14.8	Si	116.5	3	p. 284
B 655	55° 59.05′	11° 24.0′	15.0	Si	141.0	3	p. 284
B 656	56° 35.9′	12° 05.6′	22.1	H		3	
B 657	56° 35.9′	12° 05.35′	22.5	St		PD	p. 33
	56° 35.8′	12° 05.45′	22.8	(SR)			
T 1	56° 46.1′	10° 59.3′	12	FS+P		T	
(B 702)	56° 43.6′	10° 55.4′	10				
T 2	56° 43.6′	10° 55.4′	13	FS		T	
	56° 40.2′	10° 59.2′	15				
T 3	56° 46.5′	11° 00.3′	13	FS+P		T	p. 288
(B 703)	56° 42.1′	11° 10.4′	17				
T 4	56° 42.1′	11° 05.3′	20-18	FS		T	
	56° 45.9′	11° 01.8′	14				
T 5	56° 43.6′	10° 54.3′	10	FS+P		T	
(B 704)	56° 41.0′	10° 51.6′	10				
T 6	56° 36.9′	11° 07.8′	17	FS+P		T	
(B 705)	56° 42.8′	11° 05.1′	18				
B 731	56° 29.1′	12° 18.0′	26-30	S		PD	
B 732	56° 29.6′	12° 11.0′	32-33	S		PD	

locality	N. Lat.	E. Long.	depth in m	soil at bottom surface	core length in cm	sam-pler	ref.
B 733	56° 41.53′	10° 33.65′	8.0	FS		PD	
	56° 42.0′	10° 33.4′	8.2				
B 734	56° 42.1′	10° 33.4′	8.2	FS		PD	
	56° 41.5′	10° 33.65′	7.8				
B 735	56° 39.9′	10° 33.1′	7.9	FS		PD	
	56° 40.0′	10° 31.5′	7.5				
B 736	56° 40.05′	10° 31.1′	7.5	H(Ti)		D	
	56° 39.6′	10° 31.4′	9.8				
B 737	56° 39.45′	10° 31.5′	9.2	Ti		PD	p. 53
	56° 39.55′	10° 31.5′	9.0				Tab. 2
B 738	56° 41.8′	10° 33.6′	7.9	S	(100)	3	
B 739	56° 45.4′	10° 30.5′	10.0	FS		PD	
	56° 45.4′	10° 29.8′	8.9				
B 740	56° 45.35′	10° 28.9′	10.5	Ti	(70)	3	Tab. 2
B 741	56° 47.6′	10° 30.3′	9.2	FS		PD	
	56° 48.2′	10° 31.1′	9.0				
B 742	56° 54.1′	10° 31.1′	12.2	Ti		PD	p. 55
	56° 54.2′	10° 31.7′	12.8				Tab. 2
B 743	56° 54.05′	10° 35.9′	13.2	FS		PD	
	56° 53.9′	10° 36.2′	13.0				
B 744	56° 55.15′	10° 47.3′	10.0	FS		PD	
	56° 54.85′	10° 47.5′	10.0				
B 745	56° 55.2′	10° 47.3′	9.7	H		D	
	56° 55.6′	10° 47.4′	10.2				
B 746	56° 55.7′	10° 47.3′	10.2	FS		PD	
	56° 55.2′	10° 47.6′	10.2				
B 747	56° 57.05′	10° 39.8′	11.5	Sh-FS		PD	p. 289
	56° 57.2′	10° 39.7′	11.6				
B 748	56° 58.6′	10° 38.4′	10.3	FS		PD	
	56° 58.15′	10° 38.3′	10.5				
B 749	56° 59.3′	10° 34.4′	10.7	Ti		PD	p. 55
	56° 59.15′	10° 34.5′	11.4				
B 750	57° 05.3′	10° 31.55′	5.3	FS		PD	p. 290
	57° 05.8′	10° 31.7′	6.3				
B 751	57° 07.75′	10° 33.3′	6.6	FS		PD	p. 290
	57° 08.0′	10° 33.3′	7.3				
B 752	57° 19.0′	10° 38.7′	14.8	Si	123	3	
B 753	57° 20.6′	10° 38.4′	14.8	Si	132	3	
B 755	57° 27.3′	10° 36.9′	10.4	FS		3	
B 756	57° 26.85′	10° 38.1′	19.2	si. Cl	265	3	p. 291
B 757	57° 27.2′	10° 37.7′	17.6	Si-FS	252	3	p. 291
B 758	57° 27.4′	10° 37.6′	12.0	FS		3	
B 759	57° 27.4′	10° 37.7′	14.7	FS	(100)	3	
B 760	57° 27.45′	10° 37.7′	13.2	FS		PD	
	57° 27.4′	10° 37.4′	11.3				
B 761	57° 23.05′	11° 24.5′	30.5	G(Ti)		PD	p. 90
	57° 23.2′	11° 25.2′	42.0				
B 762	57° 22.8′	11° 25.3′	24.0	Ti		PD	p. 90
	57° 22.7′	11° 25.3′	24.6				
B 763	57° 15.7′	11° 28.2′	42.2	Ti		PD	p. 83
	57° 15.8′	11° 27.7′	44.3				
B 764	57° 08.5′	11° 31.9′	44.2	Ti		PD	p. 83
	57° 08.45′	11° 30.9′	39.0				
B 766	57° 20.4′	11° 20.5′	43.7	Cl		PD	
	57° 20.2′	11° 20.8′	45.0				
B 767	57° 18.7′	11° 23.1′	23.0	Ti		PD	p. 83
	57° 18.5′	11° 23.3′	31.0				

locality	N. Lat.	E. Long.	depth in m	soil at bottom surface	core length in cm	sam-pler	ref.
B 768	57° 17.85′	11° 21.2′	39.8	Cl		PD	p. 70
	57° 17.7′	11° 21.7′	40.9				
B 769	57° 13.5′	11° 24.4′	28.2	Ti		PD	p. 70
	57° 13.3′	11° 24.3′	28.0				
B 770	57° 11.4′	11° 24.4′	40-41	Cl		PD	p. 67
	57° 11.25′	11° 24.5′	50.6				
B 771	57° 09.9′	11° 25.5′	35.2	H		PD	p. 67
	57° 09.7′	11° 26.3′	75.5				
B 772	57° 08.5′	11° 26.6′	30.7	Ti		PD	p. 67
	57° 08.3′	11° 27.2′	62.7				
B 773	57° 09.5′	11° 31.9′	24.0	g. S(Ti)		PD	p. 71
	57° 09.3′	11° 31.1′	24.5				
B 774	57° 01.4′	11° 30.2′	16.3	—		3	
B 775	57° 00.55′	11° 34.7′	20.0	G		PD	p. 67
	57° 00.47′	11° 35.6′	21.0				

Description of Plates

Pl. 1. The seabed of Kattegatt, geological map

This map is based upon information from borings, dredgings and echo soundings (cf. Fig. 1) supplemented by information from the nautical charts and from fishermen, and in the Öresund region by the results of H.Brattström (1941).

Along the Swedish coast the bedrock is most probably underrepresented. In the archipelago outside Gothenburg bedrock and clay (and sand) are too mixed to be distinguishable. In the Anholt-Laesö area (soil region III, Fig. 2) the Quaternary deposits are very thick and mainly made up of drift. Two principal sections across Kattegatt are given in Figs. 4 and 5.

The ice marginal lines clearly show a recession towards NE of the main Swedish ice cover, separating one Baltic ice lob after the other in Lille Belt, Store Belt and Öresund. The division between the Öresund lobe and the NE-ice is nicely illustrated by the distinct ice marginal fork of the F5 line in NW Skåne (Fig. 19).

Pl. 2. Ice marginal lines in Southern Scandinavia

More detailed pictures of the deglaciation in Kattegatt and on the Swedish West Coast are given in Pl. 1 and Pl. 3 respectively. The corresponding glaciation curve is given in Fig. 42 (p. 182). The separation, shrinking and disappearing of one Baltic ice lobe after the other is well illustrated. On the Swedish West Coast the interstadial/stadial changes are marked. The figures on the four ice marginal lines of Younger Dryas refer to the varve chronology.

Pl. 3. Ice marginal lines and deposits on the Swedish West Coast

Along the Swedish West Coast there are two very distinct ice marginal lines, viz. the Fjärås line (10,350–10,300 BC) and the complex Moslätt/Berghem line (9,950—9,800 BC). The ice margin was more or less straight in the coastal areas, while in the areas at and above ML it became influenced by the topography. Note that a thin red line often corresponds to a more distinct terminal moraine than a broader field. As the mapped area is not yet covered by contour maps the extension of the area above ML probably needs some minor revision (especially in the Gothenburg area).

Symbols not explained on the map: black dot = pollen and C^{14} dated Late Glacial isolation level, circle = stratigraphy described, shell symbol = locality with Late Glacial shell fauna, arrow = drainage channel.

Pls. 4, 5 and 6. The Late Glacial, ALV and PTM shorelines

These three diagrams are in the same scale and can easily be compared with each other by the distance scale of the diagram prifile line. The geographic position of the diagram profile line or direction of tilting is given in Pl. 7. If a certain point in the Kattegatt — West Coast area is introduced perpendicular to that line, the shorelevel displacement at that point (from ML to PTM-7) can easily be obtained from the three shoreline diagrams.

The Late Glacial shorelines (Pl. 4): The chronology is based upon C^{14} dates (and pollen analysis) back to 10,750 BC, beyond which it is calculated from the rate of shorelevel displacement (and recession of ice and some varve series). ML is oldest in NW

Skåne, i.e. where the Baltic and Swedish ices separated (cf. Pl. 2 and Fig. 19). The shorelines of the Fjärås line, Moslätt line and Berghem line are very precisely fixed as indicated by C^{14} dates in Höghults Mosse and Klinehögkärret. The shorelines from the Alleröd and Younger Dryas periods are based upon dated isolation levels and less precisely fixed.

The ALV shorelines (Pl. 5): These shorelines are very closely fixed in age and altitude. However, ALV-1 (and ALV-0) is supposed to bend to a gentler gradient somewhere between –80 km and –150 km, though there is as yet no morphological indication of this. The Ancylus Lake in the Baltic was first dammed about 8.5 m above ALV-3, but was soon drained to the sea level by erosion.

The PTM shorelines (Pl. 6): PL is formed by PTM-2, PTM-3, PTM-5A and PTM-7. On the Bjäre peninsula PL is highly polygenous and formed by PTM-3 to PTM-5A. PTM-3 is drawn as a single line though in reality it contains two maxima.

Pl. 7. Kattegatt during ALV-1

During the "regression maximum" or ALV-1 large areas of the present seabed were land. This is indicated by peat and lacustrine layers in situ, ground crusts, shore marks, dunes, river channels and shallow sea deposits. The ALV-1 shoreline intersects the present sea level at the mouth of River Viskan, the point of which forms the 0-point (± 0 km) in the diagram profile line. The Ancient Lake Veselången was dammed as ALV-1b about 2.2 m above sea level. In Laholmsbukten and Skälderviken the coast seems to have been built out southwards, indicating a quite different circulation than at PL or today (cf. Pl. 9). In SW Kattegatt the limit between land and sea is less well fixed than elsewhere. Store Belt and the channels from Store Belt were fiords rather than rivers. Buried dwellings at the ALV-1 shoreline indicate the presence of man on the Swedish West Coast.

ALV-1 is dated at 7,750—7,330 BC. This period is characterized by syngression. The sea level was eustatically constant and the margin of tilting and upheaval was on the other side of the Highland of Småland. The extension of the sea during ALV-2 and ALV-3 is given in Fig. 110.

Pl. 8. Sections 10—15

Five sections of the delta area in Ancient Lake Veselången (cf. Fig. 75, p. 224). The sections are drawn as seen from upstream.

Pl. 9. The metachronous Postglacial Limit (PL)

North of Varberg there was a rocky fiord coast and south of Varberg a sandy or shingly lowland coast with several lagoons in the Falkenberg-Varberg area and a big spit or coastal barrier built out from SW in Laholmsbukten (probably also in Skälderviken). Kullen was an island. In the absence of contour maps PL could only be approximately drawn in the Gothenburg area.

The altitude of PL and the shorelevel displacement at any point can be obtained from Pl. 6.

Pl. 10. Section at Eskilstorp

The stratigraphy is described on p. 331. A buried beach ridge of PTM-2 is seen at about B 245. PTM-2 is closely dated in B 268. PTM-3 is here seen as a double maximum. PTM-3A is dated in B 228 and PTM-3B in B 220. The altitude is in meters above sea level.

THE SEABED OF KATTEGATT
GEOLOGICAL MAP

BY NILS-AXEL MÖRNER 1968

SCALE
0 10 20 km

- till, gravel, stones or hard bottom
- sand and coarse silt
- clay and fine silt, often muddy
- rock
- ice marginal lines
- ..... -6 m
- - - - - - -10 m
- ——— -20 m
- —·—·— -30 m
- ——··—··— -40 m
- —·—·—·— -80 m
- ..... -100 m

Skagen
Skag Bank
Herthas Flak
Frederikshavn
Vendsyssel
Limfjorden
Laesö
Kummel Bank
Tönneberg Bk.
Laesö Trind.
Böchers Bank
Kobbergrund
N.Rönner
NW-rev
Svitringen
Kims Top
Øfk
Fisken
Dame-boxerne
Tangen
Djursland
Grenå
Anholt
NW-rew
Nidingen
Malö
Fladen
Groves Flak
Varberg
Falkenberg
the Swedish West Coast
Lilla Middelgrund
Fyrbank
Rödebank
Stora Middelgrund
Halmstad
Laholmsbukten
Björe
Skälderviken
Kullen
Ängelholm
Höganäs
Öresund
Helsingör
Hälsingborg
Ven
Landskrona
Kalö Vig
Ebeltoft
Helgenäs
Samsö
Schultz gr.
Hastens Gr.
Briseis Fk.
Lilla Lyse grund
Lysegrund
Hesselö
Sejerö
Sjaellands Odde
Rösnäs
Svane gr.
Isefjord
Sjaelland
Copenhagen
Louis Fk.
Valgr.
Disk.

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ICE MARGINAL LINES in SOUTHERN SCANDINAVIA

by

NILS-AXEL MÖRNER 1968

0 50 km

Ra-trinnet
Kristiansand-trinnet
Spangereid-trinnet
Lista-trinnet
the Mosjätt/Berghem line
Younger Dryas
8.213
8.500
8.700
9.100
Alleröd Interstadial
Bölling Interst.
the Mosjätt line
the Fjäräs line
the Berghem line
Sweden
Ågård Interstad.
Torupsmoränen
the Karlslund line
Bredåkra
Jylland
-100
-20
-200
H2
G8-H1
G4
G5
G8
H1
H2
Rosenthaler line
Pommer. line

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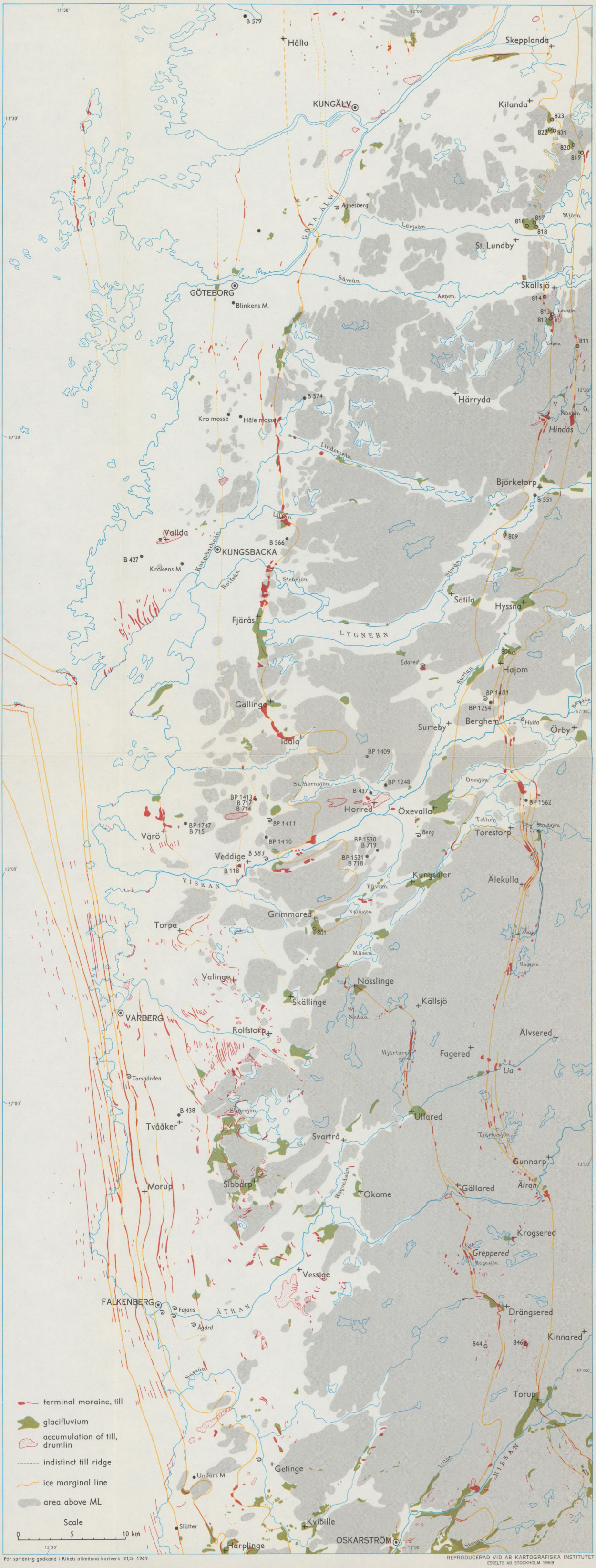
ICE MARGINAL LINES AND DEPOSITS ON THE SWEDISH WEST COAST

BY NILS-AXEL MÖRNER



För spridning godkänd i Rikets allmänna kartverk 21/3 1969

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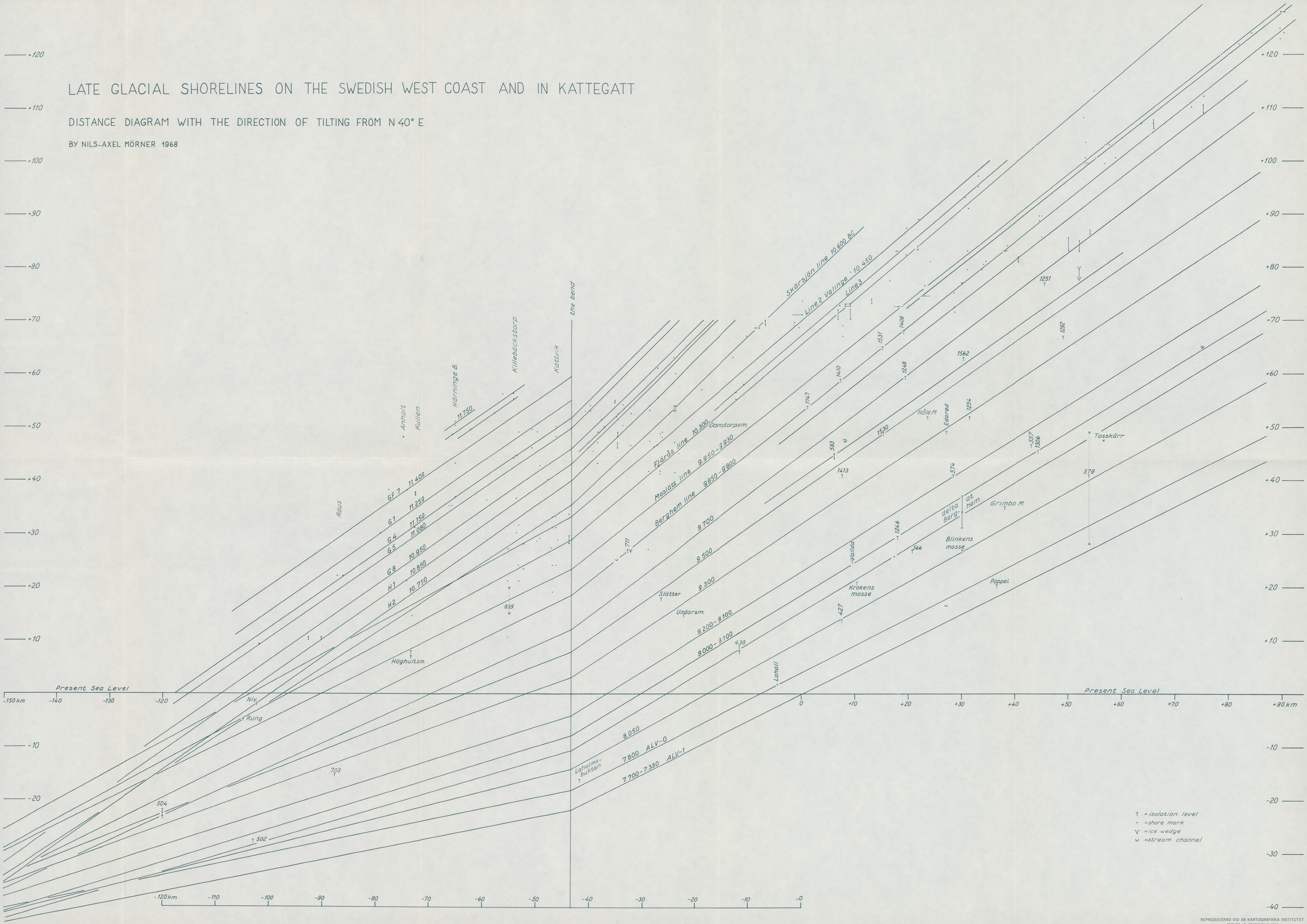
LATE GLACIAL SHORELINES ON THE SWEDISH WEST COAST AND IN KATTEGATT

DISTANCE DIAGRAM WITH THE DIRECTION OF TILTING FROM N 40° E

BY NILS-AXEL MÖRNER 1968



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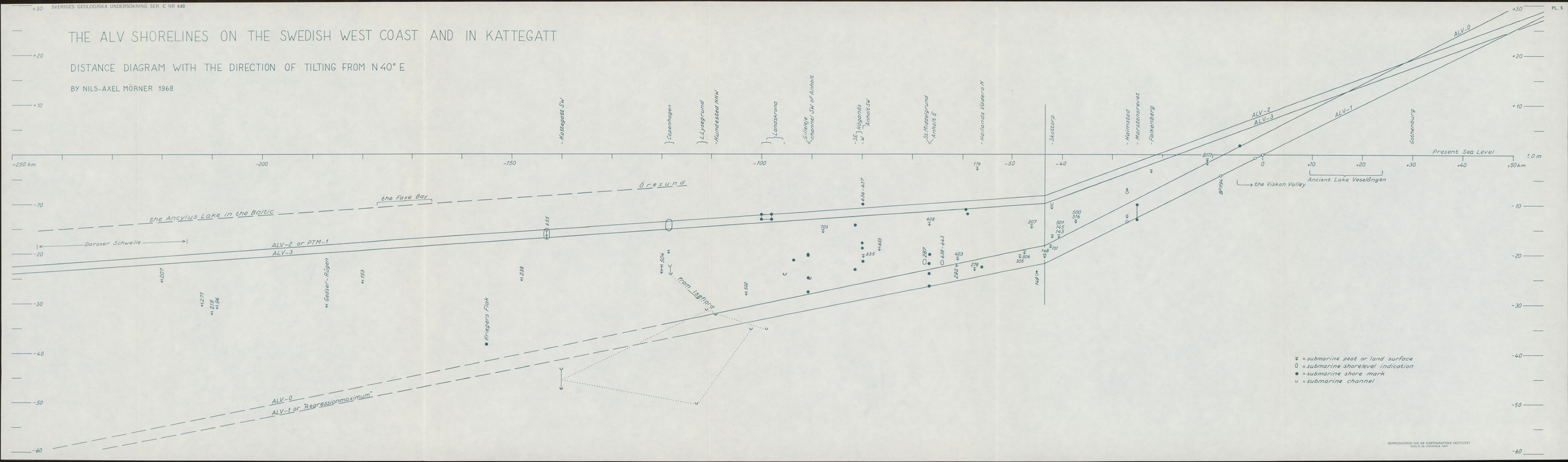
THE ALV SHORELINES ON THE SWEDISH WEST COAST AND IN KATTEGATT

DISTANCE DIAGRAM WITH THE DIRECTION OF TILTING FROM N 40° E

BY NILS-AXEL MÖRNER 1968



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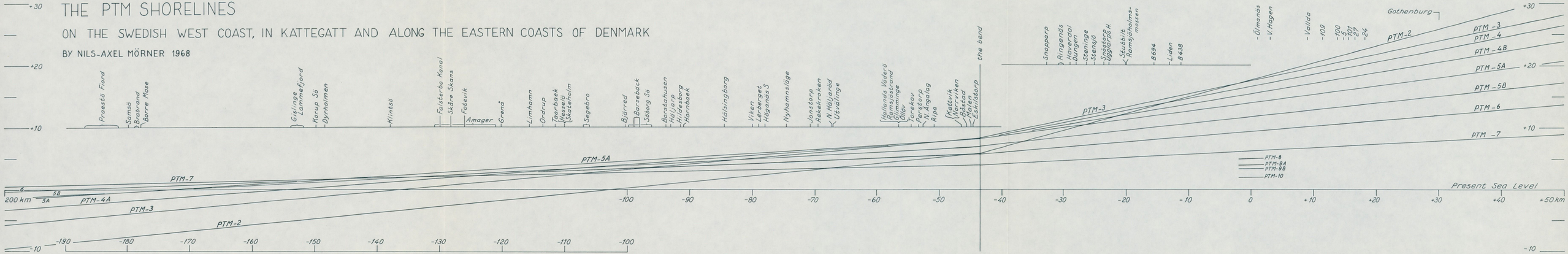
ESELTE AB STOCKHOLM 1969

THE PTM SHORELINES

ON THE SWEDISH WEST COAST, IN KATTEGATT AND ALONG THE EASTERN COASTS OF DENMARK

BY NILS-AXEL MÖRNER 1968



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KATTEGATT
during ALV-1

Scale 1:500 000

sea during ALV-1

land today

submarine features:

peat (in situ)

ground crust

shore cliff or steep slope

beach ridge or bar

dunes

river channel

N 40° E

+50 km

±0 km

-50 km

-100 km

-150 km

-200 km

Direction of tilting and diagram profile line

Ancient Lake Vesslingen

R. Viskan

R. Ätran

R. Nissan

R. Stensån

R. Saxån

Limfjorden

Mariager Fj.

Randers Fj.

12°

30'

57°

56°

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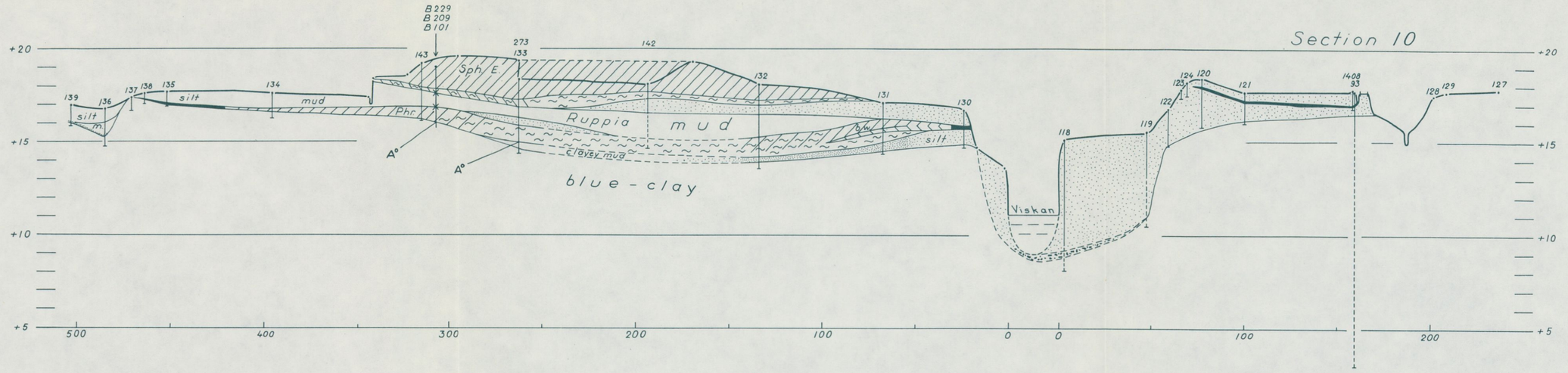
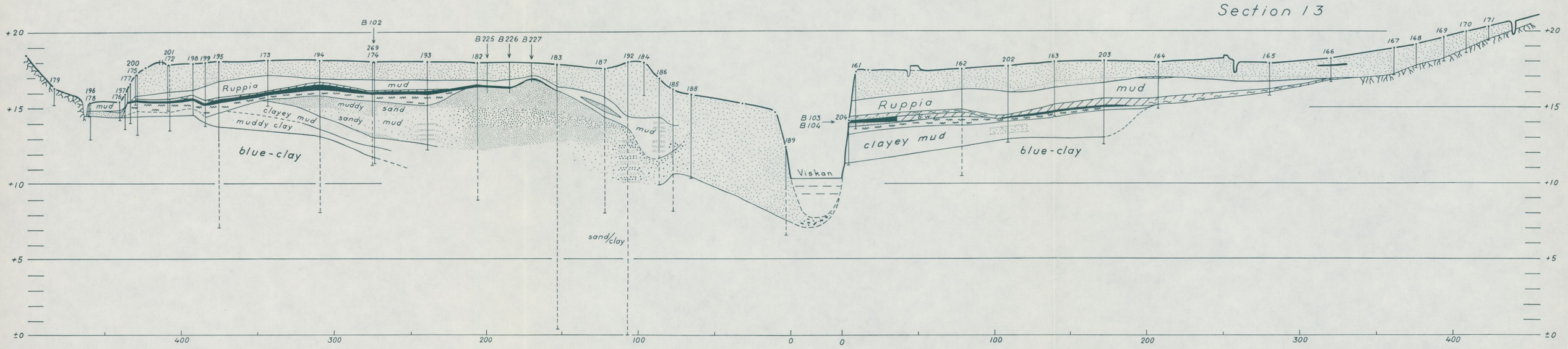
Section 10



Section 13



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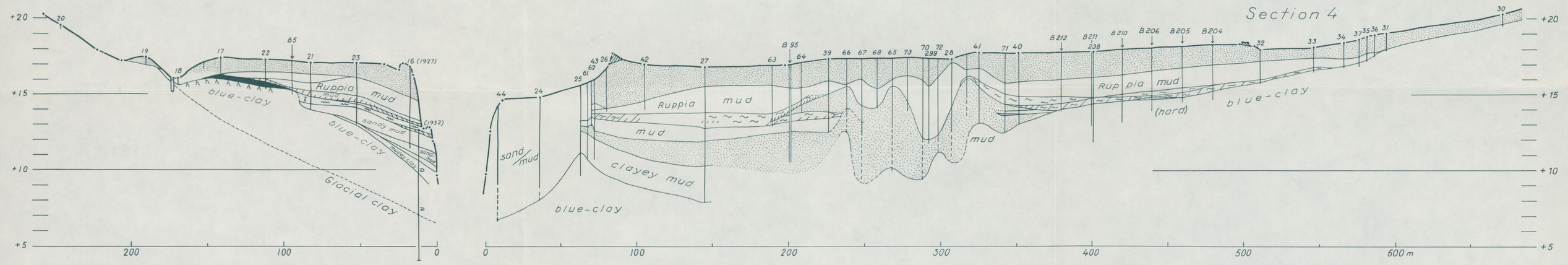
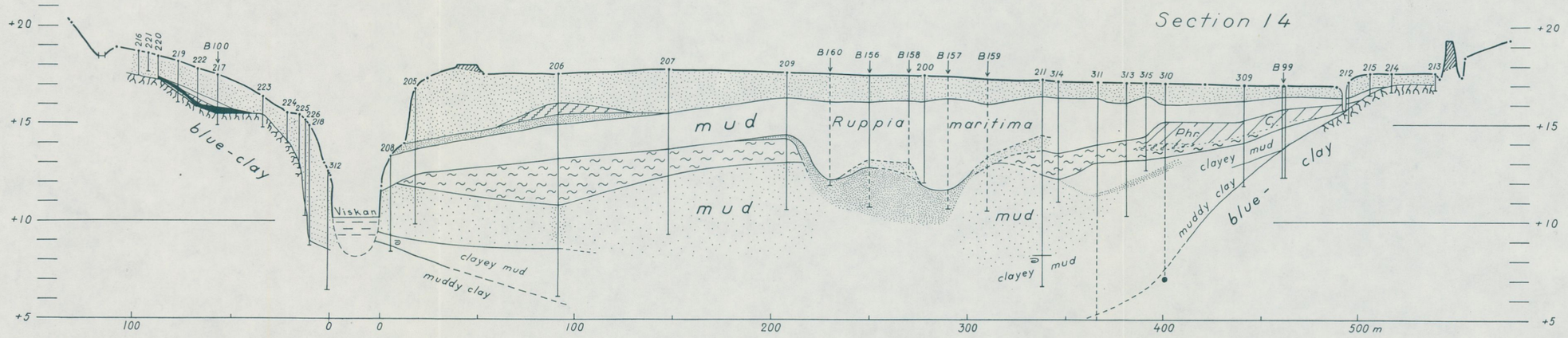


Section 14



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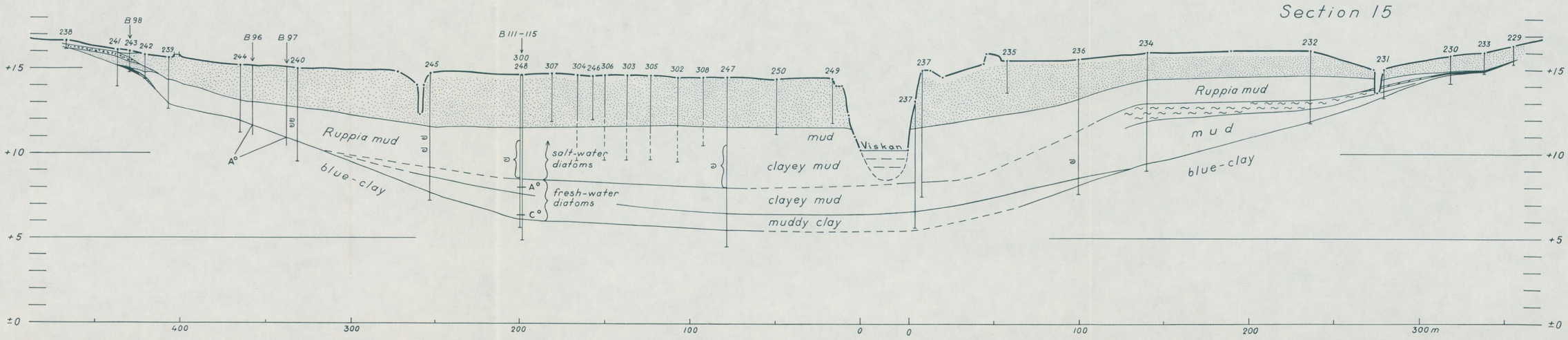

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Göta Älv
Gothenburg
Aspen
430
Onsala
Lygnern
the Viskan Valley
Varberg
Tvääker
Morup
R. Ätran
Falkenberg
R. Nissan
Halmstad
R. Fylleån
Hallands Väderö
Torekov
Båstad
the Bjäre peninsula
Mt. Hallandsås
R. Lagan
R. Vallbergaån
R. Smedjeån
R. Stensån
Mt. Kullen
Höganäs
Ängelholm
R. Rönneå
R. Vegeå
N
W
E
S
12°30'
13°
0
10 km

THE METACHRONOUS POSTGLACIAL LIMIT (PL) ON THE SWEDISH WEST COAST

Area above PL
15 Levelled section
B 722 Boring

Ur sekretessynpunkt: för spridning godkänd i Rikets allmänna kartverk 21/3 1969

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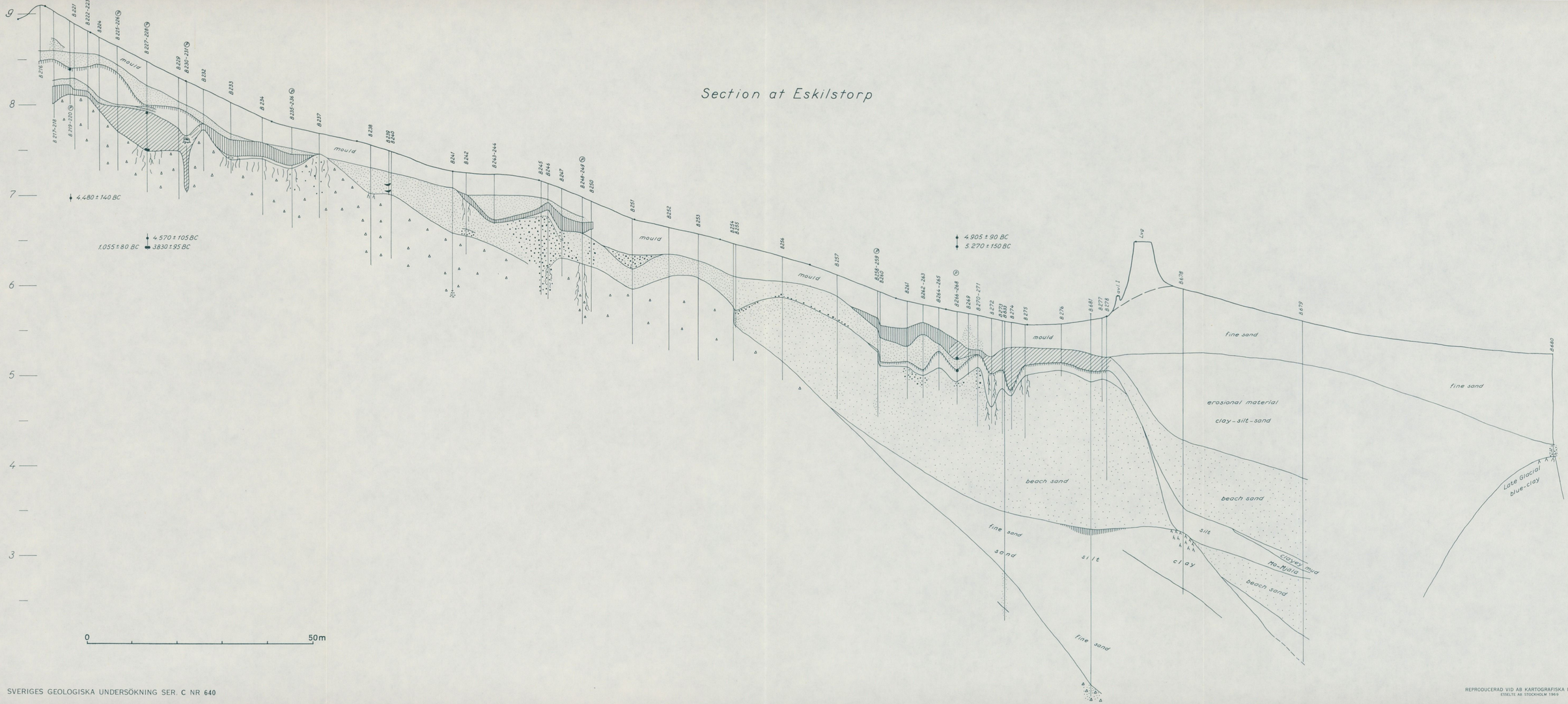
Section at Eskilstorp



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