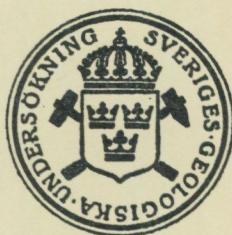


GÖSTA PERSSON

POSTGLACIAL TRANSGRESSIONS
IN BOHUSLÄN,
SOUTHWESTERN SWEDEN



STOCKHOLM 1973

SVERIGES GEOLOGISKA UNDERSÖKNING

SER C NR 684

ÅRSBOK 67 NR 3

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ISBN 91-7158-024-7

C DAVIDSONS BOKTRYCKERI AB, VÄXJÖ 1973

Textkartorna är för spridning godkända i rikets allmänna kartverk 1973-01-30.

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ABSTRACT

This paper presents the results of an investigation of the Postglacial transgressions in the central and southern parts of Bohuslän. A number of recent lakes and mires have been pollen- and diatom-analytically investigated. Some horizons have been radio-carbon dated. Some of the basins have been isolated from and inundated by the sea several times. A curve for the shore displacement is constructed and a comparison made between Bohuslän and other parts of southern Sweden and Denmark.

ACKNOWLEDGEMENTS

The present investigation was carried out at the Institute of Quaternary Geology, University of Lund.

I wish to express my gratitude to the former head of the Institute, Professor Tage Nilsson, and the present head, Professor Björn E. Berglund, for their great interest and valuable help when the field and laboratory works were carried out and this paper was written.

The material from Bräckemotet (loc. 9) was put to my disposal by Professor Carl-Axel Moberg, Dr Carl Cullberg and Dr Gert Knutsson; for this I am very thankful.

Diagrams and other information from Hogen (loc. 6) are taken from an unpublished investigation by Mrs Bodil Persson (1969), who has kindly permitted me to publish the material from this locality.

I also wish to thank Mr Sören Håkansson, who has carried out all the radio-carbon datings, Mrs Marianne Teeling, Mrs Greta Hellström and Mrs Inga Palmaer for drawing the diagrams and other figures, Mr Ernest Magnusson for the critical reading of the manuscript and to Mr Edward Bragg for correction of the English.

Introduction

The transition zone between areas with and without Postglacial transgressions is situated in Bohuslän on the Swedish west coast. The main purpose of this investigation was to study the shoreline displacement in this transition zone at the time of the Postglacial transgressions.

The shoreline displacement in Bohuslän has earlier been studied by several geologists. Hessland (1943) gives a summary of some of these older investigations, which were mainly founded on studies of marine shell beds.

Some geologists have studied the shoreline displacement by pollen- and diatom-analytical investigations of the isolations of lakes and mires from the sea. Sandegren (1924, 1931, 1952) and Thomasson (1934) describes several localities from the Gothenburg area with a distinct Postglacial transgression. Thomasson presents a very detailed shoreline displacement curve from Gothenburg, showing a complex transgression. Some information concerning the shoreline displacement is given by Sandegren (1943, 1946), although no primary material is presented in these papers. According to Sandegren the Postglacial transgressions can be traced as far north as Håлта, immediately north of Kungälv. North of Håлта Sandegren has found no transgression.

In the central part of Bohuslän Fries (1951) has investigated the vegetational history. He gives some notes on the shoreline displacement. He has not found any Postglacial transgression in the area.

Field and laboratory work

The field work for this investigation started in 1963. A great number of lakes and mires in the area between Uddevalla and Gothenburg were investigated. The stratigraphy of the basins was studied and the altitudes of their overflow thresholds were determined. On several localities in the northern part of the area traces of Postglacial transgressions were found. For this reason the investigation was concentrated to this part of Bohuslän.

The main part of the samples for pollen, diatom and radiocarbon analyses were collected and analysed during the period 1965–1968.

Samples from mires were collected with a Hiller sampler and those from the bottom sediments of lakes with a modified Livingstone sampler. The latter samples were collected from the ice during the winter. The radiocarbon analyses were carried out on samples from frozen Livingstone cores.

All samples from Bräckemotet (loc. 9) were collected directly in a section.

The samples for pollen analysis were acetolysed (Erdtman 1933); however the bleaching treatment was excluded. Many of the samples were also treated

with 40 % hydrofluoric acid at 20°C for some days in order to eliminate mineral particles.

The samples for diatom analysis were treated with 30 % hydrogen peroxide at 20°C for two weeks. Through this treatment the organic material was almost completely destroyed. The determination of the different diatom species was carried out mainly through reference to Hustedt (1931–1962) and Cleve-Euler (1951–1955). Information about the environmental requirements of the different species was obtained from Hustedt (1931–1962), Cleve-Euler (1951–1955), Halden (1922, 1929), Thomasson (1934) and Miller (1964).

The pollen and diatom analyses from Hogen (loc. 6) were carried out by Mrs Bodil Persson, from the other localities by the author.

The pollen and diatom diagrams

The pollen diagrams are constructed in the conventional way. The curves for arboreal pollen (AP) are found to the left in the diagrams. To the right, curves for certain non-arboreal pollen (NAP) and some other microfossils are found. The sum of calculation (Σ AP) includes *Corylus*.

About 500–600 AP have generally been counted in each sample. In some layers with a high content of mineral particles and low pollen concentration fewer AP were counted. The calculation sum (Σ AP) can be found in the diagrams for each sample.

The pollen zone system used in this paper is Jessen's (1935) zone system, modified by Fries (1951).

The boundaries between the zones can briefly be defined as follow:

IV/V: rational *Corylus* limit (C°), decreasing *Betula* and increasing *Pinus* frequencies.

V/VI: rational *Alnus* limit (A°).

VI/VII: rational *Tilia* limit (T°).

VII/VIII: decreasing *Ulmus* and *Tilia* frequencies.

The rational limits of *Ulmus* (U°) and *Quercus* (Q°) are situated in zone VI. Zone IV corresponds approximately to Preboreal time, zone V to Boreal time, zone VI to the transition between Boreal and Atlantic time, zone VII to Atlantic time and zone VIII to Subboreal time.

In the diatom diagrams the species have been put together into four groups: M: marine species, B: species living in brackish water, F-B: species living in both fresh and brackish water and F: fresh water species. Group F-B includes both halophile fresh water species and indifferent species. The total amount of counted shells (valves) has been used as the calculation sum. For practical reasons *Melosira islandica* has not been included in this sum because of the very high frequencies of this species in some samples. The calculation sum for each sample can be found in the diagrams. All diatom species in the analysed samples and the number of specimens found are given in Table 2.

Description of the localities

LOCALITIES 1-4

These four basins are situated in a valley with the direction NE-SW a few kilometres north of Ljungskile (Fig. 1 and 2). In the NE part, where the lake Vassbosjön (loc. 4), lake Funneshultssjön (loc. 3) and the mire at Kolbengtseröd (loc. 2) are situated, the valley is about 0.1-0.5 km wide. In the SW part, where lake Kolbengtserödssjön (loc. 1) is situated, the valley is wider (about 1 km). The lakes are probably relatively deep basins excavated in the rock by the Quaternary ice sheets. They are partly dammed by drift and glaciofluvial deposits. Björsjö (1949) has investigated these deposits.

KOLBENGTSERÖDSSJÖN (LOC. 1)

The maximum length of the lake is 1.3 km and its width about 0.8 km. The altitude of the lake is 36 m above sea-level. The outlet, Aröd å, is situated at the SW end of the lake and flows to the sea. The shores are mostly steep and a water depth of 8 m can often be found only 25-50 m from the shore. The central part of the lake is about 10 m deep. The basin is probably a deep rock excavation, partly filled with marine and lacustrine sediments of considerable thickness. In the SW end the lake is dammed by a rock threshold overlain by a terminal moraine ridge, consisting mainly of stratified sand. The ridge is 10-15 m high at the north side of the valley. At the south side there is an opening about 100 m wide in the ridge. The outlet is situated there and has eroded a narrow furrow, two metres deep. The original level of the overflow threshold seems to have been two metres above the present lake level, that is 38 m above sea-level.

Two Livingstone cores from this lake have been more closely investigated. In this paper they are referred to as Kolbengtserödssjön I and II respectively. Although both of them were collected not far from the shore (Fig. 2) the sediments were very thick. The boring equipment was not able to penetrate down to strata deposited at the time of the first isolation of the basin from the sea. In the cores several grey clay layers interbedded with brown gyttja were found.

Kolbengtserödssjön I showed the following stratigraphy (the figures indicate depth below lake surface).

0- 750 cm water

A 750-1177 cm gyttja, grey-brown, diffuse transition to B

B 1177-1187 cm clayey gyttja, brown-grey, diffuse transition to C

C 1187-1203 cm muddy clay, grey, diffuse transition to D

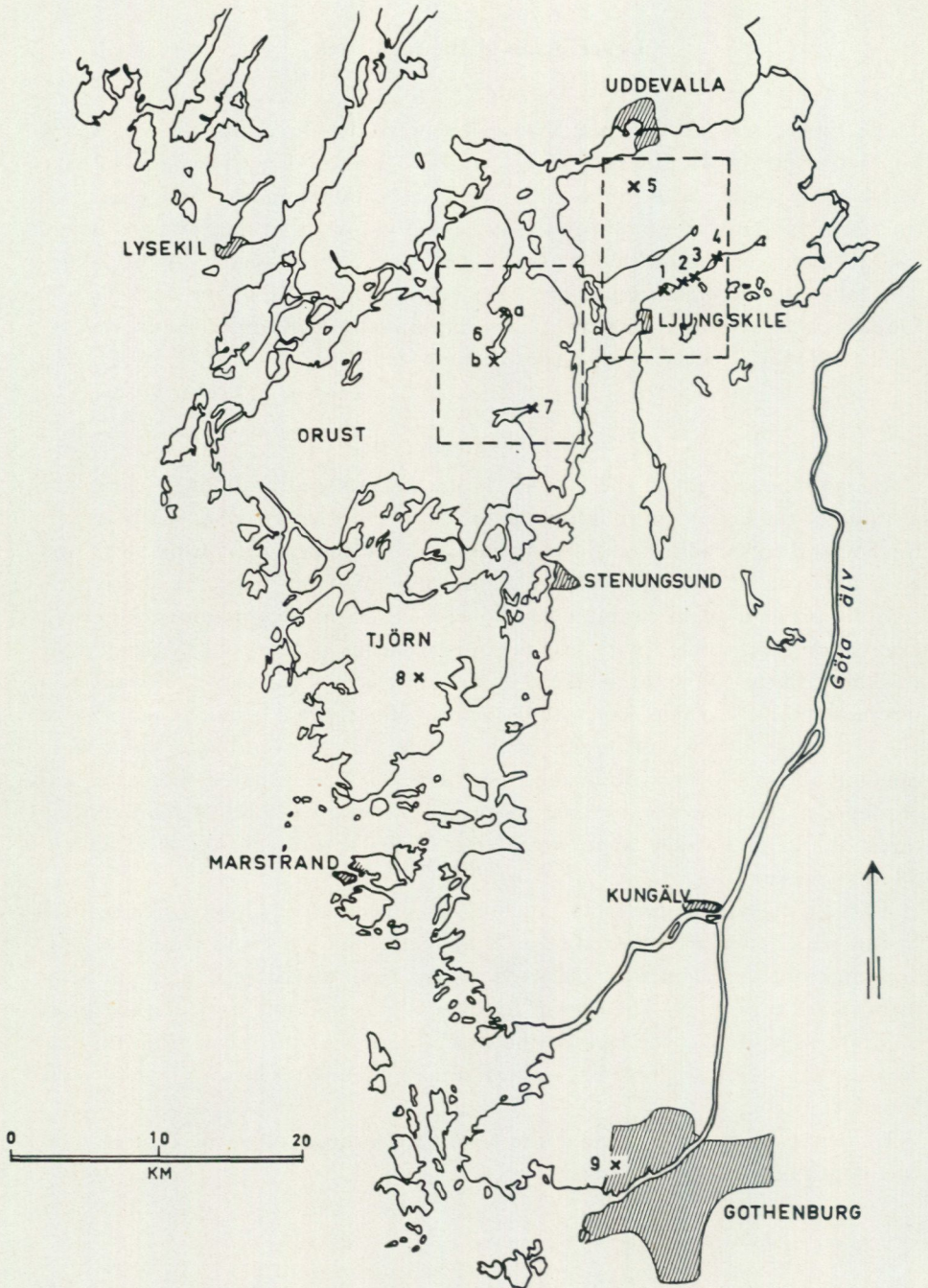


Fig. 1. Map showing the investigated localities in southern Bohuslän. The areas within the frames appear in Fig. 2 and 12.



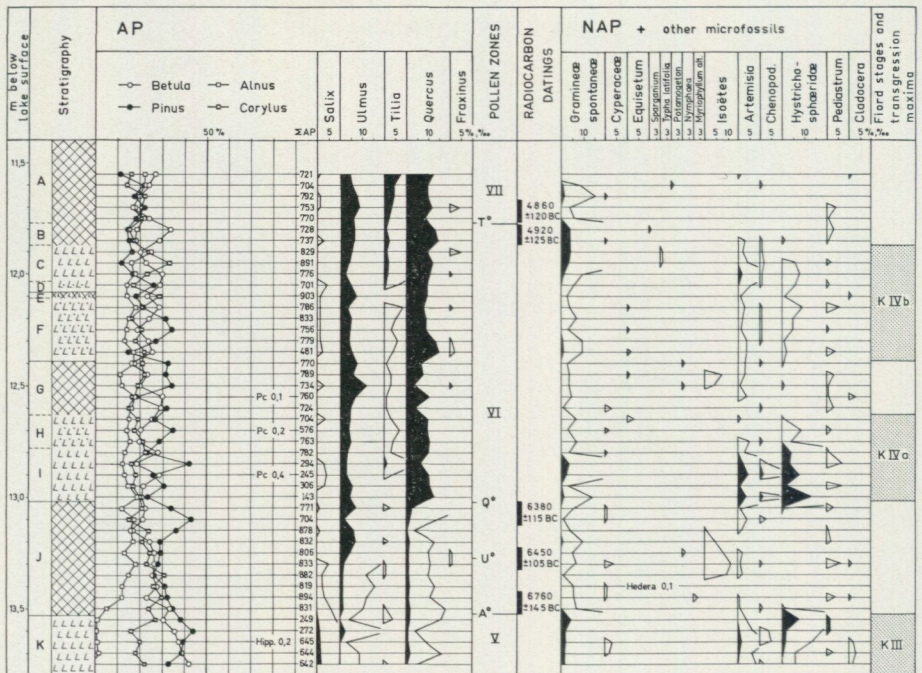
Fig. 2. Map showing localities 1-5.

- D 1203–1208 cm muddy sandy clay, grey
 E 1208–1211 cm clay gyttja, grey-brown, diffuse transition to F
 F 1211–1239 cm muddy sandy clay, grey
 G 1239–1263 cm clayey gyttja, grey-brown, diffuse transition to H
 H 1263–1278 cm sandy clay, grey, gradual change to I
 I 1278–1302 cm clay, grey, shells of *Mytilus*
 J 1302–1353 cm clayey gyttja, grey-brown
 K 1353–1380 cm clay, grey.

The part of the core between 1155 and 1375 cm below lake surface has been pollen-analytically investigated. In the pollen diagram (Fig. 3) the zone boundaries V/VI (A°) and VI/VII (T°) can be found as well as the rational limits of *Ulmus* (U°) and *Quercus* (Q°). The exact position of T° is somewhat uncertain. The rise of the *Tilia* curve is indistinct, probably due to a high rate of sedimentation. A° and Q° are very distinct, probably due to a pause in sedimentation and perhaps erosion.

In the NAP diagram the marine indicators *Artemisia*, *Chenopodiaceae* and *Hystrichosphaeridae* have distinct maxima in the clay layers. Maxima for lacustrine plants, mainly *Isoetes lacustris*, can be found in the gyttja.

KOLBENGTSERÖDSSJÖN I



G.Persson 1955-66

Fig. 3. Pollen diagram from Kolbengtserödssjön I (loc. 1). Symbols are explained in Fig. 20.

KOLBENGTSERÖDSSJÖN I

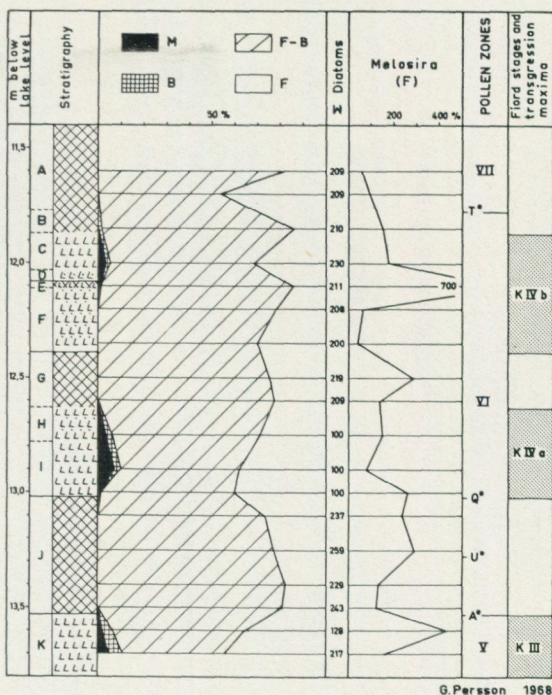


Fig. 4. Diatom diagram from Kolbengtserödssjön I (loc. 1). Symbols are explained in Fig. 20.

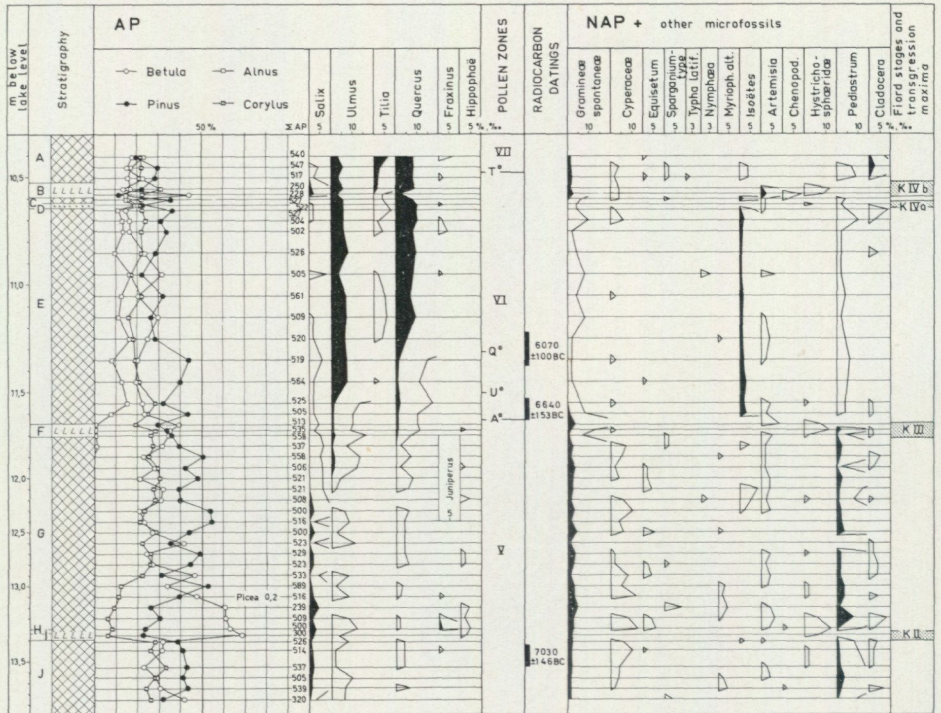
Some diatom analyses have been carried out. In the diagram (Fig. 4) small maxima for M- and B-species can be found in the clay layers. In the gyttja only F- and F-B-species were found.

Kolbengtserödssjön II showed the following stratigraphy.

0– 800 cm water

- A 800–1052 cm gyttja, brown
- B 1052–1059 cm clay, partly sandy, grey
- C 1059–1062 cm clayey gyttja, grey-brown
- D 1062–1064 cm stony sand, grey
- E 1064–1165 cm clayey gyttja, grey-brown
- F 1165–1170 cm clay, grey
- G 1170–1335 cm clayey gyttja, grey-brown, gradual change to H
- H 1335–1337 cm clay gyttja, brown-grey, gradual change to I
- I 1337–1340 cm clay, grey
- J 1340–1430 cm clayey gyttja, grey-brown.

KOLBENGTSERÖDSSJÖN II



G.Persson 1968

Fig. 5. Pollen diagram from Kolbengtserödssjön II (loc. 1). Symbols are explained in Fig. 20.

In the pollen diagram (Fig. 5) A° , U° , Q° and T° can easily be recognized. Maxima for marine indicators in the clay layers and limnic indicators in the gytta layers are found as in the diagram from Kolbengtserödssjön I.

From these two analysed profiles the following information about the history of the Kolbengtserödssjön basin can be obtained. The first isolation of the basin from the sea is not registered in the cores. The gytta layer J in boring II was formed during a lake stage somewhat after the first isolation. A salt water ingression in zone V ended this lake stage and the clay layer I in boring II was formed in a sea fiord. This fiord stage was followed by a new lake stage. Layer G in profile II was then formed. The clay layers F in profile II and K in profile I just below A° were formed in next fiord stage. In zone VI between Q° and T° two more fiord stages are registered, layers D and B in profile II and layers I-H and F-C in profile I. The last isolation from the sea is registered in the diagrams immediately below T° .

The high frequencies of F-species in the sediments deposited during the fiord stages are probably due to either the fact that the sea water in the narrow and,

at the mouth, very shallow fiord must have been rather mixed with fresh water, or to redeposition of diatom shells from older lacustrine gyttja, which was eroded when the sea inundated the basin during the later fiord stages. The first explanation seems less probable, because no high frequencies of halophile fresh water species are found in connection with the fiord stages.

Some radiocarbon datings have been carried out on samples from the Kolbengtserödssjön cores. The sampling levels and the ages obtained can be found in the pollen diagrams and Table 1. The results are discussed later in the chapter concerning chronology and vegetational history.

KOLBENGTSERÖD (LOC. 2)

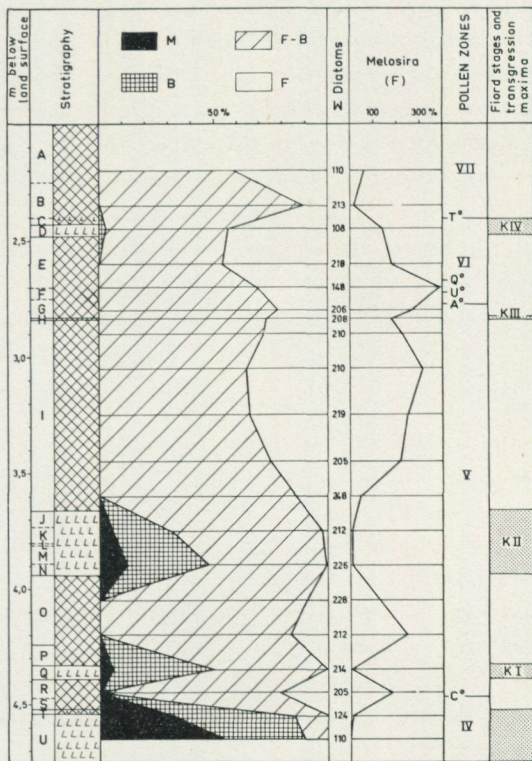
About 0.5 km N of the farm Kolbengtseröd, NE of the lake Kolbengtserödssjön, there is a small basin now occupied by a mire. The mire is partly covered with *Alnus* and *Carex* vegetation and partly cultivated. Across the mire flows a small stream, Getevadsån, to Kolbengtserödssjön. The surface of the mire is situated at an altitude of 38.5–39.0 m above sea-level. The investigation of the stratigraphy shows that there was previously a lake in the basin. The surface level of this lake is estimated to have been about 38 m above present sea-level. The overflow threshold consists mainly of sand, in which the outlet has eroded a 1.5 m deep furrow. The altitude of the original overflow threshold was probably 39.5 m above present sea-level.

Several borings in this mire have been carried out. Samples for pollen and diatom analyses were collected from a boring in the central part of the mire.

The boring showed the following stratigraphy (the figures indicate depth below land surface, which at this place has an altitude of 38.8 m).

- 0– 35 cm clay gyttja, brown-grey
- 35– 44 cm fen peat, grey-black
- 44– 57 cm gyttja, brown
- 57–130 cm *Carex* peat, brown, diffuse transition to next layer
- 130–152 cm *Phragmites-Equisetum* peat, black-brown
- 152–165 cm coarse detritus gyttja, brown, gradual change to A
- A 165–225 cm gyttja, brown, gradual change to B
- B 225–240 cm clayey gyttja, grey-brown, gradual change to C
- C 240–243 cm clay gyttja, brown-grey
- D 243–248 cm clay, grey
- E 248–270 cm gyttja, brown, gradual change to F
- F 270–275 cm gyttja, slightly clayey, greyish brown, gradual change to G
- G 275–283 cm clayey gyttja, grey-brown
- H 283–284 cm sand, grey
- I 284–366 cm clayey gyttja, grey-brown

KOLBENGTSERÖD



G.Persson 1968

Fig. 7. Diatom diagram from Kolbengtseröd (loc. 2). Symbols are explained in Fig. 20.

In the pollen diagram (Fig. 6) C° , A° , U° , Q° , and T° are recognizable. The NAP diagram shows distinct maxima for salt water indicators (*Artemisia*, *Hystrichosphaeridae*) in the clay layers and less distinct maxima for fresh water indicators in the gyttja layers.

In the diatom diagram (Fig. 7) very distinct maxima for salt water species are found in the three oldest clay layers (U, Q and J-N.) Practically no F-species were found in these layers. In the thin sand layer (H) and the youngest clay layer (C-D) the maxima for the marine and brackish water species are quite indistinct, as they were in the corresponding strata in the profile from Kolbengtserödssjön.

The diagrams from Kolbengtseröd show that this basin was isolated from the sea around C° . Three sea ingressions with lake stages between them are registered in zone V. The fourth and last sea ingression is found in the upper part of zone VI,

FUNNESHULTSSJÖN (LOC. 3)

This lake is about 0.5 km long and 0.3 km wide. The outlet, Getevadsån, flows towards SW to Kolbengtserödssjön. The lake is shallow and almost completely covered with reeds and other vegetation. The altitude of the lake is 39 m above sea-level. The overflow threshold consists of a terminal moraine. The outlet has eroded a two metre deep furrow in the ridge. The altitude of the original overflow threshold was probably 41 m above present sea-level.

Several borings have been carried out in the lake and in peatland around the lake. The stratigraphy is very complex. The pollen diagram published in this paper is from a Livingstone core from the central part of the lake. The boring showed the following stratigraphy (the figures indicate depth below lake surface).

- 0–100 cm water
- A 100–487 cm gyttja, brown, diffuse transition to B
 - B 487–489 cm clay, grey
 - C 489–494 cm gyttja, brown
 - D 494–504 cm *Phragmites* peat with pieces of wood, slightly muddy, dark brown, diffuse transition to E
 - E 504–512 cm clayey gyttja with roots from *Phragmites*, brown, diffuse transition to F
 - F 512–517 cm clay, grey
 - G 517–523 cm coarse detritus gyttja with pieces of wood, dark brown
 - H 523–529 cm clay, grey
 - I 529–539 cm coarse detritus gyttja with pieces of wood, dark brown
 - J 539–548 cm clayey gyttja, grey-brown
 - K 548–563 cm sandy clay, grey
 - L 563–567 cm clayey gyttja, brown
 - M 567–582 cm gyttja, brown
 - N 582–590 cm clay, grey
 - O 590–608 cm clayey gyttja, brown
 - P 608–612 cm clay, grey
 - Q 612–622 cm clayey gyttja, grey-brown
 - R 622–668 cm clay, grey.

The pollen diagram (Fig. 8) shows a complex sequence of strata. Marine clay belonging to zone IV is interbedded with layers of gyttja belonging to zones V and VI. These strata are overlain by *Phragmites* peat (D), which represent zone V and a part of zone VI. Accordingly, the peat and the gyttja were partly formed at the same time. This complicated stratigraphy is probably due to lifting of the peat (*plaur* formation) at different times. The *Phragmites* peat with the growing *Phragmites* have been lifted and gyttja has sedimented below the peat at the same time as the peat was growing. The peat then sank again and after

FUNNESHULTSSJÖN

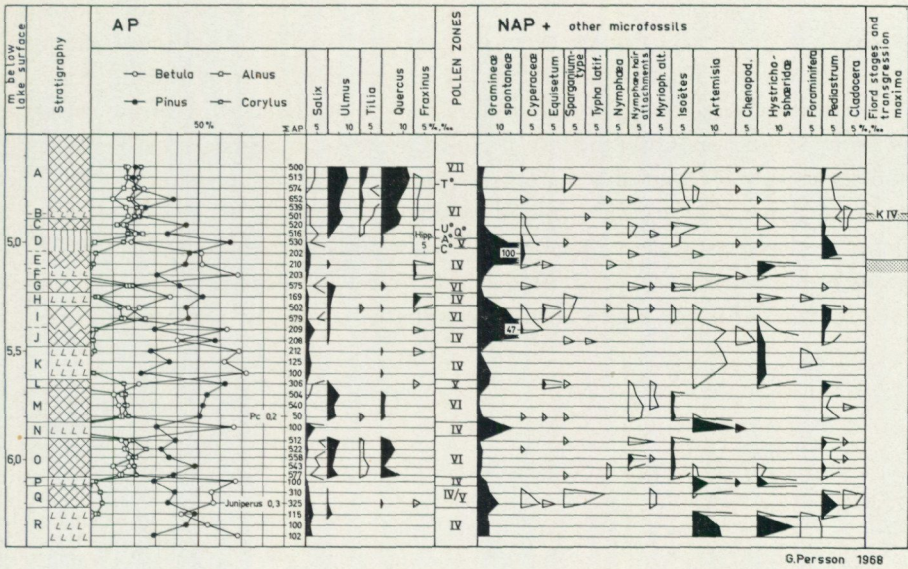


Fig. 8. Pollen diagram from Funneshultssjön (loc. 3). Symbols are explained in Fig. 20.

some time a new lifting of the peat occurred. This development was repeated several times. Each time the fracture in the sediments occurred in different strata.

The varying frequencies of the different kinds of pollen give some information about the relative ages of the different layers. The clay layers R, P, N, K, H, and F were formed as one clay layer in a sea fiord. They all belong to zone IV. An isolation from the sea is registered in the upper part of zone IV. After that isolation the gyttja layer E was formed. Soon after the isolation the lake was overgrown and formation of *Phragmites* peat began. Through a repeated lifting, gyttja was interbedded in the clay sequence below the peat. When the first *plaur* formation occurred, layer J was deposited. It probably belongs to the uppermost part of zone IV. The other gyttja layers were formed in the following order: layer Q (around the boundary IV/V), L (zone V), I (lower part of zone VI), G, M and N (middle and upper part of zone VI).

Shortly before T° the *Phragmites* peat formation ceased and gyttja (C) and clay (B) were deposited above the peat. The clay formation was caused by an ingress of the sea into the basin. After an isolation the thick gyttja layer A was formed.

Plaur formation can be caused by several factors (Björk and Digerfeldt 1965, Troels-Smith 1951). In this case it may partly be due to variations in the level of the lake surface. These variations can be caused by either climatic fluctua-

G. Persson 1968

tions or changes in groundwater level due to changes in the sea-level, which at this time was situated just a few metres below the overflow threshold of the basin. The stratigraphy in the borings from Kolbengtserödssjön and Kolbengtseröd shows that fluctuations of the sea-level really occurred during this time. None of the transgressions registered in zone V reached the overflow threshold of Funneshultssjön. Only the last of the transgressions registered at Kolbengtseröd seems to have caused a sea ingression in the Funneshultssjön basin.

During Boreal time (zone V and lower part of zone VI) the water level in Funneshultssjön seems to have been considerably lower than today. The *Phragmites* peat formed during that time is now found at a depth of about 5 m below lake surface. This low water level was probably caused by climatic factors.

VASSBOSJÖN (LOC. 4)

Lake Vassbosjön is situated at the NE end of the Kolbengtseröd valley. The lake is 1.0 km long and 0.3 km wide. It is relatively deep, about 8 m, and the shores are steep, except at the NE end at Vassbovik. The outlet, Backån, flows towards SW to Funneshultssjön. The altitude of the lake surface is 43 m above sea-level. The overflow threshold consists of a moraine ridge in which the brook has eroded a 1.5 m deep furrow. The original altitude of the overflow threshold was probably 44.5 m above present sea-level.

A number of borings have been carried out both in the lake sediments with a Livingstone sampler and at the shore at Vassbovik with a Hiller sampler. Pollen diagrams from two of these borings, one from the lake and one from the shore, are presented in this paper.

The boring in Vassbosjön showed the following stratigraphy (the figures indicate depth below lake surface).

0–400 cm water

- A 400–711 cm gyttja, brown, diffuse transition to B
- B 711–713 cm clay, grey
- C 713–776 cm coarse detritus gyttja, brown
- D 776–808 cm clayey gyttja, grey-brown, diffuse transition to E
- E 808–931 cm clay with some gravel particles and shells from marine molluscs, grey.

In the pollen diagram (Fig. 9) A^o and T^o are very distinct. There is probably a hiatus in the sequence of strata at A^o.

The basin was isolated from the sea immediately before C^o. A sea transgression reached the overflow threshold just before T^o. During this fiord stage

VASSBOSJÖN

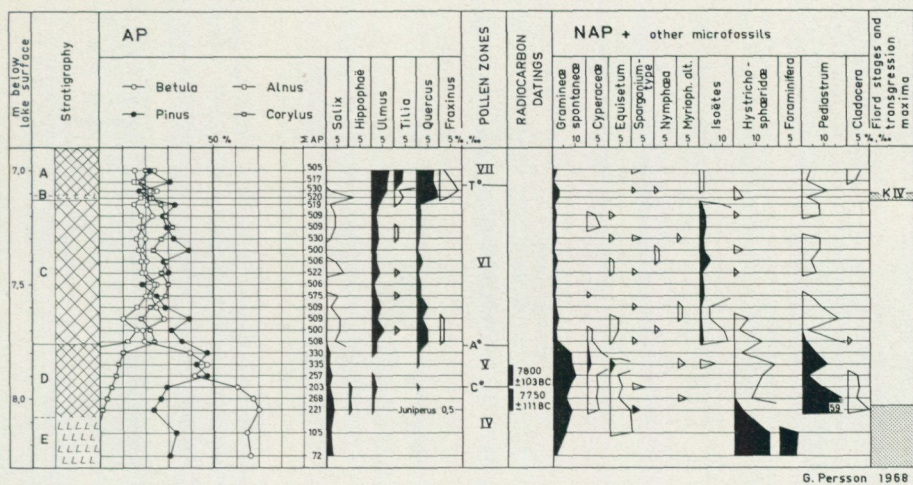


Fig. 9. Pollen diagram from Vassbosjön (loc. 4). Symbols are explained in Fig. 20.

the clay layer B was deposited. This transgression corresponds to the last one found at loc. 2 and the only one found at loc. 3.

Two radiocarbon datings have been carried out. The results can be found in the pollen diagram and in Table 1. The datings are discussed later.

The boring analysed at Vassbovik showed the following stratigraphy (the figures indicate depth below land surface, which on this place has an altitude of 44.0 m).

- A 0– 53 cm drift sand with plant remains, brown
- B 53– 63 cm *Carex* peat, brown
- C 63– 87 cm coarse detritus gyttja with *Phragmites*, dark brown
- D 87– 89 cm clayey gyttja, grey-brown
- E 89– 90 cm clay, grey
- F 90–104 cm clayey gyttja, grey-brown, diffuse transition to G
- G 104–109 cm gyttja, grey-brown
- H 109–200 cm clay, yellowish grey, partly dry.

The pollen diagram (Fig. 10) shows that there is a hiatus above the clay (H). Zone V and a large part of zone VI are missing. At the first isolation of the basin near the end of Preboreal time, the sampling point became land and the clay was dried. Gyttja sedimentation (G) began in zone VI. This was probably due to a rising lake level caused by a rising sea-level. Shortly after-

VASSBOVIK

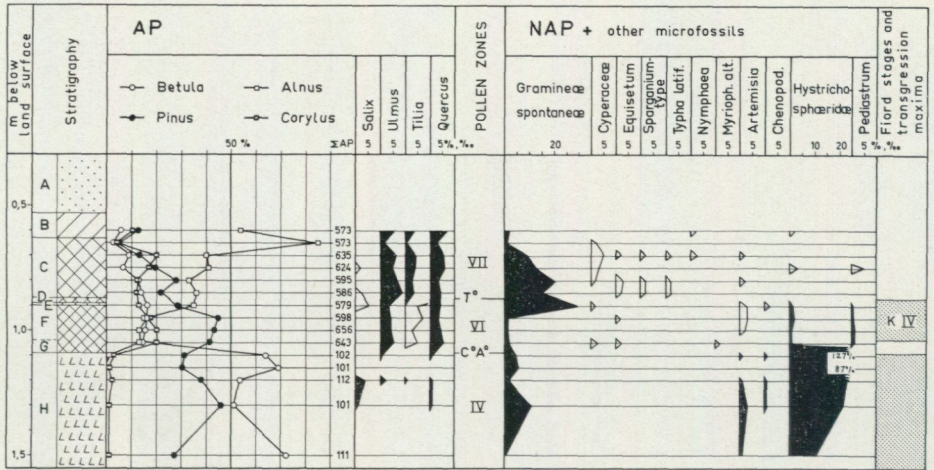


Fig. 10. Pollen diagram from Vassbovik (loc. 4). Symbols are explained in Fig. 20.

wards the rising sea inundated the basin and layers F–D were deposited. After the second isolation gyttja (C) and peat (B) were formed.

As in lake Funneshultsjön this profile indicates a low water level in the lake during Boreal time. At that time the sampling point at Vassbovik was dry and at the sampling point in the central part of the lake coarse gyttja was being formed.

CONCLUSIONS ABOUT THE DEVELOPMENT AT LOCALITIES 1–4

The development in the Kolbengtseröd valley can be described as follows. During Preboreal time (zone IV) the valley was occupied by a narrow sea fiord. Due to the intense land upheaval the water depth in the fiord rapidly decreased. The four basins Vassbosjön, Funneshultsjön, Kolbengtseröd and Kolbengtserödssjön were isolated and became lakes at the end of Preboreal time. At the beginning of Boreal time the regression changed to transgression and a new sea fiord was formed. This fiord did not reach Funneshultsjön and Vassbosjön. This first transgression maximum has been called Kolbengtseröd I (K I) in this paper. After K I was reached a new regression caused isolation of the Kolbengtseröd and Kolbengtserödssjön basins. At the middle and end of Boreal time (zone V) two transgression maxima, K II and K III, were reached. Probably K I, K II and K III reached approximately the same level in the valley.

The fourth transgression maximum (K IV) was reached in the later part of the transition between Boreal and Atlantic time (zone VI). K IV reached a higher level than K I, K II and K III and the sea fiord reached Vassbovik again.

In the borings from Kolbengtserödssjön K IV seems to be complex. Two maxima are indicated. They are called K IVa and K IVb. The diagram from Kolbengtserödssjön I indicates greater marine influence during K IVa than K IVb. Probably K IVa reached a higher level than K IVb. If this is correct K IVa in Kolbengtserödssjön corresponds to K IV in the other basins in the valley.

Fig. 18 shows a shoreline displacement curve from the Kolbengtseröd valley, constructed upon information from the six borings described above. As the isobase latitudes are different for the four basins the levels of the overflow thresholds were lowered by 2 m for Vassbosjön, 1 m for Funneshultssjön and 0.5 m for Kolbengtseröd when the curve was constructed.

GROHED (LOC. 5)

1.5 km NE of the railway station Grohed a raised bog named "Store mosse" is situated (Fig. 2). The bog has developed from an overgrown lake which occupied a shallow basin in the marine clay. The outlet flows southwards. The surface of the bog has an altitude of 37 m above sea-level, and the altitude of the old lake was probably about 33 m above present sea-level.

A boring in the south part of the bog showed the following stratigraphy (the figures indicate depth below bog surface).

- A 0– 173 cm *Sphagnum* peat, light brown
- B 173– 262 cm *Sphagnum* peat, dark brown
- C 262– 362 cm fen-wood peat, red-brown
- D 362– 418 cm coarse detritus gyttja with *Phragmites*
- E 418– 565 cm gyttja, green-brown
- F 565– 570 cm clayey gyttja, black-brown
- G 570– 640 cm muddy clay, green-grey, gradual change to H
- H 640–1100 cm clay with shells from marine molluscs, grey.

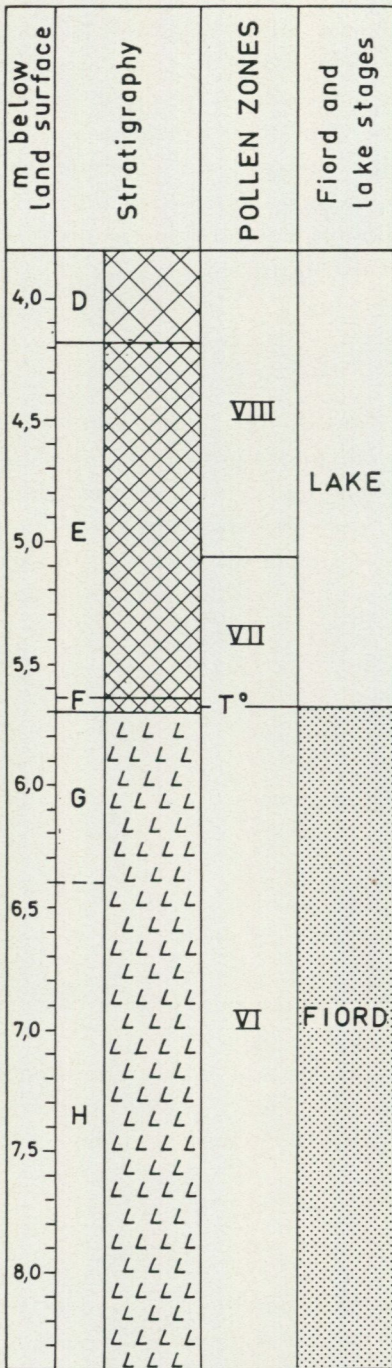
In the pollen diagram derived from this core (not published in this paper) the zone boundaries VI/VII and VII/VIII can be recognized (Fig. 11).

The profile shows only one isolation, and no signs of any transgression have been found. The isolation occurred around T°. The regressions between the Postglacial transgressions did not apparently reach the level 33 m above present sea-level in this area.

GRINDSBYVATTNET AND HOGEN (LOC. 6)

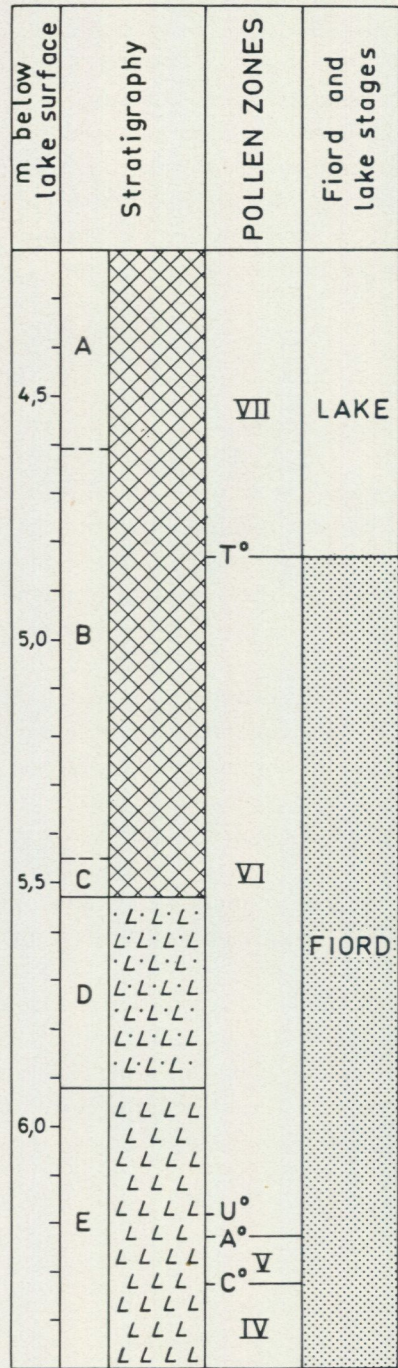
Lake Grindsbyvattnet is situated in the eastern part of the island of Orust, between Torp and Myckleby (Fig. 12). The lake is about 4 km long in the direction N–S. In some parts it is very narrow (about 50 m), but it widens

GROHED



G.Persson 1964-65

GRINDSBYVATTNET



G.Persson 1967

Fig. 11. Stratigraphy and pollen zones from Grohed (loc. 5) and Grindsbyvattnet (loc. 6). Symbols are explained in Fig. 20.

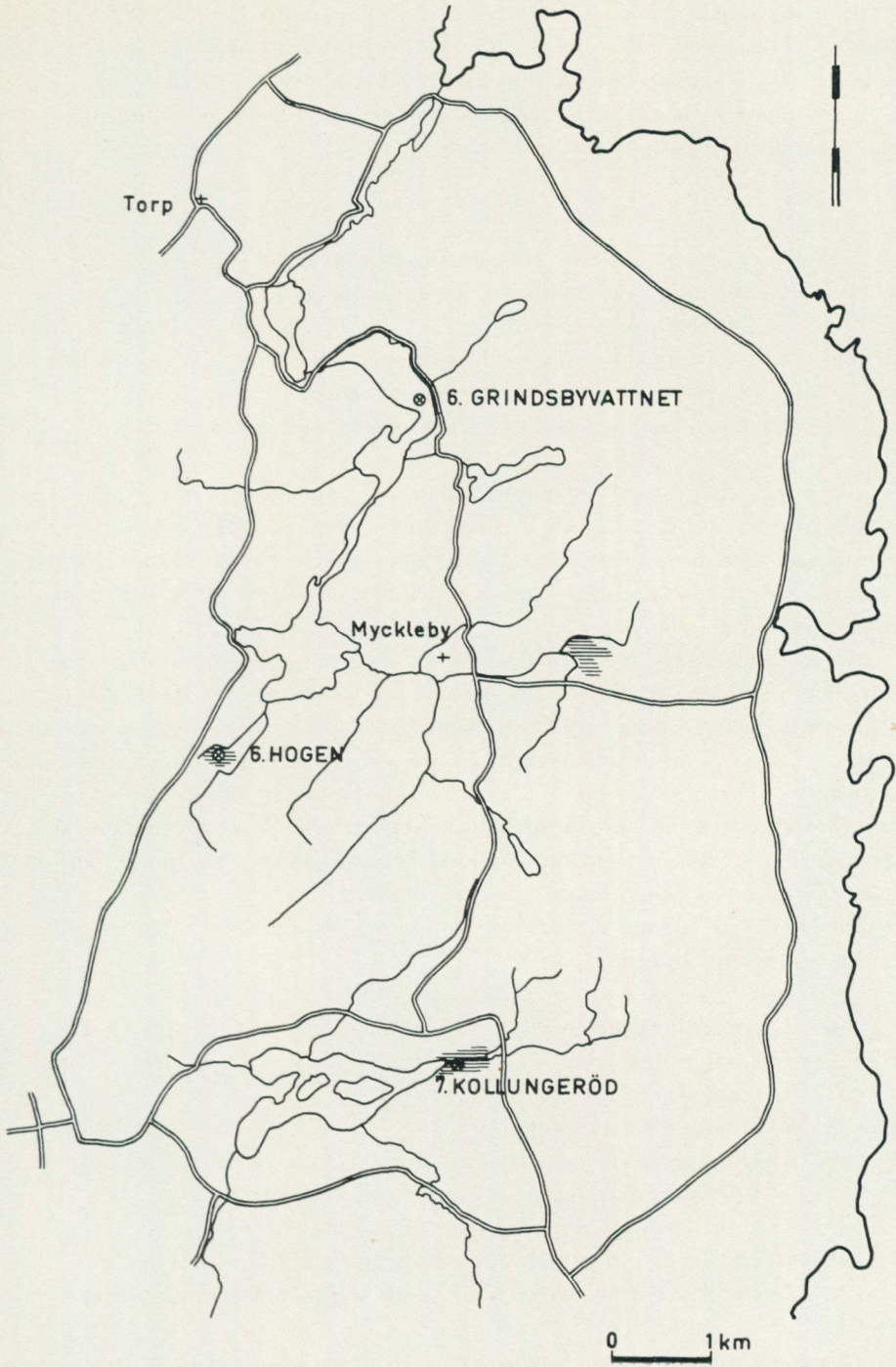


Fig. 12. Map showing localities 6 and 7.

both at the north and south ends. The outlet is situated at the NW end and flows to lake Assmunderösvattnet. The overflow threshold consists of bed-rock and the altitude of the lake surface is 30 m above sea-level.

A boring in the north part of the lake showed the following stratigraphy (the figures indicate depth below lake surface).

0–300 cm water

- A 300–461 cm gyttja, brown, diffuse transition to B
- B 461–545 cm clayey gyttja, brown, gradual change to C
- C 545–553 cm gyttja, grey-brown
- D 553–592 cm sandy clay, grey, with shells of *Ostrea*, *Nassa*, *Littorina littorea*, *Nucula nuculus* and *Tapes decussatus*
- E 592–938 cm clay, grey, with shells from marine molluscs.

The pollen diagram is not published in this paper. In the investigated part of the profile C°, A°, U°, and T° were found (Fig. 11). The rate of sedimentation seems to have increased in the lower part of zone VI, to which the greatest part of the analysed sequence belongs. Only about 10 cm of the sequence belong to zone V.

The isolation of the basin seems to have occurred about or shortly after T°. No signs of older isolations have been found. Probably the early Postglacial regressions never reached the level 30 m above present sea-level in this area.

0.6–0.7 km SW of Grindsbyvattnet at Hogen a small, partly cultivated mire is situated. The mire occupies a shallow depression in the marine clay. The overflow threshold has an altitude of 1 m above the surface of Grindsbyvattnet. This mire has been investigated by Bodil Persson (1969). The pollen and diatom diagrams are taken from that investigation.

The analysed boring showed the following stratigraphy (figures indicate depth below land surface).

- A 0–23 cm fen peat, brown
- B 23–43 cm gyttja, brown
- C 43–54 cm gyttja, black
- D 54–63 cm muddy clay, grey
- E 63–65 cm slightly clayey gyttja, brown
- F 65–137 cm clayey gyttja, grey-brown, diffuse transition to G
- G 137–148 cm clay gyttja, brown-grey, diffuse transition to H
- H 148–170 cm clayey gyttja, grey-brown, diffuse transition to I
- I 170–188 cm clay gyttja, brown-grey, with shells of *Littorina*, diffuse transition to J
- J 188–254 cm muddy clay, grey, with shells of *Littorina*, diffuse transition to K
- K 254–300 cm clay, grey, with shells of *Littorina*, *Ostrea*, *Cardium* and *Nassa*.

HOGEN

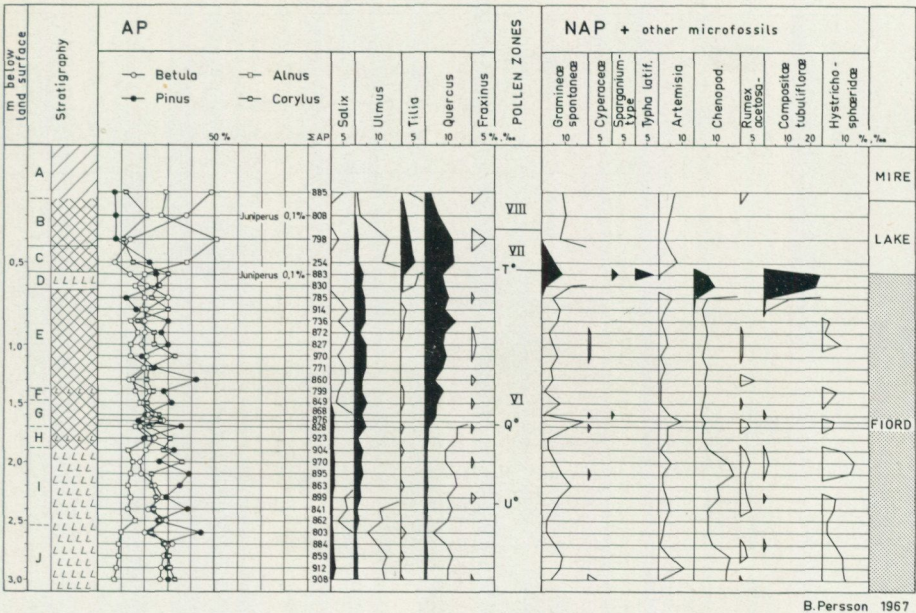


Fig. 13. Pollen diagram from Hogen (loc. 6). Symbols are explained in Fig. 20.

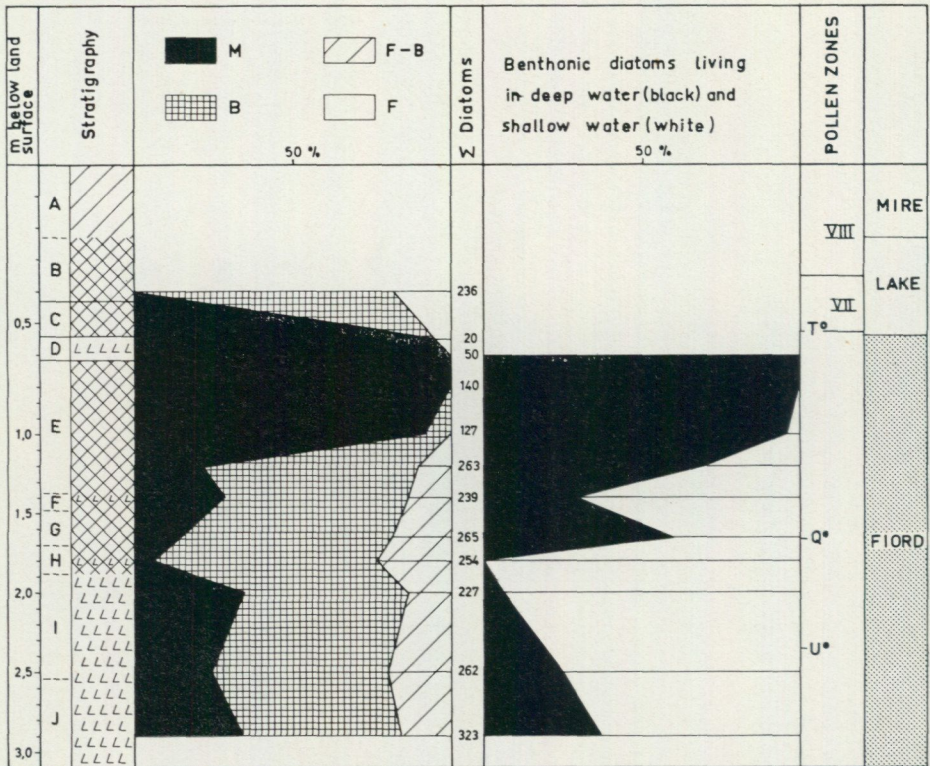
In the pollen diagram (Fig. 13) the zones VI, VII and VIII are represented. The microfossil flora indicates an isolation around T°.

Some diatom analyses have been carried out too. In the left part of the diagram (Fig. 14) the diatoms are grouped according to their different salt concentration requirements. To the right the benthonic diatom species have been divided into two groups according to their water depth requirements. The two parts of the diagram show a very similar picture. High frequencies of marine species coincide with high frequencies of species living in deep water.

The diagrams give the following information about the development of the basin. At the time when the shell-bearing clay in the lower part of the profile was deposited (lower part of zone VI) a sea fiord reached the Grindsbyvattnet and Hogen basins from the north. The shore line displacement was recessive. The diatom diagram indicates decreasing water depth and salt content during this time. At about Q° regression minimum seems to have been reached. After Q° marine and deep bottom species increase again, which indicates transgression. The maximum seems to have occurred when the clay layer D was deposited just before T°. At the regression after this maximum the basin was isolated.

The transgression maximum can be correlated with K IV in the Kolbengtseröd valley.

HOGEN



B. Persson 1967

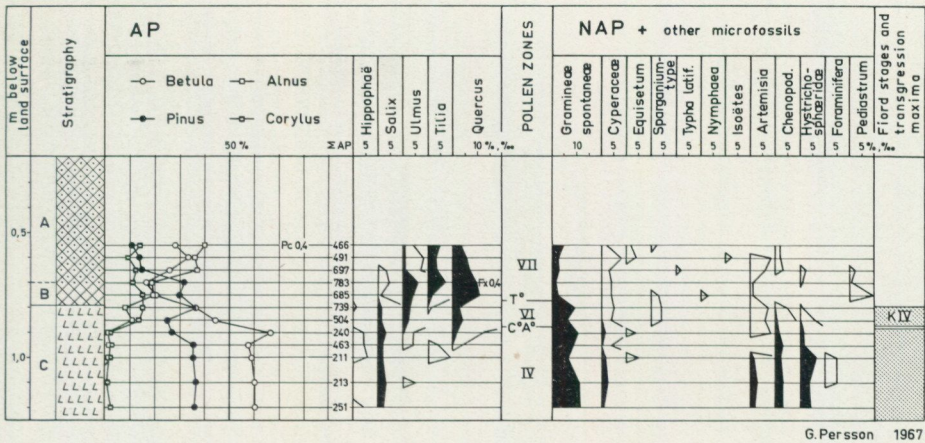
Fig. 14. Diatom diagram from Hogen (loc. 6). Symbols are explained in Fig. 20.

KOLLUNGERÖD (LOC. 7)

Kollungerödsvatten is a lake situated on the eastern part of the island of Orust (Fig. 12). The lake is 2 km long and 0.5 km wide. The original overflow threshold has been lowered by blasting. Today the altitude of the lake is 36 m above sea-level, though the original altitude seems to have been 38 m. At the east end of the lake there is a marsh which was covered with water before the lowering of the lake level. A boring there showed the following stratigraphy (the figures indicate depth below land surface).

- A 0– 70 cm muddy sand, grey-brown, gradual change to B
- B 70– 79 cm clayey gyttja, brown
- C 79–300 cm clay, grey, partly dry.

KOLLUNGERÖD



G. Persson 1967

Fig. 15. Pollen diagram from Kollungeröd (loc. 7). Symbols are explained in Fig. 20.

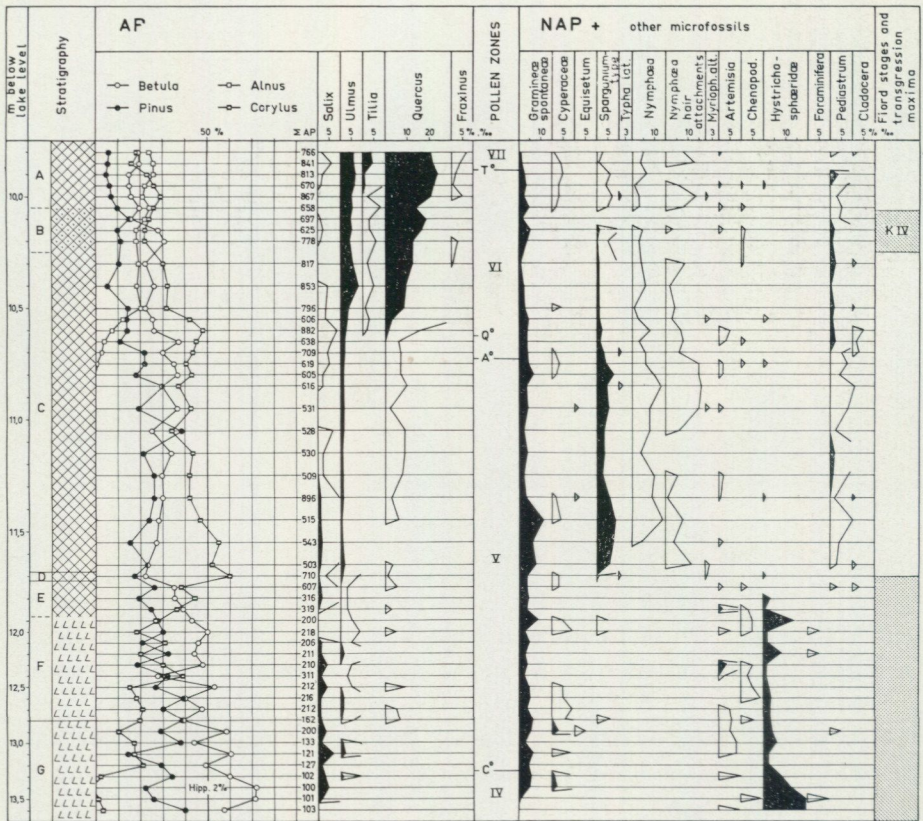
In the pollen diagram (Fig. 15) C°, A° and T° can easily be recognized. C° and A° coincide, which means that zone V is totally missing. Consequently, there has been a long interruption in the clay sedimentation. At T° a normal isolation from the sea can be found in the diagram. The stratigraphy can be interpreted in the following way. During Preboreal time (zone IV) the basin was occupied by a sea fiord. Gradually the sea-level sank and around C° the basin was isolated and a lake was formed. The water level in this lake was apparently so low that the sampling point was situated above the shore line and the clay formed previously was dried. This low water level probably was due to the climate (cf. loc. 3 and 4). During the highest transgression maximum (K IV) the overflow threshold of the basin was reached and a new fiord stage was formed. In this fiord the uppermost part of the clay was deposited. The second isolation occurred around T°. After this isolation the level of the lake was so high that gyttja was deposited at the sampling point.

TJÄRNEVATTNET (LOC. 8)

Lake Tjärnevattnet is situated on the island of Tjörn (Fig. 1). The lake is small, only 200–300 m from shore to shore, but relatively deep, about 6 m. The outlet flows eastwards over a rock threshold. The outlet has been deepened 2 m. The present lake surface has an altitude of 28 m above sea-level. Consequently, the original threshold had an altitude of 30 m.

A Livingstone boring in the central part of the lake showed the following stratigraphy (the figures indicate depth below lake surface).

TJÄRNEVATTNET



G.Persson 1968

Fig. 16. Pollen diagram from Tjärnevattnet (loc. 8). Symbols are explained in Fig. 20.

0–600 cm water

A 600–1005 cm gyttja, dark brown, diffuse transition to B

B 1005–1025 cm sandy gyttja, brown, with plant remains, diffuse transition to C

C 1025–1168 cm gyttja, dark brown

D 1168–1172 cm clayey gyttja, green-brown

E 1172–1188 cm clayey gyttja, black-grey, diffuse transition to F

F 1188–1281 cm muddy clay, brown-grey

G 1281–1379 cm clay, grey.

In the pollen diagram (Fig. 16) C°, A°, Q° and T° are recognizable. C° is relatively distinct and coincides with decreasing *Betula* frequencies. A° is

somewhat less distinct and U° is so diffuse that it has not been marked on the diagram.

An isolation from the sea occurred in Boreal time. The sandy gyttja (B) seems to have been deposited at the same time as the maximum K IV was reached. In the NAP diagram there is a minimum for the fresh water indicators in this layer. In order to determine whether this layer is a salt water sediment, three samples, one from each of the layers A, B and C, were diatom analysed.

The following distribution among the salt concentration groups were found:

Level	Stratum	M	B	F-B	F
990 cm	A	0 %	1 %	37 %	62 %
1010 cm	B	2 %	23 %	74 %	1 %
1040 cm	C	0 %	1 %	43 %	56 %

Apparently layers A and C are deposited in completely fresh water, layer B on the other hand shows a distinct salt water influence. Probably the transgression K IV just reached the overflow threshold of the basin and transformed the lake to a fiord with brackish water.

BRÄCKEMOTET (LOC. 9)

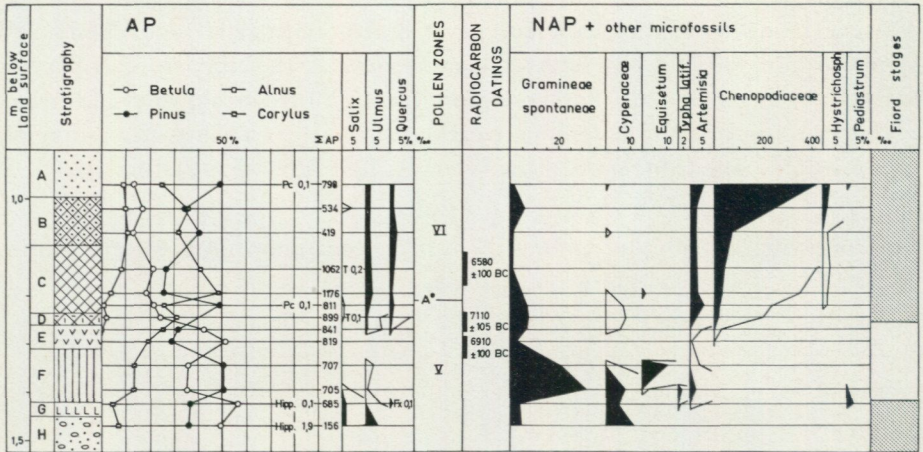
At a road construction site at Bräckemotet north of the Älvsborg Bridge in Gothenburg the following sequence of strata was found (the figures indicate depth below land surface).

- 0– 30 cm artificial filling
- 30– 69 cm stony gravelly sand
- A 69–100 cm sand
- B 100–110 cm sandy gyttja
- C 110–124 cm gyttja, brown-grey
- D 124–126 cm drift gyttja
- E 126–131 cm fen wood peat
- F 131–142 cm *Phragmites* peat
- G 142–144 cm muddy clay
- H 144–180 cm stony sandy gravel.

The altitude of the upper boundary of layer A was 19.20 m above sea-level.

The profile has been pollen-analytically investigated (Fig. 17). In the lower part of layer C, A° is found. The low frequencies of *Corylus* in the two lowest

BRÄCKEMOTET



G Persson 1966

Fig. 17: Pollen diagram from Bräckemotet (loc. 9). Symbols are explained in Fig. 20.

samples indicate that this part of the sequence was deposited around or shortly after C° . Consequently zone V is almost complete in the diagram. In zone VI the frequencies of *Ulmus* and *Quercus* are low. Perhaps U° and Q° lie above the part of the sequence that has been analysed.

Some diatom analyses have been carried out. The following distribution among the salt concentration groups was found:

Level	Stratum	M	B	F-B	F
120 cm	C	35	65	0	0
122 cm	C	46	44	0	0
125 cm	D	28	72	0	0
127 cm	E	1	3	0	0
140 cm	F	0	0	1	4
142 cm	G	84	16	0	0

Unlike layers E and F layers C, D and G show distinct marine influence.

The development registered in the profile can be interpreted as follows. During the regression of the sea from the highest shoreline, layer H was deposited. Around C° calmer sedimentation conditions were established, perhaps in a lagoon partly separated from the sea. During this stage layer G was formed. Shortly afterwards the lagoon was isolated and a shallow lake was formed.

The lake surface was covered with *Phragmites* and *Equisetum* reeds (layer F). Later the lake was transformed to a fen covered with forest. Immediately before A⁰ the rising sea-level reached the fen and a drift gyttja (D) was formed. The drift gyttja formation was succeeded by finer marine gyttja, sandy gyttja and sand.

Three radiocarbon datings have been made. The results are shown in the pollen diagram and in Table 1. They will be discussed in the next chapter.

Chronology and vegetational history

The time period, represented in the pollen diagrams in this paper, extended over the first half of the Postglacial time. The forest history of this time is characterized by the immigration of several tree species. The immigration of *Corylus*, *Alnus*, *Ulmus*, *Quercus*, *Tilia* and *Fraxinus* are registered in the investigated profiles.

In such a small area as the south part of Bohuslän, the vegetational history is probably very uniform, so that each tree species immigrated in the whole area at about the same time. For this reason a pollen-analytical correlation between two localities in the area can be used as a time correlation. On the other hand, before comparing the development in the area with other parts of Scandinavia an absolute chronology must be established. Therefore, several radiocarbon datings have been carried out. The results of all these datings are presented in Table 1. The radiocarbon analyses were carried out at the Radiocarbon Dating Laboratory at the University of Lund. For the age calculations a half-life for C¹⁴ of 5568 years was used. Corrections for deviations from normal C¹³/C¹² ratio are applied. The datings are published in the dating lists I and II from the laboratory (Håkansson 1968 and 1969). In order to simplify the comparison between the datings in this paper and the Scanian time scale (Nilsson 1964), results of age calculations based on a half-life for C¹⁴ of 5730 years are also presented in Table 1. A discussion of the age determinations follows.

PREBOREAL TIME (ZONE IV)

The zone boundary III/IV, which corresponds to the boundary between Late- and Postglacial time is not found in any of the diagrams in this paper. Only the upper part of zone IV is represented.

Zone IV is characterized by high *Betula* frequencies, generally around 60–70 %. The *Pinus* frequencies are around 30 %. *Salix* appears regularly in frequencies up to 5 %. *Hippophaë* and *Juniperus* have been found sporadically in some profiles. *Juniperus* is probably underrepresented in the analyses, due to the bad state of preservation of the pollen grains in the marine clays. A few pollen grains of *Corylus* and *Ulmus* have also been found.

BOREAL TIME (ZONE V)

The lower boundary of zone V is characterized by the rational *Corylus* limit (C°) and by decreasing *Betula* and increasing *Pinus* frequencies. In the diagrams this boundary has generally been placed where the *Corylus* curve reaches 5 %.

The zone boundary IV/V has been dated by two radiocarbon analyses from Vassbosjön (loc. 4). One sample was collected immediately beneath (Lu-220) and one above (Lu-219) the boundary. The ages are 7750 and 7800 years BC respectively. The samples are inverted as regards age. However, the difference in age is only 50 years and this is much less than the quoted errors, which are ± 111 and ± 103 years respectively.

The corresponding boundary in Scania has been dated by Nilsson (1964) at 7900 years BC. This age corresponds to an age of 7650 years BC if a half-life for C^{14} of 5568 years is used.

The datings indicate that C° is perhaps 100 years older in Bohuslän than in Scania, which is rather unexpected. This difference in age may be due to the fact that the samples from Vassbosjön possibly contain some redeposited organic material as well as clay particles from the older marine clay. Hence there is no evidence of a real difference in the age of C° between Scania and Bohuslän.

Zone V is characterized by a moderately high frequency of *Corylus*, around 10–25 %. The *Betula* and *Pinus* curves lie around 30–40 %. *Salix* is regularly found, but in lower frequencies than in zone IV. A few pollen grains from *Hippophaë* and *Juniperus* have been found. In the upper part of the zone *Ulmus* and *Quercus* appear regularly in frequencies around 2 and 1 % respectively.

A sample from Kolbengtserödssjön II (loc. 1) has been radiocarbon dated. The sample is collected from the gyttja immediately beneath the clay layer deposited during the transgression maximum K II. The age was 7030 BC.

TRANSITION BETWEEN BOREAL AND ATLANTIC TIME (ZONE VI)

The zone boundary V/VI is characterized by the rational *Alnus* limit (A°). The appearance of *Alnus* is rather abrupt and the zone boundary has generally been placed where the *Alnus* frequency reaches 3 %. In most diagrams a very rapid increase in frequency from less than 1 % to more than 10 % occurs from one analysed sample to another.

Within the zone the frequencies of *Alnus*, *Pinus* and *Betula* generally lie between 10 and 30 %. *Salix* appears more sporadically than in zone V and *Hippophaë* and *Juniperus* have almost totally disappeared. A few pollen grains of *Picea* have been found.

Among the constituents of the oak mixed forest a distinct increase of the *Ulmus* frequency can be found just above A° . Above the *Ulmus* increase a

similar increase in the *Quercus* frequency is found. These increases in the pollen frequencies from 1–2 % to 5–10 % are marked U^o and Q^o in the diagrams. *Tilia* appears only sporadically in the lower part of the zone, but in the upper part regularly in frequencies less than 1 %. A few pollen grain of *Fraxinus* have been found in the upper part of the zone.

Several radiocarbon datings of samples from this zone have been carried out. In connection with the lower zone boundary, five datings from Kolbengtserödssjön (loc. 1) and Bräckemotet (loc. 9) have been made. Three of them are from Bräckemotet, two immediately below and one above A^o. The two samples from below A^o were dated at 6910 (Lu-22) and 7110 (Lu-21) years BC. The sample above A^o was dated at 6580 years BC (Lu-20). From Kolbengtserödssjön one sample from each of the two profiles, collected immediately above A^o, has been dated. The results of the datings were 6760 (Lu-139) and 6640 (Lu-217) years BC. Accordingly the rational *Alnus* limit (A^o) seems to have the date 6900–6700 years BC in Bohuslän. In Scania Nilsson (1964) has dated the corresponding limit at 6800 years BC, which if the half-life of 5568 years is used will be about 6600 years BC.

As was the case with C^o, A^o seems to be somewhat older in Bohuslän than in Scania. The unexpectedly high ages of the samples from Kolbengtserödssjön are probably due to intermixing with older organic material redeposited from earlier formed clay and gyttja.

The real age of A^o is probably the same in Bohuslän as in Scania, that is 6600 years BC.

U^o has been dated at 6450 years BC (Lu-140) by an analysis from Kolbengtserödssjön I (loc. 1). In Scania the rational *Ulmus* limit is distinctly older than the *Alnus* limit. Thus the immigration of *Ulmus* in Bohuslän is distinctly delayed compared with Scania.

In connection with Q^o two radiocarbon datings were carried out. Both are from Kolbengtserödssjön (loc. 1). One of the samples (from profile I) was collected immediately below Q^o and was dated at 6380 years BC (Lu-141). The other (from profile II), which was collected at Q^o, got the age 6070 years BC (Lu-216). The first of these samples has a higher age than the other. This is due to a sediment hiatus in connection with Q^o. The existence of this hiatus in profile I is proved by the fact that the sea ingression at the transgression K IVa occurs after Q^o in profile II. In profile I, on the other hand, the ingression seems to occur exactly at Q^o.

ATLANTIC TIME (ZONE VII)

The lower zone boundary is defined as the rational *Tilia* limit (T^o). This limit has generally been placed where the *Tilia* frequency reaches 2–3 %.

T^o has been dated by two radiocarbon analyses from Kolbengtserödssjön I (loc. 1). The samples have been collected on each side of T^o. The results ob-

tained were 4920 (Lu-137) and 4860 (Lu-136) years BC. Hence the *Tilia* limit in Bohuslän has been dated at 4900 years BC. In Scania the corresponding limit has been dated at 6200 years BC (Nilsson 1964), which corresponds to 6000 years BC if a half-life for C^{14} of 5568 years is used. Accordingly, about 1100 years elapsed between the immigration of *Tilia* in Scania and Bohuslän. Perhaps the difference is greater; the derived age of T° in Bohuslän may be some hundred years too high, due to the possibility that the samples may contain redeposited material, as in the samples discussed above.

In most diagrams in this paper only the lower part of zone VII is represented.

The differences in the pollen flora compared with zone VI are mainly found among the mixed oak forest constituents. *Quercus* dominates with frequencies around 10 % while *Ulmus* and *Tilia* lie around 5 %. *Fraxinus* appears regularly at low frequency.

SUBBOREAL TIME (ZONE VIII)

The zone is represented in the investigated parts of the profiles from Grohed (loc. 5) and Hogen (loc. 6). The lower boundary is characterized by decreasing *Ulmus* and *Tilia* frequencies.

In the upper part of the zone *Picea* and *Carpinus* begin to occur regularly.

COMMENTS ON THE DIAGRAMS FOR NON-ARBOREAL POLLEN AND OTHER MICROFOSSILS

In the NAP-diagrams only those species, which give valuable information about the environment are included.

Among the excluded microfossils, spores from *Polypodiaceae* and pollen from *Ericaceae* are the most frequent. They occur at low frequencies in most samples. Pollen from *Compositae* and *Rumex* as well as spores from *Lycopodium* also occur regularly.

One pollen grain of *Hedera* has been found in the lower part of zone VI in Kolbengtserödssjön I (loc. 1). Also one pollen grain from *Viscum* was found in a profile from Funneshultssjön (loc. 3) in zone VI.

The curve for *Gramineae* spontaneae consists mainly of pollen from *Phragmites* reeds along the shores. The highest frequencies occur in *Phragmites* peat (Funneshultssjön and Bräckemotet). In many profiles maxima connected with regressions and isolations are found (Kolbengtserödssjön, Vassbosjön, Grohed, Grindsbyvattnet and Hogen). Obviously the *Phragmites* has been favoured by decreasing water level. The reeds have been able to colonize a new seabed consisting of marine clay.

The *Cyperaceae* pollen probably derive mainly from *Scirpus* reeds. The curves generally have considerably lower frequencies than those for *Gramineae*, but the occurrence is principally the same with maxima at the same levels.

Equisetum spores have been found in low frequencies, seldom more than 1%, in most profiles.

Pollen grains belonging to the *Sparganium* type, which may derive from either *Sparganium* or *Typha angustifolia*, occur as well as pollen from *Typha latifolia* regularly in the lacustrine gyttjas in frequencies up to a few percent.

Pollen from *Nymphaea* and *Nuphar* have been found in most profiles. Also hair attachments and inner hairs from *Nymphaea* occur.

Trapa natans occur regularly in parts of zone VIII in the profile from Grohed (loc. 5). *Trapa* nuts have been found on this locality by Thomasson (Fries 1951).

The submersed lake vegetation is represented by *Myriophyllum alterniflorum* and *Isoëtes lacustris*. *Isoëtes* is fairly common in some profiles (Kolbengtserödssjön II, Funneshultssjön and Vassbosjön).

Pollen grains of *Artemisia* and *Chenopodiaceae* occur in most profiles. They generally have distinct maxima in the marine layers. They probably derive from the sea shore vegetation.

Important marine microfossils are *Hystrichosphaeridae* and *Foraminifera*. *Hystrichosphaeridae* has distinct maxima in most marine strata. Two main forms have been identified. One form has only a few furcated processes (Fig. 41a in Fries 1951, *Hystrichosphaera furcata* according to Fries 1962), the other has several fine processes (Fig. 41b in Fries 1951, *Hystrichosphaeridium centrocarpum* according to Fries 1962). The latter is more frequent. No other difference in their appearance has been observed.

In diagrams from analyses made in 1967 and 1968 *Foraminifera* shells have been counted. They occur exclusively in marine strata. Two types of shells were found, one resembles the genus *Elphidium* and the other *Bulmina*. The *Elphidium* type is more common.

Algae belonging to the genus *Pediastrum* occur relatively frequently in most profiles, often they have maxima in lacustrine strata.

Shell fragments from *Cladocera* occur too, almost exclusively in lacustrine layers.

The Postglacial transgressions in Bohuslän

The shoreline displacement is caused by a combination of the isostatic land upheaval and the eustatic rise of sea-level. During the time before C° the isostatic factor completely dominated in central Bohuslän. Due to a warmer climate the melting rate of the land-ice increased. This caused the eustatic factor to reach such a magnitude that the effects of the isostacy and eustacy neutralized each other at about C°. In the Kolbengtseröd valley area this position of equilibrium lasted until the time of T° (Fig. 18). At that time the eustatic rise of the sea-level was almost completed and the isostacy again began to dominate.

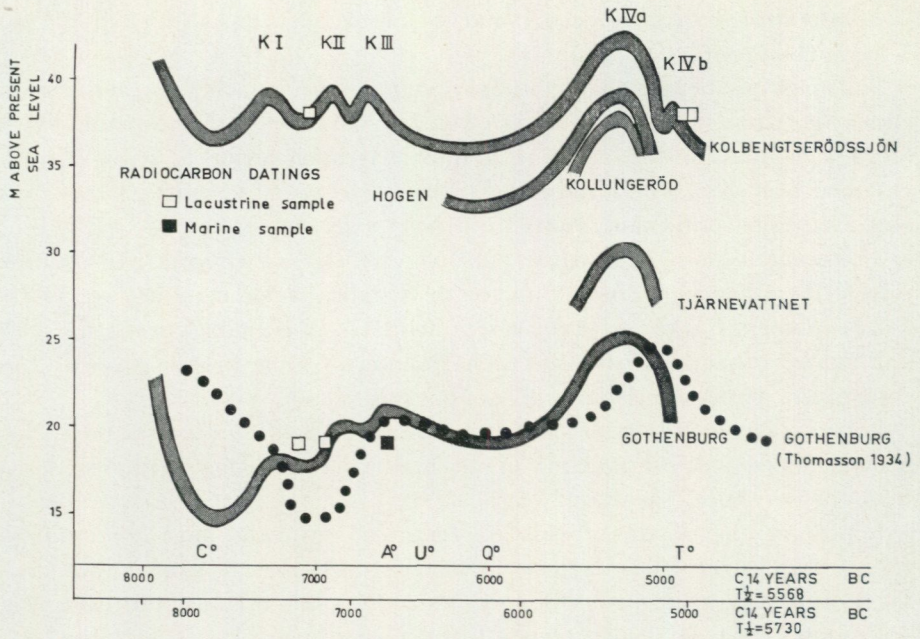


Fig. 18. Shore line displacement curves from the investigated area.

The land upheaval is probably a relatively continuous process with a successively decreasing intensity. The eustatic rise of the sea-level was probably a more irregular process with several small variations caused by changing intensity in the melting rate of the land-ice, due to climatic variations. This irregularity of the eustatic process has caused the small transgressions registered in the shore line displacement curve for the Kolbengtseröd valley (Fig. 18).

In the area north of the Kolbengtseröd valley the intensity of the land upheaval has been greater; the isostasy has probably dominated over the eustasy all the time. This resulted in a step-wise, regressive shore displacement, where the stagnation stages correspond to the transgression stages in the Kolbengtseröd area.

In the south part of Bohuslän the eustasy dominated over the isostasy during the time when equilibrium existed in the Kolbengtseröd area. This resulted in a step-wise, transgressive shore displacement between C° and T° . In the Gothenburg area the shore line displacement curve is of this type. Such a curve has been extrapolated from the Kolbengtserödssjön curve with the aid of the earlier known levels for the transgression maximum and regression minimum in the Gothenburg area (Thomasson 1934, Mörner 1969) and the dating of the transgression contact at Bräckemotet (loc. 9, Fig. 18). In Fig. 18 curves for Kollungeröd, Tjärnevattnet and Hogen are found between the curves for

Kolbengtserödssjön and Gothenburg. The time when the Kollungeröd and Tjärnevattnet basins were first isolated has not been established accurately enough to justify an extrapolation backwards for these curves.

The Gothenburg curve can be compared with the curve constructed by Thomasson (1934) for the same area. This curve can be found in Fig. 18 too. The two curves show great similarities although both regression minimum and transgression maximum are somewhat older in the new curve.

Fig. 19 gives a synopsis of chronology, pollen zones and changes of levels in Bohuslän and other parts of south Scandinavia. The Scanian zone system is compared with the zone system used in this investigation, and the transgression maxima found in this and other investigations from south Scandinavia are inserted in relation to pollen analysis and radiocarbon chronology.

In Halland and the Kattegatt area Mörner's (1969) investigations have indicated several transgressions. The transgression maximum PTM-2, according to Mörner, seems to be about as old as K IV in Bohuslän.

The older maximum in the Kattegatt area PTM-1/ALV-2 dated at 6900 years BC, corresponds to K II. A radiocarbon sample from a level just below marine clay from this transgression maximum has been dated at 7030 years BC (Lu-218).

Mörner has not found any maximum corresponding to K I or K III.

In the Kattegatt area a regression minimum occurred between 7700 and 7330 years BC. This minimum probably corresponds to the minimum before K I in Bohuslän. It falls around C^o, which has been dated at 7600 years BC. Hence K I seems to correspond to the first part of the transgression, which according to Mörner, lasted from 7330 to 6900 years BC in the Kattegatt area. Both a eustatic rise of sea-level and an isostatic land upheaval was going on during this time according to Mörner. The regression between K I and K II in central Bohuslän can be explained by the fact that the isostatic land upheaval was more intense in that area than in the Kattegatt area. For a shorter period the isostasy dominated in Bohuslän while the transgression was uninterrupted in the Kattegatt area.

The maximum K III is much more difficult to apply to the development in the Kattegatt area. The pollen diagrams show that K III occurred between K II, dated at 7000–6900 BC, and A^o, dated at 6600 BC. The regression after PTM-1/ALV-2 in the Kattegatt area lasted from 6900 to 6550 BC, when the regression minimum ALV-3 was reached.

According to Mörner the regression minimum ALV-3 lasted from 6550 to 5800 BC, when the transgression up to PTM-2 started. The diatom diagram from Hogen (loc. 6) indicates that a regression minimum between K III and K IV occurred at Q^o, which has been dated at 6000 BC. The time when the transgression up to K IV/PTM-2 begins seems to be almost the same in Bohuslän as in the Kattegatt area.

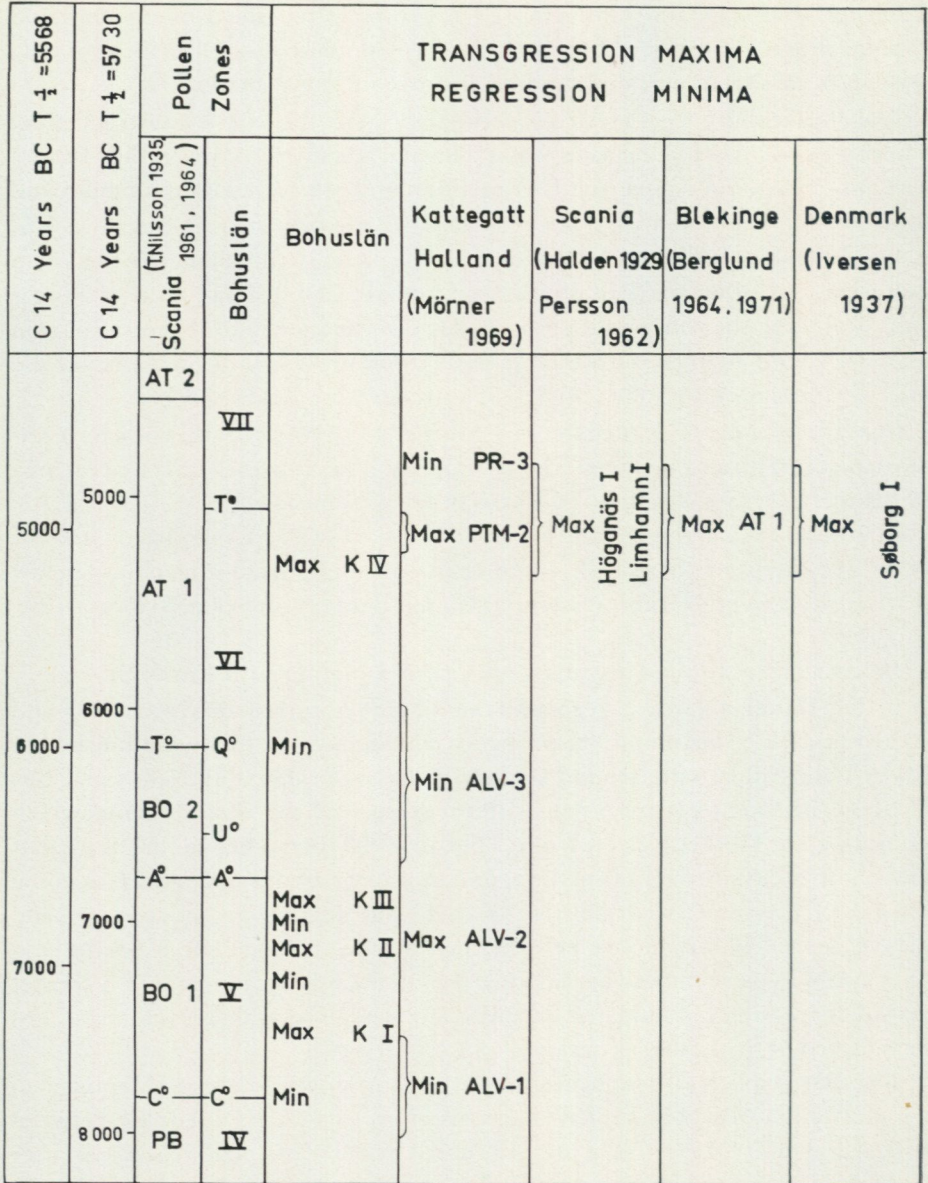


Fig. 19. Chronology and changes of level in south Scandinavia during early Postglacial time.

If Bohuslän is compared with other parts of south Scandinavia and Denmark, K IV probably corresponds to the first Höganäs transgression (Halden 1929), Limhamn I (Persson 1962), Søborg I (Iversen 1937) and the early Atlantic transgression in Blekinge (Berglund 1964 and 1971). The younger transgres-

sion in south Scandinavia are not registered in the investigated profiles from Bohuslän.

The maximum K IV in Bohuslän seems to be somewhat older than the corresponding maxima in other parts of south Scandinavia. This is probably due to an incorrect dating of T° . As mentioned above, T° is possibly somewhat younger than the radiocarbon datings indicate. If it is so, K IV is also younger than the age shown in Fig. 19, and the correlations with other areas is better.

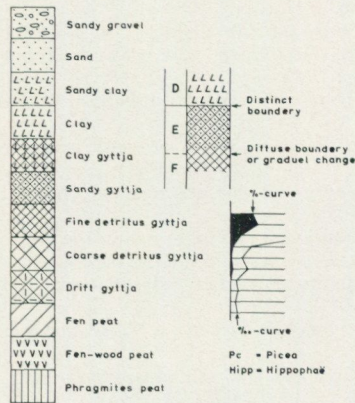


Fig. 20. Explanations of symbols.

Summary

The results of this investigation can be summarized in the following way.

1. The rational limits of *Corylus* (C°) and *Alnus* (A°) probably have the same age in Scania and Bohuslän. Their ages seem to be 7 650 and 6 600 years BC respectively.
2. The immigration of *Ulmus* and *Quercus* occurred some hundreds of years later in Bohuslän than in Scania.
3. The rational *Tilia* limit (T°) is much younger in Bohuslän than in Scania. The radiocarbon ages are 4 900 and 6 000 years BC respectively.
4. Indications of Postglacial transgressions have been found as far north as the Kolbengtseröd valley in central Bohuslän.
5. The maximum of the Postglacial transgression has been dated to the upper part of pollen zone VI (5 100–5 300 BC) in Bohuslän. The first Postglacial regression minimum has been dated to around the boundary between pollen zones IV and V (7 650 BC).
6. The Postglacial transgression is complex. In the Gothenburg area and the south part of Bohuslän the shoreline displacement curve shows a step-wise transgression. In the north part of Bohuslän the shoreline displacement probably was mainly regressive during the same time. In the transition area (Ljungskile–Uddevallå area) no greater changes in the sea-level appeared. However, 4–5 small transgressions have been proved during this time.

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Table 1. Radiocarbon datings

Sample no	Locality	Level in cm below surface	Pollen-analytical dating	Radiocarbon age BP $T^{1/2} = 5568$ years	Radiocarbon age BC $T^{1/2} = 5568$ years	Radiocarbon age BC $T^{1/2} = 5730$ years	$\delta C^{13} \text{ ‰}$
Lu-136	Kolbengtserödssjön I	1167-1177	immediately above T ^o	6810 ± 120	4860	5060	-30.2
Lu-137	Kolbengtserödssjön I	1177-1187	immediately below T ^o	6870 ± 125	4920	5130	-29.8
Lu-141	Kolbengtserödssjön I	1302-1312	below Q ^o	8330 ± 115	6380	6630	-27.9
Lu-140	Kolbengtserödssjön I	1322-1332	at U ^o	8400 ± 105	6450	6700	-25.1
Lu-139	Kolbengtserödssjön I	1342-1352	immediately above A ^o	8710 ± 145	6760	7010	-29.8
Lu-216	Kolbengtserödssjön II	1122-1137	at Q ^o	8020 ± 100	6070	6310	-29.8
Lu-217	Kolbengtserödssjön II	1154-1164	immediately above A ^o	8590 ± 153	6640	6890	-29.1
Lu-218	Kolbengtserödssjön II	1340-1350	in zone V, immediately below K II	8980 ± 146	7030	7300	-29.1
Lu-219	Vassbosjön	785- 795	immediately above C ^o	9750 ± 103	7800	8090	-26.3
Lu-220	Vassbosjön	795- 805	immediately below C ^o	9700 ± 111	7750	8040	-26.9
Lu- 20	Bräckemotet	111- 118	above A ^o	8530 ± 100	6580	6840	-19.3
Lu- 21	Bräckemotet	124- 131	below A ^o	9060 ± 105	7110	7380	-28.1
Lu- 22	Bräckemotet	128- 134	below A ^o	8860 ± 100	6910	7180	-27.8

Table 2. Diatoms found in the analysed samples.

Species	Salt content group	Kolbengtserödssjön I																	
		sampling level in cm below lake surface																	
		1160	1170	1185	1200	1210	1220	1235	1250	1260	1275	1290	1300	1310	1325	1340	1350	1360	1370
<i>Achnanthes brevipes</i>	B	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>calcar</i>	F	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—
<i>clevei</i>	FB	—	—	—	—	—	—	—	1	—	—	—	—	1	—	—	—	—	—
<i>exigua</i>	F	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—
<i>lanceolata</i>	FB	3	3	3	—	1	—	3	1	3	1	4	—	2	—	—	—	—	—
<i>östrupi</i>	F	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—
<i>Actinoptychus undulatus</i>	M	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Amphora holsatica</i>	B	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Anomoeoneis sculpta</i>	B	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Asterionella formosa</i>	F	—	—	—	—	—	5	3	—	—	1	2	1	16	11	—	—	—	1
<i>Biddulphia aurita</i>	M	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Campylodiscus bicostatus</i>	M	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
<i>echineis</i>	B	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cocconeis clandestina</i>	M	—	—	—	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>costata</i>	M	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	2
<i>pediculus</i>	FB	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>pinnata</i>	M	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—
<i>placentula</i>	FB	—	1	1	4	—	1	1	4	2	1	2	—	4	8	3	2	6	3
<i>scutellum</i>	M	—	—	—	2	—	—	—	—	—	—	1	—	—	—	—	—	—	1
<i>disculus</i>	F	1	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Coccinodiscus bathyomphalus</i>	M	—	—	—	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>concinus</i>	M	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>curvatus</i>	M	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>decrescens</i>	M	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>excentricus v. fasciatus</i>	M	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>kützingi</i>	M	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>lineatus</i>	M	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>nodulifer</i>	M	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>rothi</i>	M	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>thori</i>	M	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cyclotella comta</i>	F	35	46	—	26	—	4	13	20	—	3	10	5	14	—	—	—	—	7
<i>kützingiana</i>	F	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	15
<i>v. planetophora</i>	F	—	47	28	24	30	31	38	33	34	24	20	34	33	47	40	45	37	79
<i>v. radiosa</i>	F	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>v. schumanni</i>	F	—	—	1	20	—	4	4	—	9	—	6	—	—	—	—	—	—	2
<i>meneghiniana v. plana</i>	B	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
<i>stelligera</i>	F	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Cymbella cistula</i>	FB	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>hungarica</i>	F	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>prostrata</i>	FB	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>turgida</i>	F	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1
<i>ventricosa</i>	F	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Diatoma elongatum</i>	FB	—	—	—	1	—	—	—	2	—	1	—	—	—	—	—	—	—	1
<i>vulgare</i>	FB	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
<i>Diploneis didyma</i>	B	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>elliptica</i>	F	—	—	—	—	—	1	—	1	—	—	—	—	—	1	—	1	—	1
<i>interrupta</i>	B	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>smithi</i>	M	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	4
<i>Epithemia sorex</i>	FB	—	—	—	—	—	—	—	1	1	1	—	—	1	—	1	1	—	1
<i>turgida</i>	FB	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—
<i>v. westermanni</i>	B	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>zebra</i>	FB	—	—	—	—	1	1	—	—	1	—	—	—	—	1	—	1	—	—

Species	Salt content group	Kolbengtserödssjön I																	
		sampling level in cm below lake surface																	
		1160	1170	1185	1200	1210	1220	1235	1250	1260	1275	1290	1300	1310	1325	1340	1350	1360	1370
<i>Rhoicosphenia curvata</i>	FB	—	—	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Rhopalodia gibba</i>	FB	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—
<i>gibberula</i>	B	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>musculus</i>	B	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Stauroneis nobilis</i>	FB	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>phoenicenteron</i>	F	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Stephanodiscus astrea</i>	FB	—	—	—	—	4	—	1	2	2	—	—	—	11	13	6	3	—	—
<i>v. minutulus</i>	FB	—	24	24	83	70	46	50	71	44	19	24	44	74	121	140	61	30	35
<i>Stephanopyxis turris</i>	M	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Surirella ovalis</i>	B	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>Synedra cristallina</i>	M	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>parasitica</i>	F	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>pulchella</i>	FB	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>tabulata</i>	B	—	—	—	4	—	—	—	—	—	—	3	2	—	—	—	—	—	4
<i>ulna</i>	FB	7	1	7	2	1	3	4	1	—	1	1	1	3	2	—	—	—	2
<i>Tabellaria fenestrata</i>	FB	157	81	140	54	100	108	80	81	104	38	11	13	78	54	37	126	35	53
<i>flocculosa</i>	F	3	2	1	—	1	—	2	—	1	—	—	—	—	—	—	—	—	—
<i>Thalassiosira baltica</i>	B	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
<i>decipens</i>	M	—	—	—	—	—	—	—	—	—	3	1	1	—	—	—	—	2	2

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Växjö 1973 C Davidsons Boktryckeri AB

Printed in Sweden

ISBN 91-7158-024-7