1. Note on *Balanus hammeri* (ASCANIUS) as hydrological indicator

By

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With a diatom analysis

By

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1. Introduction.

The demands of *Balanus hammeri* (ASCANIUS) are distinct as regards food which consists mainly of small copepods living in water of high salinity, viz. so-called Atlantic water.

Atlantic water does not, as a rule, occur in the very coastal zone, but in depths at some distance off the shore. However, it happens that *Balanus hammeri* occurs in Quaternary deposits obviously settled in rather shallow water near the shore. In such cases, Atlantic water must have ascended as reaction currents induced by outflowing great streams.

The presence of *Balanus hammeri* in Quaternary deposits of this kind indicates, in other words, outflows of great masses of water. Consequently, when dating such deposits, we also date the outflows. In the present case I want to know the age of an ancient outflow in N. Bohuslän, W. Sweden, indicated by a *Balanus hammeri* necrocoenosis.

The importance of *Balanus hammeri* as an indicator of such special hydrological conditions as now mentioned was pointed out by ODHNER (1927 and 1930) in his interpretation of the genesis of the large shell beds at Uddevalla in middle Bohuslän.

Enormous quantities of *Balanus hammeri* shells are accumulated in the Uddevalla shell beds. However, the species is reported from many other localities on the Swedish west coast (cf. Fig. 1). Many of these occurrences have certainly nothing to do with reaction currents and outflowing streams, but several of them must be regarded as having been formed under such conditions.

There is no reason to assume that all these deposits were accumulated contemporaneously. *B. hammeri* is eurytherm to a great extent (cf. next chapter), and it can be expected to be found in deposits from all Quaternary stages, provided that suitable hydrological conditions existed. *B. hammeri* is thus of little importance as an indicator of the age of Quaternary deposits.

The dating must be performed by means of pollen analyses. However, it happens that this method has to be completed by indicative sedimentologic, faunistic, and diatomologic data. This was the case in the present dating.

2. On the thermal demands of Balanus hammeri.

Balanus hammeri is widely distributed in our day, but nowhere is it a common species. Its European distribution extends from England over the Faeroes to Iceland and to Sweden and Norway. In Sweden the species is found occasionally, mainly in the Väderöfjord, and in Norway it occurs from the Bergen region and further northwards. It also lives along the coast of Murman to the outer part of the White Sea. Its greatest frequency occurs in the Norwegian Finnmark. In America it has been mentioned chiefly from Massachusetts and Nova Scotia. Moreover, *Balanus hammeri* is reported from the Nordre Strömfjord, Greenland (also fossil in Greenland).

BROCH (1924, p. 115) who was not aware of the fact that the species is able to live in Greenland stated that *B. hammeri* "is an exclusively Boreal species which occurs in the Boreo-Arctic transitional area in infrequent numbers, but cannot live in the high-Arctic region in negative temperatures".

The idea of the thermal demands of the species is somewhat varying in a paper of ASKLUND 1936 dealing with Quaternary deposits including,

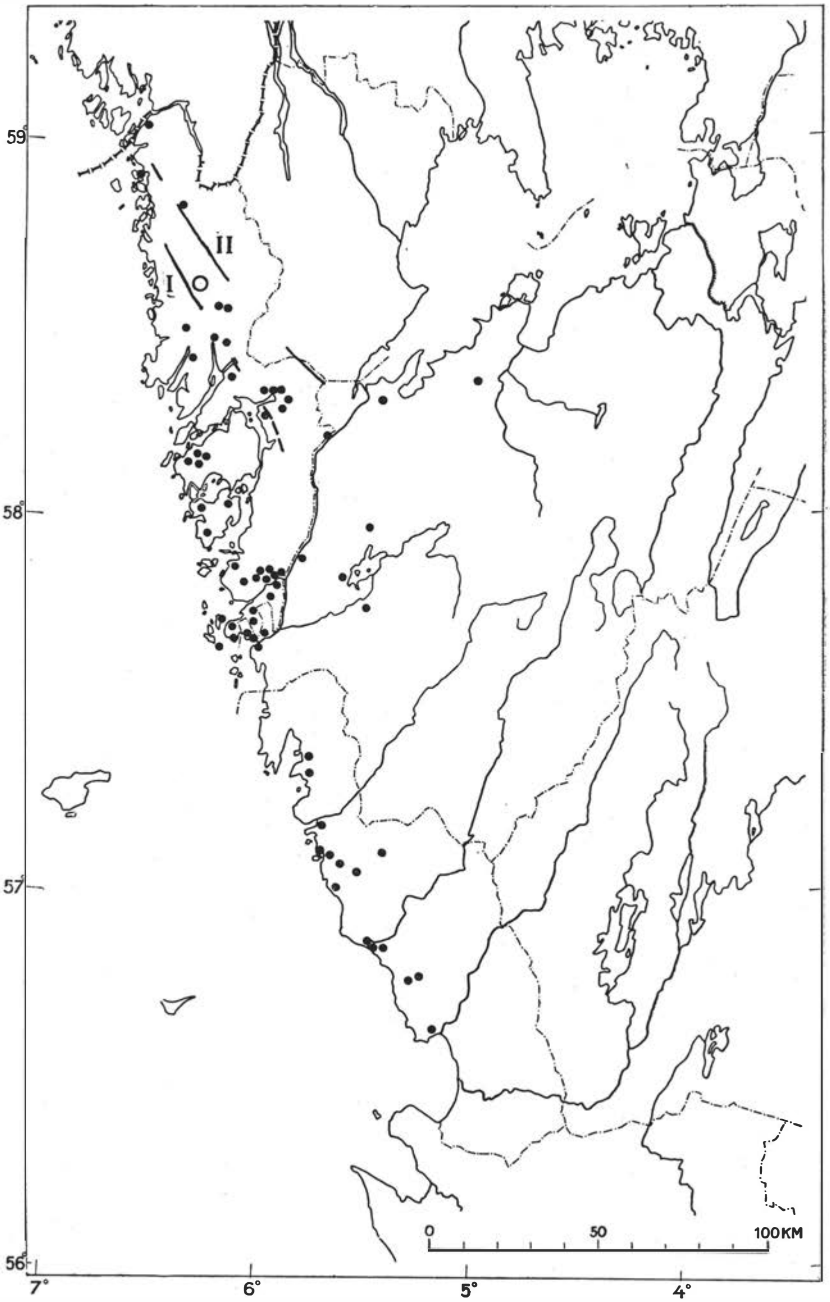

Fig. 1. Map showing Quaternary occurrences of *Balanus hammeri* on the Swedish west coast. Compiled from data presented by HÄGG 1948. The locality described in this paper marked by a circle. I = the Tanum — Svarteborg terminal moraine. II = the Bullaren — Krokstad terminal moraine.

inter alia, this species: it is mentioned as Boreal (p. 30), Boreo-Arctic (p. 45), low Glacial-Boreal (p. 52) and middle Glacial-low Glacial (p. 59). The presence of this species in late-Glacial sediments in Halland, W. Sweden, is interpreted as caused by an early Goti-Glacial considerable amelioration of climate (cf. op. cit. p. 45, 49, and 60).

When discussing the thermal conditions of *B. hammeri* very great importance must be attached to the Greenland occurrence. This is only a single find, and nothing is known about the frequency of the species in Greenland. It may be noticed, however, that mainly soft bottom biocoenoses have been investigated there and, furthermore, that *B. hammeri* is not easy to dredge up from those hard bottoms where it lives. It is considered a remarkable event to dredge a *B. hammeri* specimen in the Väderöfjord (the Swedish habitat of *B. hammeri*). The species is perhaps not so very rare in Greenland. In the Collections of the Inst. of Palaeontology of Uppsala there is, for instance, an old Greenland find of *B. hammeri* (2 specimens). These had lived on a whale. This, of course, does not prove that the specimens lived in Greenland waters; they might just as well have been transported there as dead shells from the Norwegian Finnmark, for instance. However, the possibility may not be excluded that at least one of the specimens lived in Greenland waters judging by the fact that dried parts of soft tissues remain in the interior of the shell.

Even if the Nordre Strömfjord find should be singular it shows nevertheless that *Balanus hammeri* has the ability to live in an ice fjord. It has also been observed in Quaternary deposits obviously settled just outside a land-ice. ASKLUND (1936, p. 14) gives a list of species in such a deposit which is a case in point. The presence of *Portlandia arctica* (GRAY), which is common in waters outside glaciers and land-ices, indicates that the sediment was settled near the Ice border. The fact that *B. hammeri* and *Portlandia arctica* exclude each other within late-Glacial Halland deposits is certainly due to their different ecological demands: *B. hammeri* lives in clear and current ocean water where the sedimentation of minerogene fine-particles is infrequent, but *P. arctica* prefers those places where these particles are precipitated abundantly. There is no reason to conclude that this mutual exclusion is due to thermal changes, as interpreted by ASKLUND (cf. HESSLAND 1943, p. 319 f. and p. 21 in this paper).

According to JENSEN 1942, p. 30, *B. hammeri* can "live under arctic conditions at a temperature which, in the middle of the summer, is very near 0° C". The temperature at the bottom of the Nordre Strömfjord where the living specimen was found was 0.3—0.2° C. (end of June).

In addition, I have calculated some mean temperature data from the vicinity of the Söndre Strömfjord which is situated somewhat S of the Nordre Strömfjord. The data have been collected from Publikationer fra det Danske Meteorologiske Institut: Isforholdene i de arktiske Hav 1897—

1939. They refer to the surface water at the mouth of the fjord. It would have been better to know the temperature of the deep water where *B. hammeri* lives, but the bottom temperature had not been measured.

Jan.	Febr.	March	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Ice	Ice	Ice	0.8°	0.9°	2.0°	3.9°	4.5°	3.9°	1.8°	0.9°	Ice
			Ice 12 years						Ice 20 years	Ice 29 years	One year 0.9°

3. Locality investigated.

The locality investigated is situated about 350 m E of the Klingseröd farm, Kville parish, N. Bohuslän (or about 3.8 km NW of the southernmost point of the Southern Bullaren lake). The height above the sea is 99 m. It is situated in a rocky region with the depressions filled with sediments. The depression including the *Balanus hammeri* stratum discussed here is small, and the surrounding Archaean rocks are fairly flat.

The substratum of the stratal sequence is morainic matter. Above that is a marine clay (about 3.6 m) rich in shell-bearing organisms; *Balanus hammeri* forms a thin layer about 75 cm above the morainic stratum. The marine clay is overlain by freshwater sediments consisting of more or less calcareous *gyttja* (necron mud) in the lower part and non-calcareous coarse necron mud in the upper; the freshwater layer is about 1 m thick. The stratal sequence is finished upwards by deciduous fen-wood peat (2 m); this is what has been left after exploitation of the overlying peat.

Samples were taken by means of a can-auger; intervals between the samples were 10, 5, and 2.5 cm.

4. Discussion of the pollen diagram.

(Cf. Plate)

The whole stratal sequence has been examined by pollen analysis. Since, besides the *B. hammeri* horizon, I was especially interested in the shell-bearing limnic stratum, the shortest interspaces between the samples analysed occur there.

For the time being it is somewhat difficult to interpret pollen diagrams from N. Bohuslän, since the development of the vegetation has been incompletely studied, especially the earliest stages. However, the development of the vegetation in middle Bohuslän is now being studied by Dr. M. FRIES. I had the opportunity to see his diagrams which are being elaborated at the Inst. of Palaeontology, and to discuss the history of the vegetation with him. Of further importance is the fact that I have also investigated pollenanalytically 10 other stratal sequences from N. Bohuslän ("Calcareous fresh-water sediments" etc.; paper in press).

A continuous *Tilia* curve is not developed. According to S. FLORIN 1944, Pl. IX, *Tilia* began to form a continuous curve in middle Sweden about 5.000—5.100 B. C. which indicates the present stratal sequence to be older than this date.

The continuous *Alnus* curve begins at about the sample 459. This part of the stratum was thus formed about 6.300 B. C., contemporaneously with the VG2 in the Väner system (v. POST 1947, p. 300).

The beginning of the continuous *Corylus* curve is not distinct, but a period characterized by a fairly abundant *Corylus* vegetation appeared at about the sample 487. The Boreal hazel maximum is not very pronounced in this stratal sequence, but it maintains this character with other localities in the area; somewhat more to the west the hazel maximum is much more pronounced.

Further downwards in the sequence of strata the great *Betula* maximum, or the *BM* (sample 501), is found, which was developed about 7.000 B. C. (v. POST 1947a, p. 210), i. e. at about the transition from finiglacial to postglacial time; in the Väner system it corresponds to the VFG3 — VFG4 (v. POST 1947, p. 300).

The part of the stratal sequence prior to the *BM* is difficult to date. The following features in the pollen representation may be noted, however.

The frequency of arboreous pollen is very low in the zone somewhat below the *BM* (samples 516—524); this may indicate an unfavourable climate. Very low frequencies also occur in lower sections, such as in the samples 544—546.

Below the *BM* there are especially two sections characterized by the fact that the *Betula* curve is superior to that of *Pinus,* viz. in the sections 528—534 and 560—563. One of them may represent the Alleröd period. There are, however, different opinions on the dating of this period.

DE GEER was of the opinion that the Alleröd period is of different age in different localities (cf. BERLIN and MOHRÉN 1942, p. 16). CLEVE-EULER has assumed that there were several Alleröd periods; huminose layers of Alleröd type are stated to appear in different parts of the late-Glacial stage indicating repeated ameliorations of climate (1939 and 1947, p. 95). Other authors assert that at least Scanodanian Alleröd localities are synchronous (cf. NORDMANN 1940).

NILSSON (1935, p. 485) assumed that the Alleröd period occurred during the recession of the Land-Ice across Småland to the Middle Swedish terminal moraines. These moraines should have been accumulated during the following deterioration of climate (the later *Dryas* period). MOHRÉN (BERLIN and MOHRÉN 1942, p. 21), FÆGRI (1945, p. 102), and SANDEGREN (ALIN and SANDEGREN 1947, p. 37) suggest that this idea is not unlikely. v. POST

(1947, p. 304) states that "the period ends in the Salpausselkä stage". Later Prof. v. POST has communicated verbally that the Alleröd period seems to have appeared just after the Göteborg terminal moraine (cf. p. 8).

The Alleröd period is characterized by a more intensive production of pollen than the immediately previous and following periods as shown in Danish and Scanian deposits (cf. NILSSON 1935, p. 472). According to NILSSON, the *Betula* curve dominates, forming an image of the *Pinus* curve. *Alnus, Tilia, Picea,* and *Corylus* occur occasionally. MOHRÉN also points out the fact that pollen of Gramineae, Cyperaceae and terrestrial herbs are abundant (BERLIN and MOHRÉN 1942, p. 20). In the previous period the pollen frequency was generally low, acc. to NILSSON. *Pinus* dominates. *Alnus* and *Corylus* occur fairly often, *Alnus* sometimes rather abundantly; *Tilia* and *Ulmus* appear sporadically in the whole zone (*Tilia* seems to be inferior to *Ulmus*). In the period succeeding the Alleröd period the pollen frequency is low. *Betula* dominates over *Pinus*, but not so much as in the Alleröd period. *Alnus, Picea*, and *Corylus* occur now and then; they seem to be more common than in the Alleröd period.

MOHRÉN (BERLIN and MOHRÉN 1942) has investigated some stratal sequences in Småland in order to ascertain whether the Alleröd pollen spectrum is traceable northwards. He found that this is the case as far as N. Småland, but that the heat character of the period diminishes northwards. MOHRÉN, moreover, examined a stratal sequence from Göteborg where he found that *Pinus* dominates also during the period referred by him to the Alleröd stage (op. cit. p. 22). This period is characterized by an increase of the *Betula* curve. A few *Alnus* and *Corylus* pollen grains occur contemporaneously. SANDEGREN (ALIN and SANDEGREN 1947, p. 37) referred to the Alleröd period a section of a deposit at the Göta älv including *Alnus, Corylus, Picea*, and *Quercus;* the content of *Betula* is high in parts of this section.

As long as there are different opinions among the pollen analysts with regard to the dating of the Alleröd period, it is scarcely possible to identify it with certainty in the present diagram. Nor is this of decisive importance for the dating of the *Balanus hammeri* stratum. It is noticeable, however, that sections below the *BM* with high *Betula* values presumably indicate periods of climate amelioration (cf. above). Some support for this idea is the mode of occurrence of *Artemisia* in the stratal sequence. It mainly forms a continuous curve below the *BM* indicating that at this time the land was open minerogene soils for the most part (cf. ERDTMAN 1946). But in the middle part of the section 528—534 (where the *Betula* curve dominates) *Artemisia* is infrequent or absent which may be due to a change of soil type probably caused by climatic amelioration. Such presumed changes of climate and the hydrological data arrived at by sedimentologic, faunistic, and diatomologic investigations of the stratal sequence is here the base for a calculation of the age of the *B. hammeri* stratum. These questions are discussed in the following pages.

5. The minerogene sedimentary phase.

(Cf. Plate)

The substratum of the marine clay is morainic matter. The sediment just above the bottom layer (sample 563) has a very wide granulometric dispersion with a predominance of large-sized fractions. As early as sample 562, which is situated 5 cm higher, these fractions have decreased considerably, and the small-sized fractions have increased. This became more pronounced in sample 556 situated 40 cm above the bottom stratum. In the *B. hammeri* layer, which appears about 25—50 cm higher up, the sediment became well sorted; the large-sized fractions as well as the small-sized are infrequent, the main quantity being of medium size, chiefly *mo* (acc. to ATTERBERG's classification). During the next stage in development (samples 546, 543, and 540) the granulometric dispersion changed somewhat; especially the small-sized fractions increased. At higher levels the granulometric dispersion slightly decreased, but during the final phase of the marine stage the sediment became unsorted again.

This development may be interpreted in the following way. The Ice had receded about 2 km from the Tanum-Svarteborg terminal moraine when the morainic substratum was accumulated. This terminal moraine, which disappears northwards into the sea at about the island of Råssö, between Strömstad and Grebbestad, is traceable southwards in many localities. It traverses the inner part of the Saltkällefjord and the Byfjord somewhat W of Uddevalla (Sunningen). The outwash plains which constitute the military camp Backamo seem to be confined to it. Further southwards it may continue as the so-called Göteborg moraine (according to MUNTHE-JOHANSSON-SANDEGREN 1924, p. 99 and Pl. II).[1] This one continues, in Halland, in the famous Fjärås bräcka. The Göteborg moraine is stated to be dated geochronologically to about 10,000 B. C. (cf. v. POST 1947, p. 299). Provided that the Tanum-Svarteborg moraine really continues in the Göteborg moraine it is thus of the same age. The substratum of the Klingseröd deposit is somewhat younger since, as mentioned, it was formed when the Ice had receded about 2 km from this moraine.

The poor sorting of the sediment just above this stratum may indicate that the Ice was still just in the vicinity. But at the accumulation of the *Balanus hammeri* bed it had receded so far from Klingseröd that larger particles were not transported to this place, nor larger quantities of very fine particles, which were probably precipitated, on account of electrolytic agglomeration (reaction currents), nearer the Ice margin. The distance to the Ice margin at

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[1] After this paper went to press, an investigation of S. Bohuslän Ice front lines has appeared (BJÖRSJÖ, N.: Israndstudier i södra Bohuslän. Sveriges Geol. Unders. Ser. C, No. 504. Stockholm 1949). According to BJÖRSJÖ, the Tanum-Svarteborg terminal moraine continues as the Göteborg moraine.

that time is impossible to ascertain with any great exactitude. However, the Ice had probably not reached the Bullaren-Krokstad moraine which runs about 11 km NE of Klingseröd. The continuation of this terminal moraine runs between Vänersborg and Trollhättan and is distinctly traceable through Västergötland; the moraine is called the Vänersborg moraine by MUNTHE (1941). The reason for my assumption that the Ice had not reached this moraine at the deposition of the *B. hammeri* bed is that a stratum somewhat above this bed (samples 540—546) was probably formed during a halt of the Ice front which may correspond to this moraine. Arboreous pollen are few in the samples 540 and 544—546 indicating possibly a deterioration of climate which may be considered to be registered by a halt in the Ice recession. The granulometric composition of the sediment had changed inasmuch as small-sized fractions had increased. This may mean that the outflow from the Ice had decreased. The glacial streams continuing into the sea were not strong enough to transport larger particles to this place. The increase of the minute fractions, on the other hand, may be explained by the fact that the outflow streams had become too weak to raise reaction currents which supply electrolytes. On this account the fine particles could be transported more seawards than earlier before being agglomerated and precipitated.

The succeeding increase of medium-sized particles and pollen frequency possibly means that the Ice receded from a stationary position on account of a climate amelioration.

During all this development the depth of water diminished. Finally, waves and surf could act upon the glacigene layers covering the Archaean hills to the west. The upper part of the marine stratal sequence was obviously to a great extent formed because of this redeposition (probably from about sample 526). The granulometric sorting became especially poor when the hills emerged above sea level. The sedimentation then occurred in stagnant water enclosed by rock hills on all sides and connected with the sea by narrow passages. Sediments of different granulometry were transported to this area but few were carried away. Hence, a very bad granulometric sorting appeared just before the area was parted from the sea (especially the sample 496).

The content of sulphur increased through the marine stratum, indicating not only intensified supply of necron substances, but also that the water became progressively more stagnant.

6. Fauna.

Owing to the fact that the samples were very small (about 0,5—2 g) statements about the macrofossils are not very representative. As a matter of fact, larger samples might also have given a more complete picture of small-sized faunal groups. However, the samples form a dense series, and

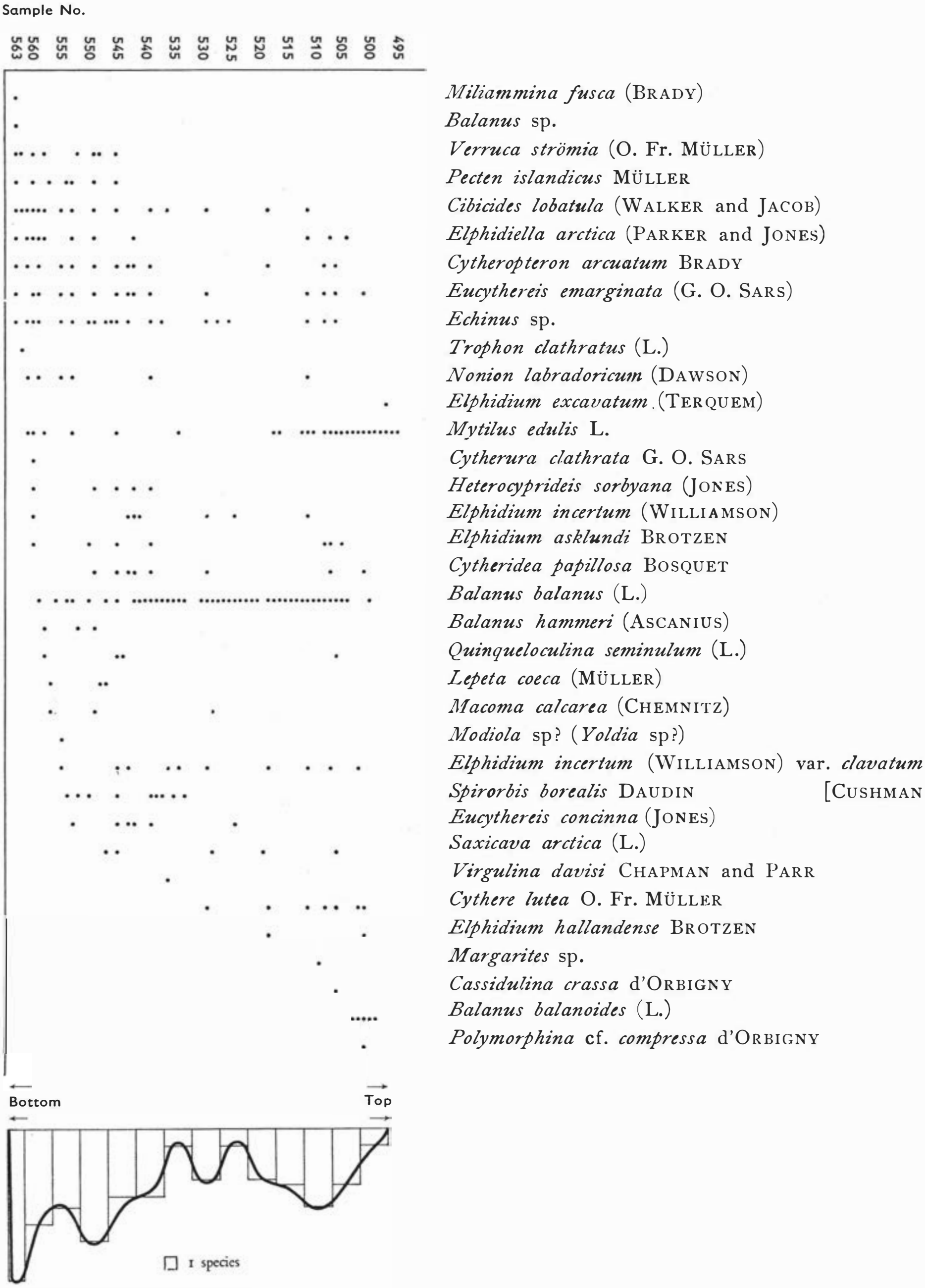

Fig. 2. Distribution of marine species observed. Occurrences of species marked by dots. Figures referable to pollen samples (cf. Plate).

the animal distribution curve based on a histogram (each bar, as a rule, representing 5 samples) may give an idea of the intensity and variation of the necrotope. The distribution curve and the occurrence of the separate species observed are shown in Fig. 2.

First, it may be mentioned that all the species occur in the Arctic Sea. Many of them do not appear further south than the Norwegian Finnmark and the Trondheimsfjord. One of them, *Cytheropteron arcuatum* BRADY, is purely Arctic.

As shown by the distribution curve the number of species is high in the bottom-most part of the marine clay precipitated when the margin of the Ice was just in the vicinity, judging from the granulometric composition of the sediment. In the lowermost 10 cm of this stratum 16 species were observed: 6 foraminifera, 4 ostracods, 3 molluscs, 2 cirripeds, and 1 echinoderm.

According to statements by travellers in the Arctic region, animal life is abundant in the water just outside glaciers. This may partly be explained by the fact that salt water is carried there as reaction currents. Among the present species there are indicators both of high salinity and currents. High salinity is indicated by the ostracod *Eucythereis emarginata* G. O. SARS, which is recorded to require $> 20‰$ (ELOFSON 1941, p. 284), and currents by the cirriped *Verruca strömia* O. Fr. MÜLLER. The immediate expansion of the foraminiferal and ostracodal faunae gives evidence of a lively supply of open sea water. The fact that the foraminifera are juvenile to a great extent, and that among the ostracods the alate and very thin-shelled *Cytheropteron arcuatum* BRADY (which is thus easily movable) is the most common species may suggest reaction currents. The presence of carnivores such as *Trophon clathratus* L. and *Echinus* cf. *dröbakiensis* MÜLLER is explained by an abundant animal life.

The number of species is practically identical in the following samples up to 555. *B. hammeri* appeared here, represented by a few fragments in sample 558. The five-sample sequence 551—547 includes the richest *B. hammeri* occurrence (especially sample 549). *Spirorbis borealis* DAUDIN is also abundant there, and bryozoa occur; these types, like *B. hammeri*, indicate lively current action.

After this period current action must have decreased, judging from the fact that the following species disappeared: *Balanus hammeri*, *Verruca strömia*, *Spirorbis borealis*, and the bryozoa; *Pecten islandicus* MÜLLER and *Lepeta coeca* (MÜLLER) which also prefer current water had likewise disappeared. In the continuation the number of species diminished, and the individual frequency was also fairly low.

Around sample 510 the number of species increased distinctly. This is partly due to the fact that a new biotope, rich in animals, had been formed, viz. an algal biotope on the Archaean hills surrounding the deposit, above all W of it. Evidence of this new formation is given especially by the abundance of *Cythere lutea* O. Fr. MÜLLER which is a most characteristic member of algal biocoenoses. The fact that *Mytilus edulis* L. is very abundant shows also that the water had become shallow. Around sample 503 the change of level had proceeded so far that the Archaean hills to the west had emerged above sea level, judging by the fact that *Balanus balanus* (L.) had been succeeded by *B. balanoides* (L.) which is characteristic just of the *fjaer*.

Many of the foraminifera and ostracods in this upper richly fossiliferous section of the clay layer are very likely redeposited from older parts of the clay.

7. Diatoms.

Dr. ASTRID CLEVE-EULER has graciously examined a sequence of samples with respect to diatoms. The species observed are enumerated in the tables I—III, p. 14—18.

Dr. CLEVE-EULER has commented on the tables in the following way:

"Five different diatom zones are discernible.

1. Samples 468—481. *Pinnularia cardinalis* zone. Extremely few diatoms. Fresh water.
2. Sample 487. *Mastogloia-Fragilaria* zone. Practically fresh water.
3. Samples 493—495. Shore-lake flora with, inter alia, *Cymbellae* and *Epithemiae*. Individuals very abundant. Practically fresh water.
4. Samples 497—501. Transitional zone with *Scoliopleura* and *Hyalodiscus*. Few diatoms. Brackish water.
5. Samples 506—562. *Coscinodiscus* zone. Sea water. Samples 511—539 more or less rich in diatoms. Samples 541—561 poor in diatoms. Sample 562 no diatoms.

With but few exceptions, epiphytes do not occur below sample 538 which indicates fairly deep water. Among the epiphytes above this sample *Cocconeis scutellum* is the most abundant.

The marine diatom association has a decidedly kryophile character. Forms indicating temperate conditions do not occur. The diatom flora is very much reminiscent of the Ice Sea flora described by CLEVE and GRUNOW (1880). Of special interest is *Coscinodiscus divisus* GRUNOW, which has not been reported previously from Scandinavia.

It is an interesting fact that freshwater species occur throughout the marine clay, a few even from the very bottom part of the clay, especially *Melosira islandica* subsp. *helvetica* O. M. All the freshwater species constitute a uniform and representative so-called *arenaria* flora, which indicates that the locality has received outflows from great inland waters during the whole sea stage. The species are litoral for the greater part; they formed an abundant flora when the locality was isolated from the sea (samples 493—495).

A special group of diatoms appeared in the *Scoliopleura* zone and in the following shore-lake zone. The appearence of these species indicates

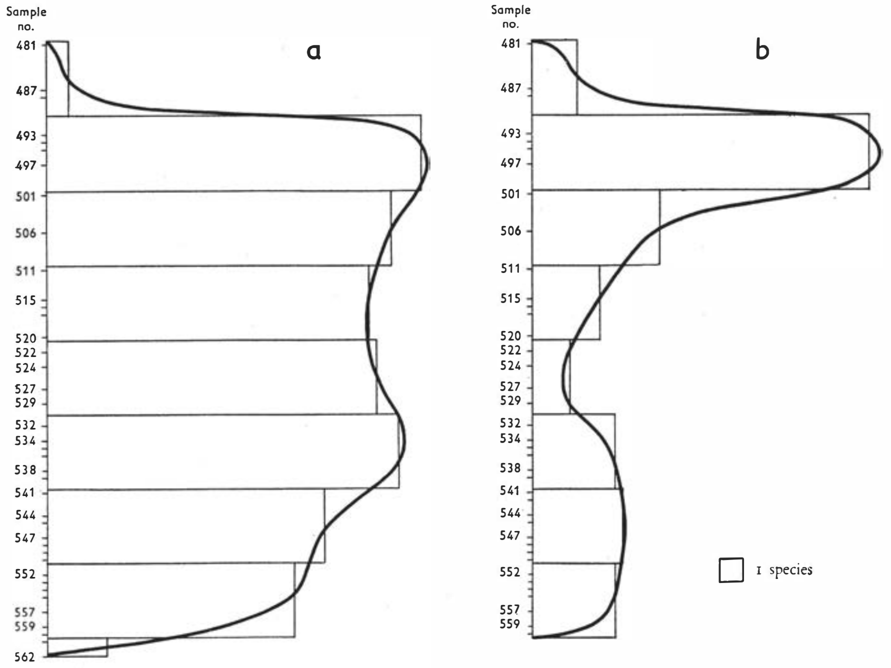

Fig. 3. Distribution of diatom species. *a*. Marine species. *b*. Freshwater and indifferent species. Figures referable to pollen samples (cf. Plate). The species are enumerated in tables, p. 14—18.

that the passages to the open sea had become very narrow and that currents from the sea had no longer free admittance. These species are partly distinctive of small lakes and ponds and partly they are euryhaline lagoon types, such as *Cymbella caespitosa* (KZ) A. CL. and *Navicula oblonga* KZ."

To these statements by Dr. CLEVE-EULER only some remarks may be added pertaining to the presence of organisms other than diatoms indicative of the character of the sediment in the transitional zone between the marine and limnic layers. These data confirm the evidence of the diatoms.

The sediment is crowded with *Mytilus* prisms up to sample 495, and foraminifera and ostracods are included in great quantities; this is the uppermost sample of the marine clay. Sample 494 is a lagoon layer consisting of a clayey calcareous mud with single specimens of the freshwater gastropod *Armiger crista* (L.), but fairly great quantities of *Mytilus* prisms occur also; these were obviously transferred into the lagoon from the sea or redeposited from older layers. In 493 the freshwater gastropod *Gyraulus arcticus* BECK had grown numerous, and freshwater mussels belonging to the genus *Pisidium* had appeared. The content of freshwater calcareous precipitates and the number of plant remains had increased considerably. Minute fragments of *Mytilus* may still be observed.

Table 1 (marine species).

	468	481	487	493	494	495	497	501	506	511	515	516	517	520	522	524	527	529	532	534	535	536	538	539	541	542	544	545	547	548	549	550	552	553	554	555	557	559	560	562
Rhabdonema arcuatum (Ag.) Kz.							r	r	+	r	+	r	r	r	—	r	r	—	—		r	c	—	—		—	—		1	r	r		r		1	1	1	r		1
Coscinodiscus oculus-iridis E.								2	+	c	cc	+	—	c	cc	c	cc	+	+	c	+	c	+	+	r	c	+	+	—	+	+	r	+	r fr	r	4	2	+	—	1 fr
*Coscinodiscus divisus Grun.								—	—	+	c	+	r	c	c	c	c	+	+	+	+	c	—	+	1	+	r	r	—	—	r	2	—	1	2	2	2	r	r	
Trachyneis aspera (E.) Cl.							r	4	+	3	+		4	—	—	r	+	+	—	—	r	+	+	+	1 fr	+	r	1	2	—	2	r	2	2	1	1	r	r	1	
*Nitzschia vitrea v. major Grun.																																						1		
Navicula digito-radiata Greg.						c	+		1														1			1											1	1		
*Navicula distans (W. Sm.) Cl.											1			2	1			1				1								1		1	2		1		1	1		
*Rhabdonema arcuatum v. maxima Cl.							1											1												1	2		1	2				1		
Rhoicosphenia marina (Kz.) W. Sm.						1		r				r								r	1	1												2	1			1		
Synedra affinis Kz.							1	+	1	r	r			r	r	r		+							1						1		1					1		
*Trachyneis aspera v. intermedia Grun.									2		1				2	1					1		—	—		1	r			1	1			1			1	2		
*Triceratium arcticum Brightw.																														1			1	2			1	1		
*Achnanthes arctica Cl.														1		2				1				1			1				2				1		2	1		
*Amphora terroris E.								4	4	4	4	2		3	3	r	2	r				1	1	3		2				1	1							1		
Coscinodiscus neoradiatus A. Cl.											2						r		r	+	—	+	r	r	1	r	+	1	1	1	r	3	1		2		1	r		
*Coscinodiscus subglobosus Cl. & Grun. = Thalassiosira gravida Cl.								1	r	c	c	+	r	cc	cc	cc	—	+	+	+	—	+	+	+		r	r		2	r	r	1	—	1	2		3	2		
Diploneis borealis (Grun.) Cl.							2		2	3		1	1	2		1	1	1	1		1	1	1	2		3			1									1		
Diploneis entomon (E.) A. S.					1	2	2		3					1	2	1	1	2		1		3	4	1		2				1	1	1		1			1	1		
*Achnanthes grönlandica Cl.											1			2	2	4																					1			
*Biddulphia aurita (Lyngb.) Bréb.							2	+	4		3			2	2			2		1		4							1	2	1						2			
Cocconeis scutellum E.							1					+					r	+	r		r	r	+	1									1				2			
Coscinodiscus asteromphalus v. subbulliens (Jörg.) A. Cl.																							r														1			
Grammatophora arctica Cl.															r							1		1		1											1			
Navicula directa W. Sm.									—		—	1								1		2	1	1		2											1			
*v. cuneata Østr.						r		2						3	r	r	1	2																						
Nitzschia dubia W. Sm.			1									2						2					1								1		1				1			
Paralia sulcata (E.) Kz.			1					1	2		1		2		2bd	1	2bd	1bd		1bd	1bd	r	1bd	2bd				1bd		1bd		1	2bd	3bd	3bd	1	3			
Plagiogramma Gregorianum Grev.							1	4			2			2											3					1					2		2			
Rhabdonema minutum Kz.							r	+	+	2		2		2			1		r								r			2			1				1			
Coscinodiscus lineatus E. (vel sublineatus Grun.)									1																					2						1				

Grammatophora arcuata E.									—	3	—		3	r	r	r	r	+	r	1	r	—	r	r	1				2	r	1	2		1	1					
**Navicula directa* v. *lata* Østr.																																			1					
**Synedra kamtschatica* Grun.									2		2	r		2	3	2						1		1								1			2					
**Coscinodiscus bathyomphalus* Cl.																					1	2												2						
Hantzschia marina (Donk.) Grun.																															1	1								
Actinoptychus undulatus (Bail?) Ralfs.																															1									
Chaetoceros diadema E.									r					3				1				2									1									
Cocconeis costata Greg.																		1						2							1									
**Grammatophora macilenta* v. *subtilis* Grun.																3								1							1									
Amphora angusta (Greg.) Cl.														1		2				1		1				1				1										
Campylodiscus Thuretii Bréb.											1						1	1			1	1	1	1					1	1										
**Diploneis clathrata* Østr.							2	1					1	1	1	1						1		1						2										
Nitzschia angularis W. Sm.																										1														
Scoliopleura tumida (Bréb.) Rbh. (*Nav. tumida* Bréb.)				1		2	++	2	2																	1														
Achnanthes brevipes Ag.					1	r	2																			1														
Cocconeis scutellum v. *ornata* Grun.																								1		2														
**Gomphonema grönlandicum* Østr.																2								1																
Opephora Kittonii A. Cl.																								1																
Opephora marina (Grun.) Pet.								r														1		1																
Achnanthes brevipes v. *incurvata* Østr.														1										1																
Amphora crassa Greg.																						1		2																
Caloneis liber (W. Sm.) Cl.							1														1			1																
Campylodiscus angularis Greg.						1	3	3						2			1					1		1																
Diploneis splendida (Greg.) Cl.							1					1								1				1																
Cocconeis quarnerensis Grun.							1					2											r																	
Licmophora spp.								1				1				1	1						1																	
Navicula latissima Greg.							1	1															1																	
Navicula lyra v. *elliptica* A. S.											1							1				1																		
**Navicula algida* Cl.									3		2			1	3			1		1		1																		
Amphora angulosa Greg.																						1																		
Diploneis bombus E.																						1																		
Grammatophora angulosa E.							1		2		1						r	r																						
**Nitzschia* (*Bacillaria*) *socialis* v. *kariana* (Grun.)					r				1			1		1		r		1																						
**Fragilaria arctica* Grun.																—																								
**Navicula directa* v. *remota* Grun.																--																								

Table II (brackish water species).

	468	481	487	493	494	495	497	501	506	511	515	516	517	520	522	524	527	529	532	534	535	536	538	539	541	542	544	545	547	548	549	550	552	553	554	555	557	559	560	562
Nitzschia hungarica Grun.						c									r	r																								
Nitzschia lanceolata W. Sm.														2	1	2																								
Synedra investiens W. Sm. (*Thalassionema nitzschioides* Grun. e.p.)								1			r	r	r	r	r	r																								
Nitzschia sigma W. Sm.							1	1							1																									
Amphora proteus Greg.							1	1				1																												
Chaetoceros laciniosus Schütt												1																												
Nitzschia (*Bacillaria*) *paradoxa* (Gmel.) Grun.												r																												
Hyalodiscus scoticus (Kz.) Grun.							r	+	—		r																													
Amphora marina W. Sm.								1			2																													
Diploneis subcincta (A. S.) Cl.						r		3		1																														
Nitzschia punctata (W. Sm.) Grun. α *curta* mh.					3	+			1																															
Diploneis incurvata (Greg.) Cl.							1		1																															
Cymbella pusilla Grun.								r																																
Cymbella salinarum Grun.								—																																
Fragilaria construens v. *subsalina* Hust.				r	r	r		r																																
Gyrosigma balticum (E.) Cl.							2	r																																
Hyalodiscus stelliger Bail.								1																																
Mastogloia Braunii Grun.				—	r	r		1																																
Nitzschia apiculata (Greg.) Grun.								2																																
Pinnularia quadratarea A. S.							+	1																																
Mastogloia Dansei Thw.				r		r	1																																	
Navicula cancellata Donk.						1	1																																	
Nitzschia marginulata Grun.							+																																	
Rhopalodia musculus (Kz.) O. M.							1																																	
Caloneis formosa (Greg.) Cl.							1																																	
Diploneis didyma (E.) Cl.						1	2																																	
Triceratium antediluvianum (E.) Grun.				fr.	2	+																																		
Amphora commutata Grun.						+																																		
Anomoeoneis sculpta (E.) Cl.						r																																		
Caloneis amphisbaena v. *subsalina* Donk.						1																																		
Gyrosigma Spencerii (W. Sm.) Cl.						c																																		

Cymbella caespitosa (Kz.) A. Cl.					r	r																																		
Melosira lineata Kz. (= *Borreri Grev.*)						+																																		
Diploneis interrupta (Greg.) Cl.						2																																		
Diploneis Smithii (Bréb.) Cl.						2																																		
Mastogloia Smithii Thw.		2	c	r	r																																			

Table III (fresh water species).

Epithemia sorex Kz.				—	c	+			r				1																										1	
Gyrosigma attenuatum (Kz.) Cl.				+	c			—					2								1					2			1	1								1		
Cymbella cymbiformis (Ag.) Kz.				r	r	r												1																				1		
Melosira islandica subsp. *helvetica* O. M.											2	2	1	2	2	7						4		1	2	1	1		2		3	1		4	3		8			
Campylodiscus hibernicus E.				r	+	c		r	1								fr.					1				1											1			
Cocconeis placentula E.				cc	cc	cc	1										r					2				4									1					
Epithemia proboscidea Grun.				cc	cc	c		—	r			1										1				5				1					1					
Cocconeis pediculus E.																																		1						
Didymosphenia geminata (Lyngb.) M. S.				+																														1						
Epithemia Hyndmanii W. Sm.																																		1						
Epithemia zebra (E.) Kz.			1	c	cc	c		1	5				1										1		1	1				1				1						
Epithemia alpestris W. Sm.				+	1							1														1				1	1									
Cymbella lanceolata E.					+	c		r														1	1			1			1	1										
Cymatopleura elliptica v. *nobilis* Htz.				r	+	r																								1										
Amphora ovalis Kz.			1	r	c	+	1	2		2							1									1			1	1										
Epithemia turgida (E.) Grun. with v. *granulata* (E.) Grun.				c	cc	c		1			1		1									2							1											
Cymbella turgida Greg.																										1														
Cymbella helvetica Kz.				c	c	+		2																		1														
Rhopalodia gibba (E.) O. M.				c	r	r		2	1																1															
Cymbella balatonis Grun.																						1																		
Cymbella leptoceros (E.) Grun.				c	r	r			1				1									1																		
Cymbella parva (W. Sm.) Cl.				+	r	+			c				1																											
Navicula vulpina Kz.				r	1							1																												
Cymbella ventricosa Kz.									1																															
Achnanthes Hauckiana Grun.								r																																
Amphora libyca E.				r	+	r		r																																
Cyclotella antiqua W. Sm.				r	—			1																																
Navicula oblonga Kz. with v. *lanceolata* Grun.				+	—	c		2																																

	468	481	487	493	494	495	497	501	506	511	515	516	517	520	522	524	527	529	532	534	535	536	538	539	541	542	544	545	547	548	549	550	552	553	554	555	557	559	560	562
Navicula gracilis E.						—																																		
Navicula viridula Kz.						r																																		
Navicula hungarica v. *capitata* (E.) Cl.						2																																		
Caloneis silicula subsp. *limosa* v. *inflata* (Grun.) May.						1																																		
Pinnularia sudetica Hilse.				r	1	1																																		
Nitzschia linearis W. Sm.					r	—																																		
Navicula tuscula E.					r	2																																		
Navicula rhyncocephala Kz.				r		r																																		
Navicula radiosa Kz.				+	r	r																																		
Synedra ulna v. *biceps* (Kz.) and v. *danica* (Kz.)				r		+																																		
Cymbella robusta A. Cl.				r	—	r																																		
Cymatopleura solea W. Sm.					1	2																																		
Stauroneis phoenicenteron E.				r		r																																		
Amphora pediculus Kz.				+	+	r																																		
Denticula sp.					2																																			
Navicula cuspidata Kz.					1																																			
Synedra capitata E.				r	2																																			
Pinnularia major Kz.				r	1																																			
Gomphonema constrictum E.				2	r																																			
Cymbella Ehrenbergii with v. *delecta* A. S.				r	r																																			
Cymbella affinis Kz.				r	r																																			
Cymbella angustata (W. Sm.) Cl.				r																																				
Cymbella Cesarii (Rbh.) Grun.				r																																				
Cymbella cistula Hempr.				r																																				
Gomphonema acuminatum v. *pusilla* Grun.				1																																				
Fragilaria construens (E.) Grun.		r	c	r																																				
Mastogloia lacustris (Grun.) A. Cl.			+																																					
Epithemia Mülleri Fricke		1																																						
Pinnularia cardinalis E.		1																																						

An asterisk in front of names indicate Arctic index species r Single specimens — Rare + Fairly common c Common—abundant cc Very abundant

8. Concluding summary.

The main purpose of the present investigation is to date the *Balanus hammeri* zone. By this procedure a great outflow of water is also dated (cf. introduction).

The dating of the *B. hammeri* zone by means of pollen analysis is somewhat vague and needs therefore, if possible, to be made more precise by means of other data indicative of the age.

As mentioned above (p. 8) the morainic substratum of the clay layer (uppermost part just below sample 563) was deposited when the Land-Ice had receded about 2 km from the Tanum-Svarteborg terminal moraine (which seems to be the northern continuation of the Göteborg moraine, cf. p. 8). The very poor sorting of the sediment in the bottom part of the clay as well as the rich and current wanting fauna included indicate that the Ice margin was just in the vicinity during this time (p. 8 and 11).

The amelioration of climate which seems to have occurred at that time (high *Betula* values) is possibly identical with the Alleröd period in v. POST's conception, which according to him probably appeared just after the formation of the Göteborg moraine (p. 7).

We have further suggested that a deterioration of climate which may have caused the formation of the Bullaren-Krokstad-Vänersborg terminal moraine is traceable in the present stratal sequence (samples 540—546). This consideration is based on the following facts:

1. The production of arboreous pollen became partly low, possibly indicating a climatic deterioration.

2. The sediment became rather poorly sorted after having been well sorted during the previous accumulation of the *B. hammeri* bed. The small-sized fractions increased, probably indicating that the outflow from the Ice had diminished (argumentation p. 9), i. e. the Ice border became stationary.

3. Animals indicating lively current action (cf. p. 11) vanished entirely at sample 545 after having been in part numerous from the beginning of the sedimentation of the clay layer. This certainly means that the outflow of melting water became too weak to raise reaction currents (i.e. the Ice border became stationary).

As *B. hammeri* is most abundant just below this section the *B. hammeri* stratum must be concluded to have been formed when the Ice, on its recession from the Tanum-Svarteborg moraine, had nearly reached this stationary position of the Ice border, which is most probably the Bullaren-Krokstad moraine.

A question now is, where did the many freshwater diatoms of the marine clay come from. CLEVE-EULER considered them to be derived from a large lake (p. 12). This lake might thus have occurred somewhere eastwards and have disembogued in this area. But such a lake may scarcely have existed since the Ice front stood just in the vicinity. The diatoms may, in fact, have lived in the surface layer of the sea outside the Ice. Great quantities of freshwater must have been stored there, especially during periods of intense melting.

MOHRÉN, who found freshwater diatoms in late-Glacial marine clays in Göteborg, alleged reasons for the conception that the surface layer of the sea consisted of freshwater to such an extent that freshwater diatoms could live there (1945, p. 260).

Indications of the further development during the marine stage support the dating of the *B. hammeri* horizon now deduced.

A period of climatic amelioration, indicated by the *Betula* frequency being high, arboreous pollen rather abundant, the open soil species *Artemisia* infrequent or absent, has possibly occurred during the retreat of the Ice to the Middle Swedish moraines. The following section (samples 516—528) is characterized by a mainly low frequency of arboreous pollen and a slight increase of *Artemisia*, and on that account it may have been developed during a climatic deterioration, not unlikely that which gave rise to the Middle Swedish terminal moraines. Freshwater diatom frequency was low in this period and that of planktonic marine diatoms was high, i.e. the outflow of melting water seems to have decreased. The granulometric composition of the sediment was scarcely influenced, however, by the diminished outflow, which may mean that the distance to the Ice border had now become rather great.

9. On other Balanus hammeri deposits of the Swedish west coast.

Some of the many *B. hammeri* deposits of the Swedish west coast have been dated previously.

One deposit was dated by SANDEGREN (pollen analysis), viz. that of Nol at the Göta älv (ALIN and SANDEGREN 1947, p. 31). SANDEGREN referred the stratum which includes *B. hammeri* to the Alleröd period. It is of interest to note that freshwater diatoms of the same type as in the locality here investigated occur together with *B. hammeri* and continued to be deposited after the formation of the *B. hammeri* stratum just as at Klingseröd.

ASKLUND dated two *B. hammeri* deposits in Halland by means of pollen analyses (1936, p. 83 f.). One sample from each locality was investigated. The deposits were referred to the Alleröd period, but whether this is correct is hardly possible to decide, because of the fact that only one sample from each locality was analysed.

ASKLUND (1936) has pointed out that *B. hammeri* is very abundant in late-Glacial deposits of Halland. These interesting deposits should be investigated by means of series of analyses of pollen and sediment, as well as of fauna and diatoms. Important knowledge may thus be obtained about those outflows which obviously caused the formation of the *B. hammeri*-bearing strata. Many of the strata were probably accumulated just outside the Ice front (cf. above, p. 4), such as the Ågård stratal sequence (ASKLUND 1936, p. 8). The bottom-most stratum which includes *B. hammeri* and several carnivorous gastropods but not *Portlandia arctica* (GRAY) is a sand-mixed clay. The evidently rather coarse sediment and the fauna may indicate that the Ice front was in the vicinity. Such surroundings may be tolerated by *B. hammeri* but are not favourable for *P. arctica*. The overlying stratum is a roughly laminated clay lacking *B. hammeri; Balanus balanus* L., *Macoma calcarea* (CHEMNITZ), *Saxicava arctica* L., and two carnivorous gastropods are still present. The Ice front may have receded somewhat from Ågård at that time, and the water may have become less saline judging from the lamination. Diminution of salinity must have continued, however, resulting in an overlying minutely laminated glacial clay. The distance to the Ice front seems to have increased, and the Kattegatt basin may have been filled with melt-water. *P. arctica* appears in this sediment which is exactly of the type where it can be expected to occur.

ODHNER (1927) dated the large *B. hammeri* beds at Uddevalla in an inductive way; he interpreted them to have been formed when a great outflow of water through the ancient Vänersborg-Uddevalla sound took place. He could not precisely calculate the age of the beds, but pointed out that their formation may have begun at the first drainage of the Baltic Ice Lake and possibly continued to the Ancylus period (1927, p. 79).

A more accurate dating may be possible, however. The great shell beds do not offer datable stratal sequences, but *B. hammeri* also occurs in probably pollen-bearing clay layers, accessible in many parts of that town.

CLEVE-EULER (1947, p. 101) interpreted the Uddevalla beds as having been formed at a transgression which she thought to have occurred at the beginning of the last glaciation when Scandinavia was depressed on account of the heavy ice sheet load. Thus, Bohuslän should have been practically non-glaciated and covered by the sea during the last glaciation.

This interpretation is scarcely tenable, however. If Bohuslän should have been inundated such as just mentioned, glacigene layers from previous glaciations resting on the Archaean plateaus should have been transported mainly eastwards by waves and surf and have been deposited east of the plateaus. Shells of *fjaer* organisms (especially *Balanus balanoides*) living on the plateaus during the beginning of the transgression should have been carried there, and thereafter, as the water deepened, organisms from the algal biocoenoses of the plateaus. Further on, soft bottom endobiotopes might have been developed on the top of the shell beds. But such a sequence of strata was never observed during my investigation of N. Bohuslän shell beds in 1943, nor, as far as I know, by any other student. The opposite stratal sequence is encountered, on the contrary, which shows that the shell beds were formed during the regression after the last glaciation.

Concerning the origin of the Uddevalla *B. hammeri* beds; they were scarcely formed during a transgression. The premises for this suggestion as presented by CLEVE-EULER in 1926, and still held in 1947, are not applicable in this case. No transgression is required, according to the able and certainly correct interpretation of their genesis by ODHNER. Nor do transgressive sequences of strata, such as mentioned above, occur.

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Bibliography.

ALIN, J. 1944. Förmodade gotiglaciala boplatser i Göteborgstrakten. Geol. Fören. Förh. Bd. 66, H. 3. Stockholm.

ALIN, J., and SANDEGREN, R. 1947. Dösebackaplatån. Sv. Geol. Unders. Ser. C, No. 482. Stockholm.

ASKLUND, B. 1936. Den marina skalbärande faunan och de senglaciala nivåförändringarna. Sv. Geol. Unders. Ser. C, N. 393. Stockholm.

BERLIN, H., and MOHRÉN, E. 1942. Zwei Riesenhirschfunde aus Südschweden. Lunds Geol. Fältklubb. Lund.

BROCH, H. 1924. *Cirripedia thoracica* von Norwegen und dem norwegischen Nordmeere. Videnskapsselsk. Skr. I. Mat.-Nat. Kl. No. 17. Kristiania.

CLEVE-EULER, A. 1926. Skalbankar och nivåförändringar i Skageracksområdet. Geol. Fören. Förh. Bd. 48, H. 3. Stockholm.

—— 1939. Allerödstadier och senglacial utveckling i det södra Östersjöområdet. Ibid. Bd. 61, H. 3. Stockholm.

—— 1946. Om den sista landisens bortsmältning från Södra Sverige, den s. k. Baltiska issjön, tappningarna vid Billingen och Degerfors samt Vätterns historia. Stockholm.

CLEVE-EULER, A. 1947. Zur Geographie der Eiszeit und zur spätglazialen Entwicklung des Nordens, besonders Schonens. Bull. Geol. Inst. Upsala. Vol. XXXII. Uppsala.

CLEVE, P. T., and GRUNOW, A. 1880. Beiträge zur Kenntnis der arctischen Diatomeen. K. Svenska Vet. Akad. Handl. Bd. 17, No. 2. Stockholm.

ELOFSON, O. 1941. Zur Kenntnis der marinen Ostracoden Schwedens. Zool. Bidr. Uppsala. Bd. 19. Uppsala.

ERDTMAN, G. 1943. Pollenspektra från svenska växtsamhällen jämte pollenanalytiska markstudier i det södra Lappland. Geol. Fören. Förh. Bd. 65, H 1. Stockholm.

—— 1946. Palynologiska synpunkter på pioniärfasen i den svenska florans invandringshistoria. Sv. Bot. Tidskr. Bd. 40, H. 3. Stockholm.

FÆGRI, K. 1945. Pollenanalysen. Viking. (Norsk Arkeol. Sällsk.). Oslo.

FLORIN, M.-B. 1944. En sensubarktisk transgression i trakten av södra Kilsbergen enligt diatomésuccessionen i områdets högre belägna fornsjölagerföljder. Geol. Fören. Förh. Bd. 66, H. 3. Stockholm.

FLORIN, S. 1944. Havsstrandens förskjutningar och bebyggelseutvecklingen i östra Mellansverige under senkvartär tid. Geol. Fören. Förh. B. 66, H. 3. Stockholm.

GOËS, A. 1894. A synopsis of the arctic and Scandinavian recent marine Foraminifera. K. Svenska Vet. Akad. Handl. Bd. 25, No. 9. Stockholm.

HÄGG, R. 1948. Några meddelanden om kvartära och recenta cirripeder. Geol. Fören. Förh. Bd. 70, H. 2. Stockholm. (Literary data on Quaternary distribution of *Balanus hammeri* collected in this paper.)

HESSLAND, I. 1943. Marine Schalenablagerungen Nord-Bohusläns. Bull. Geol. Inst Upsala. Vol. XXXI. Uppsala.

JENSEN, A. S. 1942. Two new Greenland localities for deposits from the Ice Age and the post-glacial warm period. K. Danske Vid. Selsk. Biol. Medd. Bd. XVII, No. 4. København.

MOHRÉN, E. 1945. Något om de hydrografiska förhållandena i Göteborgstrakten vid övergången mellan sen- och postglacial tid. Geol. Fören. Förh. Bd. 67, H. 2. Stockholm.

MUNTHE, H. 1941. Om Nordens, främst Baltikums, senkvartära utveckling och stenåldersbebyggelse. K. Svenska Vet. Akad. Handl. Ser. 3, Bd. 19, No. 1. Stockholm.

——, JOHANSSON, H. E., and SANDEGREN, R. 1924. Göteborgstraktens geologi. Göteborg.

NILSSON, T. 1935. Die pollenanalytische Zonengliederung der spät- und postglazialen Bildungen Schonens. Geol. Fören. Förh. Bd. 57, H. 3. Stockholm.

NORDMANN, V. 1940. De danske Anskuelser om Allerødlagene. Geol. Fören. Förh. Bd. 69, H. 2. Stockholm.

ODHNER, N. 1927. Några fakta till belysning av skalbanksproblemet. Geol. Fören. Förh. Bd. 49, H. 1. Stockholm.

—— 1930. Skalbankarna vid Uddevalla. Naturens Liv. H. 10 and 11. Stockholm.

VON POST, L. 1947. Hallands marina fornstränder. Geol. Fören. Förh. Bd. 69, H. 3. Stockholm.

—— 1947 a. Viskaundersökningens resultat (Results of the Viskan Valley investigation). Ibid. Bd. 68, H. 2. Stockholm.

SANDEGREN, R., and JOHANSSON, H. E. 1931. Beskrivning till kartbladet Göteborg. Sv. Geol. Unders. Ser. Aa, No. 173. Stockholm.

SANDEGREN, R. 1943. Hippophaë rhamnoides L. i Sverige under senkvartär tid. Sv. Bot. Tidskr. Bd. 37, H. 1. Stockholm.

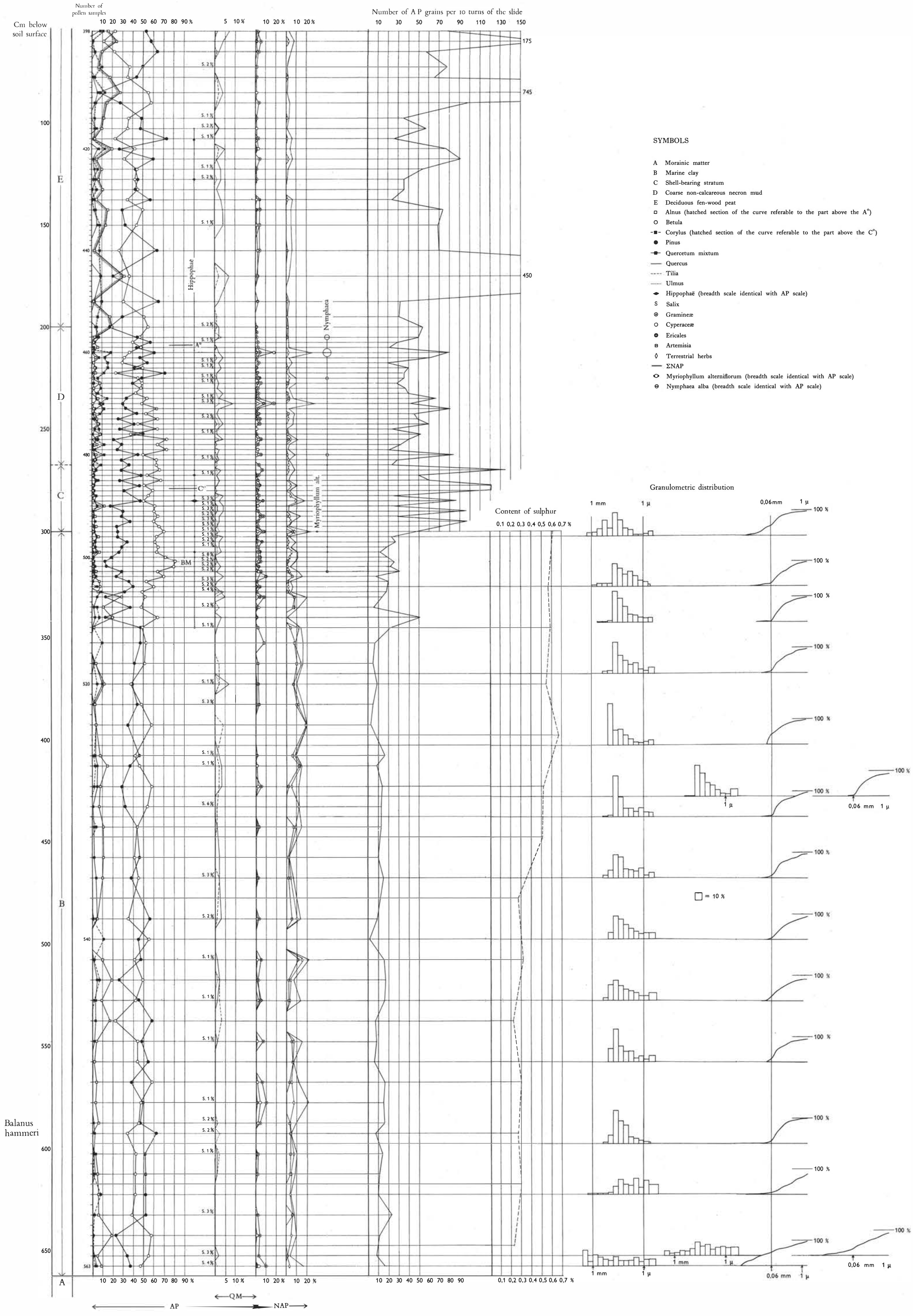
SARS, G. O. 1925—1926. An account of the Crustacea of Norway. Vol. IX. Parts IX—XIV. Bergen.

STEPHENSEN, K. 1933. Havedderkopper og Rankefødder. Danmarks Fauna, 38. København.

WHITEAVES, J. F. 1901. Catalogue of the marine invertebrata of Eastern Canada. Geol. Surv. Canada. Ottawa.

Plate I.

Stratal sequence of the *Balanus hammeri* bearing locality, pollen diagram, sulphur content, and granulometric distribution. A. Morainic matter. B. Marine clay. C. Shell-bearing calcareous freshwater layer. D. Coarse non-calcareous necron mud. E. Deciduous fen-wood peat.


Cm below soil surface
Number of pollen samples
10 20 30 40 50 60 70 80 90 %
5 10 %
10 20 %
10 20 %
Number of AP grains per 10 turns of the slide
10 30 50 70 90 110 130 150
175
745
450
100
150
200
250
300
350
400
450
500
550
600
650
398
420
440
460
480
500
520
540
563
E
D
C
B
A
Hippophae
Nymphaea
Myriophyllum alt.
A°
C°
BM
S. 1 %
S. 2 %
S. 3 %
S. 4 %
S. 5 %
S. 6 %
Balanus hammeri
SYMBOLS
A Morainic matter
B Marine clay
C Shell-bearing stratum
D Coarse non-calcareous necron mud
E Deciduous fen-wood peat
□ Alnus (hatched section of the curve referable to the part above the A°)
○ Betula
-■- Corylus (hatched section of the curve referable to the part above the C°)
● Pinus
—■— Quercetum mixtum
—— Quercus
---- Tilia
······ Ulmus
◆ Hippophaë (breadth scale identical with AP scale)
S Salix
⊙ Gramineæ
○ Cyperaceæ
● Ericales
⊟ Artemisia
◊ Terrestrial herbs
—— ΣNAP
⬭ Myriophyllum alterniflorum (breadth scale identical with AP scale)
⊖ Nymphaea alba (breadth scale identical with AP scale)
Granulometric distribution
Content of sulphur
0,1 0,2 0,3 0,4 0,5 0,6 0,7 %
1 mm
1 µ
0,06 mm
100 %
□ = 10 %
10 20 30 40 50 60 70 80 90
AP
QM
NAP