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# LATE WEICHSELIAN MARINE SEDIMENTS CONTAINING SHELLS, FORAMINIFERA, AND POLLEN, AT ÅGOTNES, WESTERN NORWAY

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Marine sediments, mainly clay and silt, deposited at a water depth of 20–30 m are described. The base of the succession is radiocarbon dated to 12,220 ± 150 B.P., the upper part to 10,230 ± 180. The shells indicate water temperatures similar to those of northern Norway today. These shells and shells from other localities suggest that warm Atlantic water entered the Norwegian Sea prior to 12,600 B.P. The pollen diagram from the sediments has the same main trends as in diagrams from limnic sediments covering the same period, except for high percentages of *Alnus*. The age and correlation of several Late Weichselian events are discussed.

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Large areas of Hordaland were deglaciated during the Allerød Chronozone (Figs. 1 and 14) (Mangerud 1970, 1972 b, Aarseth & Mangerud 1974). Later, during the Younger Dryas Chronozone, the ice front re-advanced by at least 40 km. The maximum extent of the inland ice during this re-advance is marked by the Herdla moraines (Aarseth & Mangerud 1974).

The Ågotnes locality discussed in the present paper lies 2–3 km outside the Herdla moraines (Fig. 1), and includes sediments of both Allerød and Younger Dryas age.

The stratigraphical terminology used here is in accordance with the proposals of Mangerud et al. (1974). The boundaries of the chronozones (Younger Dryas, Allerød, etc.) are defined in conventional radiocarbon years.

## The Ågotnes locality

The coast of Hordaland, including Sotra, is characterized by bare bedrock. Loose, Quaternary sediments are mainly found in topographical depressions. Investigation of these sediments is usually possible only by coring. In the investigated locality, an excavated section was accessible for just one day in the summer of 1970. Field work was, however, limited by dangerous slides in the clayey sediments.

The locality is situated on the landward side of the island Sotra (Figs. 1 and 2), close to the shore of Hjeltefjorden, however, only 6 km from the open North Sea.

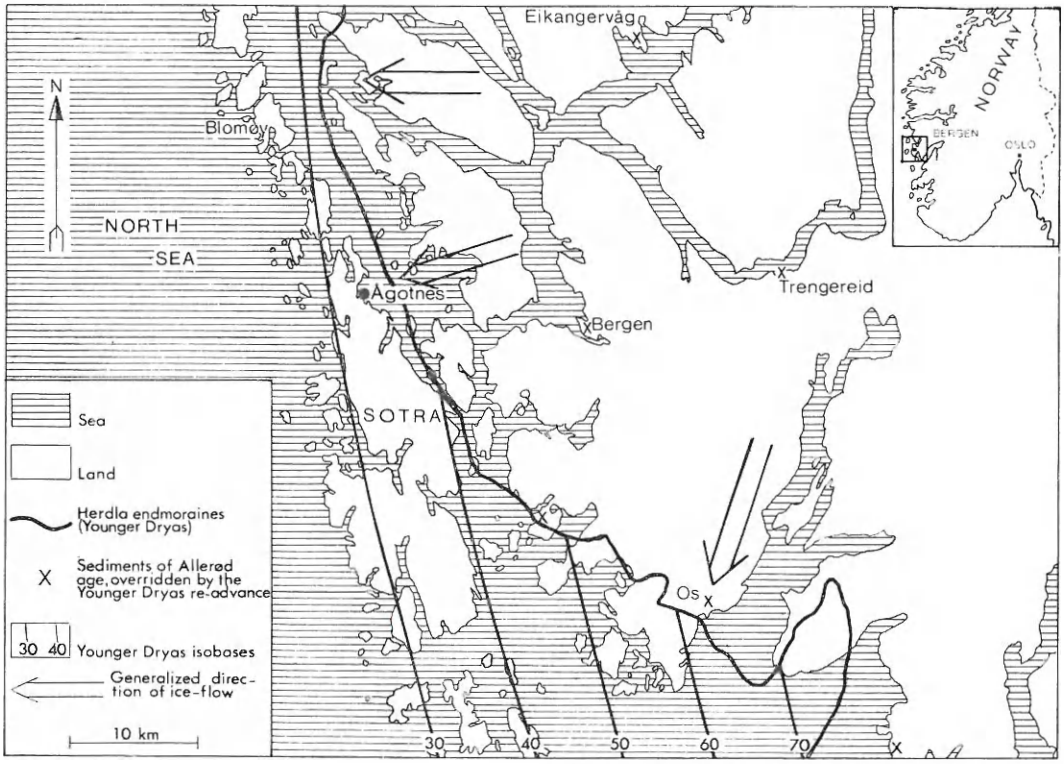


Fig. 1. Location of the Ågotnes locality in Hordaland. Younger Dryas isobases are extrapolated from Aarseth & Mangerud (1974, fig. 11).

It lies on a small peninsula (Fig. 2), with a maximum height of 29 m a.s.l. From the highest point the bedrock, with small patches of till and littoral sand, slopes gently eastward towards the investigated locality (Fig. 3) at ca. 12 m a.s.l.

The bedrock is gneiss, forming small escarpments with crests parallel to the NNW strike, and dip slope inclined eastwards. The locality lies at the foot of one of these escarpments (Figs. 3 and 4).

Details of the locality are shown at Figs. 4 and 5. The sediments were best exposed in the southern wall of the excavation, and the sequence in this wall is shown at Fig. 6.

## Grain-size analysis

Particles above 16 mm were excluded from the analysis, those coarser than 0.063 mm were sieved, with a sieve interval of one phi unit. The finest (< 0.063 mm) were analysed by the pipette method, with readings for each phi unit. In all samples organic material was removed with $H_2O_2$ before analysis.

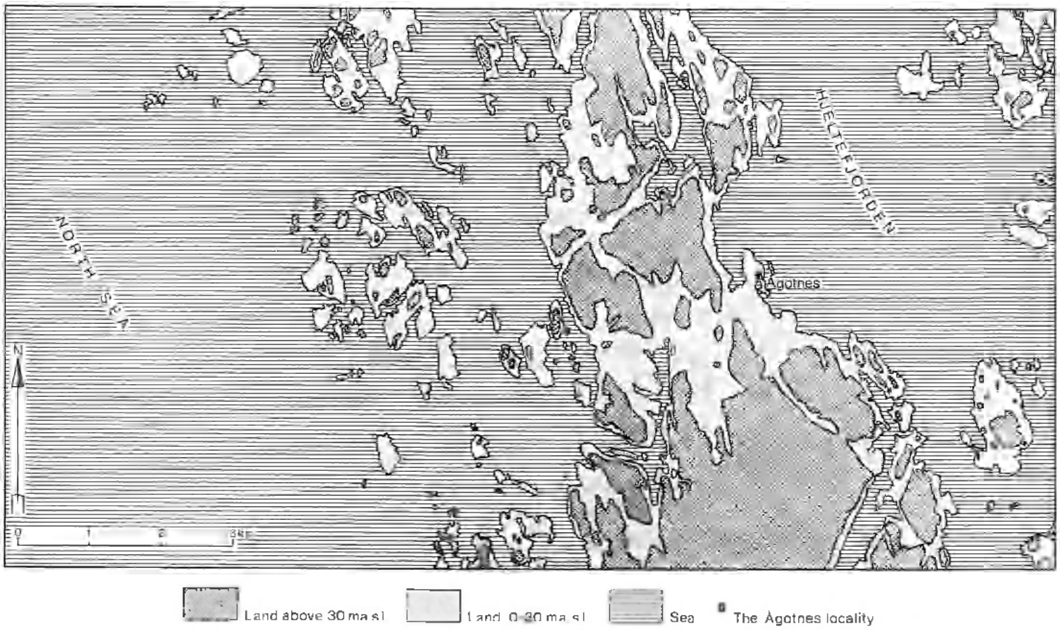


Fig. 2. Map of the area around Ågotnes. During the Late Weichselian the sea level was approximately 30 m above that of the present day, and the map therefore gives an impression of the contemporary paleogeography.

Fig. 3. Photography of the Ågotnes locality after construction work had removed most of the sediments described. The bedrock wall is thus man-made. The photograph is taken towards the summit of the peninsula (NW). The northern edge of the sediments is marked with stippled line along the base.

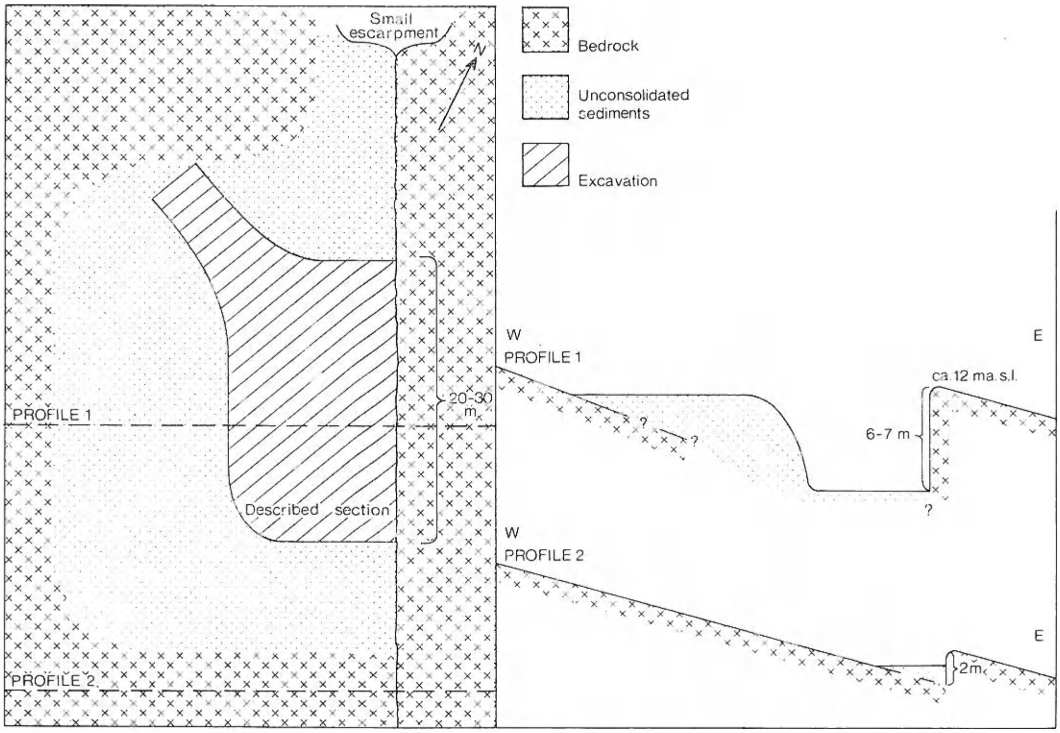


Fig. 4. To the left sketch map of the Ågotnes locality. To the right the geological profiles. The 'described section' indicated on the map is shown in Fig. 6.

In Norway a modified Wentworth scale proposed by Doeglas (1968, fig. 1) is now used, and this scale is applied here (Fig. 7).

McCammon (1962) and Folk (1966) discussed the efficiency of the different parameters used for grain-size distribution. However, in routine analysis of fine-grained sediments, one does not always obtain the necessary percentiles for the most efficient parameters. In the present study, I have therefore used the measure of Folk & Ward (1957) for the mean grain size:

$M_Z = (\Phi 16 + \Phi 50 + \Phi 84)/3$,

and that of Inman (1952) for sorting (standard deviation)

$S = (\Phi 84 - \Phi 16)/2$.

Even so, to obtain the value for Φ16, some curves had to be extrapolated.

Selmer-Olsen (1954) analysed a large number of Norwegian Quaternary sediments of different geneses, and presented the results in a useful Md – So diagram. In order to compare the sediments from Ågotnes with his results, I have constructed a similar diagram (Fig. 9), assuming that

$M_Z = Md$

and recalculating the sorting coefficient

$$So = \log_{10} \frac{Q75}{Q25}$$

Fig. 5. Photograph of the excavation taken towards the SE. The main section shown in Fig. 6 is in the shadow, with the bedrock wall to the left.

of Selmer-Olsen (1954) to be related to the standard deviation expressed in phi units (S):

$$S = 2.46So$$

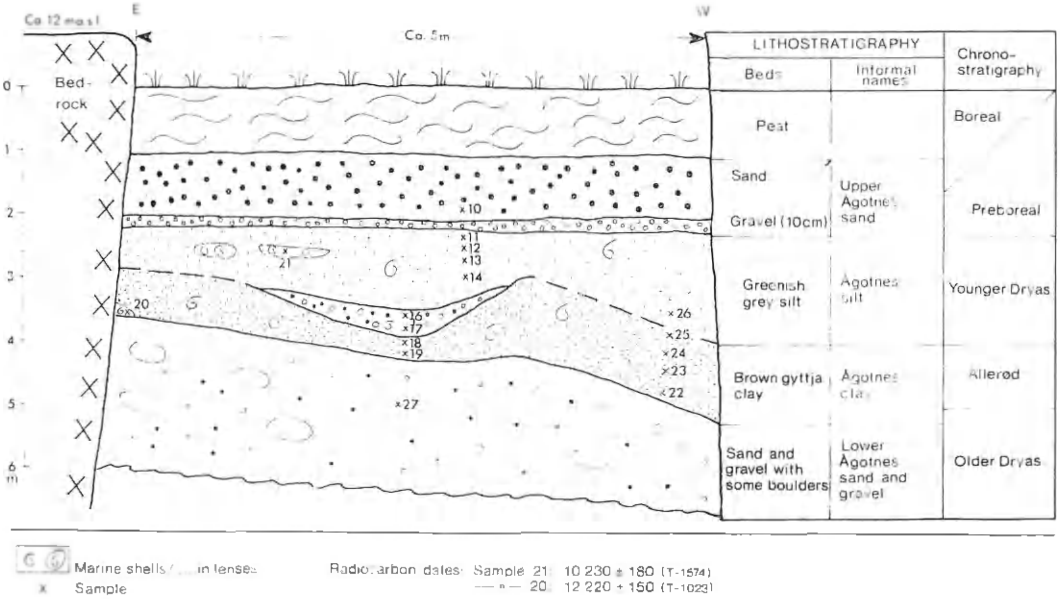


Fig. 6. The described section. The position for all samples discussed is given in numbers.

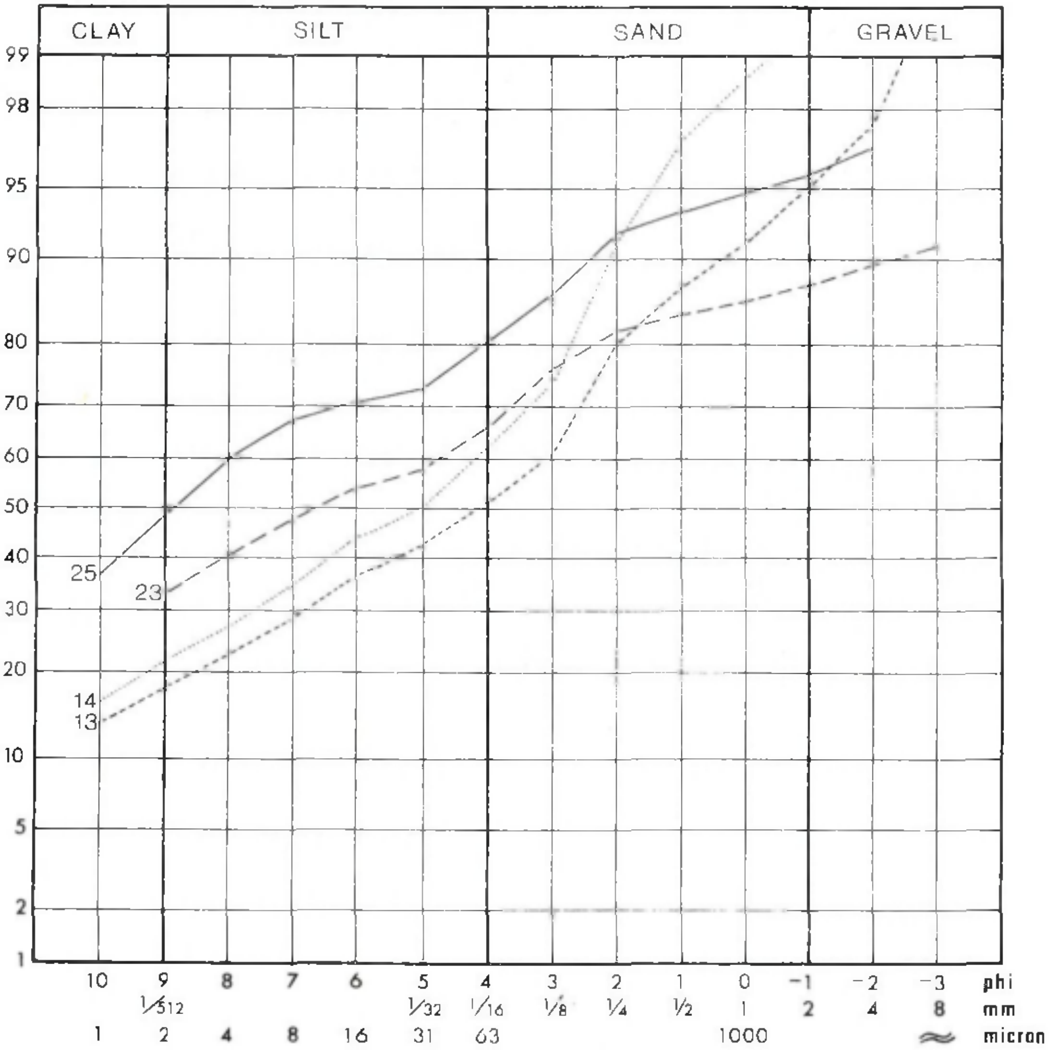
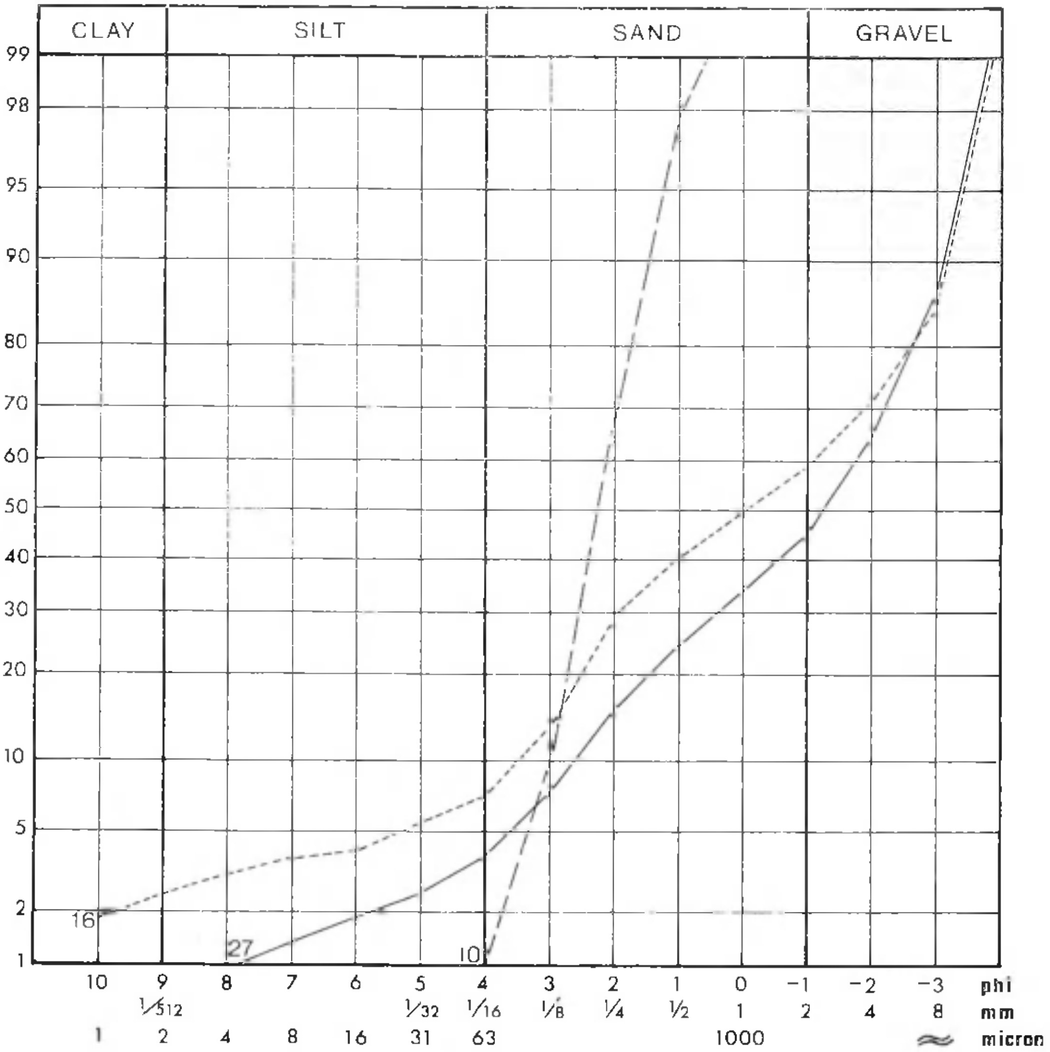


Fig. 7. Grain-size distribution. Cumulative curves on probability-paper. For locations of samples, see Fig. 6. Sample 27: Sand and gravel in the bottom of the excavation. Sample 16: The lense of sand and gravel between Ågotnes clay and Ågotnes silt. Sample 10:

## The sediment sequence

The sequence consist of 5 main units (Fig. 6). At the base is a bed of sand and gravel at least 2 m thick, followed by a ca. 1 m thick bed of brown gyttja clay, with a gradual upward transition to a bed of greenish grey silt. Marine shells are frequent in both the clay and silt beds.

Above the silt is a 1 m thick bed of well-sorted sand (sample 10, Fig. 7) with a thin underlying bed of gravel. This sand is a littoral sediment, deposited during the Holocene uplift. The sequence is capped by a 1 m thick bed of peat of Holocene age.



Upper Ågotnes sand. Sample 23 & 25: Brownish gyttja clay (Ågotnes clay). Sample 13 & 14: Greenish grey silt (Ågotnes silt).

All the beds are physically restricted to the small depression, and I will therefore not define any formal lithostratigraphic units. For the correlation with other sequences, the name Ågotnes is, however, attached to each bed (Fig. 6) in an informal nomenclature (Hedberg 1970:16).

### *The sand and gravel (lower Ågotnes sand and gravel)*

This bed was poorly exposed, partly because the overlying sediments constantly slumped down, and partly because the bottom of the excavation was filled with water. In the northern part the sand and gravel were seen in direct contact with the bedrock, and I assume this to be the case also in the deeper parts of the pit, though possibly with a veneer of till between the bedrock and this bed. It consists mainly of very poorly sorted sand and gravel (sample 27, Fig. 7). However, some boulders were also found throughout the bed, and near the bedrock wall (to the east in Fig. 6) the boulders dominate. All the pebbles are angular or sub-angular, suggesting a short distance of water transport. An encrustation of calcareous algae was observed on some pebbles.

I assume that this bed was deposited more or less directly from the glacier front, followed by some rolling and sliding on the sea floor. From other field observations in Hordaland the water depth during the deposition can be estimated to 20–30 m.

### *The brown gyttja clay (Ågotnes clay)*

This was the most striking sediment of this sequence as marine sediments from the deglaciation period very seldomly have brownish colours. Shells occur frequently throughout the bed, giving clear evidence of its marine origin. The shells occurred partly in small lenses, and partly as isolated individuals, many of them in growth positions. The variable thickness of the bed, from 30 cm up to 100 cm, and the variable strike and dip of some internal bedding planes are to be expected in such a small sedimentary basin. However, due to the slumping, it was not possible to map the internal structures.

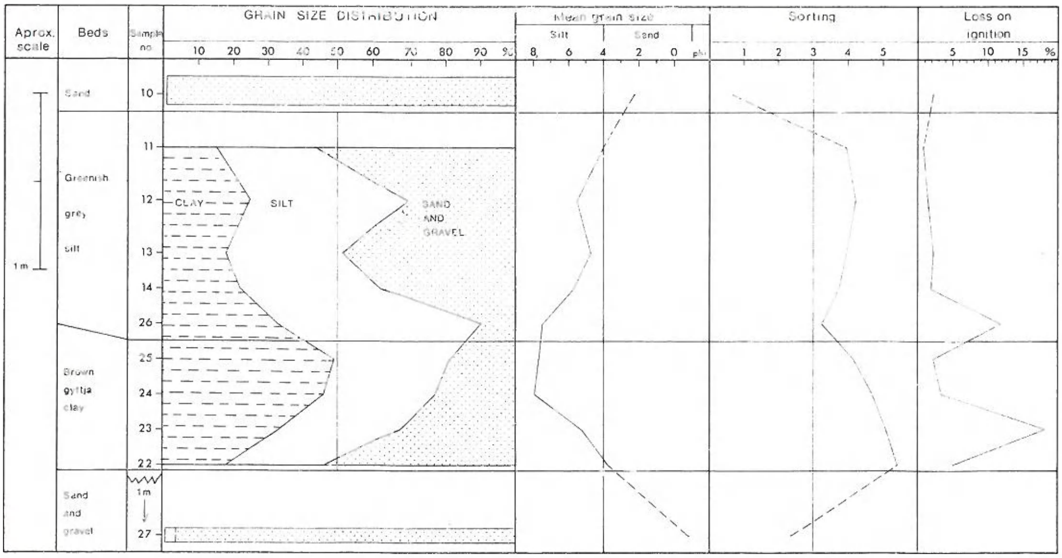


Fig. 8. Parameters of grain-size distributions and losses on ignition for some of the samples arranged in stratigraphical order (Fig. 6). The same samples were used in the pollen analysis (Fig. 12).

The brownish colour is most probably caused by the high content of organic material. The loss on ignition (Fig. 8) is generally higher in the brown Ågotnes clay than in the greenish grey silt above. From the well-defined difference in colour, one should have expected even more consistent differences in organic content between samples from the two beds.

The sediments in the Ågotnes clay are very poorly sorted (Figs. 7 and 8), being mixtures of gravel, sand, silt and clay. Even some cobbles and boulders were observed. Thus the term Ågotnes clay is used for the bed as a whole and because of the high clay content.

In the middle of the section (Fig. 6) a lens of sand and gravel (sample 16, Fig. 7) occurs between the Ågotnes clay and the Ågotnes silt, indicating an unstable sedimentary environment. Most probably this is a slump deposit from shallower water sediments. Below this lens the Ågotnes clay is thinner, partly due to compaction, but probably mainly as a result of erosion.

### *The greenish grey silt (Ågotnes silt)*

The boundary between the Ågotnes clay and the Ågotnes silt is a smooth transition, showing no hiatus, and indicating that the depositional environment changed gradually. The Ågotnes silt is 50–120 cm thick, and has a very sharp boundary with the overlying gravel.

Marine shells occur also in this bed, but less frequently than in the Ågotnes clay.

The sediment of the Ågotnes silt is poorly sorted (Figs. 7 and 8), although the sorting is better than in the clay below (Figs. 8 and 9). Some cobbles and boulders were observed.

### *The genesis of the Ågotnes clay and silt beds*

As stated above, there can be no doubt that both beds are marine. The sediments are very poorly sorted, compared with normal marine sediments (Fig. 9). Some of the samples had a considerable content of calcareous marine organisms, and to find the influence of these on the grain-size distribution, the $CaCO_3$ in 4 samples was removed with 10 % HCl. It can be assumed that this treatment did not influence the mineral particles significantly, as limestones do not occur in the bedrock. The $CaCO_3$ was mainly found in the clay fraction, the result of treatment being that the mean grain size increased somewhat, and the sorting became considerably better (Fig. 9). One must, however, realize that some of the $CaCO_3$ removed was biogenetic material deposited as sedimentary particles, and that the grain size distribution of the physically deposited sediment, probably lay somewhere between the curves of the HCl-treated and untreated samples. (Sylvi Haldorsen (pers. com.) has later found that several clay minerals were also dissolved in the HCl-treatment, and my conclusions on the $CaCO_3$ content are therefore erroneous.)

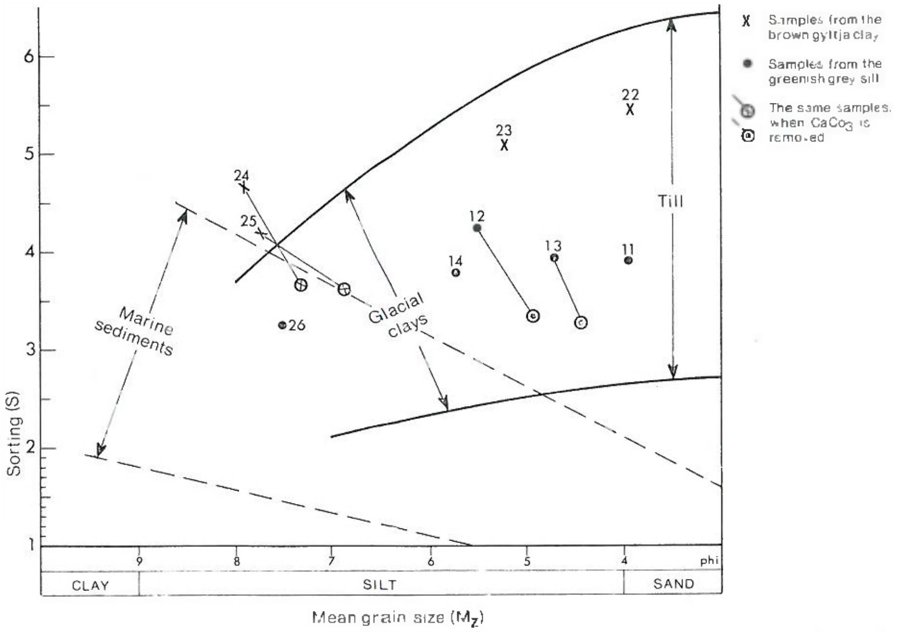


Fig. 9. Mean grain size versus sorting (= standard deviation) from the Ågotnes clay and Ågotnes silt. The boundaries found by Selmer-Olsen (1954) for some sediment types are indicated. His values for sorting and median are recalculated according to formulas given on p. 26.

The sediments studied were deposited in a depression with a diameter of approximately 50 m. From the summit of the peninsula situated approximately 200 m away, there is a gentle slope down into the depression (Fig. 3). With higher sea level prevailing at the time of deposition, this depression must have acted as a sediment trap, retaining particles rolling, or slumping down the sea floor, in addition to the deposition of fine particles from suspension. This probably explains the grain-size distribution of these sublittoral sediments: The water was calm enough for the deposition of clay, but nevertheless there was a supply of coarser particles.

The relative sea level may have fluctuated some metres during the sedimentation period. Although this cannot be substantiated, it is clear that in this sublittoral environment, with water depths of 20–30 m, sedimentation was very sensitive to variation in the sea level, and the vertical variation in the grain sizes may partly be due to sea-level variations. The infilling of the depression itself is also of importance. The decreasing content of clay may simply be a result of the decreasing depth of the depression. I also presume that the top of the Ågotnes silt is determined by this infilling, and later wave erosion.

The influence of the glacier on the sedimentary environment is very difficult to interpret. Nevertheless, the parallelism for the curves of grain-size distribution (Fig. 8 to the left) and pollen (e.g. *Betula*, Fig. 12) is striking and indicates a climatic (glacial) influence on the supply of mineral particles.

The colours also indirectly depend on climate, as the brown Ågotnes clay is from the Allerød Chronozone, while the greenish grey Ågotnes silt is from the Younger Dryas, with advancing glaciers (Fig. 14).

As mentioned, the lower Ågotnes sand and gravel were probably deposited close to the ice front. The sharp lithological boundary to the Ågotnes clay indicates that a hiatus exists, and the clay was probably deposited some tens of kilometres distant from the glacier front (see foraminifera p. 38). The colour reflects high organic production during the Allerød, and the upward change in colour the lower productivity during the climatic deterioration. During the Younger Dryas Chronozone, the ice advanced towards the locality, and stopped as a calving glacier in the fjord, only 2–3 km to the east. The sediments have not been disturbed by ice, and they have been used to prove that the ice advance did not reach this island (Aarseth & Mangerud 1974: 16). The increasing grain size upwards in the Ågotnes silt may partly be due to the approaching ice, through sediment supply from icebergs. Possibly, however, the sediments deposited during the period when the ice front was closest are lost in a hiatus at the top of the Ågotnes silt.

## Radiocarbon dates

Two radiocarbon dates have been obtained, both from marine shells. The datings were carried out at The University of Trondheim, Radiological Dating Laboratory. The calculation method used includes a correction of 410 years for the apparent age of sea water (Mangerud 1972b: 146). However, the apparent age of marine shells from the coast of Norway is 440 years (Mangerud & Gulliksen 1975), and the dates are therefore corrected for the additional 30 years. This additional correction could be ignored for the geological problems, but is significant for dates having a standard deviation of only 100–150 years. Other shell dates referred in this paper are corrected in a similar way, and should therefore be directly comparable with dates of terrestrial material. Also whale-bone dates are corrected for an apparent age of 440 years. The Libby half life of 5570 years is used for all dates.

Both samples of shells were rinsed in destilled water, and the outer 10–20 % removed in diluted HCl.

The first sample (sample 20, Fig. 6) was from a shell lense situated at the base of the Ågotnes clay, close to the bedrock wall, containing *Balanus* sp. and *Mya truncata.* Measurements of the stable carbon isotopes gave $\delta^{13}C = + 1.5‰$ rel. PDB. The dating result was (T – 1023): 12,220 ± 150 years B.P.

The second sample (sample 21, Fig. 6) was from a shell lens approximately in the middle of the Ågotnes silt. The dated shells were mainly of *Balanus balanus,* with a few pieces of *Mya truncata, Hiatella arctica,* and *Astarte elliptica.* The corresponding results of this sample were $\delta^{13}C = -0.2‰$ rel. PDB, the radiocarbon age being (T – 1574) 10,230 ± 180 years B.P.

The radiocarbon dates provide the most important information on the age of the sediments, and the results are indicated on the section (Fig. 6), the pollen diagram (Fig. 12), and the correlation chart (Fig. 14).

## Marine shells and palaeo-positions of the Polar Front

At the beginning of this century, marine shells were one of the main aids

Table 1. Identified marine shells (molluscs and balanides) in samples 20 and 21 (Fig. 6). Numbers are only approximate, as many of the bivalves were broken, and the fragments are counted as individuals.

| Species | Number of shells in the samples 20 | 21 | Recent distribution and references |
|---|---|---|---|
| Gastropods | | | |
| *Puncturella noachina* (Linné) | 4 | 1 | Cold waters on both hemispheres (Fretter & Graham 1962). Svalbard–Greenland to the British Isles (Sars 1878). |
| *Lepeta caeca* (Müller) | 14 | | N. America, Svalbard–Greenland to the British Isles (Sars 1878, Fretter & Graham 1962). |
| *Gibbula cf. cineraria* (Linné) | 21 | | Northern Norway to the Mediterranean Sea (Sars 1878 Nordsieck 1968). |
| *Moelleria costulata* (Möller) | | 1 | Greenland–NE America, Northern Norway (Sars 1878), to the Bay of Biscay (Nordsieck 1968). |
| *Alvania mighelsi* (Stimpson) | | 7 | N. America, Greenland, Svalbard, and the extreme NE Norway (Warén 1974). |
| *Alvania scrobiculata* (Möller) | | 1 | Greenland, Iceland, Svalbard, and the extreme NE Norway (Warén 1974). |
| *Omalogyra atomus* (Philippi) | 4 | | Northern Greenland to the Mediterranean Sea (Fretter & Graham 1962). |
| *Trophon truncatus* (Strøm) | 1 | | Svalbard–Greenland to the Bay of Biscay (Feyling-Hanssen 1955, Nordsieck 1968). |
| *Trophon sp.* | | 1 | |
| *Lora sp.* | | 2 | Arctic waters (Sars 1878). |
| Bivalves | | | |
| *Modiolus modiolus* (Linné) | 6 | | Circumpolar. The White Sea to the Bay of Biscay (Tebble 1966, Nordsieck 1969). |
| *Chlamys islandica* (Müller) | 2 | | Greenland–Svalbard to Lofoten. A few occurrences in western Norway (Wiborg 1963). |
| *Astarte elliptica* (Brown) | | 1 | Greenland–White Sea to the northern British Isles and Massachusetts (Ockelmann 1958, Tebble 1966). |
| *Thyasira sarsi* (Philippi) | | 2 | Novaya Zemlya to Oslofjorden (Jensen & Spärch 1934, Feyling-Hanssen 1955). |
| *Macoma calcarea* (Chemitz) | 3 | 4 | Arctic circumpolar. Greenland to the North Sea (Ockelmann 1958). |
| *Mya truncata* (Linné) | 7 | 10 | N. America, North Greenland and Svalbard to the Bay of Biscay (Strauch 1972). |
| *Hiatella arctica* (Linné) | 6 | 6 | World-wide (Jensen & Spärck 1934, Strauch 1968). |
| Sum | 68 | 36 | |
| Balanides | | | |
| *Balanus balanus* (Linné) | Innumerable fragments | | Circumarctic, extending to the Lusitanian region (Feyling-Hanssen 1955). |

for Quaternary stratigraphic studies in Norway (e. g. Brøgger 1900–1901, C. F. Kolderup 1908). After the introduction of the radiocarbon method, interest in shells was renewed, mainly from the point of view of dating. It is hoped that a comprehensive study of several properties (e.g. Strauch 1968, 1972b, Andrews 1972, 1973, Mangerud 1972b) of the Late Weichselian and Holocene shells of Norway can be undertaken. An improved knowledge of marine shallow-water environments would be of great importance in correlation of the terrestrial and the deep sea records.

Here only radiocarbon dates and a list of determined shells are included (Table 1). Most of the shells were identified by cand.real. Per Wikander; the specimens of *Alvania* were identified by Dr. Anders Warén.

Shells occurred throughout the Ågotnes clay and the Ågotnes silt. However, large numbers of shells were only collected from the two lenses of shells (sample 20 and 21, Fig. 6). As samples were collected from lenses which were mainly mechanical accumulations, they contain shells derived from different habitats. For instance, *Balanus balanus,* dominating in both samples, was probably partly attached to the bedrock wall, while *Mya truncata* lived burrowed in the bottom.

The faunas of both samples (Table 1) indicate colder water than in the area today. Several of the species now live in more northerly waters, and near their southern limits they only occur at great depth. As the water depth at the present locality did not exceed 30 m, the species should be compared with their present-day shallow-water occurrence. In open water, *Chlamys islandica* does not occur today south of Lofoten. Further south it is only found in fjords with relatively cold deep water. The two *Alvania* species (in sample 21) are found along the northeast coast of Finnmark only (Fig. 10), and in even colder waters (Table 1).

In both samples, however, some more southerly species *(Thyasira sarsi, Modiolus modiolus,* and *Gibbula cineraria)* also occur; their northern limit lies at present between Norway and Svalbard. Of these three species *Thyasira* found in sample 21 seems today to extend further into the Barents Sea than *Modiolus* and *Gibbula* found in sample 20.

I conclude that sample 21 (Younger Dryas) suggests that the water temperature was approximately the same as today along the northern most coast of Finnmark (Fig. 10), or even slightly colder. Using the surface temperatures given by Sætre (1973, table 1) for Korsfjorden and Vardø, this means that the mean yearly temperature was 3.8° C lower than today. The difference was greatest for the summer (July–Sept. 6.5° C) and smallest for the winter (Jan.–May 1.6° C). The assemblage of sample 20 indicates slightly warmer water than for sample 21, and can be compared with the fauna of larger parts of the northern Norwegian coast from Troms to Finnmark (Fig. 10).

Of special interest is the occurrence in sample 20 of *Modiolus modiolus,* a species with large shells and therefore usually included in field studies of Quaternary geology. The northern boundary of the present-day distribution of *Modiolus modiolus* lies very close to the oceanographic Polar Front (Fig. 10), that is the physical-oceanographic boundary between Atlantic water and Polar (Arctic) water (e.g. Dietrich 1963, fig. 227). *Modiolus modiolus* (= *Volsella modiola* Linné in Feyling-Hanssen 1955: 133) occurs in northern Norway and the southwestern part of the Barents Sea. Wiborg (1964) reports that its habitat is near Bjørnøya, but it does not reach as far north as Svalbard, where it is a guide fossil for deposits from the Holocene climatic optimum (Feyling-Hanssen 1955: 133).

*Littorina littorea* (Linné) has a very similar distribution to *Modiolus modiolus* (Feyling-Hanssen 1955: 160, Nordsieck 1968: 40). Also *Mytilus edulis* Linné has a nearly similar distribution, but seems to tolerate slightly colder water, as it occurs in Greenland (Ockelmann 1963: 61–63, Hjort & Funder

Table 2. The occurrence of three 'guide-fossils' for the Atlantic water south of the Polar Front in radiocarbon dated Late Weichselian sediments in Hordaland.

| | | | | 0 – Shells of the species are dated<br>x – The species occur in the sample | | |
|---|---|---|---|---|---|---|
| Chronozones | Lithostratigraphy | Locality | Radiocarbon dates | *Modiolus modiolus* (Linné) | *Mytilus edulis* (Linné) | *Littorina littorea* (Linné) |
| Younger Dryas | | | | Not found | | |
| Allerød | | Os | 11,250 ± 110, T – 1021 | 0 | | x |
| | | Trengereid | 11,230 ± 200, T – 1161 II | x | | |
| | | | 11,530 ± 150, T – 1162 B | x | | |
| Older Dryas | | Eikangervåg | 11,900 ± 140, T – 846 | x | | |
| | | Ågotnes | 12,220 ± 150, T – 1023 | x | | |
| Bølling | Ulvøy Till | | | | | |
| | Blomvåg Beds | Blomvåg | 12,400 ± 90 T – 1882 | | 0 | |
| | | | 12,540 ± 150, T – 1697 | 0 | | |
| | | | 12,540 ± 180, T – 1696 | 0 | | |
| | | | 12,670 ± 350, T – 139 | | 0 | x |

1974) and is more frequent in Holocene deposits at Svalbard (Feyling-Hanssen 1955) where it possibly has reappeared in recent time (Feyling-Hanssen & Olsson 1960: 125).

These three species, and other low-arctic and boreal species, can therefore be used as 'guide-fossils' for Atlantic water south of the Polar Front, remembering that their limiting factors are not identical to the definition of the Polar Front. Probably, the most important factor for these three species is temperature, while the Polar Front is usually defined by salinity. These two factors are, however, inter-related in the surface water.

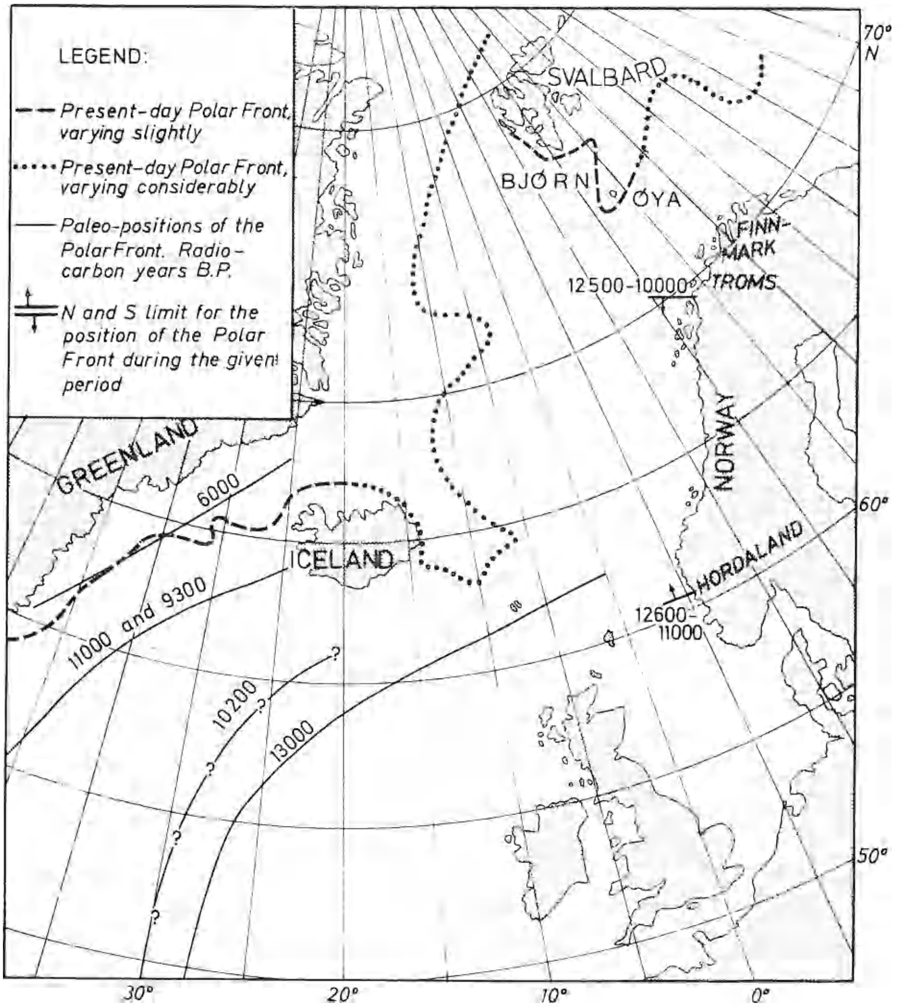


Fig. 10. Map of the North Atlantic Ocean and the Norwegian Sea. Position of the present-day Polar Front according to Dietrich (1963, fig. 227). Palaeo-positions of the Polar Front in the North Atlantic after Ruddiman & McIntyre (1973, fig. 6).
Along the Norwegian coast the Polar Front was situated between Hordaland and Troms during the period 12,000–11,000 B.P. During the period 11,000–10,000 B.P. the Polar Front was pressed southwards, and it is uncertain if it reached the Norwegian coast.

Table 2 lists the known occurrences of the three discussed 'guide-fossils' in radiocarbon-dated Late Weichselian sediments in Hordaland. Even at 12,600 B.P. all three species occurred, and one must conclude that the Polar Front was situated north of Hordaland at that time. This makes it possible to extend the results of Ruddiman & McIntyre (1973) from the Atlantic Ocean into the Norwegian Sea (Fig. 10).

Soon after (12,200–12,000 B.P.), the inland-ice reached the North Sea (Fig. 14) at the coast of Hordaland, but this event probably did not influence the position of the Polar Front significantly.

From the Allerød Chronozone, *Modiolus modiolus* is found at several localities (Table 2), and *Littorina littorea* at one, again indicating that the Polar Front was situated further north.

The faunas of the Younger Dryas sediments are clearly colder, and none of the three mentioned species are found. This may indicate that the Atlantic water did not reach the coast of Hordaland. It may, however, only be a local environmental response to the major glacial re-advance which took place in Hordaland during the Younger Dryas Chronozone (Fig. 14).

Along the coast of Norway north of Hordaland, marine shells occur frequently in Late Weichselian/Early Holocene sediments. However, very few of them are precisely enough dated to be used in a discussion on the location of the Polar Front. From Troms (Fig. 10), Andersen (1968: 70–71) has given an extensive list of species from radiocarbon-dated sediments, covering the period from ca. 12,500 years B.P. (the Bølling Chronozone) to ca. 9500 years B.P. (the Preboreal Chronozone). The faunas of Troms are of distinctly colder type than the contemporaneous faunas in Hordaland, and none of the three 'guide-fossils' were found there. Several of the faunas described from Troms lived, however, near ice fronts, and at that time a steep ecological gradient obviously existed from the calving glaciers in the fjords to the open ocean.

My preliminary conclusion is that the Polar Front between the Atlantic water and the cold Arctic water was situated between Hordaland and Troms during the Bølling and Allerød Chronozones. In both areas the Younger Dryas faunas were clearly colder than the Allerød faunas, indicating that the front moved southwards during the Younger Dryas (cf. Ruddiman & McIntyre 1973), and possibly that the warm Atlantic water did not reach the coast of Norway during the Younger Dryas.

## Foraminifera

The foraminifera were identified by cand.real. Ivar Miljeteig. The methods and the taxonomy follow the practice of Feyling-Hanssen et al. (1971).

The foraminifera were investigated for two reasons: firstly to follow the change of environment from the brown Ågotnes clay to the greenish grey Ågotnes silt; secondly, as a contribution to the correlation of terrestrial and marine sediments.

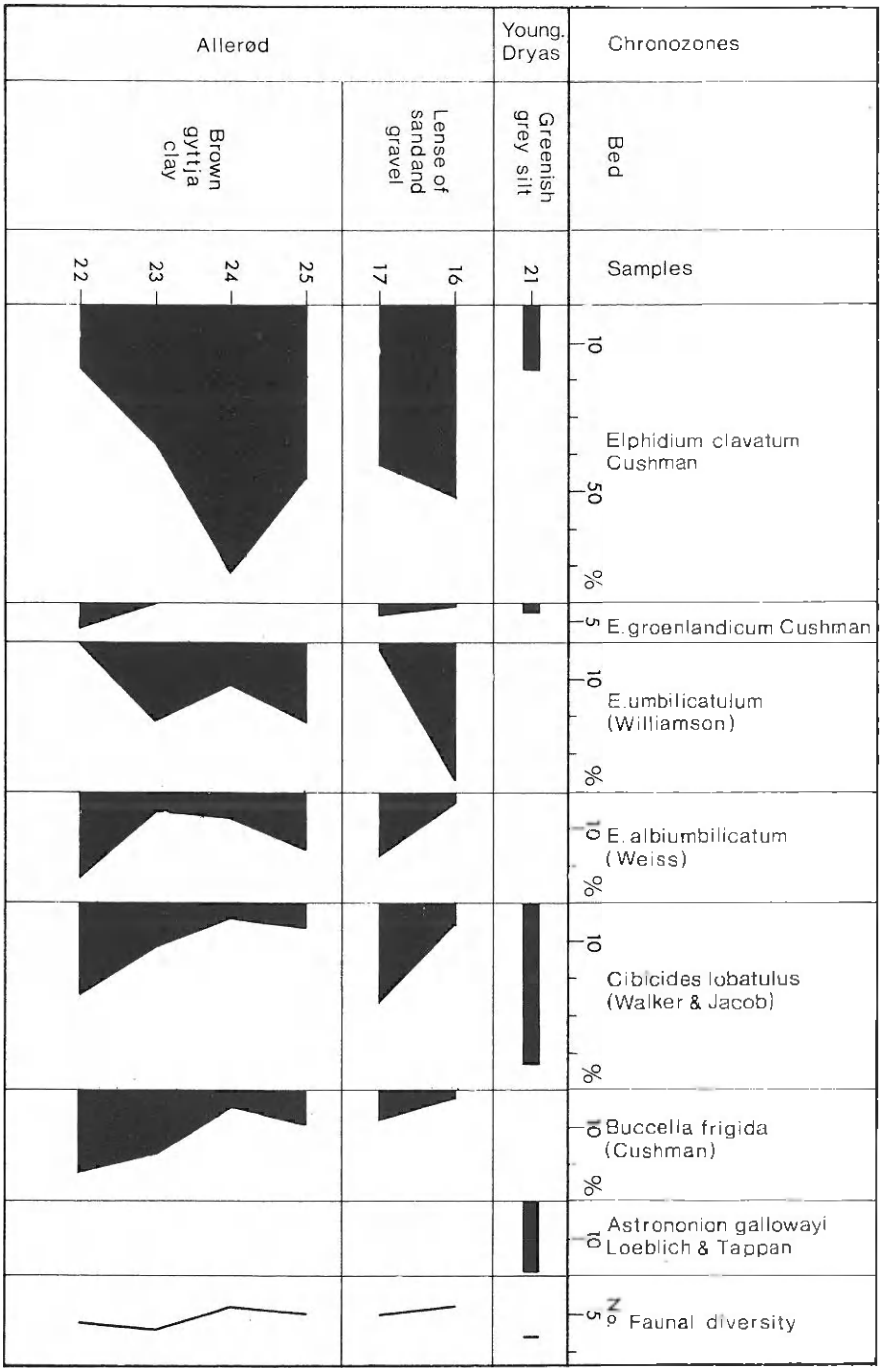


Fig. 11. Composition of the benthic foraminifera occurring in at least one sample with a frequency of more than 5 %.

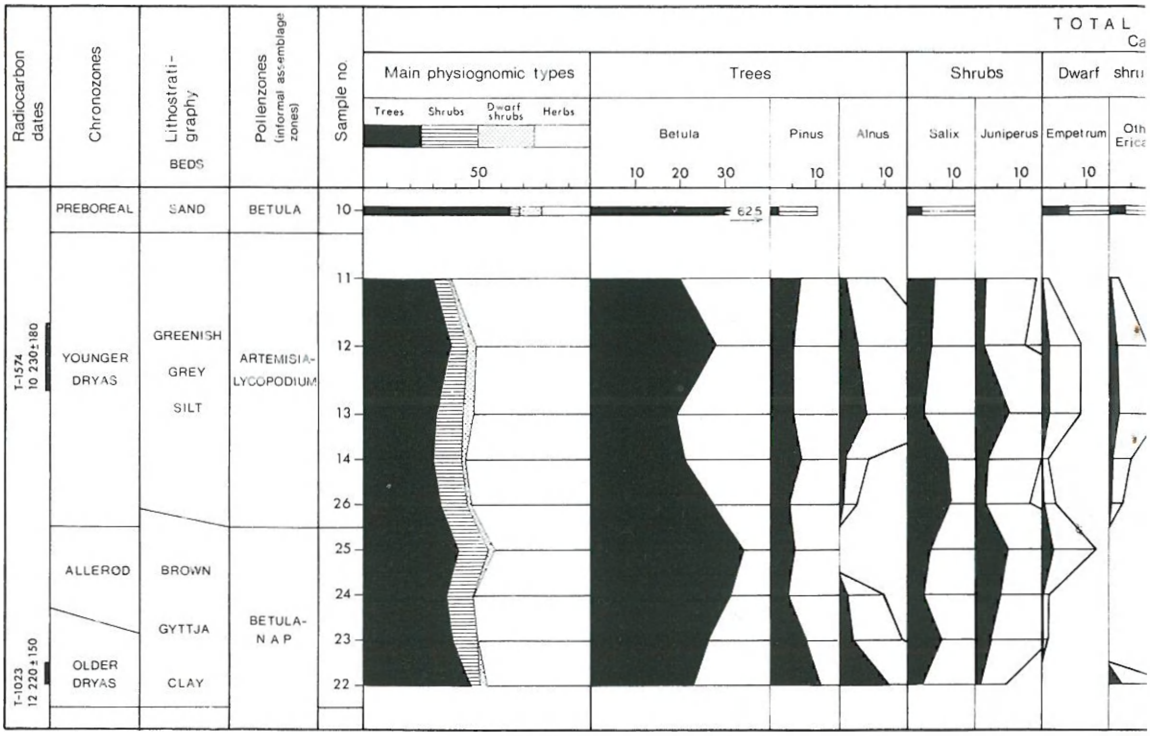
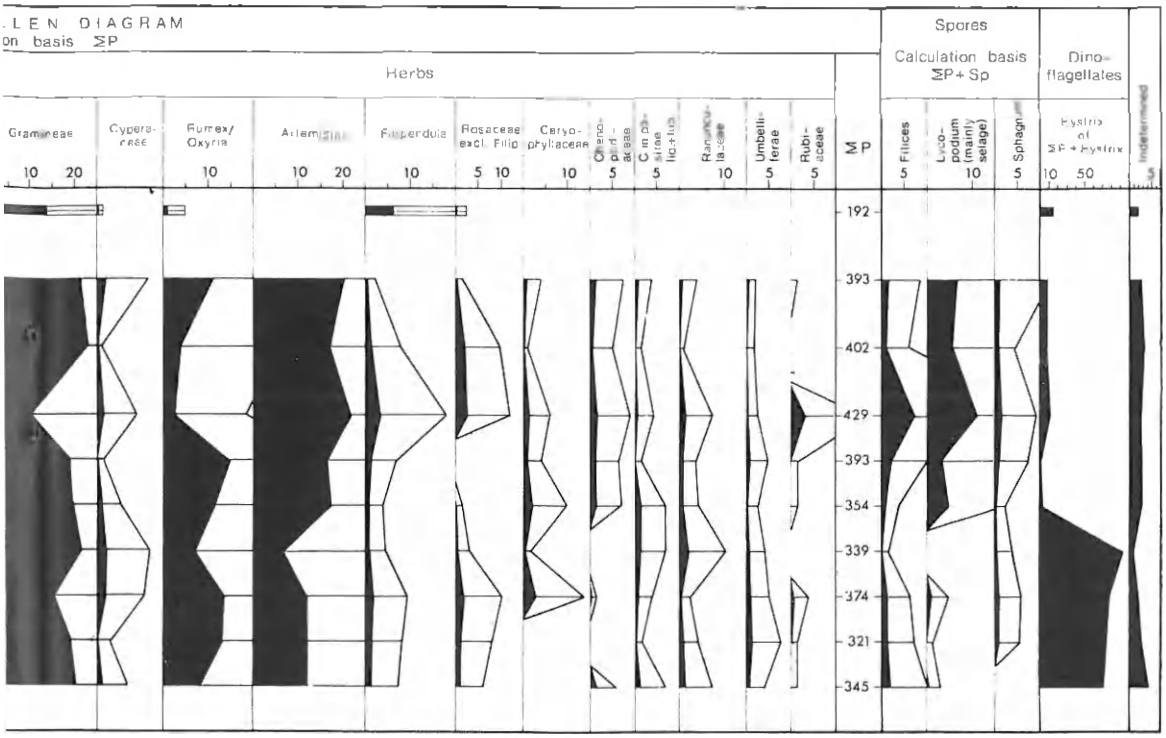


Fig. 12. Diagram of pollen, spores, and Hystrix. The black silhouette curves are on the same scale for all pollen and spore types. Five times exaggeration is indicated by silhouettes with horizontal lines at the sample levels.

In the Ågotnes clay foraminifera were abundant; between 600 and 5,000 specimens per 100 g dried sediment were found in all samples. Even in the lens of sand and gravel (samples 16 and 17) foraminifera were frequent. However, in the Ågotnes silt (samples 11–14 and 26) foraminiferas were rare, and therefore one of the aims of the investigation could not be fulfilled. In a small sample (no. 21) from the shell-rich lens in the Ågotnes silt, foraminifera were abundant (Fig. 11). I therefore assume that foraminifera were also originally present in the silt, and that their absence today is due to post-depositional dissolution. In the shell lens the interstitial water was more alkaline and the foraminifera were preserved.

In all samples (Fig. 11) the foraminifera assemblages are typical for shallow-water environments. The species identified are those common in Late Pleistocene and Holocene sediments identified in Norway and Denmark (Feyling-Hanssen 1964, Feyling-Hanssen et al. 1971, Aarseth et al. 1975).

According to the records in Feyling-Hanssen (1964) and Feyling-Hanssen et al. (1971), *Elphidium umbilicatulum* (= *E.excavatum* in Feyling-Hanssen 1964) and *Elphidium albiumbilicatum* indicate that the sea water was not extremely cold. Both species occur frequently in the lower two units (Fig.



11). For the Ågotnes clay, this accords with the conclusions drawn on the bases of the molluscs (sample 20), and also with the assumption that the glaciers had retreated far into the fjords during the Allerød. Concerning the lens of sand and gravel between the clay and silt (Fig. 6 and 11), the foraminifera assemblages indicate that it belongs to the Allerød and not to the Younger Dryas.

The two species mentioned above are not found in sample 21 from the Ågotnes silt. On the other hand, the assemblage found in this sample is nearly identical to that described by Nagy (1965: 113) from Treskelbukta, Spitsbergen, collected 3–6 km from calving glaciers. It is not possible to draw definite conclusions from this single sample, which in addition was too small to be statistically reliable. Nevertheless, it is striking that it indicates the same environment as indicated by the sediment and shells.

## Pollen, spores, and Hystrix

Pollen analysis was mainly performed to investigate the possibilities of this method for the correlation of terrestrial and marine sequences along the coast of Norway. Concerning the general problems involved in pollen analysis of marine sediments, reference is made to Groot & Groot (1966).

The preparation technique was slightly modified from that of Zagwijn & Veenstra (1966: 546) and Vorren (1972: 237). Separation in bromoform, diluted with alcohol to a sp. gr. 2.2, was repeated 2 to 4 times. We find that separation in heavy liquids gives much cleaner preparations than the HF treatment (Fægri & Iversen 1966: 69), generally used in Scandinavia. The pollen counts were carried out by cand.real. E. Sønstegaard and cand.real. K. Skår.

### *Diagram and zones*

The results are shown in a total pollen diagram (Fig. 12), which with small modifications is commonly used for Late Weichselian sediments in northwestern Europe. Long-distance transported pollen are also included in the pollen sum (Mangerud 1970: 127). The spores are not included in the sum of pollen, even though this would perhaps be more logical (e. g. Birks 1973: 222). In the present diagram, the number of spores are, however, so low that the pollen curves would not have significantly changed if the spores had been included.

I have subdivided the sediments biostratigraphically into informal pollen assemblage zones (Mangerud et al. 1974). Many of the pollen curves show a marked change between sample 25 and 26. *Betula* starts to decrease, but for this species the boundary could just as well have been placed between sample 26 and 14. Because of the generally high NAP content and the *Betula* maximum, the lowermost zone is called the *Betula*-NAP assemblage zone. Also the succeeding zone has a very high NAP content, and I have selected two of the important species with a marked increase at the lower boundary, and termed it the *Artemisia-Lycopodium* assemblage zone. Sample 10 is different from all the others; as it has a *Betula* content of 62.5 % I have simply named it the *Betula* assemblage zone.

### *Sedimentation conditions for pollen*

The pollen curves (Fig. 12) are continuous and relatively even. I therefore assume that dynamic sorting of pollen during the sedimentation has been minimal in spite of the near-shore depositional environment. Berglund (1973) found much more irregular curves in similar sediments from Gothenburg. Sample 10, from the well-sorted sand, may be an exception. The important feature of this sample, however, is that it contains 62.5 % *Betula* and no *Corylus*. Since the pollen of *Betula* and *Corylus* are similar, both in size and form, a dynamic separation seems unlikely, and the sample therefore was almost certainly deposited before the immigration of *Corylus*.

### *Long-distance transported pollen*

It is generally assumed that pine *(Pinus)* did not grow in Norway during the Allerød and Younger Dryas Chronozones. According to Berglund (1966:

144) the northern boundary of pine during the Allerød lay in northwestern Germany and southeastern Sweden. In the present diagram *Pinus* constitutes 4–11 % of the total pollen. These figures are very similar to the percentages of *Pinus* in the Blomøy diagram (Mangerud 1970) and the Brøndmyra diagram (Chanda 1965), while Hafsten (1963) found slightly higher percentages from Lista, which was, however, situated closer to the pine forests.

Of the mixed oak forest constituents only 1 *Ulmus* pollen and 2 *Querqus* pollen were found altogether. These numbers are also comparable with the numbers usually found in Late Weichselian limnic sediments. Very few other exotic pollen are identified.

### *Alnus*

*Alnus* pollen is also generally considered to be long-distance transported when found in Late Weichselian sediments, even in southwestern Sweden (Berglund 1966: 38). Considering the low percentages generally found, this belief is probably correct. In the present diagram, however, *Alnus* has a maximum of 11 % in the lowermost sample, and is found in all samples except 25. The mean for the Late Weichselian samples is 3.6 %, compared to 6.5 % for *Pinus*. This is remarkably higher than for limnic sediments (Table 3) and I am therefore considering four possible interpretations:

1. *Alnus* pollen has been redeposited.
2. *Alnus* pollen is enriched in marine sediments.
3. The *Alnus* pollen present is exotic, and brought in through atmospheric circulation.
4. *Alnus* grew in western Norway during the Late Weichselian.

1. Redeposition of *Alnus* is unlikely, as pre-Weichselian sediments are extremely rare in the area (Mangerud 1972a). If *Alnus* were redeposited, also other redeposited pollen should have occurred.

Table 3. The content of *Alnus* pollen in Late Weichselian sediments in southern (Lista) and western Norway.

| | Depositional environment | Maximum in one spectrum. % of total | Mean of all samples. % of total | No. of samples in which *Alnus* is found | Total no. of samples |
|---|---|---|---|---|---|
| Lista (Hafsten 1963) | Limnic | 2 | < 1 | 12 | 15 |
| Brøndmyra (Chanda 1965) | Limnic | 0.5 | ~ 0 | 3 | 35 |
| Blomøy (Mangerud 1970) | Limnic | 2.4 | ~ 0 | 1 | 12 |
| Ågotnes | Marine | 11 | 3.6 | 8 | 9 |
| Four other localities in Hordaland | Marine | 5.6 | 1.8 | 8 | 8 |

2. A marine overrepresentation would explain the difference in content of *Alnus* pollen in marine and limnic sediments (Table 3). Especially striking is the difference between the marine sediments at Ågotnes (Fig. 12), with abundant *Alnus* pollen, and the limnic sediments at Blomøy (Mangerud 1970), deposited during the same period, located only 16 km to the north, and having nearly no *Alnus* pollen.

However, marine overrepresentation of *Alnus* is not reported from previous analysis of marine sediments. Combined with the other arguments below, I find this explanation unlikely, though it has to be considered in future investigations.

3. Considering long-distance transport, it is stated above that the fre-

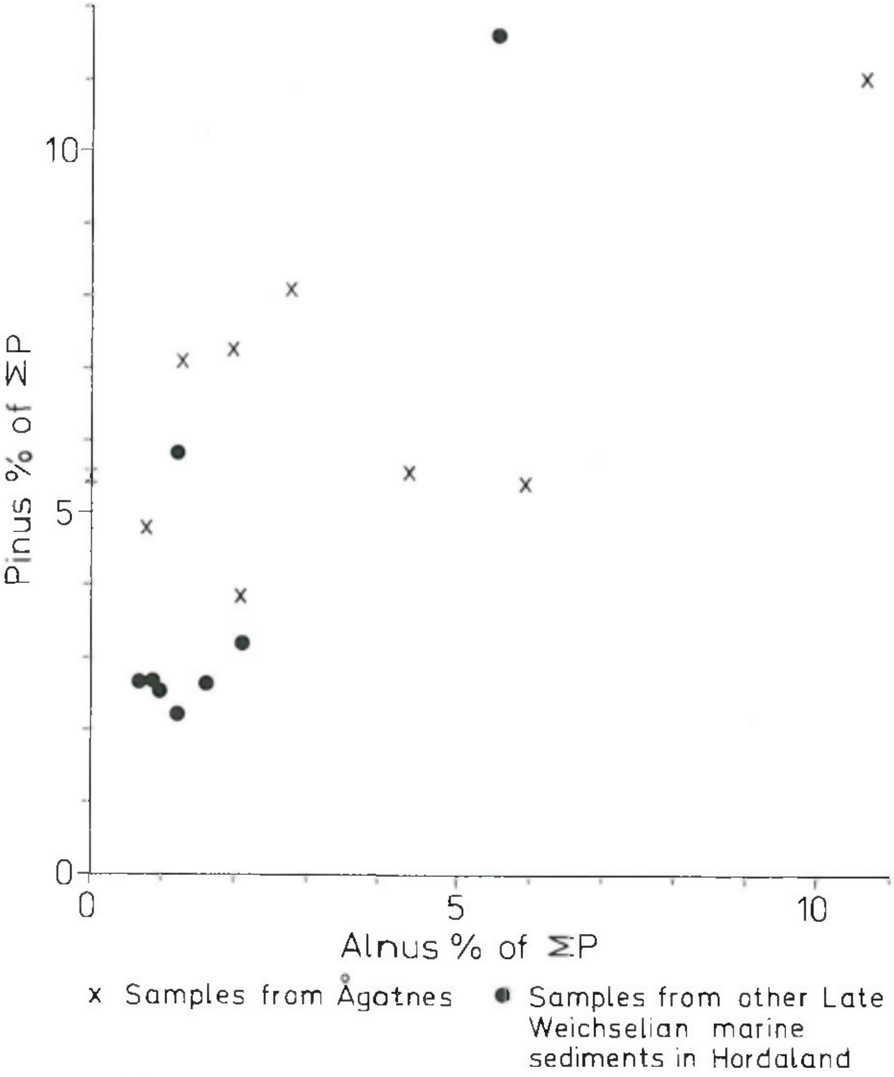


Fig. 13. Relative pollen frequences of *Alnus* versus *Pinus*. Percentages calculated as in the pollen diagram (Fig. 12).

quencies of *Pinus* and QM are similar to those of the other Late Weichselian diagrams, and very few other exotic pollen occur. *Alnus* is the only significant exception. However, when comparing the percentages of *Alnus* and *Pinus* in each spectrum (Fig. 13), a slight correlation appears, which may indicate a long-distance origin of *Alnus*.

In present-day tundra environments *Alnus* is one of the relatively important constituents of the pollen rain (Birks 1973), especially in Greenland and Canada (Fredskild 1973: 198–201) were *Alnus* occurs much more frequently in the northern forests near the tundra than in Europe. In Svalbard (Hyvärinen 1968, 1970) *Alnus* constitutes a considerable part of the exotic pollen during the Holocene. The percentages are, however, always very low compared with *Pinus* and *Betula*.

A striking feature of the present diagram, favouring the hypothesis of exotic origin of *Alnus* pollen, is that the *Alnus* curve is lowest in Allerød and highest in Older Dryas and Younger Dryas, when the local production was lowest.

4. The main indication of the presence of *Alnus* in Hordaland during the Late Weichselian is the high relative frequencies of *Alnus* pollen. In pollen diagrams from the boundary area of *Alnus incana* in northern Norway, the percentages of *Alnus* seldom exceed 2 %, even when copses of alder occur close to the locality (K. D. Vorren, 1972 and pers. comm. 1974, compare also Kelly & Funder 1974: 12–16, and Tallantire 1974: 533).

The pollen diagram (Fig. 12) exhibits a normal vegetational development for the Late Weichselian in western Norway, indicating that it really reflects the existing vegetation, and thus that also *Alnus* was present.

Reite (1968: 278–279) reports a find of *Alnus* wood in a clay deposit at Sunnmøre, ca. 250 km north of Hordaland; marine shells in the clay were radiocarbon dated to Allerød (11,620 ± 120). He believed that the wood found in these deposits did not come from the Allerød vegetation, and assumed that it was either driftwood, or that it had been rebedded. However, this find would be in accordance with *Alnus* growing in western Norway during the Late Weichselian.

Two species of *Alnus* occur in the present vegetation of Scandinavia (Hultén 1971: 153): *Alnus glutinosa* (L.) Gaerth. and *Alnus incana* (L.) Moench. Of these *A. glutinosa* is a southerly species, and could certainly not have grown during the Late Weichselian. *A. incana* has thermic demands similar to *Pinus silvestris* (Tallantire 1974: 536), and should have been able to grow in the fringe areas of Scandinavia during the Allerød. Its actual distribution at that time is, however, not known; probably it was located further to the east (Tallantire 1974: 539).

However, the possibility cannot be excluded that a species not growing in Scandinavia today was present, though we have not tried to identify *Alnus* pollen to species level. One possible species is the North American *Alnus crispa*, which in Greenland today has a southern limit nearly identical with the northern limit of *Betula pubescens* (Fredskild 1973: 199). Assuming that this species did grow in western Norway during the Late Weichselian, the maxima and minima in the pollen diagram (Fig. 12) and the lack of its pollen in southern Scandinavia could be explained. If it occurred in local copses, the difference in *Alnus* frequencies in the diagrams from different localities is also reasonable.

At present I must leave the question of the abnormally high percentages of *Alnus* open; however, my personal opinion is that a species of *Alnus* did grow in western Norway during the Late Weichselian.

### *Late Weichselian vegetation*

The conclusion regarding the number of exotic pollen indicates that the source area for the major part of the pollen and spores is relatively restricted. This is also the conclusion when considering the main composition of pollen, which is typical of the Late Weichselian of southwestern Norway (Fægri 1940, Hafsten 1963, Chanda 1965, Mangerud 1970).

Instead of attempting a closer identification of the area of provenance, I emphasize that over short distances there must have been several different vegetational types. Within 20 km of the locality there were long shores against the open ocean, deep inlets and fjords, hills and mountains of all elevations up to 600 m a.s.l. and slopes in all directions. As pointed out before (Mangerud 1970: 128), the uneven and patchy distribution of soil is also a very important factor when interpreting pollen diagrams from the naked rock coast of Hordaland. We are forced to envisage a landscape with a mosaic of different plant communities.

Pollen diagrams from small ponds, such as the one from Blomøy (Mangerud 1970), represent the vegetation of a small area, and therefore relatively few of these communities. The response to climatic changes of this vegetation will often be clear, and the interpretation of the pollen diagram relatively simple. Diagrams from larger lakes, and especially the present one from the sea, represent in this area the entire mosaic of the vegetational types, and the results of climatic changes are much more complex.

I have previously concluded (Mangerud 1970: 127) that arboreal birch grew in Hordaland during the Allerød Chronozone. This is also indicated by studies of pollen morphology from other localities in Hordaland. In the present diagram the maximum of *Betula* is only 34 %, and I therefore assume that there were only copses of birch on the most favourable habitats, with deep soil and good exposition. *Betula* decreases markedly from the *Betula*-NAP zone (Allerød) to the *Artemisia-Lycopodium* zone (Younger Dryas). In favourable places there were also juniper shrubs during both Allerød and Younger Dryas.

Compared with the diagram from Blomøy, the percentages of *Salix* and *Cyperaceae* are much lower, while *Artemisia* is much higher. This must imply that the present diagram mainly reflects the vegetation of drier habitats that the Blomøy diagram, probably a grass-herb heath or tundra on hill slopes. It cannot be determined whether *Artemisia* was scattered throughout the vegetation, or restricted to certain habitats (cf. discussion in Berglund 1966: 125–126). Nevertheless, it indicates large areas of other communities than the snow-bed communities (Hafsten 1963: 334) during both Allerød and Younger Dryas, as concluded by Øvstedal & Aarseth (1975) on other evidence.

*Artemisia* increased from the *Betula*-NAP zone (Allerød) to the *Artemisia-Lycopodium* zone (Younger Dryas), as it did in Lista (Hafsten 1963), while it decreased in Brøndmyra (Chanda 1965). In the present area I assume that the light-demanding *Artemisia* took over many of the favourable habitats from retreating *Betula* and *Juniperus*.

Hyvärinen (1975) has described an *Artemisia* zone of Younger Dryas age from northern Norway and correlated it with similar zones in eastern Finland and central Russia. An *Artemisia*-rich vegetation was also typical for southern Scandinavia during the Younger Dryas (Berglund 1966: 126), and the present diagram indicates that a similar vegetation even occurred in western Norway. If this vegetation indicates a continental climate, the latter would explain some of the contradictory climatic conclusions reached from Younger Dryas snowlines and fossil icewedges (Mangerud & Skreden 1972: 94).

*Lycopodium* (almost exclusively *L. selago)* has a remarkable increase from the *Betula*-NAP zone to the *Artemisia-Lycopodium* zone, and during the latter zone it was an important constituent of the tundra vegetation.

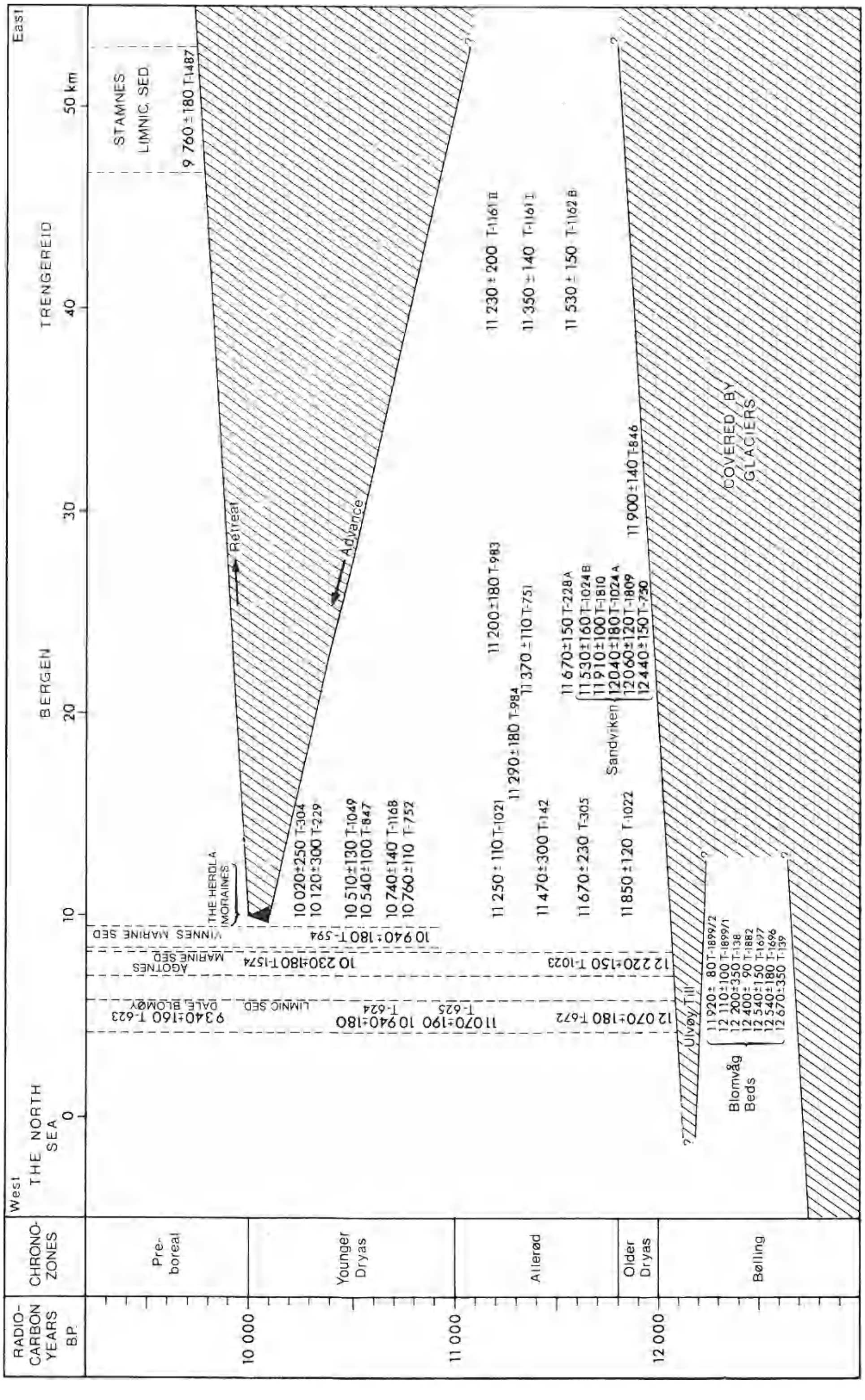
### *Hystrix*

A group of microfossils usually called Hystrix (or Hystrichosphaerids) by Scandinavian palynologists, and used as indicators of marine environments, are now being identified as resting spores (cysts) of dinoflagellates, and several species have been identified (Nordli 1951, Wall & Dale 1967, Wall 1970). In this study Hystrix was only counted, without identification of the types present. Their relative occurrence (Fig. 12) is, however, rather remarkable.

In the lowest 4 samples there are 3–16 Hystrix for each pollen, while in the other samples there are 0.04–0.02 Hystrix for each pollen. The drastic change in the frequency of Hystrix occurs simultaneously with the change of the colour of the sediments, and also with the onset of the change of the terrestrial components. Certainly, the decrease of Hystrix indicates changes in the environment; whether the important factor was temperature, icedrift cover, salinity, depth or others, is, however, impossible to determine on the basis of the present material.

## Correlations

The correlation of the sequence at Ågotnes with events in Hordaland during the Allerød and Younger Dryas has been discussed earlier, and the main conclusions are summarized in Fig. 14.


RADIO-CARBON YEARS B.P.
10 000
11 000
12 000
CHRONO-ZONES
Pre-boreal
Younger Dryas
Allerød
Older Dryas
Bølling
West
East
THE NORTH SEA
BERGEN
TRENGEREID
0
10
20
30
40
50 km
STAMNES LIMNIC SED.
9 760 ± 180 T-1487
DALE, BLOMØY
9 340±160 T-623
AGOTNES MARINE SED.
10 230±180 T-1574
VINNES MARINE SED.
10 940±180 T-594
LIMNIC SED.
11 070±190 T-625
10 940±180 T-624
12 220±150 T-1023
12 070±180 T-672
THE HERDLA MORAINES
Retreat
Advance
10 020±250 T-304
10 120±300 T-229
10 510±130 T-1049
10 540±100 T-847
10 740±140 T-1168
10 760±110 T-752
11 250 ± 110 T-1021
11 290±180 T-984
11 200±180 T-983
11 470±300 T-142
11 370 ± 110 T-751
11 670±230 T-305
11 670±150 T-228 A
11 850 ±120 T-1022
Sandviken
11 530±160 T-1024 B
11 910±100 T-1810
12 040±180 T-1024 A
12 060±120 T-1809
12 440±150 T-750
11 900±140 T-846
11 230 ± 200 T-1161 II
11 350 ± 140 T-1161 I
11 530 ± 150 T-1162 B
COVERED BY GLACIERS
Ulvøy Till
Blomvåg Beds
11 920± 80 T-1899/2
12 110±100 T-1899/1
12 200±350 T-138
12 400± 90 T-1882
12 540±150 T-1697
12 540±180 T-1696
12 670±350 T-139
?

The age of the Ågotnes clay is, however, of importance in the dating of older events, and radiocarbon dates recently obtained from other localities necessitate a re-evaluation of some earlier correlations.

At Blomvåg, on the island Blomøy (Fig. 1), fossil-bearing sediments underlying a till were excavated in 1942/43 (Undås 1942, Mangerud 1970: fig. 5). Since this sequence is decisive in the interpretation of the Late Weichselian in western Norway, the beds are given formal lithostratigraphical names, the type locality being the graveyard at Blomvåg. The till is named the Ulvøy Till, a name derived from an island just to the south of the type locality. The sediments beneath the till become the Blomvåg Beds, which include all the sediments between the Ulvøy Till and the underlying till or bedrock at the type locality.

The first radiocarbon dates from the Blomvåg Beds gave 12,670 ± 350 and 12,200 ± 350 (Nydal 1960: 88), but the exact position of the dated material within the Blomvåg Beds is not known. Further samples from the collections of the Geological Museum, University of Bergen, were dated recently. Two shell samples, both mainly *Modiolus modiolus,* collected from the base of the Blomvåg Beds gave 12,540 ± 180 (T-1696) and 12,540 ± 150 (T-1697). Also from the top of the unit two samples were selected, one of shells *(Mytilus edulis)* which gave (T-1882) 12,400 ± 90, and one of whale bone, which was dated with two different pretreatments: Treatment with diluted HCl gave (T-1899/1) 12,110 ± 100 and the EDTA method recommended by Olsson et al. (1974: 180) gave (T-1899/2) 11,920 ± 80, when corrected for an apparent age of 440 years. The correlation with other dates (Fig. 14) indicates that the whale-bone dates may be slightly too young.

Although the section at Blomvåg, and thus the Ulvøy Till, is not accessible today, both the site and the samples from the excavation have been studied. After discussions with the scientists who visited the locality in 1942–43, there can be little doubt that the Ulvøy Till represents a basal till, and indicates an ice advance.

At Dale, just 600 m north of the Blomvåg locality, a pollen diagram (Mangerud 1970) from limnic sediments situated stratigraphically *above* the Ulvøy Till has been obtained (Fig. 14). Dating of the lowermost limnic sediments gave 12,070 ± 180 (T-672), slightly younger than most dates from the top of Blomvåg Beds.

The Ågotnes locality is situated 15 km southeast of Blomvåg (Fig. 1). The direction of glacial striae suggests that Ågotnes was ice covered during the deposition of the Ulvøy Till; the entire sequence at Ågotnes must,

Fig. 14. Schematic profile of the Hordaland area, modified from Mangerud (1970, 1972a, 1973), with additional radio-carbon dates from Aarseth & Mangerud (1974) and unpublished material. The profile is mainly parallel to the direction of ice movement, the North Sea coast lying to the left. Dates between vertical stippled lines are from sediments undisturbed by ice. All the others are from sediments overrun by glaciers. All dates are corrected for apparent age (p. 33).

therefore, be younger than the Ulvøy Till (Fig. 14). Nevertheless, the date obtained from the Ågotnes clay (12,220 ± 150, T-1023) is slightly older than those for the whale-bone from the Blomvåg Beds. Clearly, the duration of the ice advance that produced the Ulvøy Till was short (100–200 years?), and is within the limits of uncertainty for radiocarbon dates from sediments deposited immediately before and after the advance. The clear stratigraphical evidence for the advance at Blomøy is therefore very important. Based on the dates cited above, the age of the Ulvøy Till can be bracketed within the time interval 12,400–12,000 years B.P., and the most probable age is 12,300–12,200.

A section in Sandviken, Bergen (Mangerud 1970, 1972b), was correlated with the Blomvåg Beds on the basis of $^{14}$C dates. However, an error in the calculation of the ages of two samples from this exposure has been discovered; only the first date obtained (12,440 ± 150, T-750) now supports this correlation. At present 5 dates are available from Sandviken (Fig. 14), the mean age being 12,000 B.P. The conclusion must be that the Sandviken sediments are, in all probability, younger that the Ulvøy Till.

In spite of uncertainties in the exact age of the Ulvøy Till, it now seems quite clear that it is older than the Older Dryas Chronozone (Fig. 14). The vegetational changes during the Older Dryas Chronozone in southern Scandinavia (Mangerud et al. 1974), and the British Isles (Pennington 1975), and the ice advance which deposited the Ulvøy Till, were therefore either the result of two separate climatic events, or there existed some time lag in the response to the same climatic change. In the latter case, the change must have taken place before the Older Dryas Chronozone as defined by Mangerud et al. (1974). The Skarpnes (cold) event in northern Norway (Andersen 1968: 35) seems to be of the same age as the Ulvøy Till.

No indications of another re-advance during the Older Dryas Chronozone have so far been found in Hordaland. It is, however, very difficult to identify details in the glacial history during this episode, since all the sediments have been overridden by the re-advance during the Younger Dryas Chronozone (Fig. 13). Minor halts and re-advances may therefore be obscured.

## Conclusions

At Ågotnes there is a sequence of marine sediments from the Older Dryas Chronozone, through the Allerød and Younger Dryas, to the Preboreal Chronozone. The sediments are not disturbed by ice, and thus prove that the Younger Dryas re-advance did not extend as far as this locality.

The age of the base of the sequence (12,220 ± 150 years B.P.), combined with other radiocarbon dates from Hordaland, indicates that the Ulvøy Till is older than the Older Dryas Chronozone, and thus that the re-advance which deposited the till took place in the Bølling Chronozone.

Warm Atlantic water entered the Norwegian Sea prior to 12,600 B.P. The Polar Front, between the Atlantic water and the Arctic water, was situated between Troms (northern Norway) and Hordaland during the Bølling and Allerød Chronozones. During the Younger Dryas the Atlantic water possibly did not reach the coast of Hordaland.

The environment on the coast of Hordaland during the Allerød Chronozone seems to have been very similar to that of the coast of Troms and Finnmark (northern Norway) today. The vegetation was open with copses of birch *(Betula pubescens* coll.) and shrubs of juniper *(Juniperus communis)* and willow *(Salix* sp.). The littoral and shallow-water shell faunas included species (e.g. *Modiolus modiolus, Thyasira sarsi, Littorina littorea, Gibbula cineraria)* whose present-day distribution has a northern limit in or immediately to the north of Finnmark, and also species (e. g. *Chlamys islandica, Alvania scrobiculata)* which today are uncommon south of Troms and Finnmark.

Due to glaciers, the ecological gradients from the inland towards the coast were certainly steeper in Hordaland during Allerød times, compared with Troms and Finnmark today. We do not know the exact position of the glaciers which existed at that time, but they were probably calving in the inner parts of the fjords.

During the Younger Dryas the environment changed drastically: The glaciers advanced many tens of km; most of the trees disappeared, as did the most of the temperate molluscs; the foraminifera faunas changed; and the organic production in the sea, including Hystrix, decreased.

The pollen diagram from the shallow-water marine sediments at Ågotnes can be correlated with diagrams from limnic sediments, indicating that pollen can be an important tool in the correlation of terrestrial and marine records along the coast of Norway.

In Hordaland, Late Weichselian marine and terrestrial sediments are closely correlated by means of radio-carbon datings. We have, however, also tried to investigate several aspects of the sediments and fossils, in order to provide a basis for the correlation of sediments which cannot be radiocarbon dated.

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