

Diatom Stratigraphy Related to Late Weichselian Sea-level Changes in Sunnmøre, Western Norway

SVEN ERIK LIE, BJØRG STABELL & JAN MANGERUD

Lie, S. E., Stabell, B. & Mangerud, J. 1983: Diatom stratigraphy related to Late Weichselian sea-level changes in Sunnmøre, Western Norway. *Norges geol. Unders.* 380, 203-219.

In sediment cores from four small basins from 44 to 26 m above sea-level, the boundaries between marine, brackish and lacustrine sediments are precisely identified through their distinct diatom stratigraphy. In all basins the diatom successions demonstrate a development from marine to lacustrine environments. The basins, today being lakes or bogs, were isolated from the sea between 12.400 and 9.200 radiocarbon years B.P., at the end of the Late Weichselian. The emergence was fast during the Bolling and Allerød (12.000-11.000 yr BP), and slower during the Younger Dryas (11.000-10.000 yr BP). The slow emergence was probably a main reason for the formation of the morphological distinct Younger Dryas shore-line.

Sven Erik Lie, Norsk Hydro, Petroleum Division, Boks 641, N-9401 Harstad, Norway

Bjorg Stabell, Universitetet i Oslo, Institutt for geologi, Boks 1047, Blindern, Oslo 3, Norway

Jan Mangerud, Universitetet i Bergen, Geologisk Institutt, avd. B, Allégt. 41, N-5000 Bergen, Norway

Introduction

Raised former beaches are frequent in Sunnmøre in Western Norway (Fig. 1). One such prominent level is the Younger Dryas shore-line, correlated with many cirque moraines (Reite 1967, Mangerud et al. 1979). However, it was earlier not known whether the better morphological development of this line was due to a transgression, a stillstand in relative sea-level changes, or faster erosional depositional processes during the Younger Dryas. The main object of our study was therefore to establish a relative sea-level curve based on stratigraphical investigations for the area, and thereby solve the problem.

During the last few years a Younger Dryas transgression has been demonstrated further south in Western Norway (Anundsen 1978, Anundsen & Fjeldskaar, in press, Krzywinski & Stabell, in press, Thomsen, 1982) where a Younger Dryas re-advance of the ice-sheet is known (Mangerud 1977, Sindre 1980). In Sunnmøre the front of the ice-sheet was situated much further inland (Sollid & Sørbel 1979) and only cirque glaciers were formed along the coast (Mangerud 1980). Sea-level curves from this area would therefore be of major significance for understanding the geological and geophysical processes governing sea-level changes along glaciated coasts. In this paper we will mainly present the results of diatom studies from the Ålesund area. The

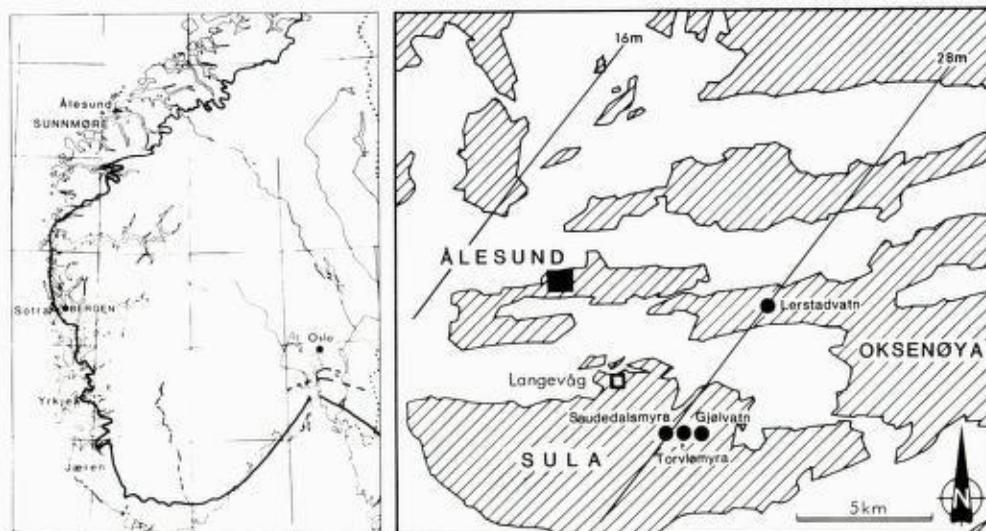


Fig. 1. To left a key map of southern Norway. The Younger Dryas end moraines are marked with heavy lines. To the right a map of the Ålesund area, land areas hatched. The Younger Dryas isobases (16 and 28 m) are indicated according to Reite (1967).

lithostratigraphy, pollen-stratigraphy, radiocarbon datings and a more extensive discussion of the sea-level curves and shore-lines will follow in subsequent papers.

Methods

For establishing relative sea-level curves we used the classical method of coring lakes at different altitudes (e.g. Hafsten 1960, Kjemperud 1981a) to determine the sequence of marine and lacustrine beds, and to date these changes. We used diatoms for interpretations of whether the sedimentary environments were saline, brackish or fresh.

This study includes four basins situated below the marine limit, which by means of terraces is determined to 45 m a.s.l. around Ålesund. Three localities lie less than one kilometre apart on the island Sula, south of the town of Ålesund. The fourth (Lerstadvatn) is situated on the same isobase (Reite 1967, Sollid & Kjenstad 1980), but 5 km further north (Fig. 1).

The chronostratigraphical classification follows Mangerud et al. (1974), where the chronozones were defined in radiocarbon years. For the identification of the boundaries we have obtained approximately 20 radiocarbon dates (Lie & Lømo 1981, Kristiansen pers. comm.) which will be published on a later occasion.

Lithostratigraphy

The sediments in the four investigated basins are so similar that a lithostratigraphical correlation can easily be made, and we will therefore give a common description. The total sequence is subdivided into five informal

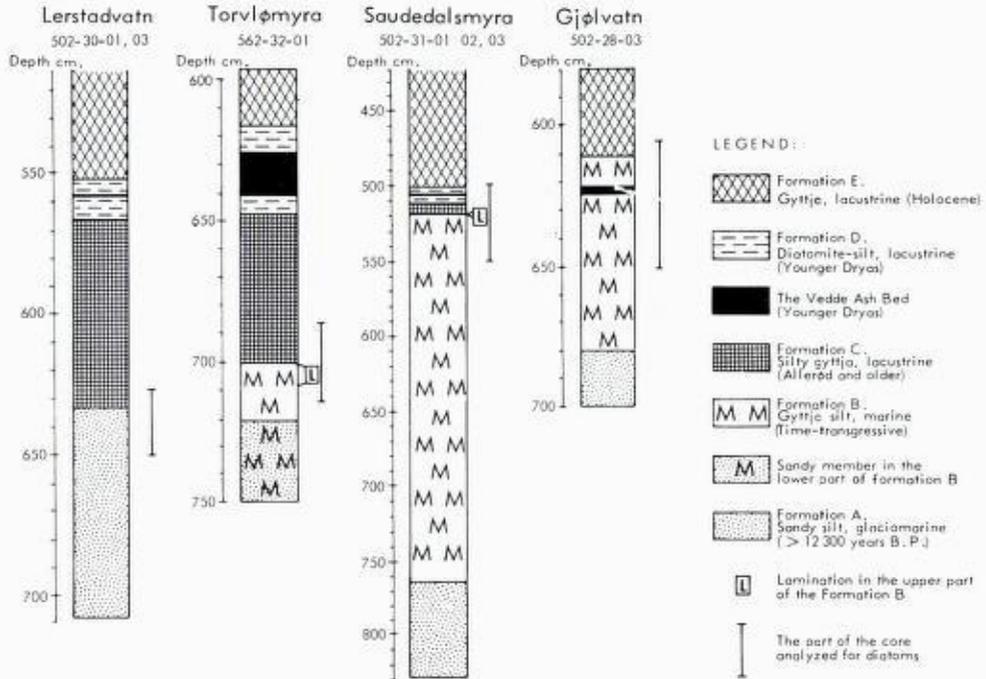


Fig. 2. The lithostratigraphy of the investigated cores. The numbers below the locality names are the core numbers. Note the smaller depth scale used for Saudedalsmyra compared to the three other localities.

formations (Fig. 2), lettered from A to E from the base. Only in Saudedalsmyra are all five formations present.

Formation A. Sandy silt. This formation consists mainly of grey silt, with beds of silty sand and clayey silt. The loss on ignition is <2%, and macrofossils have not been found. The formation is interpreted to be of glaciomarine origin, and older than 12,300 years B.P.

Formation B. Gyttja silt. Brownish grey to grey gyttja silt. The main difference from formation A is the higher organic content and the brownish colour. The formation is generally homogeneous, but at some sites well defined red, red-brown and green laminae occur in the upper (brackish) part. Fragments of marine shells are common, except in the upper part. The sediments are marine and, at the top, brackish.

Formation C. Silty gyttja. The main characteristic is its much higher organic content than the underlying and directly overlying formations. The colour varies between greyish, greenish and brownish, but brownish colours dominate. Beds with abundant plant remains occur. The lower boundary is normally a smooth transition, whereas the upper boundary is sharp. This formation is entirely lacustrine, and its age Allerød and partly older.

Formation D. Diatomite-silt. This formation consists of a pale green to yellowish-grey silt. It has a very high content of diatom frustules, thus the name diatomite-silt. The Vedde Ash Bed with an age of $10,600 \pm 60$ years

B.P. (Mangerud et al. in press.) is found near the midpoint of this formation in three of the basins. The sediments are lacustrine, and of Younger Dryas Age.

Formation E. Gytta. This is a brown, fine detritus gyttja. It is lacustrine and of Holocene age.

Diatom analyses

The sediment samples for diatom analyses were prepared after a simplified version of the procedure described by Schrader (1973).

- 1) Each sample was boiled in 35% H₂O₂ in a small beaker.
- 2) A part of the solution was poured into a centrifuge glass, distilled water added and centrifuged for 2 min. at a speed of 1200 rev. per min. Water with suspended clay was decanted.
- 3) Water was again added and the rest of point 2 repeated 4 times.
- 4) A few drops of the residue were spread on a cover-glass, evaporated and embedded in Hyrax mounting medium.

The analyses were carried out using a Zeiss research microscope with the objectives 100/1.30 and 63/1.4 with phase contrast. The calculation basis for the relative frequencies was approximately 200 valves in each spectrum. *Fragilaria* spp. were counted separately and are not included in this sum. The results are presented in two types of diagrams. The construction of these diagrams is based on Florin (1946). One diagram shows the succession of the most dominant species. In the other diagram the taxa are grouped with regard to their preference for the salt content of the water, according to the halobion system of Kolbe (1927) modified by Hustedt (1957). The polyhalobous taxa prefer salinities higher than 30‰, the mesohalobous between 30 and 0.2‰, and oligohalobous taxa can live in both brackish and fresh water. The oligohalobous halophilous show an optimum in slightly saline water, and the oligohalobous indifferent taxa prefer fresh water. The halophobous group includes exclusively freshwater species which have an upper tolerance boundary at 0.2‰ S. The diagrams include mainly the sediments around the transition zone from marine to lacustrine sedimentary environments (Fig. 2). Samples from other parts of the cores have been examined without quantitative counting of the diatoms, to look for major changes in the salinity of the environment. The marine, brackish, 'halophilous', and freshwater diatom zones are based on the change in the diatom composition (Kjemperud 1981b). More precisely they may be classified as paleo-environmental zones.

The transition from polyhalobous/mesohalobous to oligohalobous assemblages indicates the change in sedimentary environment from marine/brackish to freshwater, often called the isolation contact, because at that time the lake was isolated from the sea. The isolation contact represents in the sediment sequence the time of emergence of the lake's threshold above high tide (Ingmar 1973) (see discussion in Stabell 1982). In this area the present tidal

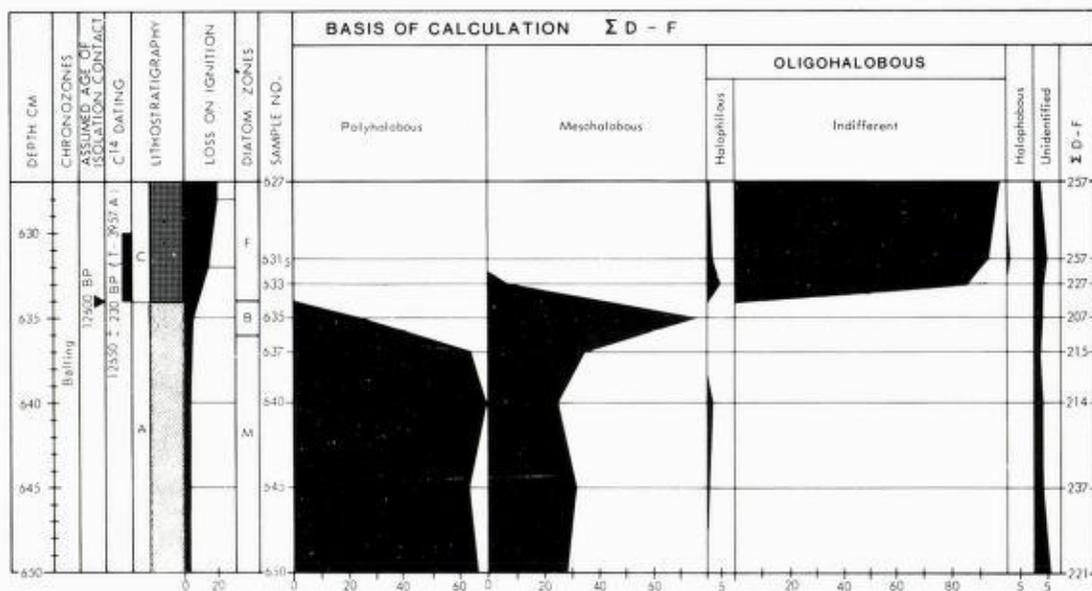


Fig. 4. Diatom diagram from Lerstadvatn with taxa grouped with regard to their preference for the salt content of the water. See text to fig. 3.

and the mesohalobous *Navicula digitoradiata*. The occurrence of *N. digitoradiata* could indicate a periodic lowering of the salinity in the fiord, possibly due to meltwater from the retreating ice-sheet.

At 635 cm there is a peak of the mesohalobous group to 75% occurrence, mainly as a result of the flourishing of *Navicula salinarum* and *Nitzschia hungarica*. This diatom assemblage defines the brackish diatom zone. The spectrum above (633 cm) is almost totally dominated by oligohalobous indifferent taxa. *Navicula pusilla* is described as oligohalobous indifferent (Simonsen 1962) but by Hendeby (1964) observed as common in brackish water. It has a very limited stratigraphical distribution just above the isolation contact. The peak of *N. pusilla* and a 6% occurrence of *Nitzschia frustulum* may define a slightly saline environment. However, due to the rich flourishing of typical freshwater species such as *Cymbella ventricosa* and *Pinnularia interrupta* at the same level, we do not define this as a halophilous zone. The isolation contact is defined between 635 and 633 cm and coincides with the lithological transition from formation A to formation C at 634 cm. Sediments just above this boundary (634–630 cm) are C¹⁴-dated to 12.650 ± 230 yr BP (T-3957 A). Many shell datings indicate the deglaciation of this area to about 12.400 yr BP (Mangerud et al. 1981 and unpublished) and we therefore assume that an age of 12.400 to 12.300 yr BP is most likely for the isolation contact in Lerstadvatn. This is only slightly outside one standard deviation of the obtained date.

Torvlømyra, 35 m a.s.l.

The bog *Torvlømyra* is at the north-east end of the island Sula (Fig. 1) (UTM 576 258). The main basin is about 100 m long and only 10 m wide. Conti-

nuous Late Weichselian stratigraphy is found only in the north-eastern part of the bog. The analysed sediment cores range from 750 to 560 cm below the bog surface (Fig. 2). The lower half of formation B is a sandy member, suggesting a high-energy sedimentary environment. This has been caused by a tidal current (E-W) when the sea-level was above the thresholds in both ends of the basin. The difference in elevation between the thresholds is only one metre.

The ten analysed diatom samples represent the beds between 715 and 687 cm in the formations B and C (Figs. 5 and 6). The two lowermost spectra show a marine diatom assemblage. *Rhabdonema minutum* is the dominating species, which besides *Diploneis subcincta* and *Cocconeis scutellum* give a high percentage of the polyhalobous group. At level 710 cm the polyhalobous is still dominating, but both the mesohalobous *Navicula digitoradiata* and *Hyalodiscus scoticus* show high frequencies and indicate a transition to brackish conditions. The mesohalobous group reaches a peak of about 55% at 705 and 703 cm. A flourishing of *Achnanthes hauckiana*, *Navicula salinarum* and *N. halophila* is followed by *Synedra tabulata*, *Achnanthes delicatula* and *Mastogloia elliptica*. Species of the 'Clypeus-flora' (Florin 1946), which are typical for brackish/freshwater-transition sediments around the Baltic, are not registered. However, both *N. halophila* and *M. elliptica* can be included in that group (Ingmar 1973). The two last named are common in Late- and post-Weichselian sediments in Sunnmøre, and their frequency peaks are very often in the

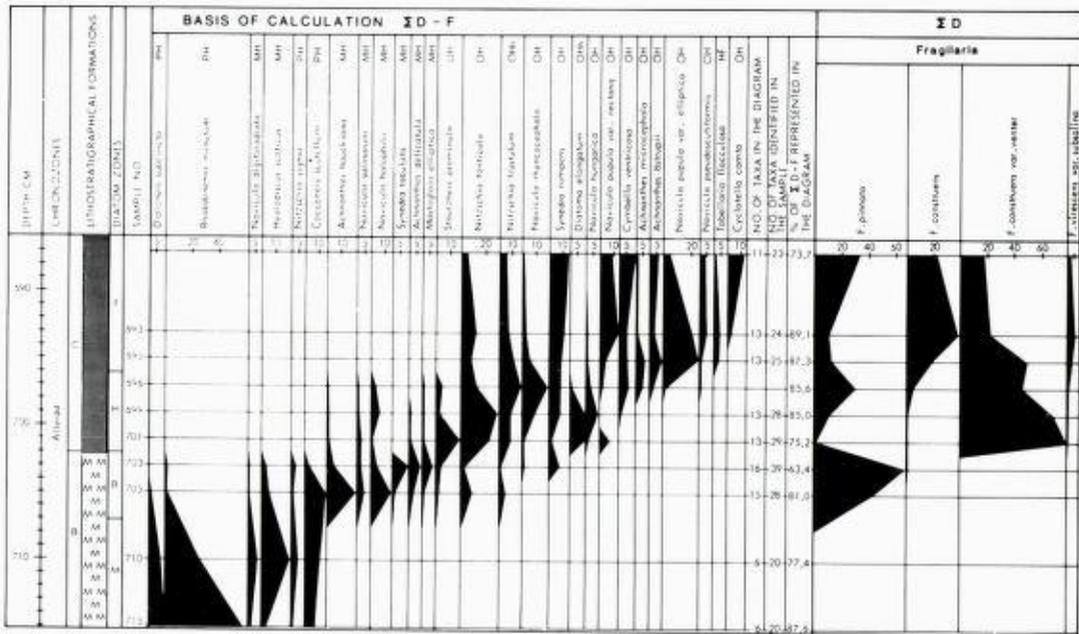


Fig. 5. Torvlømyra 35 m a.s.l. Succession and distribution of the most dominant diatom taxa. See text to fig. 3.

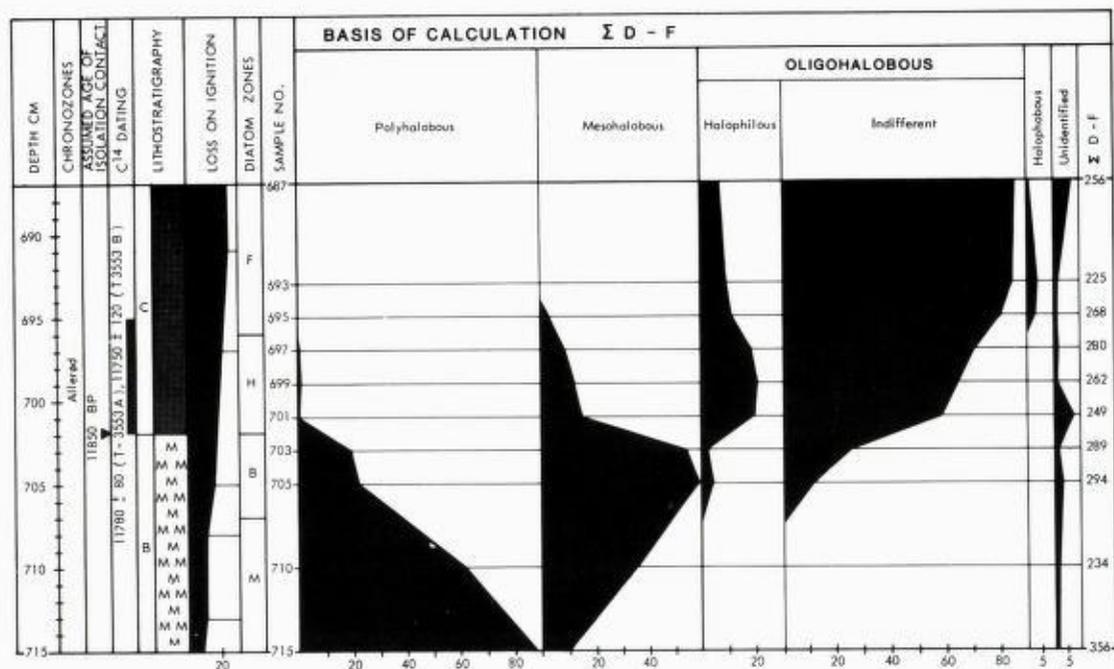


Fig. 6. Diagram from Torvlømyra with taxa grouped with regard to their preference for the salt content of the water. See text to fig. 3.

sediments just beneath the isolation contact. A marked increase of the oligohalobous group at 701 cm indicates the upper limit of the brackish zone and thus defines the isolation contact.

The mesohalobous group still reaches an occurrence decreasing from 15 to 9 percent in the three lowest levels in the freshwater zone. This, together with a high frequency of the halophilous species *Nitzschia frustulum*, *Diatoma elongatum* and the occurrence of *Pinnularia globiceps* and *Rhopalodia gibberula* support the definition of a halophilous diatom zone. Only 1 to 2 percent of the polyhalobous group are registered through this zone, which indicate just a slight input of saline water. During the time of isolation from the sea the lake was surrounded by fiords. A sporadic supply of sea water by wind and waves in rough weather may have influenced the salinity in the basin for some time after the threshold rose above the littoral zone. A stratigraphically well defined halophilous diatom zone is favoured by a slow land uplift, which also may explain that this zone is more than 5 cm thick in Torvlømyra. The upper limit of the halophilous zone is defined by the first appearance of the halophobous taxon *Tabellaria flocculosa*. A sample of the silty gyttja between 701 and 695 cm was radiocarbon-dated to 11.780 ± 80 yr BP (T-3553 A, NaOH soluble) and 11.750 ± 120 yr BP, (T-3553 B, insoluble in NaOH). The radiocarbon dates give the ages of approximately the centre of the sample. Based on a probable rate of sedimentation, the age of the isolation contact (702 cm) can be estimated to 11.850 yr BP.

Saudedalsmyra, 30.2 m a.s.l.

Saudedalsmyra is a 140 m long and 65 m wide bog situated about 50 m downstream of Torvlømyra (UTM 575 253). The cores were taken in the deepest part of the basin near the centre of the bog, and represent the sediment between 828 to 380 cm beneath the bog surface (Fig. 2).

The diatom analyses represent the beds between 550 to 500 cm in formations B, C, D and E (figs. 7 and 8). The marine diatom zone include the four lowermost samples. As in Lerstadvatn the mesohalobous *Navicula digitoradiata* shows high frequencies among the typical marine species such as *Rhabdonema minutum* and *Plagiogramma staurophorum*. The brackish zone is defined by an increase of mesohalobous taxa, both in diversity and total occurrence. But even though the mesohalobous group is dominant in number of taxa, the polyhalobous *Melosira sulcata* (syn. *Paralia sulcata*) is the most common species in this zone. At the levels 523 and 521 cm it almost totally dominates the assemblage (more than 90%). *M. sulcata* is a marine species tolerating salinities as low as 5–3‰ (Simonsen 1962). It is a bottom dwelling form, but sometimes found among the marine plankton, particularly after winter gales (Hendey 1964). A 5% occurrence in a freshwater zone, as recorded by Stabell (1980), may be explained as allochthonous. However, the great dominans of *M. sulcata* in Saudedalsmyra must represent the autochthonous flora.

The large number of *Melosira sulcata* gives a peak of the polyhalobous group just before the isolation from the sea (Fig. 8), and causes low relative frequencies of the mesohalobous taxa (Fig. 7). However, the mesohalobous group shows a succession similar to the brackish zone at other localities, and the zone boundaries are therefore defined disregarding the *Melosira* peak. The isolation contact is in all cases defined to 518 cm depth.

The halophilous zone is only represented by sample 516 cm. At the time of isolation the basin was connected to the sea by a 300 m long and 10 to 30 m wide channel. Later, when it became a lake, it was therefore well protected against the influence of sea-water. This can explain why the halophilous diatom zone is less developed on this site compared with Torvlømyra. A 3 cm thick sample from the silty gyttja above is radiocarbon-dated to 11.130±140 yr BP (T-3958 A), and from that the date of the isolation estimated to have been approximately 11.150 yr BP.

The sea level of the transition Younger Dryas/Preboreal time is registered only 3 m below the threshold of Saudedalsmyra (see Gjølvatn below). Saudedalsmyra is therefore very sensitive for possible transgressions during the Younger Dryas. A transgression of that age is known further south in Western Norway (Anundsen 1978, Anundsen & Fjeldskaar, in press, Krzywinski & Stabell, in press). The beds representing the Late Allerød and Younger Dryas were therefore carefully analysed in order to discover possible transgression sequences within this period. However, no marine influence was detected in the sediments above the isolation contact.

The diatom succession in the freshwater diatom zone shows a noticeable change at the lower boundary of formation D. The number of taxa is reduced more than 30%. A decrease in the occurrence of *Navicula pupula* var. *elliptica*,

An abrupt transition to an assemblage almost totally dominated by lacustrine taxa can be correlated with the marked lithological boundary between formation B and formation E. A rapid regression in the relative sea-level may explain the lack of a halophilous zone.

Radiocarbon datings of the gyttja above the isolation contact gave the ages 9760 ± 110 yr BP (T-3552 B, NaOH insoluble) and 10.000 ± 140 yr BP (T-5352 A, NaOH soluble) The isolation is estimated to 9900 yr BP.

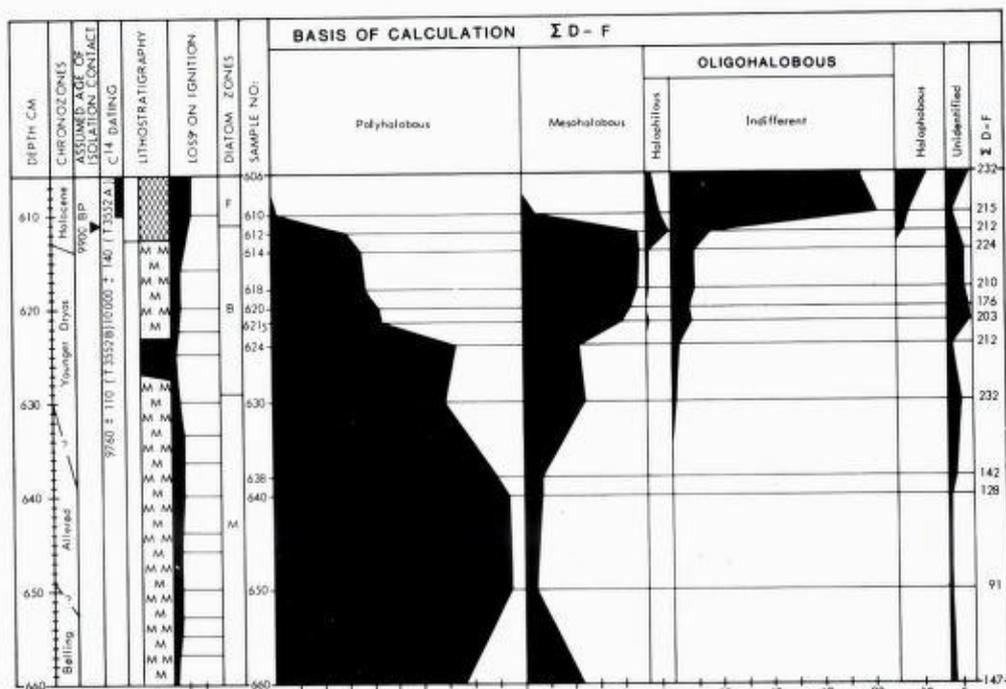


Fig. 10. Diagram from Gjølvatn with taxa grouped with regard to their preference for the salt content of the water. See text to fig. 3.

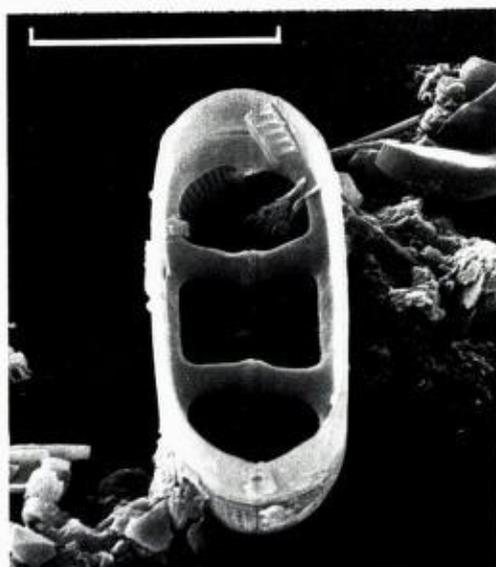


Fig. 11. *Diatomella? salina* Voigt. Note the narrow septae, distinguishing it from the freshwater species *D. balfouriana* Grev. Line is 10 μ m.

The *Fragilaria* succession

The isolation contact has been defined without regard to *Fragilaria* spp. Even though they occur in great quantities in the marine/lacustrine transition zone and often dominate the lacustrine floras, it is difficult to point out a general succession for the *Fragilaria* species. *F. pinnata* and *F. virescens* var. *subsalina* show high frequencies both in marine/brackish and lacustrine environments in Saudedalsmyra while they occur only in the freshwater zone at Lerstadvatn. For the species *F. construens* var. *venter* a peak is registered just above the isolation in Lerstadvatn, Torvlømyra and Saudedalsmyra and it may be used as an indicator for the first lacustrine sedimentation. Also in Gjølsvatn this taxon increases rapidly above the isolation contact, but here it continues to increase upwards. Both because of their uncertain salt tolerance boundaries and their total dominance at some levels, *Fragilaria* spp. are kept out of the calculation basis for the diagrams. In the dissolved diagrams, the most commonly occurring *Fragilaria* taxa are presented.

Conclusions

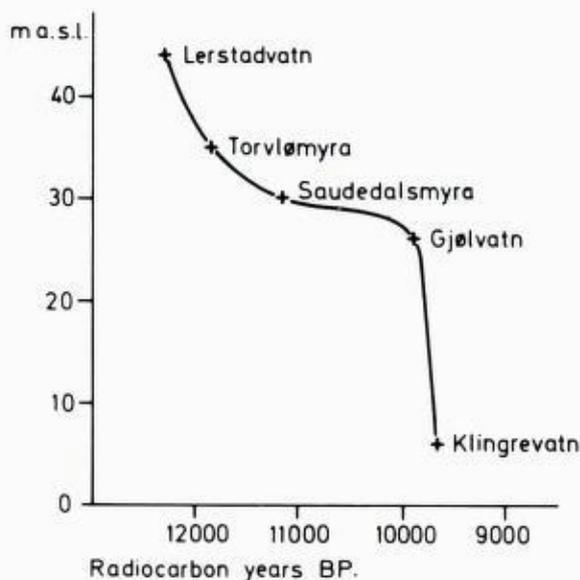
The boundaries between marine, brackish and lacustrine sediments are precisely identified by means of the diatom stratigraphy. At three of the localities the boundary between the brackish and freshwater diatom zones coincides with lithological changes. In Saudedalsmyra the lithostratigraphical boundary between formations B and C is slightly below the isolation contact. Before the diatom analyses were carried out, there were in all basins other alternative interpretations for the position of the boundary between marine and lacustrine sediments.

In some of the cores, and in many cores from Sunnmøre not described in this paper, the brackish sediment is an algal gyttja, distinctly laminated with reddish, greenish and blackish colours. This has earlier been described from the area around Bergen (Kaland et al. in press), and appears to be an important criterion for the marine-lacustrine transition in the type of sedimentary environments used for this study. However, the exact position of the isolation contact within a laminated blackish sequence is still to be determined by diatom analysis.

Using the age obtained for the isolation contact to define the time the sea-level (high-tide) was at the level of the threshold of each of the lakes, we obtain a relatively sea-level curve as shown in Fig. 12. The ages are partly based on palynological correlations by Lømo (in Lie & Lømo 1981) and Kristiansen (pers. comm.) which will be published later.

The sea-level curve shows an early, rapid regressive shore displacement following the deglaciation at approximately 12.300–12.400 years B.P. The speed of shore displacement slowed down considerably during the Younger Dryas. This slow relative shore displacement change is probably the main reason for the morphologically well developed Younger Dryas shoreline.

Fig. 12. Shore displacement curve for the Ålesund area. Note that the bend at about 10 000 yr BP has not been precisely dated. Gjølvatn is believed to have been isolated during a period of rapid regression. The course of the curve after the isolation of Gjølvatn is based on unpublished material collected by Kristiansen & Mangerud. The regression minimum (approximately 9000 yr BP) is situated below present sea-level (Hafsten 1979).



However, in many places, e.g. at the front of the numerous glaciers ending in or near the sea, the depositional processes certainly worked faster than during the Allerød.

We have cored a large number of lakes, both further inland (where basins at the critical altitudes are few) and towards the coast. The preliminary results indicate that the 11.000 year shoreline is slightly steeper than the 10.000 year line. Thus the shore displacement during Younger Dryas was faster further inland than around Ålesund. The lines probably crossed west of Ålesund, so at the outermost coast there was a transgression during the Younger Dryas.

The sea-level history is thus very different from Yrkje (Anundsen 1978, Anundsen & Fjeldskaar, in press) and Sotra (Krzywinski & Stabell, in press). This will not be discussed further here, as it will be treated in detail in a forthcoming article on the shore displacement, but a possible cause is the difference in the behaviour of the front of the Scandinavian ice-sheet (Mangerud 1980). In the Yrkje-Sotra area there was a major Younger Dryas re-advance contributing to the transgression (Fjeldskaar & Kanestrøm 1980, Fjeldskaar 1981). Such a transgression is lacking at Ålesund where a re-advance is not known.

Acknowledgements - This paper resulted from a work project (led by Mangerud) where also Inger-Lise Kristiansen and Leif Lomo were actively participating in coring, lithostratigraphical work, pollen-analysis, correlation, etc. The conclusions are therefore partly based on their unpublished work. Eivind Sønstegeard and Hans Petter Sejrup also participated in collection of some of the cores. All radiocarbon dates were performed at the Trondheim laboratory, under the supervision of Reidar Nydal and Steinar Gulliksen.

Urve Miller in consultation with Maj-Britt Florin, Michael Talbot and Jørn Thiede read through the manuscript critically. Michael Talbot corrected the English language.

The work was financially supported by the Norwegian Research Council for Science and the Humanities (NAVF) and Norges Geologiske Undersøkelse. To the mentioned colleagues and institutions we proffer our sincere thanks.

REFERENCES

- Anundsen, K. 1978: Marine transgression in Younger Dryas in Norway. *Boreas* 7, 49-60.
- Anundsen, K. & Fjeldskaar, W. in press: Observed and theoretical Late Weichselian shorelevel changes related to glacier oscillations at Yrkje, southwest Norway.
- Fjeldskaar, W. 1981: Late-glacial movements of sea level and crust in Fennoscandia. Dr. sient. thesis 1981, Seismological Observatory, University of Bergen, Norway.
- Fjeldskaar, W. & Kanestrøm, R. 1980: Younger Dryas Geoid-deformation caused by deglaciation in Fennoscandia. In: Mørner, N. A. (ed.): Earth rheology, isostasy and eustasy. John Wiley & Sons, 569-574.
- Florin, M.-B. 1946: Clypeusfloraen i postglacial fornsjölagerföljder i östra Mellansverige. Geol. Fören. Stockh. Förh. 68, 429-458.
- Hafsten, U. 1960: Pollen-analytic investigation in South Norway. In: Holtedahl, O. (ed.): Geology of Norway. *Norges geol. Unders.* 208, 434-462.
- Hafsten, U. 1979: Late and Post-Weichselian shore level changes in South Norway. In: E. Oele, R. T. E. Shüttenhelm & A. J. Wiggers (editors): The Quaternary History of the North Sea. *Acta Univ. Ups. Symp. Univ. Ups. Annum Quingentesium Celebrantis* 2, 45-59.
- Hendey, N. I. 1964: An Introductory Account of the Smaller Algae of British Coastal Waters. Part V: Bacillariophyceae (Diatoms). Ministry of Agriculture, Fisheries and Food, Fishery Investigations, Ser. 4, 317 pp.
- Hustvedt, F. 1957: Die Diatomeen des Fluss-Systems der Weser im Gebiet der Hansestadt Bremen. Abh. Naturw. Ver. Bremen 34, 181-440.
- Ingmar, T. 1973: Sjöinsnörningar från aktualeologiska synpunkter. En översikt. University of Lund, Department of Quaternary Geology, Report 3, 48-90.
- Kaland, P. E., Krzywinski, K. & Stabell, B. in press: Radiocarbon Dating of Transitions between Marine and Lacustrine Sediments and their Relation to the development of Lakes. *Boreas* 1983.
- Kjemperud, A. 1980a: A shoreline displacement investigation from Frosta in Trondheimsfjorden, Nord-Trøndelag, Norway. *Norsk geol. Tidsskr.* 61, 1-15.
- Kjemperud, A. 1980b: Diatom changes in sediments of basins possessing marine/lacustrine transitions in Frosta, Nord-Trøndelag, Norway. *Boreas* 10, 27-38.
- Kolbe, R. W. 1927: Zur Ökologie, Morphologie und Systematik der Brackwasser-Diatomeen. Die Kieselalgen des Sperenberger Salzgebietes. Pflanzenforsch. 7, 146 pp.
- Krzywinski, K. & Stabell, B. in press: Late Weichselian sea level changes at Sotra, Hordaland, western Norway. *Boreas* 1983.
- Lie, S. E. & Lomo, L. 1981: En lito- og biostratigrafisk undersøkelse av marine og limnisk sediment i Ålesund-området. Cand. real. thesis, Department of Geology, University of Bergen, Norway.
- Mangerud, J. 1980: Ice-front variations of different parts of the Scandinavian Ice Sheet, 13 000-10 000 Years BP. In: Lowe, J. J., Gray, J. M. and Robinson, J. E. (eds.): Studies in the Late-Glacial of NW Europe, 23-30. Pergamon Press.
- Mangerud, J., Andersen, S. T., Berglund, B. E. & Donner, J. J. 1974: Quaternary stratigraphy of Norden, a proposal for terminology and classification. *Boreas* 3, 109-128.
- Mangerud, J., Larsen, E., Longva, O. & Sønstegeard, E. 1979: Glacial history of western Norway 15,000-10,000 BP. *Boreas* 8, 179-187.
- Mangerud, J., Gulliksen, S., Larsen, E., Longva, O., Miller, G., Sejrup, H.-P. & Sønstegeard, E. 1981: A Middle Weichselian ice-free period in Western Norway: The Ålesund Interstadial. *Boreas* 10, 447-462.
- Mangerud, J., Lie, S. E., Furnes, H., Kristiansen, I.-L. & Lomo, L. in press: A Younger Dryas ash bed in Western Norway and its possible correlations with the tephra in cores from the Norwegian Sea and the North Atlantic. *Quaternary Research*.
- Reite, A. J. 1967: Lokalglaciation på Sunnmøre. *Norges geol. nders.* 247, 262-287.
- Schrader, H. J. 1973: Proposals for a standardized method of cleaning diatom-bearing deep-sea and land-exposed marine sediments. *Nova Hedwigia Beih.* 45, 403-409.
- Simonsen, R. 1962: Untersuchungen zur Systematik und Ökologie der Bodendiatomeen der westlichen Ostsee. *Int. Rev. Ges. Hydrobiol. Syst. Beih.* 1, 144 pp.
- Sindre, E. 1980: Late Weichselian ice-front oscillations in the Hardanger-Sunnhordland District, West Norway. Continental Shelf Institute. Publication no. 102, March 1980. 16 pp.
- Sollid, J. L. & Sørbel, L. 1979: Deglaciation of western Central Norway. *Boreas* 8, 233-239.

- Sollid, J. L. & Kjenstad, K. 1980: Hovedflaten (Yngre Dryas' Havnivå) som basis for kvartær kronologi i Midt-Norge. Et metodeforsøk. *Norsk geogr. Tidsskr.* 34, 93-96.
- Stabell, B. 1980: Holocene shorelevel displacement in Telemark, southern Norway. *Norsk geol. Tidsskr.* 60, 71-80.
- Stabell, B. 1982: Changes in diatom floras in Late Quaternary western and southern Norwegian marine and freshwater sediments: Response to basin isolation from the sea. Dr. scient. thesis 1982, Department of Geology, University of Oslo, Norway.
- Thomsen, H. 1982: Late Weichselian shore-level displacement on Nord-Jæren, south-west Norway. *Geol. Fören. Stockh. Förh.* 103, (for 1981), 447-468.
- Voigt, M. 1957: Note sur le genre «Diatomella». *Revue algologique* 3, 68-71.