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ACOUSTICAL REFLECTION PROFILES, SEDIMENTS AND LATE QUATERNARY HISTORY OF THE NORWEGIAN CHANNEL NORTH OF BERGEN[1]

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ABSTRACT

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Acoustical reflection profiles of the area show four sedimentary units which reflect depositional events in and since the last glaciation. Two units (4 and 3) have a morainic character. The morainic units are covered by late Weichselian glacio-marine (unit 2) and Holocene (unit 1) sediments. The distribution of the postglacial basin infill has been mapped and shows that at present sedimentation rates are low.

Storm induced wave abrasion of Vikingbank has resulted in selective removal of fines from west to east. The recent hydrographic regime is expressed in the distribution of the sand fractions, in the carbonate- and organic carbon content, and in the C/N ratios of the bottom sediments. Pockmarks are present along the western slope of the Channel which becomes highly dissected and irregular towards the south.

INTRODUCTION

The Norwegian Channel (Norwegian Trough or Norwegian Trench) and the Skagerrak are a prominent feature of the North Sea (Fig. 1). They form a 900 km long, rather narrow (80-90 km), elongated basin with a maximum depth of 700 m in the Skagerrak and a depth of 500 m where it debouches into the North Atlantic Ocean (Fig. 2).

Until now only limited attention has been given to its late Quaternary sedimentary history. This is the more astonishing as this basin forms presumably the most extensive area in the North Sea where recent sedimentation occurs (EISMA, 1973; MCGAVE, 1973; VAN WEERING ET AL., 1973; MOYES ET AL., 1974; VAN WEERING, 1975, 1981; JØRGENSEN ET AL., 1981). Apart from this, the construction of pipelines from various oil fields in the Norwegian sector of the North Sea to the shore requires an extensive knowledge of recent and subrecent sediments and sedimentary processes (HOVLAND & INDREEIDE, 1980).

This paper deals with the interpretation of acoustical profiles obtained with the R.V. 'Aurelia' in the Norwegian Channel north of Bergen during cruises in 1973-1976 and with sedimentological analyses of bottom sediment samples collected in the same area from 1975-1978. It follows earlier publications on the distribution and character of late Quaternary sediments in the Norwegian Channel south of Bergen (VAN WEERING ET AL., 1973; VAN WEERING, 1977) and the Skagerrak (VAN WEERING, 1975, 1977, 1981, 1982).

GEOLOGICAL SETTING

The Norwegian Channel forms part of the transition zone between the relatively stable Fennoscandian Shield and the North Sea Basin, a region of major subsidence. In the centre of the North Sea Basin the Tertiary and Quaternary deposits reach a maximum thickness of 3500 m, of which the Quaternary deposits form the upper 1000 m (CASTON, 1977). However, the Tertiary strata wedge out towards the E and are locally absent in the Norwegian Channel (RONNEVIK ET AL., 1975).

Seismic measurements in the Norwegian Channel west of Bergen have shown that in the Norwegian Channel Quaternary sediments rest with an angular unconformity on Tertiary, Mesozoic, or, close to the coast, Precambrian rocks. The Norwegian Channel evidently has been formed mainly by glacial erosion during the ice-ages (FLØDEN & SELLEVOLL, 1972; SELLEVOL & SUNDVOR, 1974; BRAITHWAITE ET AL., 1974; BALLARD, pers. comm., 1976). The Quaternary deposits have a thickness that varies from 220-240 m in the centre of the Channel off Bergen to about 500 m at the shelf edge, while in

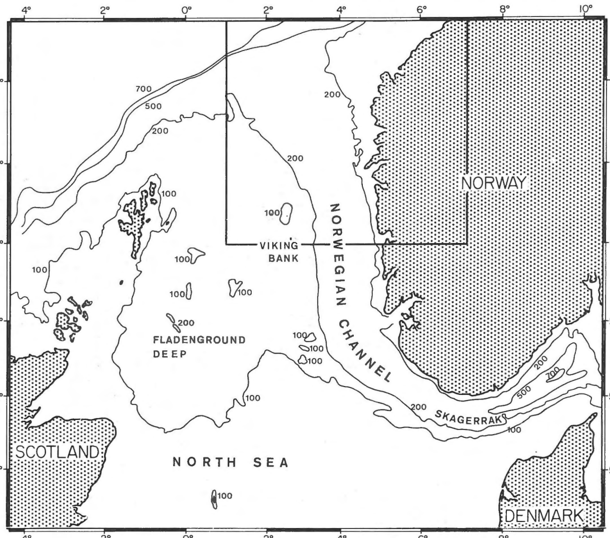

Fig. 1
Map of the northern North Sea with main depth contours and thestudy area. Depth in metres.

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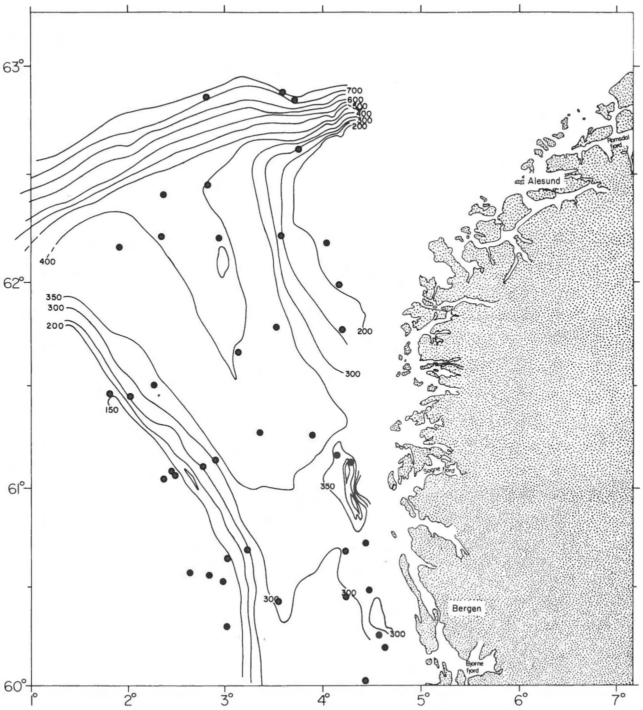


Fig. 2
Bathymetric map based on the acoustical profiles and on published data. Depth in metres.

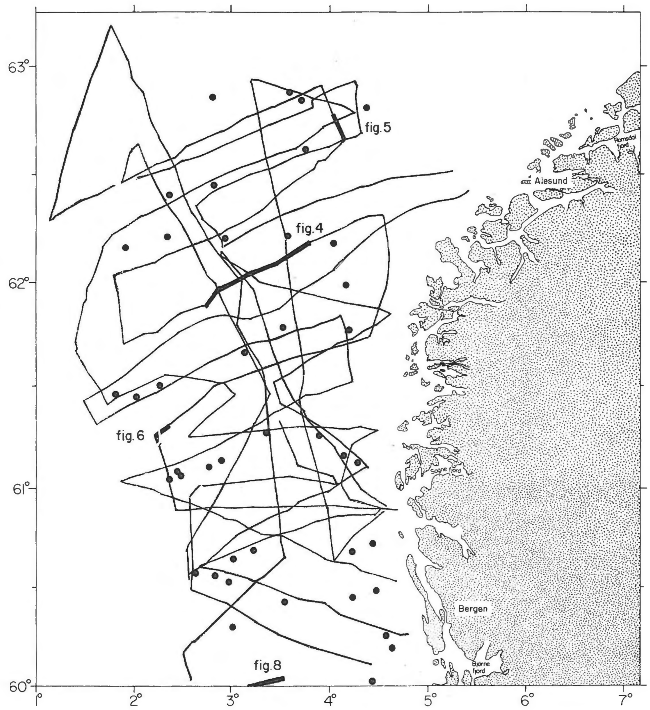


Fig. 3
Position of track lines obtained during surveys in 1973-1976. Heavy lines refer to location of illustrations mentioned in the text.

cross section the Quaternary cover is locally very thin along the coast (BRAITHWAITE ET AL., 1974), and is about 45-50 m along the western flank (SELLEVOLL & SUNDVOR, 1974).

Within the Quaternary deposits there is a number of acoustic reflectors which can be recognized over large distances and which indicate two main directions of transport, one across and the other along the axis of the Norwegian Channel towards the north (SELLEVOLL & SUNDVOR, 1974). A sparker section from Karmøy to Frigg across the southern part of the Norwegian Channel reveals a complex Quaternary sequence with many discontinuous reflectors, which can be regarded as erosional planes (SOPP & READ, 1977; READ, pers. comm., 1982). The same has been found in the southwestern Skagerrak and in the Norwegian Channel off Egersund. During various periods of the Pleistocene the ice sheets extended from Norway far to the west and were in contact with the seafloor.

The series of banks and gravel patches along the western margin of the Norwegian Channel, depicted by PRATJE (1951) as terminal moraines, therefore can be considered as moraines which were deposited during a late-Weichselian retreat stage and which subsequently have been partly winnowed.

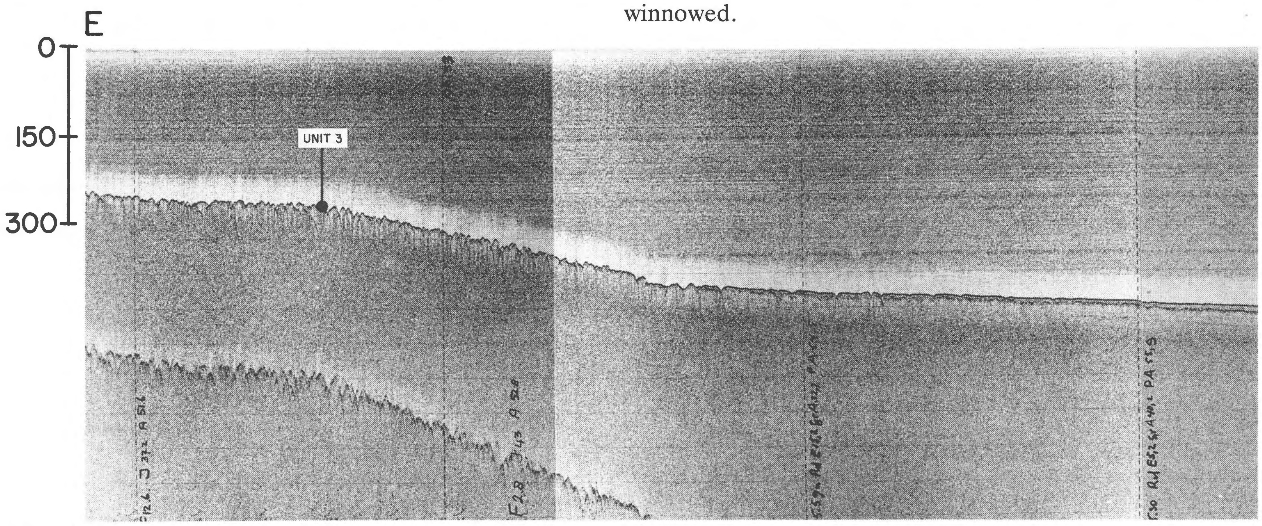


Fig. 4 (continues on facing page)
E-W acoustical reflection profile across the Norwegian Channel. For location see Fig. 3. Acoustical units are indicated. Note the irregular topography along the eastern slope of the Channel. Vertical exaggeration × 20. Scale in metres.

Little is known of the most recent sediment cover of the seafloor, apart from some samples off the Sognefjord collected by HOLTEDAHL (1955). The sediments are grey silty clays. Sampling close to the Norwegian coast south of Bergen revealed a Holocene toplayer of variable thickness resting on sediments with a cold water foraminiferal fauna indicative of a Weichselian age (BRAITHWAITE ET AL., 1974). Studies of the seabottom in an area off the Norwegian west coast north of Bergen (ELVERHØI, 1979) indicated the presence of tills of probably Weichselian age that are locally covered by late Glacial unconsolidated muds and sands. The latter were ascribed to erosion by the Norwegian Coastal Current. NORVIK (1980) presented data on a number of cores from the eastern, shallow part of the Norwegian Channel and recognized the same lithology as mentioned by ELVERHØI (1979).

METHODS

Continuous acoustical reflection profiling was carried out simultaneously with shallow seismic reflection profiling along the tracks shown (Fig. 3). In a later stage a number of sediment samples was taken by grab and piston corer. In the present study only the results of the analysis of the acoustical reflection profiles and of the grab samples will be discussed.

The acoustical reflection profiling equipment consisted of 4 hull-mounted 3,5 kHz transducers that were used in combination with a 2000 W transceiver which was coupled to a Correlating Echo Sound Processor (CESP). Processed echoes were recorded on a Raytheon Precision Graphic Recorder. For the calculation of the sediment thickness of these unconsolidated sediments a sound velocity of 1500 m/s has been assumed. The bottom sediments were collected with a Van Veen grab. On board a subsample of about 1 litre was taken and stored at 4°C. The remainder was wet sieved through 3 and 2 mm sieves. The coarse material was collected for further study. Grain size analyses at whole phi-intervals were carried out using standard sieve and pipette methods (FOLK, 1968). The sediments were dispersed in sodium diphosphate solution, sometimes in combination with an ultrasonic treatment.

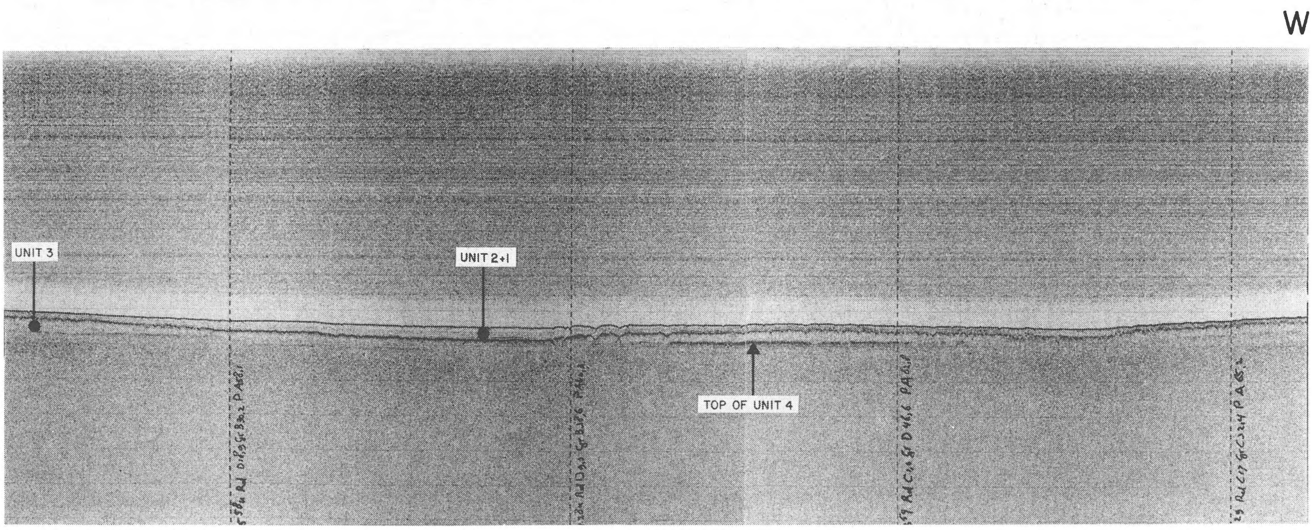
The carbonate content of the surface samples was measured by the Scheibler method, a method which is comparable to the method described by HÜLSEMANN (1966). In a later stage an automatic standard EGTA titration was carried out to determine the amount of Ca. This was then combined with the amount of Mg (determined by atomic absorption spectrophotometry) and considered to represent the total amount of carbonate. Organic carbon was removed with phosphoric acid, and by adding $K_2S_2O_8$ to the remainder, the organic content was estimated from the amount of CO_2 gas developed. Nitrogen was measured using the standard Kjeldahl digestion method.

RESULTS

Acoustical reflection profiles

Subbottom profiling in the Norwegian Channel south of Bergen (VAN WEERING ET AL., 1973) and in the Skagerrak (VAN WEERING, 1975) revealed the presence of several acoustical units with different internal characteristics. These were also recognized in the northern part of the Norwegian Channel. On all profiles a deposit can be recognized that is characterized by hyperbolic internal reflections (probably pebbles and boulders) and by the absence of internal stratification (Figs 4 and 5). The top of this deposit has a rather irregular relief, which is expressed in the covering sediments. This unit (3) is underlain by a deposit with similar internal characteristics (unit 4) but with a strong flat reflector on top. Both units were interpreted as glacial drift deposits.

Unit 3 is covered, mainly in the deeper parts of the Channel, by two younger deposits one of which shows the presence of many parallel internal reflectors which can be traced over large distances. These internal reflectors vary in intensity and are, especially in the more southern part of the



area, separated by transparent layers. This unit (2) has been interpreted as a glacio-marine deposit, presumably of late Weichselian age. The top unit (1) is acoustical transparent and contains no or few, weak internal reflectors. This unit is considered a mud deposit mainly settled out of suspension during the Holocene.

Unit 3 deposits extend all across the Norwegian Channel and are covered only in the deepest part of the Channel by unit 1 and 2 (Figs 4 and 7). Unit 3 sediments are found on the seafloor both along the western and along the eastern slope towards Norway, where they are covered only locally with a thin veneer of younger sediments. This has resulted in a rugged topography (Fig. 4) along the eastern slope of the Norwegian Channel .

Between 62° and 62°30′N along the eastern slope off the Norwegian coast there is a plateau in waterdepths less than 200 m (Fig. 2). Here the seafloor is for the greater part composed of unit 3 sediments which form a series of ridges parallel to the depth contours. Along the northeastern slope of the Channel (Fig. 5) there are a number of ridges that also consist of unit 3 sediments. In the depressions between ridges unit 1 and unit 2 sediments are found locally.

Only the shallower part of the western slope of the Norwegian Channel is composed of unit 3 sediments. Off Vikingbank the eastern edge of the North Sea platform is relatively steep (Fig. 6). The unit 3 sediments that form the flat top of Vikingbank have apparently been eroded. This relief disappears towards the north and to the south.

Unit 2 and unit 1 sediments cover the deepest part of the Channel and pinch out towards the sides. Differentiating these units becomes difficult in the northern part of the area of survey as a result of the gradual thinning of the total sediment cover on top of unit 3 and of the pinching out of unit 1 and 2 sediments to the north. Therefore these units, which are assumed to represent the late Weichselian and Holocene sediment infill of the Norwegian Channel, have been mapped together (Fig. 7). The greatest thickness is found in a small basin off Bergen (50 m) and in a depression along the western side of the Channel (43 m). The differences in thickness are mainly due to the irregular relief of unit 3. This is especially clear in the area west of Bergen. Off Vikingbank and along the western side of the Trench towards the north the upper two layers fill a narrow depression and attain a maximun thickness of slightly more than 10 m (Fig. 7). This feature has disappeared in the northwestern part of the study area.

Along the axis of the basin the sediment thickness on top of unit 3 decreases markedly in a northerly direction. In the northern part of the study area unit 2 and 1 form only a veneer of less than 5 m. In the northern part the seafloor has a more irregular character due to the presence of unit 3 sediments at shallow depth beneath the seafloor.

The seafloor immediately south of 60°N is particularly irregular (Fig. 8) due to a great number of notches and incisions in the units 2 and 1 which here form the seafloor. These incisions are found in great numbers all along the western slope of the Channel in waterdepths down to 350 m. This relief has also been observed further south (VAN WEERING ET AL., 1973) where it is far less irregular, and in the north (HOVLAND, 1981). It has been described as pockmarks (VAN WEERING ET AL., 1973; HOVLAND 1981). Pockmarks occur in large numbers along the shallower parts of the flanks of the Channel, they are less numerous towards the axis of the Channel, and they are only isolated features in the central part of the Channel. Pockmarks (KING & MACLEAN, 1970) are

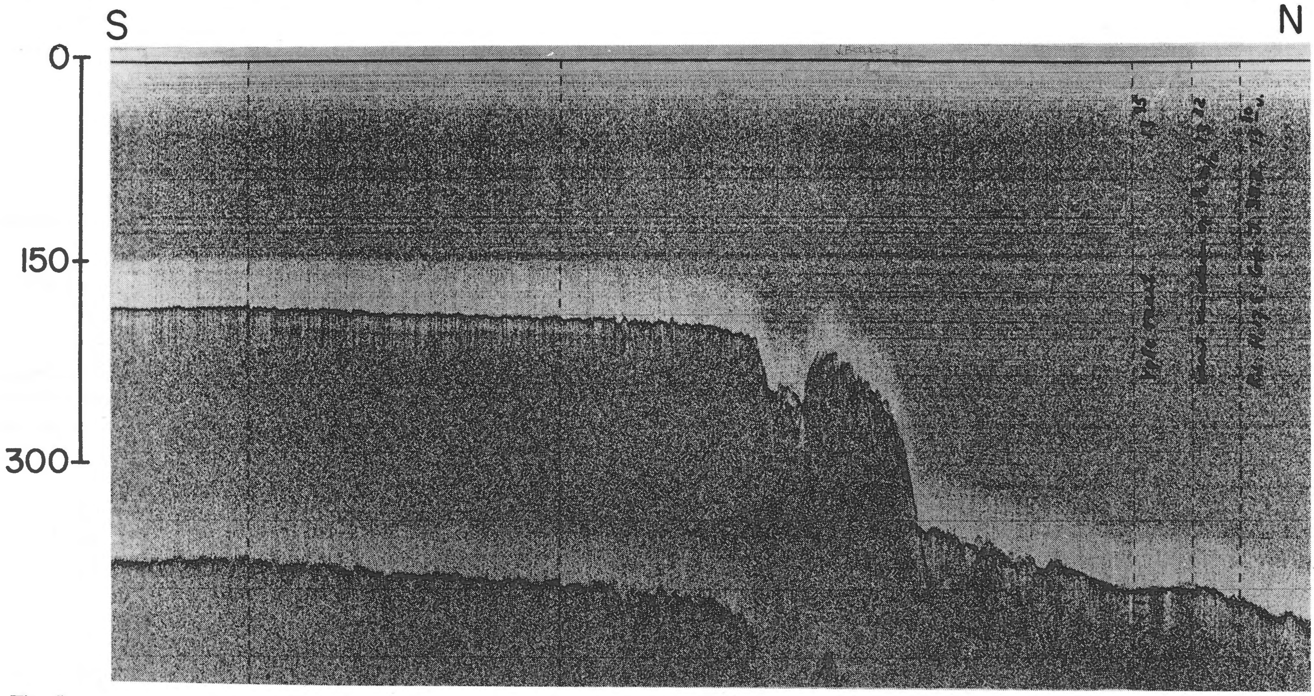


Fig. 5
Morainic ridge along the northeastern part of the study area. For position see Fig. 3. Vertical exaggeration × 20. Scale in metres.

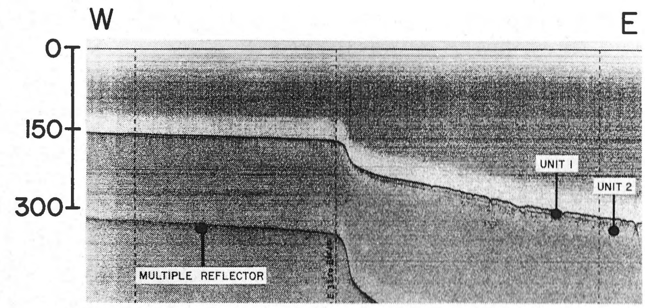


Fig. 6
Cliff-like character of the western slope of the Norwegian Channel off Vikingbank. For location see Fig. 3. Vertical exaggeration × 20. Scale in metres.

thought to form by release of gas through the sediments. Whether this gas is recent, attributed to methane formation by decomposition of organic matter, or is the result of leakage from deeper sources is as yet not clear.

Surface sediments

The amount of gravel in the surface sediments of the Norwegian Channel is generally low. Only on the relatively shallow plateau that forms the eastern margin of the Norwegian Channel, where unit 3 sediments are exposed on the seafloor, gravel occurs in larger amounts (Fig. 9a). Up to 30% of the fraction > 62 μ consists of gravel, mainly in a clayey matrix. This elongated patch of coarse sediments coincides with the presence of a ridge that is composed of unit 3

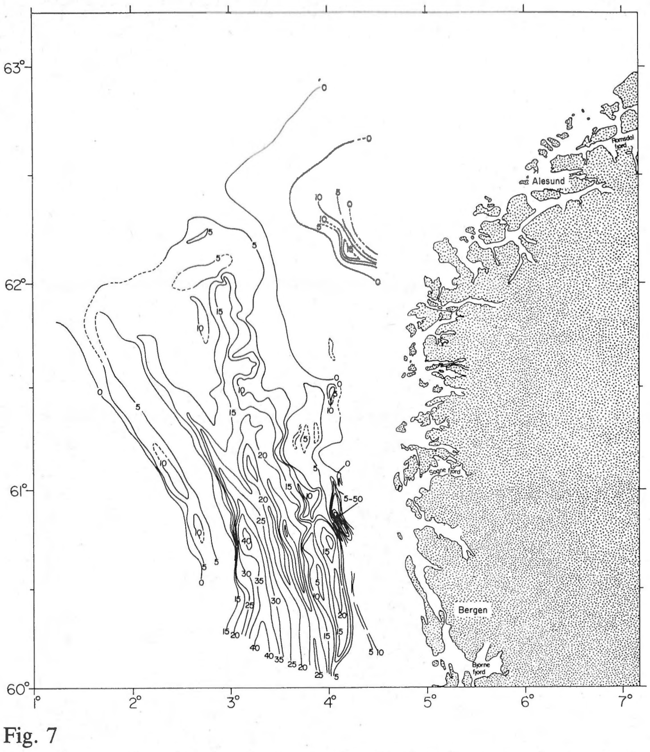


Fig. 7
Isopach map showing the thickness distribution (in metres) of units 2 and 1 in the northern part of the Norwegian Channel.

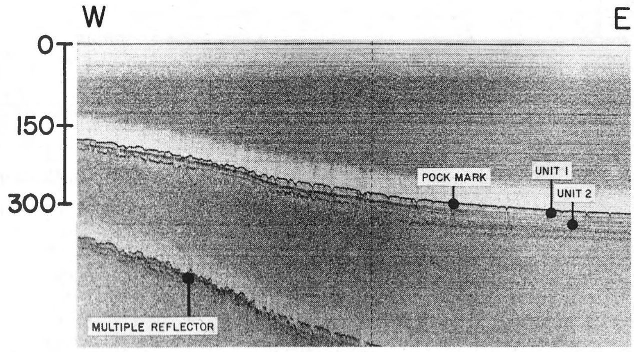


Fig. 8
Irregular relief in units 2 and 1 sediments along the western slope of the Norwegian Channel, caused by manyfold occurrence of pockmarks. For location see Fig. 3. Vertical exaggeration × 20. Scale in metres.

sediments. The irregular relief of this area is well expressed in the local values of 5% or less, that are found in depressions between the ridges or gravel patches. The blanketing effect of post Weichselian deposition of units 2 and 1, which contain almost no or very little (<< 5%) coarse grained material, is evident in the deeper parts of the Channel.

The median grainsize reflects a gradual fining of the sediments from the margins towards the axis of the Channel (Fig. 9b). The increase in median grain size towards the north along the axis of the Channel reflects the gradual pinching out of both unit 2 and unit 1 sediments in this direction. The $Ø_{50}$ values in the eastern part of the Channel clearly reveal the presence of submarine ridges composed of unit 3 sediments.

The sand fraction (62-2000 μ) forms the largest constituent of the surface sediments along the slopes and in the northernmost part of the study area (Fig. 10a). In the eastern part in a narrow, long zone parallel to the slope, locally 90% of the sediments consist of sand.

The western part of the Norwegian Channel is also composed of sandy deposits; at Vikingbank over 90% of the sediments along the slope consists of sand, with a rapid decrease towards the east.

The amount of very fine sand as part of the sand fraction is only very small (Fig. 10b); it reaches a maximum along the western slope of the Trench and forms about 50% of the sand fraction in the deepest part. There is a slight decrease in very fine sand content along the outlet of the Norwegian Channel, while towards deeper water again an increase is found.

The carbonate content of the samples (Fig. 11a) is fairly high. Values in excess of 20% are found in the deeper parts of the basin, with locally exceptional values of 50 and 30%. These values are associated with a high amount of biogenic components in the sediment. The carbonate percentages are well below 10% along the eastern flank of the Channel and even below 5% at Viking bank. There is a good correlation between the carbonate content of the samples and the amount of fine grained material (< 63 μ). Only for a limited number of samples, all obtained from the shallower western flank of the Channel, this relationship does not hold (see Fig. 12a).

The organic carbon content is low, even in the deepest part of the Channel, where the finest sediments are found at the seafloor (Fig. 11b). Here values just above 1% are found. The values in the northern part of the Norwegian Channel are well below 0.5%, with a slight increase towards deeper water along the axis of the Channel. There is a good correlation between the amount of organic carbon and the content of fine grained material (< 63μ), although some scatter is obvious (Fig. 12b).

Nitrogen in the bottom sediments is only present in very small amounts (Fig. 13a); the highest values are found in the centre of the basin and along the continental slope, whereas along the slopes of the Norwegian Channel the amounts are below 0.50%, mostly even less (0.20-0.30%). The C/N ratio

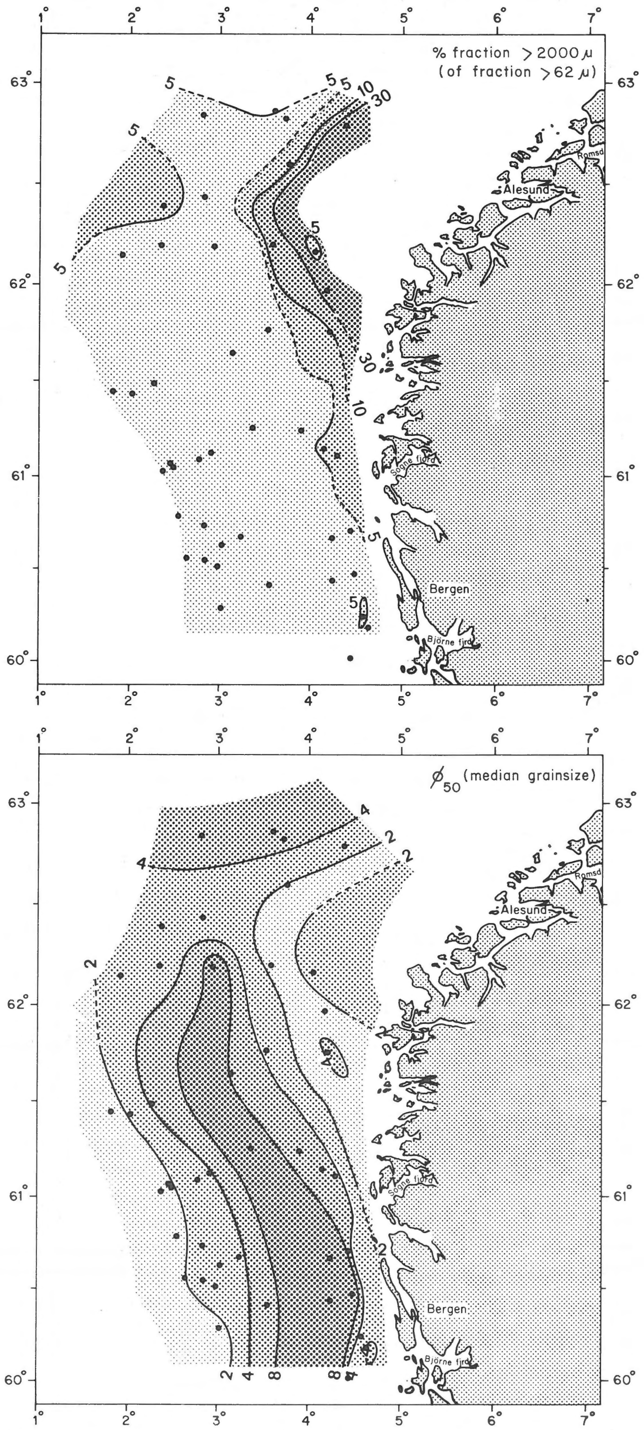


Fig. 9 a-b
Maps showing the distribution of gravel (upper) and of the median grainsize (Ø50) (lower) of the bottom sediments of the northern Norwegian Channel.

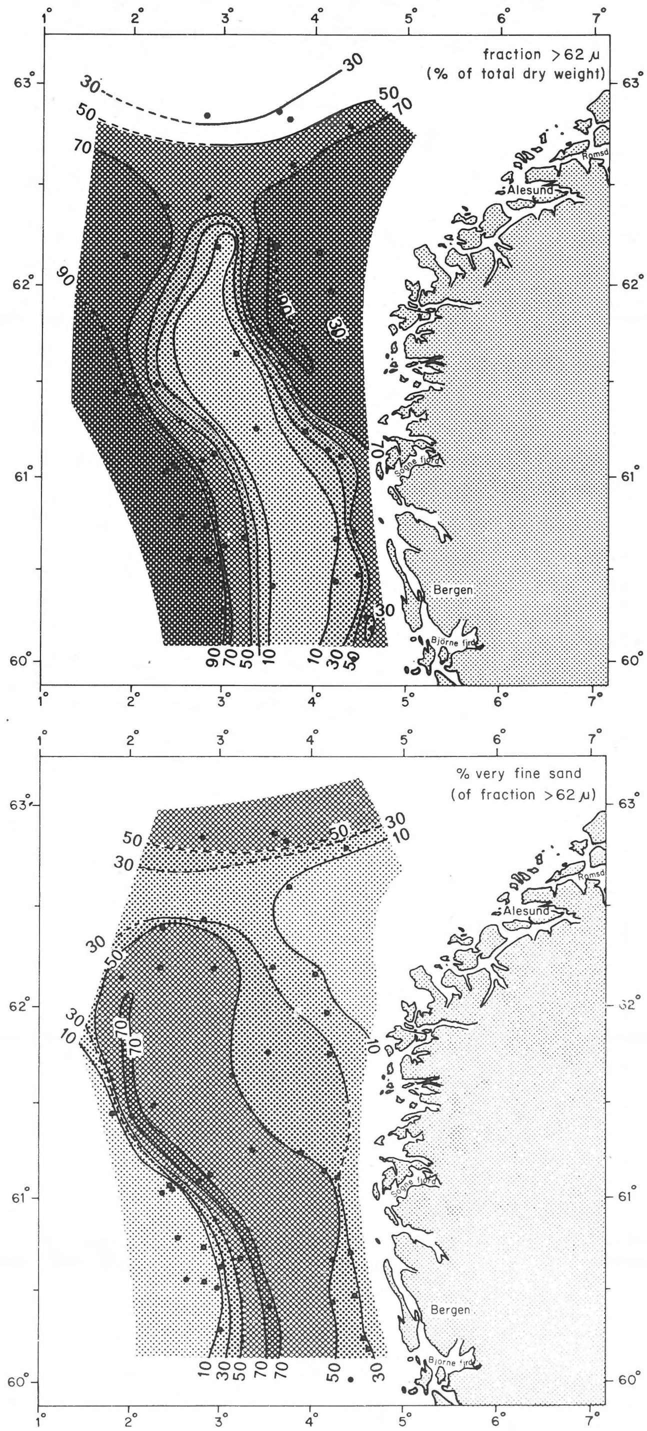


Fig. 10 a-b
Maps showing the distribution of the fraction > 62μ (upper) and of the very fine sand fraction (62-125μ) (lower) as percentages of the sand fraction.

gives a clear distribution pattern (Fig. 13b). Lowest values of C/N are found along both slopes in the area from 60°-61°N, the values ranging from 6-8. In the centre of the Channel the values are a little higher, 8-10. The highest ratios are found in the northernmost part of the area, where generally the C/N ratios are between 10 and 20, with local peak values of over 30. There is a general tendency of increasing C/N ratio along the axis of the Channel towards the north.

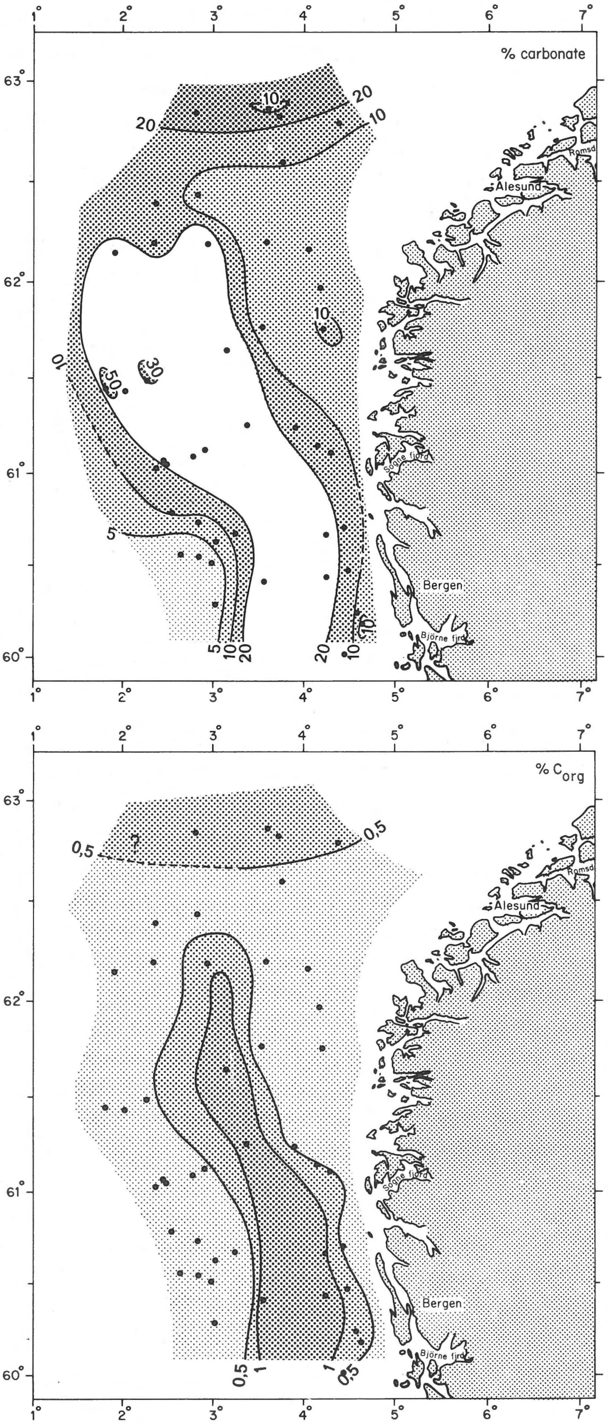


Fig. 11 a-b
Maps showing the distribution of carbonate (upper) and of organic carbon (lower): in the bottom sediments of the northern Norwegian Channel.

DISCUSSION

During the last glaciation, the ultimate reach of Scandinavian glaciers was as far west as the Shetlands (HOPPE, 1974) and the British and Scandinavian glaciers must have met in the North Sea area north of 60°N (JANSEN, 1976). The ice movements in the Norwegian coastal areas were directed more or less normal to the coast (VORREN, 1977). Thus, there is no doubt that the Norwegian Channel region was ice covered, at least from about 27 000-25 000 B.P., after the initial expansion of the ice sheet, until the ice had retreated to the present coastline.

The deglaciation of the Bergen area and the adjoining area further north has been discussed by a.o. AARSETH & MANGERUD (1974) and by MANGERUD ET AL. (1979). They concluded that the ice front reached the coast shortly before 12 600 B.P. and that during the late Weichselian the ice front moved back and forth.

Both acoustic units 3 and 4 were interpreted as boulder-rich, morainic deposits (VAN WEERING ET AL., 1973). The flat, rather strong top reflector of unit 4 contrasts strongly with the hummocky irregular relief of unit 3. The most plausible explanation is that unit 4 was deposited and eroded by the same ice sheet that subsequently formed unit 3. This then would indicate that during a rather long period the ice sheet

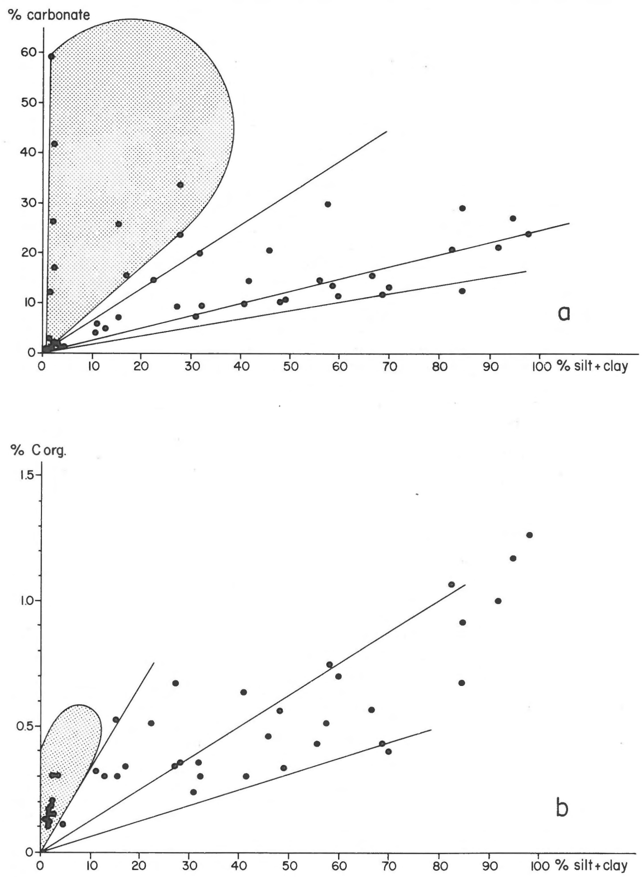


Fig. 12 a-b
Relationship between the amount of fine grained material (fraction < 62μ) and carbonate content (upper) and content of organic carbon (lower). Dotted area denotes samples located off Vikingbank.

was grounded on the bottom of the Norwegian Channel. This fits with the observed overconsolidation of late glacial clays in the northern part of the North Sea (LØKEN, 1976) which has been attributed to ice loading.

In the Bergen area the ice reached the coast shorthly before 12 600 B.P. (MANGERUD ET AL., 1979). In the northeastern part of the study area shells from a glacio-marine clay with a radiocarbon age of 12 500 B.P. and 13 000 B.P. from outside a morainic ridge indicate that in that period the ice front there also had a position rather close (40 km) to the coast. The date suggest that unit 3 sediments were formed when the ice started to retreat from the western side of the Channel (approximately 18-15 000 B.P.) until about 12 600 B.P., when the ice had retreated to the present coastline. Thus, unit 3 deposits are slightly older in the western part of the Channel than in the eastern part and the surface of unit 3 sediments therefore is time transgressive. If this is indeed true for unit 3 it holds also for unit 4 which in its upper part is only slightly older than unit 3. However, erosion by the ice sheet will have produced a hiatus in the stratigraphic record of unknown duration. This means that unit 4 is, at least along the western side of the Channel, older than 18 000 BP.

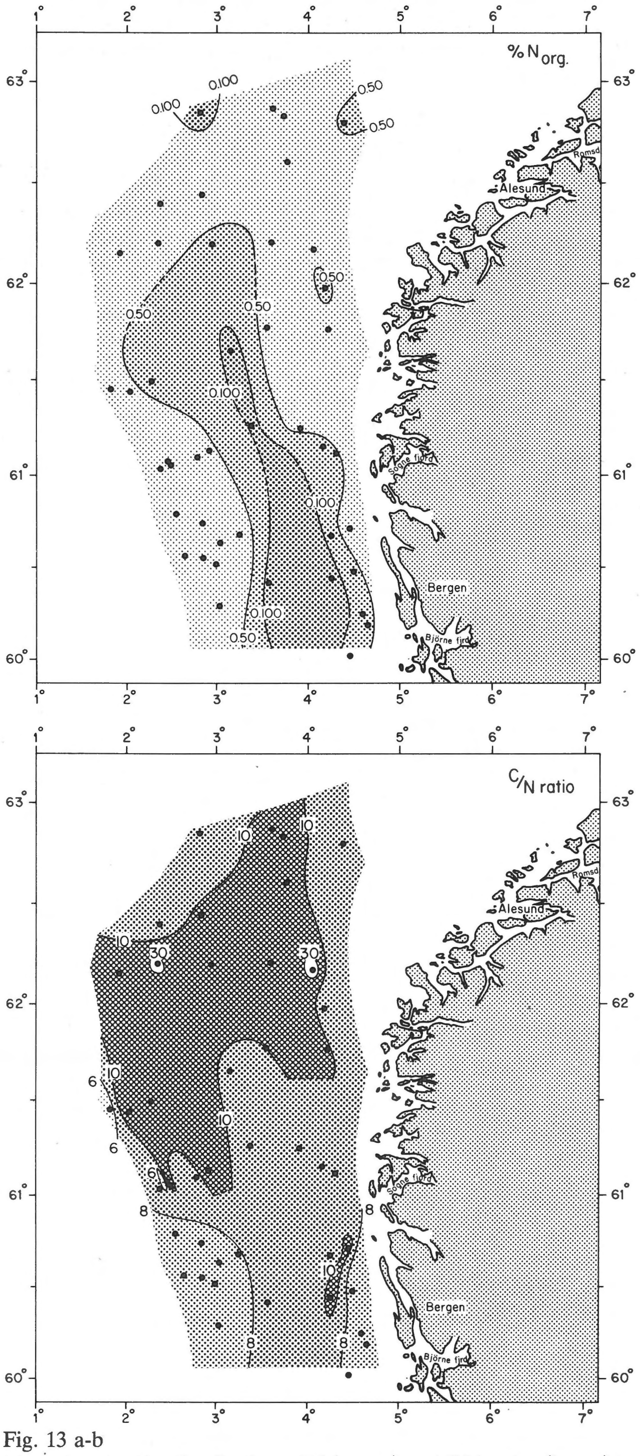


Fig. 13 a-b
Maps showing the distribution of N (upper) and C/N ratios (lower) in bottom sediments of the northern Norwegian Channel.

The retreat of the ice has probably also produced the huge morainic ridge along the northeastern slope of the study area and the strong relief on the sea floor (figs 4 and 5). HOLTEDAHL & SELLEVOLL (1972) described ridges along the upper continental slope in waterdepths down to 500 m in a nearby area as morainic ridges. Apparently the ridge observed along the continental slope (Fig. 5) forms part of a series of ridges that parallel the depth contours and which were formed in late Weichselian time. The deposition of unit 2 started presumably directly after the deglaciation. Unit 2 sediments follow the underlying relief of unit 3 closely, are apparently fine grained and loosely packed, and they sometimes are characterized by internal hyperbolic reflectors. If the latter is taken as an indication for deposition by icebergs under the influence of melting ice, unit 2 is a glacio- marine sediment with a variable texture that has been deposited during the late Weichselian. In fact, cores from unit 2 sediments contain considerable amounts of ice rafted detritus and cold water foraminifera (LE FOURNIER, 1975). This was also found by ELVERHØI (1979) and by NORVIK (1980) for an area closer to the Norwegian Coast and by VAN WEERING (1982) in the Skagerrak.

During the initial retreat of the ice towards the Norwegian coast, the northern part of the North Sea was a shallow sea characterized by vigorous wave action. Together with a probably still rather small tidal component, due to the return of the Atlantic water into the Norwegian Sea (MANGERUD, 1977), this may have resulted in the partial erosion of shallower portions of the seafloor, for example Viking bank. The cliff face observed along the eastern side of Viking bank would in this view be the result of erosion of the top of the bank in combination with an eastward directed transport of the finer, eroded components to the deeper Norwegian Channel, rather than be a submerged beach as advocated by DEKKO & ROKOENGEN (1978). Erosion may have continued well into the Holocene until sea level had risen sufficiently to keep the seabed in the area out of the reach of waves, except heavy storm waves, which still may touch bottom, even now.

During the rise in sea level succesively larger and larger parts of the North Sea were drowned and became subject to reworking. This will have brought large amounts of material in suspension, which subsequently were deposited in the deeper Norwegian Channel. The deposition of unit 1 in the northern part of the Norwegian Channel ceased probably around 8 000 B.P. when a tidal current pattern similar to that of the present became established in the North Sea (EISMA ET AL., 1979). The Skagerrak then became the main depôt centre and the supply along the Norwegian Channel towards the north decreased. This is shown in the profiles as a gradual lateral pinching out of unit 1 towards the north. Apparently there has been a decrease in the amount of material which was available for transport under influence of northerly-directed bottom currents.

The present-day distribution of the surface sediments still largely reflects the late Weichselian and early Holocene situation. Fines are being deposited at a very low rate in the deeper, northern part of the Norwegian Channel. This is reflected in the median grainsize, in the sand content and in the amount of very fine sand of the surface sediments. The relict character of part of the shelf is expressed in the irregular relief and in the amount of gravel in the sediments. They indicate that the present-day currents along the eastern and western slope of the Norwegian Channel are probably strong enough to prevent settling of fines. This is corroborated by the data of EISMA & KALF (1978) concerning the amount of suspended matter in the northern part of the Norwegian Channel.

The distribution of the carbonate fraction partly reflects the influence of the Atlantic current; the carbonate consists of foraminiferal skeletons of which a considerable part is planktonic. The high percentages of 50 and over 30 are due to the presence of probably wave-transported biogenic debris along this part of the Channel. If the debris is of recent age the importance of wave, storm-induced erosion of the seabed may be much greater even at this water depth than thought previously.

The organic carbon content is clearly related to the occurrence of fines in the bottom sediments (Fig. 11b), as is the presence of nitrogen (Fig. 13a). C/N ratios are generally considered as indicators for the influence of different types of organic matter in the sediments. C/N ratios of 6 or lower are characteristic for marine organisms, while values of 15 or higher are produced by the remains of higher plants in the sediments (MÜLLER, 1977). Low C/N ratios on the other hand are believed to be due to ammonium fixation in the interlayers of aluminium silicates, e.g. illites and vermiculites, in the bottom sediments (MÜLLER, 1977).

In the study area the differences in illite and vermiculite content are not so pronounced that they could be held responsible for the observed differences in C/N ratio between the northern and more southern part of the area. Thus the higher values in the northern part, which coincide roughly with the presence of unit 2 sediments on the seafloor, are attributed to a higher contribution of land-derived sediments. In contrast, the southern part of the study area, where unit 1 sediments are found, has low C/N ratios and represents fresh, marine deposits. These observations confirm the interpretation of the acoustical profiles.

CONCLUSIONS

In the northern part of the Norwegian Channel morainic sediments are found on the seafloor. These sediments are covered only in the deeper parts by late Weichselian and Holocene sediments. The postglacial sediments wedge out towards the north, while in the southern part they attain a maximum thickness of 43 m. The acoustical character points to a glacio marine, late Weichselian origin for unit 2 and to deposition from suspension in the Holocene for unit 1. This pattern is supposed to be characteristic for a rapid retreat of an ice sheet across a marginal channel. The Quaternary sediments in the Norwegian Channel presumably display cyclic alternations of this sequence.

The distribution of the bottom sediments to some extent reveals the change in hydrographic regime since the deglaciation of the area. Along the western flank of the Norwegian Channel wave induced erosion, possibly in combination with higher bottom current velocities has resulted in the deposition of fines into the Norwegian Channel, indicating a transport from west to east. This has probably been an important process in the late Weichselian and early Holocene. Whether this process is still active is not clear, although there are indications for easterly directed transport of recent biogenic debris along the slope of the Channel. The amounts of carbonate and the distribution of the median grainsize, as well as the relation between the organic carbon content and the fraction $< 63\ \mu$ do reflect the influence of the present-day hydrographic and depositional pattern. At present there is only very little sedimentation.

C/N ratios are highest in the northern part of the study area and they probably reflect a higher terrestrial input in the late Weichselian or early Holocene. There are pockmarks along the western flank of the Norwegian Channel in waterdepths down to 350 m. Towards the south they become highly irregular and more numerous, while in the northern part they are few in number and are difficult to distinguish because of the already irregular relief of the seafloor. Isolated pockmarks are found in the central part of the Norwegian Channel.

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