# Sea-bed sediments and sediment accumulation rates in the Norwegian part of the Skagerrak

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Grain-size analysis show that the sea-bed sediments over large areas in the Norwegian Trench and along its northern slope consist of homogeneous silty clay with a clay content of 50-75% and generally less than 2% sand. Sediments on the plateau along the Norway-Denmark median line are dominated by fine and very fine sands, which become coarser at shallower water depths towards the southeast, where sand constitutes up to 80% of the sediments, and silt and clay approximately 10% each. These sediments are transported into the Skagerrak mainly by the Atlantic Current, the currents from the North Sea and the Jutland Current, and originate from sea-floor erosion in the North Sea, from rivers on the continent and in Britain and from coastal erosion between Denmark and the English Channel.

Sedimentation rates in the Norwegian Trench and on the plateau along the Norway-Denmark median line are generally 10-20 cm/100 years, increasing to more than 30 cm/100 years in the southeastern parts of the investigated area. Areas of sedimentation rates >50 cm/100 years are located on the southeastern and eastern slopes of the Norwegian Trench. Areas of high sedimentation rates generally occur where there is a reduction in hydraulic energy and sediment transporting competency of the ocean currents. It is estimated that 18.6 mill. tons of sediment (dry weight) accumulate in the Norwegian part of the Skagerrak annually.

Along the upper part of the southern slope of the Norwegian Trench and on the plateau towards Denmark there is an upward coarsening trend in the uppermost 30 cm of the sediments on the sea bottom. This indicates that over the past 150-250 years there has been a change in the direction and/or magnitude of the major current systems, leading to an increased supply of coarser-grained material from the southwest, while fine-grained material has been transported into the deeper parts of the Skagerrak.

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## Introduction

The Norwegian part of the Skagerrak is dominated by the Norwegian Trench, which is a glacially eroded sedimentary basin trending parallel to the coast of Norway (e.g. Holtedahl 1993). The Skagerrak and the Norwegian Trench (Fig. 1) are the deepest and largest basins of the North Sea, and form a major sink for fine-grained material (Eisma & Kalf 1987, Van Weering et al. 1993a). More than half of the sediments deposited in the North Sea are deposited in the Skagerrak (Eisma & Irion 1988).

The sea-bed sediments in the Skagerrak have previously been studied by a number of authors (see review by Van Weering et al. 1993b), but have never been sampled in a dense and regular grid allowing detailed analysis of lateral and vertical distribution patterns. In the period 1991-1995 the Geological Survey of Norway, as coordinator, together with several other institutions, carried out a sea-bed investigation programme in the Norwegian part of the Skagerrak (Figs. 1 and 2) to map this important area of sediment deposition. During the project, more than 12,000 km of shallow seismic reflection data (Ottesen et al. 1994) and more than 850 short cores from 132 sampling stations (Fig. 2) (Bøe 1995) were acquired in the Norwegian part of the Skagerrak in order to map bedrock and Quaternary geology, sea-bed sediments and the state of pollution in the sea-bed sediments. In this contribution we present some results from the sea-bed sediment mapping carried out during the project.

## Bathymetry and hydrography

The Skagerrak basin reaches a maximum depth in excess of 700 m approximately 50 km to the southeast of Arendal (Fig. 1). Along the northwestern margin of the Norwegian Trench there is a gradual shallowing towards mainland Norway, although in a broad belt along the coast, especially in the northeast, there is an irregular topography. Along the southeastern margin of the deep basin there is a shallowing towards the median line between Denmark and Norway. At 250-300 m water depth there is a decreasing gradient of the slope as one enters a gently northwestward sloping plateau. To the west there is a gradual shallowing of the Norwegian Trench, while in the east the trench widens before it terminates to the southeast of Langesund (Fig. 1).

The volumetrically most important current entering the Skagerrak consists of Atlantic water, which enters the North Sea north of Shetland (Fig. 1) (Rodhe 1987, Aure et

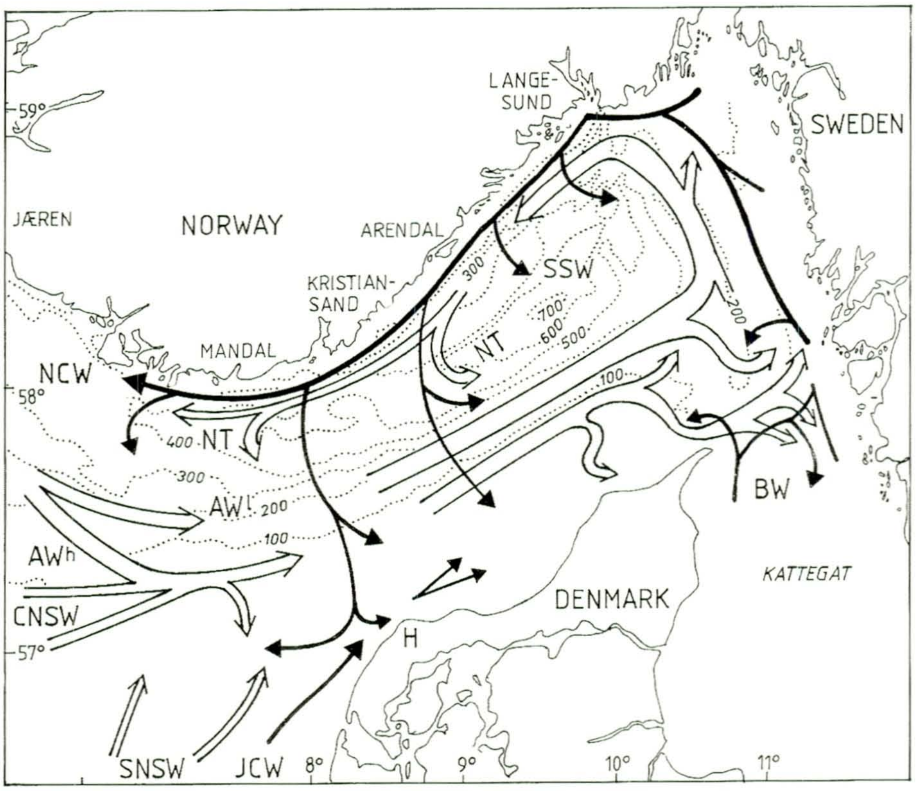


*Fig. 1. Bathymetry in metres and general circulation of water masses in the Skagerrak and adjacent areas. Open and filled arrows indicate subsurface and surface water masses respectively. Aw$^h$, Atlantic water high (shallow) and Aw$^l$, Atlantic water low (deep) together constitute the Atlantic Water Current. BW: Baltic water (Baltic Current); CNSW: Central North Sea Water (Central North Sea Current); JCW: Jutland coastal water (Jutland Current); NCW: Norwegian coastal water (Norwegian Coastal Current); SNSW: Southern North Sea water (Southern North Sea Current); SSW: Skagerrak surface water; NT: Norwegian Trench; H: Hanstholm. Modified from Danielsen et al. (1991).*

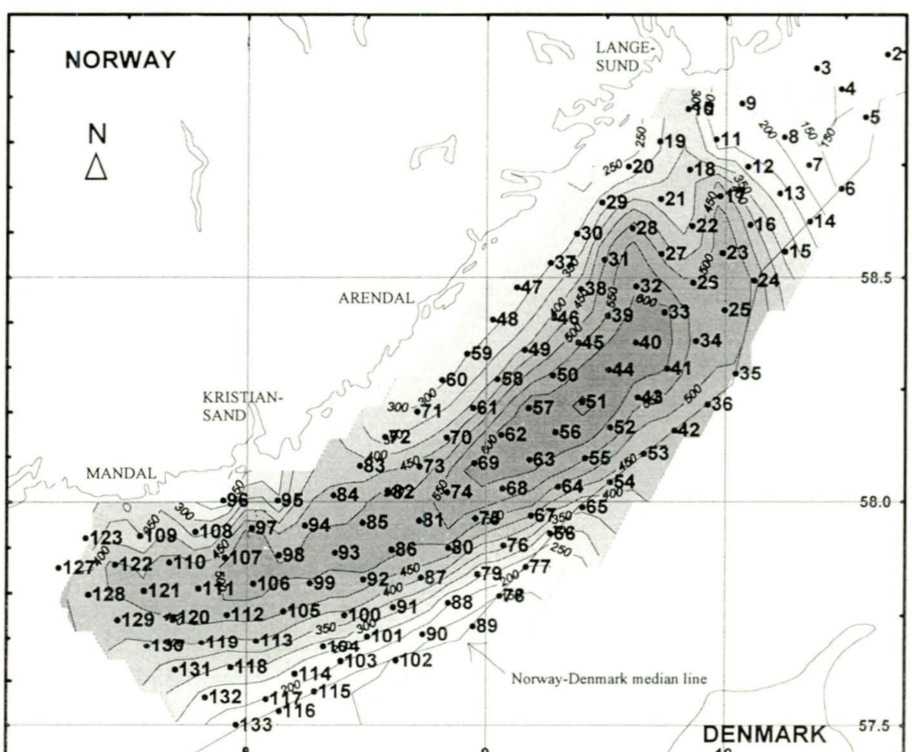


*Fig. 2. Coring stations and bathymetry in the Norwegian part of the Skagerrak.*

al. 1990, Danielsen et al. 1991). The inflow of Atlantic water consists of two partly separable currents: 1) a direct inflow along the southern slope of the Norwegian Trench with a deep core located above the 150 m bottom contour; 2) a branch along the 70 m bottom contour, on the Danish side (Aure et al. 1990). Investigations on the regional hydrography by Svansson (1975), Rodhe (1987) and Fonselius (1990) have shown that the other main components of the anticlockwise circulation in the Skagerrak are the influx of Central North Sea water and Southern North

Sea water, and English Channel water, Continental Coastal water and Jutland Coastal water, which together make up the Jutland Current (Fig. 1). At the outlet of the Kattegat, the Jutland Current mixes with Baltic water and then continues along the Swedish west coast to Norway, where it turns towards the southwest to become the Norwegian Coastal Current. As the water flows along the Swedish and Norwegian coasts it is mixed with fresh water from the rivers and the fjords.

# Methods

A total of 132 stations were sampled, the locations of which are shown in Fig. 2. At Stations 2-75, cores were retrieved by a Niemistö corer, while a multicorer was used at Stations 76-133. The sedimentary characteristics of one core (59 mm core diameter and core length generally less than 50 cm) from each of the 132 sampling stations were described, including sedimentary structures, textures and composition (Bøe 1993, 1994, 1995). Sea-bed sediment samples (0-2 cm depth) from all stations were analysed on a Leco carbon analyser to obtain total carbon (TC) and total organic carbon (TOC). These data are presented as maps of carbonate and TOC content. Subsamples for grain-size analysis were taken at the seabed (approximately 3 cm core depth) and at 30 cm core depth and analysed by standard sieving techniques (fraction >63 μm) and Sedigraph (fraction <63 μm). Based on the grain-size analysis and the map of Holocene sediment distribution (Rise et al., this volume), a sea-bed sediment map and a map of sediment types at 30 cm core depth were compiled.

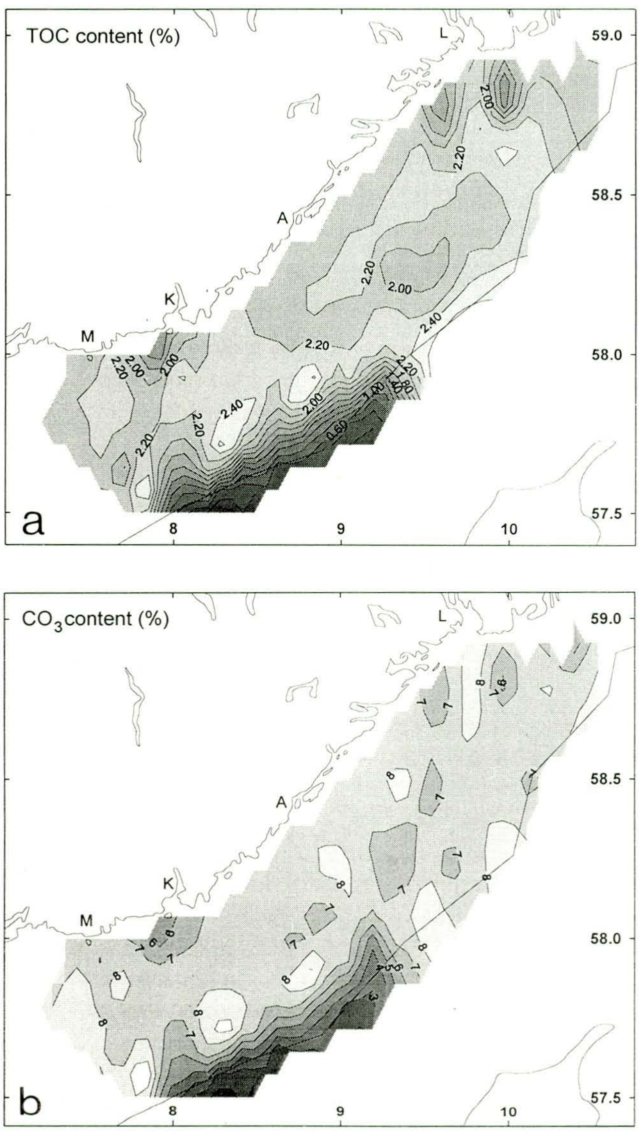


*Fig. 3. Total organic carbon (TOC) (a) and carbonate ($CO_3$, % of total dry weight) (b) content of sea-bed sediments (0-2 cm core depth) in the Norwegian part of the Skagerrak.*

# The Norwegian Trench below 350 m water depth and adjacent areas to the north

The very dark grey, homogeneous silty clays which dominate the Norwegian Trench and adjacent areas (Fig. 1) are moderately to strongly bioturbated, and whole and disintegrated shells, up to several centimetres in diameter, occur. The most common trace fossils are Chondrites and Planolites, but vertical spreiten burrows (Teichichnus) and feeding-spreiten (Lophoctenium) also occur, with burrows up to 4 cm diameter. A dark greyish-brown layer a few centimetres thick at the surface is enriched in organic carbon (up to 2.4% TOC, Fig. 3a) and manganese (Sæther et al., this volume), and commonly contains tubes made by polychaetes. The sea-bed sediments generally contain 7-11% carbonate (Fig. 3b).

Grain-size analysis shows that the sea-bed sediments at 3 cm depth consist of moderately sorted silty clay with a clay (<2μm) content of 50-75%. The majority of the samples contain 60-70% clay, with the highest clay contents in the deepest parts of the trench (Figs. 4a and 6). The silt content of the sea-bed sediments is generally 30-40% (Fig. 4b). No systematic variation in the clay or silt content has been detected; however, in a zone trending southeastwards from Langesund the silt content is reduced to approximately 25%. The sand content of the seabed sediments is generally 1-2% (Fig. 4c), while gravel constitutes less than 1%. Material in the gravel fraction consists entirely of bioclastic carbonate, dominated by shells and shell fragments of mainly foraminifers and bivalves, while in the sand fraction there is also siliciclastic material.

Downcore, a slight decrease in sand content is common. The median grain size of the sediments at 3 cm depth varies from 0.7 μm to 2.0 μm (Fig. 4d), while at 30 cm depth it is 0.1-0.2 μm smaller. In the northeastern part of the investigated area the sediments at 30 cm depth

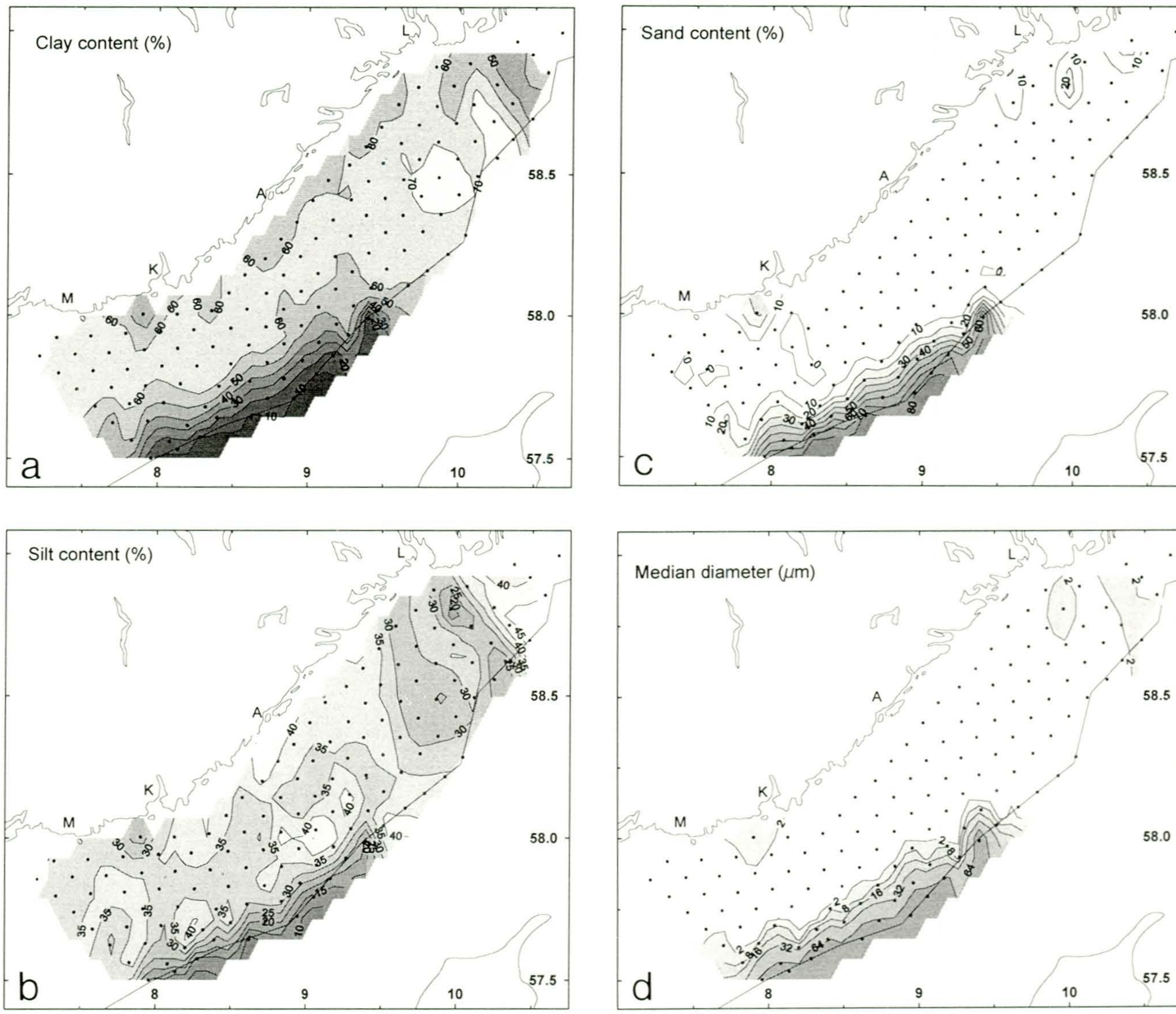


*Fig. 4. Clay content (a), silt content (b), sand content (c) and median diameter (d) of the sea-bed sediments (3 cm core depth) in the Norwegian part of the Skagerrak. M: Mandal; K: Kristiansand; A: Arendal; L: Langesund.*

consist of silty clay (Fig. 7), and are less variable in composition and finer-grained than the sediments on the sea floor (Fig. 6).

Based on reflection seismic data, a narrow area of erosion/non-deposition has been located to the southeast of Arendal (Fig. 6). Van Weering (1981) refers to a sample with median diameter in the fine to very fine sand fraction and with a clay content of less than 30%, and the area therefore probably consists of sand-silt-clay.

## The southern slope of the Norwegian Trench above 350 m water depth and the plateau towards the Danish median line

Along the southern and southeastern slope of the Norwegian Trench there is a change from silty clay to sand-silt-clay (Fig. 6) at about 350 m water depth, while at about 200 m water depth there is a change to silty sand. At water depths shallower than 150 m the sediments consist of up to 80% of well-sorted sand, predominantly in the very fine and fine sand fractions, while silt and clay each represent about 10% (Figs. 4a-4c). The sands are usually moderately bioturbated, and ripple cross-lamination and flaser lamination occur. Shells and shell fragments are present throughout the cores, while the colour of the sediments varies from dark grey to olive grey. TOC is within this area reduced to approximately 0.5%, while carbonate constitutes ca. 3%. Downcore there is generally an up to 10% increase in the content of both silt and clay, while the sand content decreases by up to 15% (the median diameter in the surface samples close to the median line reaches 105 mm, while at 30 cm depth in the cores there is a reduction to 101 μm, Fig. 4d). Gravel generally makes up less than 1% of the sediment, and is composed predominantly of bioclastic carbonate. The

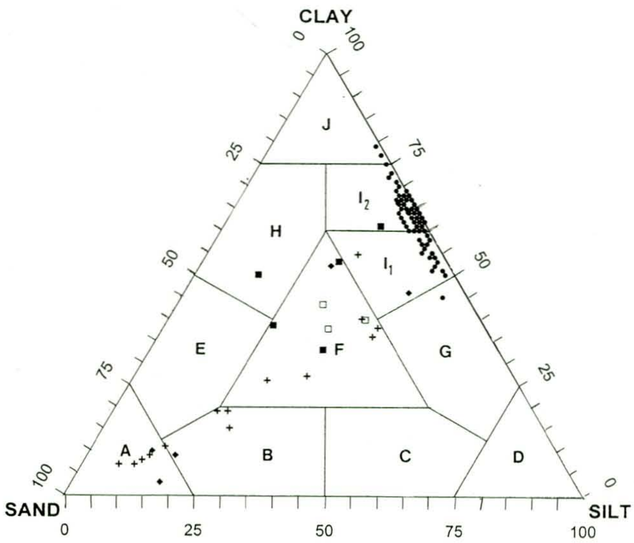


*Fig. 5. Triangular diagram (modified from Shepard (1954)) showing grain size distribution of the sea-bed sediments at 3 cm core depth. Dots: cores with silty clay; filled squares: cores with glacial/reworked glacial deposits along the coast of Norway; empty squares: cores from the area of erosion/non-deposition on the southern slope of the Norwegian Trench; crosses: cores from the plateau along the Danish median line; diamonds: cores with a clear upward-coarsening trend from the plateau along the Danish median line; A: sand; B: silty sand; C: sandy silt; D: silt; E: clayey sand, F: sand-silt-clay; G: clayey silt; H: sandy clay; $I_1$: silty clay (<60% clay); $I_2$: silty clay (>60% clay); J: clay.*

upward coarsening is especially well expressed in an area along the border to Denmark, stretching from Station 65 in the northeast to Station 78 in the southwest (Fig. 2). At Stations 65 (355 m water depth) and 66 (269 m water depth), there are sharp, possibly erosional boundaries between 5 cm thick layers of fine sand on top of silty clay/clayey silt, and sandy silt on top of clayey silt, respectively. At 30 cm depth below the sea floor the northward extent of the area of sand-silt-clay has been reduced, and the lobe of silty clay (<60% clay content) stretching northwestward into the deepest parts of the Skagerrak has almost disappeared (Fig. 7). The boundary between sand-silt-clay and silty clay occurs at water depths of 250-300 m, which is less than at 3 cm core depth, and clayey silt occurs in the northeasternmost parts of the sand and sand-silt-clay areas.

Along the upper part of the southern slope of the Norwegian Trench, to the south of Kristiansand, an area of zero Holocene thickness has been interpreted from seismic reflection data (Rise et al., this volume). Within this area glaciomarine deposits are exposed at the sea floor, with Cretaceous bedrock outcropping in a narrow zone. To the south of the area of zero Holocene thickness, early Holocene reflectors are truncated, showing that erosion has occurred or still occurs, while to the north the Holocene unit onlaps and pinches out, and there is a zone of non-deposition. Four of our sampling stations (Stations 91, 113, 118 and 131) from the area of erosion/non-deposition (Fig. 6) record sediments very different from the silty clays to the north and the silty sands to the south. At these four stations the sea-bed sediments consist of grey-coloured and moderately bioturbated sediments with 40-50% clay, 30-40% silt, up to 25% sand and a few percent gravel. Shells and shell fragments are concentrated in lay-

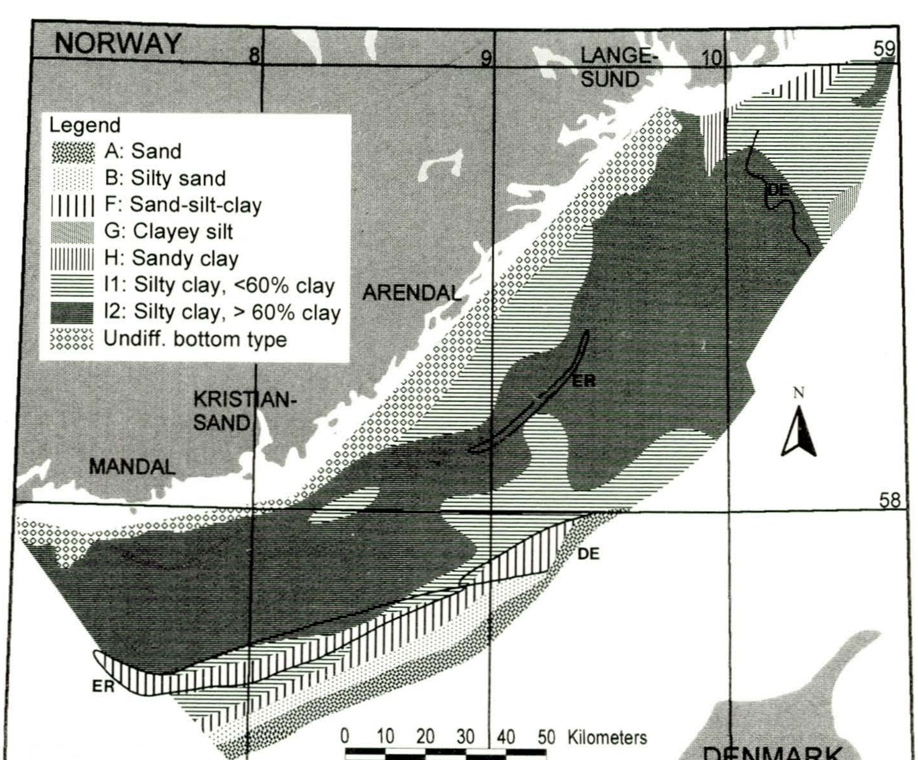


*Fig. 6. Sea-bed sediments at 3 cm core depth (see Fig. 5 for explanation of legend) in the Norwegian part of the Skagerrak. ER: Areas of erosion/non-deposition on the southern slope of the Norwegian Trench and along the southeastern slope of the Arendal terrace. DE: Areas with thick Holocene deposits.*

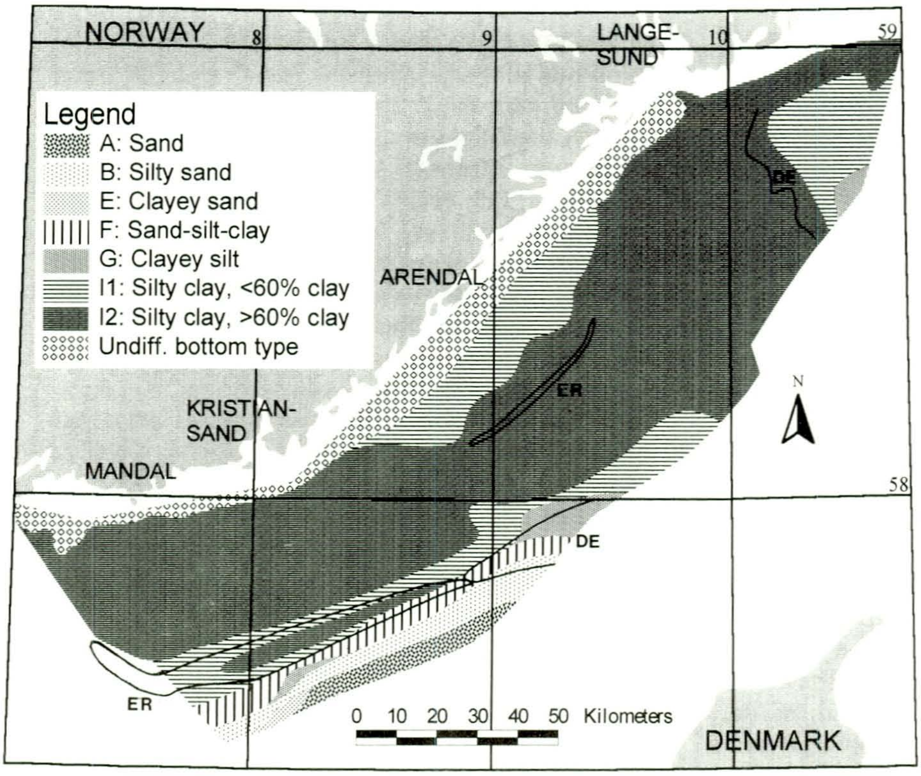


*Fig. 7. Sediment type at 30 cm core depth (see Fig for explanation of legend) in the Norwegian part the Skagerrak. ER: Areas of erosion/non-depositi on the southern slope of the Norwegian Tren and along the southeastern slope of the Arend terrace. DE: Areas with thick Holocene deposits.*

ers at Station 131, while pebbles up to 2 cm in diameter occur concentrated in the interval 9-15 cm depth at Station 91. At Station 91 there is a sharp boundary at 15 cm core depth and at Station 118 there is a transitional boundary at 13 cm depth, where the poorly sorted intervals overlie grey, well-sorted and moderately bioturbated silty clay (containing isolated pebbles at Station 91). At Station 113 the sediment contains scattered pebbles throughout.

## Areas along the coast of Norway

An approximately 10 km wide zone along the coast of Norway (Fig. 6) is characterised by small, sediment-filled depressions, and there is considerable variation in sediment composition, both laterally and vertically. At Stations 96 and 127 (Fig. 2) the sediments consist of grey, poorly sorted and moderately bioturbated sandy and pebbly clay/silty and sandy clay with pebbles up to 3 cm in diameter. At Stations 3 and 20 grey, moderately bioturbated silty clays are overlain by 7 cm and 15 cm thick, dark grey layers of sandy clay with silt, separated by erosion surfaces. At Station 11 dark grey, moderately bioturbated silty clay with isolated pebbles is overlain by a 15 cm thick, poorly sorted layer of sandy clay with pebbles up to 5 cm in diameter and shell fragments up to 1 cm in diameter.

## Sediment accumulation rates

Measurements of present sediment accumulation rates carried out by a number of authors and institutions and by different methods were combined with the map of Holocene sediment thickness (Rise et al., this volume) and sea-bed sediment descriptions to synthesize a map of approximate sediment accumulation rates throughout the Norwegian part of the Skagerrak (Fig. 8). The majority of the sedimentation rates have been obtained by the $^{210}$Pb method, but also sedimentation rates obtained from foraminifera and anthropogenic pollution were used (Jørgensen et al. 1981, 1990, Erlenkeuser & Pederstad 1984, Müller & Irion 1984, Iversen & Jørgensen1985, Thiede 1985, Van Weering et al. 1987, 1993a, Bojesen-Koefoed 1992, Dennegård et al. 1992, Anton et al. 1993, Hass 1993, Meyenburg & Liebezeit 1993, Paetzel et al. 1994, Kunzendorf et al., this volume and previously unpubl. data).

The lowest sediment accumulation rates occur along the axis of the Norwegian Trench, with rates of 10-15 cm/100 years (Fig. 8). On the plateau along the Norway-Denmark median line sedimentation rates up to 21 cm/100 years have been measured; however, from seismic and bathymetric data it is evident that erosion may prevail locally (see below). The area of erosion/non-deposition terminates to the east in a narrow trench. Sediment accumulation rates up to 98 cm/100 years have been measured in an area of thick Holocene deposits, to the north and east of this trench. In the northeasternmost part of the Norwegian Trench, sediment accumulation

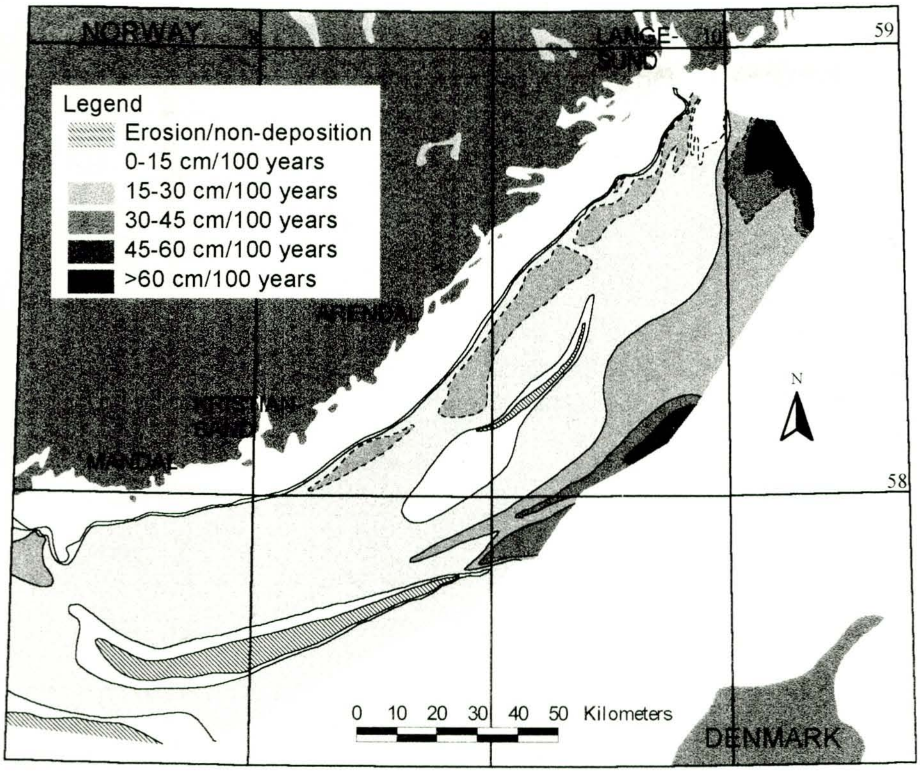


*Fig. 8. Sediment accumulation rates in the Norwegian part of the Skagerrak based on $^{210}Pb$ derived accumulation rates, thickness of Holocene sediments and sea-bed sediment typesa*

rates up to 110 cm/100 years have been measured. The latter area also coincides with a zone of thick Holocene deposits.

Along the coast of Norway we assume that rates of deposition vary, with high rates in small basins, alternating with topographic highs characterised by little deposition and even erosion. To the south and southeast of the area of variable sedimentation rates (Fig. 8), rates up to 30 cm/100 years are indicated where thick Holocene deposits occur. Only one measurement has been obtained (southwest of Mandal) to confirm the interpretation, which is therefore very uncertain. It is possible that most of these sediments were deposited during the early Holocene land uplift, filling topographical depressions, and that the present sediment accumulation rates are lower.

# Discussion

Sediments deposited in the Norwegian part of the Skagerrak are transported from the southwest by the Jutland Current and the currents from the southern and central North Sea, and from the west by the Atlantic Water Current (North Sea Task Force 1993). These sediments are derived from sea-floor erosion in the North Sea, especially during large winter storms (Eisma & Kalf 1987), from the North Atlantic Ocean, from the rivers surrounding the southern North Sea (e.g. Kuijpers et al. 1993) and from coastal erosion. Smaller amounts come from the atmosphere, primary production and the Baltic (Eisma & Irion 1988). Late Holocene mineralogy and composition support a southerly origin for much of the fine-grained material deposited in the Skagerrak (Rosenqvist 1985, Kuijpers et al. 1993, Pederstad et al. 1993, Zøllmer & Irion 1993).

Several areas in the southern North Sea and along the eastern coasts of the North Sea, from Britain to Hanstholm in Denmark (Fig. 1) exhibit annual erosion of up to 600 g/m$^2$ (Pohlmann & Puls 1994). Also along the southwestern slope of the Norwegian Trench, where bottom-current velocities may reach 30-40 cm/s (Delhez & Martin 1992), there is evidence of strong erosion (Rise et al., this volume). Previous estimates of sediment accumulation in the Skagerrak vary from 17 mill. tons of suspended matter deposited in the Skagerrak and the Norwegian Trench per year (Eisma & Irion 1988) to 28 mill. tons dry weight deposited in the Skagerrak per year (Van Weering et al. 1987). Our estimate, based on measured and estimated sediment accumulation rates (Fig. 8) and dry bulk densities measured at every sampling station (Rise & Bøe 1995), is 18.6 mill. tons dry weight deposited in the Norwegian part of the Skagerrak (south of 59°N and east of a line between Jæren and Hanstholm in Denmark) (Fig. 1) per year. This is in good agreement with the figures of Van Weering et al. (1987).

The grain sizes of the Holocene sea-bed sediments closely reflect current velocities, with sandy, predominantly traction transported sediments in shallow areas with strong bottom currents (Fig. 1). There is a distinct fining of the sediments with increasing water depths (Figs. 2 and 4). This was also observed by Van Weering (1981), who described a northward (from Denmark towards Norway) stepwise transition from well sorted sand (traction transported) to well sorted sand/moderately sorted silt and clay (traction and suspension transported) and finally moderately sorted silt and clay transported in suspension.

To the south and east of the area of erosion/non-deposition, on the southern slope (Fig. 6), there is rapid variation in sea-bed sediment type over relatively short distances. Ripple, flaser and lenticular lamination in the sea-bed sediments indicate deposition from suspension as well as bedload due to fluctuating current strength. In this area there is a bottom nepheloid layer developed, from which near bottom suspension deposition of resuspended material takes place (Van Weering et al. 1993a, Lepland & Stevens, this volume). Some of the variation in sediment type may be the result of local hydrographical variations, where changing weather conditions may change the direction and magnitude of the major ocean currents (e.g. Larsson & Rodhe 1979) and thereby the sediment supply. Detailed bathymetry and seismic reflection data indicate the presence of gravity slides in the area of high sedimentation rates on the southern slope, in water depths of 250-450 m, and vertical and lateral grain-size variations are probably associated with these features. These data also show the existence of large relict sand waves (which have migrated towards the southeast) in a wide area along the median line, in water depths shallower than 250-300 m. It is probable that the variation in sediment type to some extent can be explained by differences in depositional setting between the crests and the troughs of these ancient sand waves. There are also NE-SW trending elongated depressions, up to 45 m deep, 300 m wide, 1500 m long, and probably caused by combined gas escape and current erosion, showing that large local variations in current regime and depositional environment exist.

The highest sediment accumulation rates in the Skagerrak (Fig. 8) occur in the northeast, where there is a large vortex formed by the Atlantic Current, the Jutland Current, the Baltic Current and the Norwegian Coastal Current. The very high sediment accumulation rates have been explained by a large area in the centre of this vortex where current velocities are low, and where suspended material is allowed to settle through the water column to the bottom (Eisma & Kalf 1987). We interpret the high sediment accumulation rates on the southern slope of the Norwegian Trench, further southwest, to reflect a reduction in hydraulic energy and sediment transporting competency of the ocean currents. This may be due to increasing water depths and decreasing slope angle in the predominant transport direction, leading to deposition of suspended fines and sandy material. Model simulations of bottom flow velocities and current directions carried out during this project by the Institute of Marine Research, as well as the elongated depressions on the sea floor, show the predominant bottom-water current direction in this area to be towards the northeast, ca. 20° to the north of the depth contours. In addition, it is probable that east of the outlet of the narrow trench in the eastern termination of the area of erosion/non-deposition, there is a de-focusing of the currents along the slope, leading to high rates of deposition.

The coarsening-upward trend observed in the sea-bed sediments along the southern slope of the Norwegian Trench and on the plateau towards Denmark indicates that there has been an increased supply of coarse-grained material over the past 150-250 years. This may be due to changes in the directions and magnitudes of the major ocean current systems. One can speculate if this reflects an increasing importance of the Jutland and North Sea Currents relative to the Atlantic Water Current, with increasing supply of coarse-grained material from the southwest. Hass (1993) speculated whether the upward-coarsening trend observed in long cores in the area of Stations 87 and 91 reflects climatic conditions in this century comparable with those reported from the Little Ice Age, with increasing bottom current strengths and very high sedimentation rates due to higher frequencies of westerly winds and storms changing the circulation patterns. Also Jørgensen et al. (1981) interpreted the upward coarsening, close to Stations 65 and 66, to be due to increased bedload transport caused by a gradual increase in bottom current strength. During the Little Ice Age, sediments in this area were occasionally deposited at a rate of up to 500 cm/100 years (Hass 1993). Two long cores (spanning the past 1000 years) from the eastern part of the area of high sediment accumulation rates, between Stations 53 and 54, contain silty clays characterised by a contourite-like sedimentation pattern (Hass 1993), which was interpreted to reflect climatically induced, fluctuating bottom currents. Recently, Hass & Kaminski (1995) have proposed that the last phase of the Little Ice Age (1750-1900) was characterised by stormy westerlies which were likely to amplify water circulation in the Skagerrak and thereby cause transport of coarser-grained sediments, while the maximum of the Little Ice Age (1550-1750) was dominated by calmer, more easterly winds. Also Nordberg (1991) and Alve (1995) have interpreted changes in the major current systems flowing into the Skagerrak during the past hundreds of years.

The fine-grained sediments which cover most of the investigated area, including the Norwegian Trench, show little variation in grain size in the uppermost 30 cm of the sea-bed, and are interpreted as hemipelagic and near-bottom suspension deposits (see Lepland & Stevens, this volume) deposited at a relatively slow rate. In these deepest parts of the Skagerrak, waters are normally replaced every 2-3 years by episodic inflow from the northwest along the axis of the Norwegian Channel, though rapid changes can occur when bottom water cascades into the Norwegian Trench from the west during very cold winters (Ljøen 1981). During such events slightly coarser-grained material may possibly be transported into the deep basin. The highest organic carbon and carbonate contents in the Norwegian Skagerrak occur in the Norwegian Trench;

however, there is a slight reduction in carbonate content in the deepest parts of the trench, which might indicate that carbonate dissolution occurs. A similar conclusion was reached by Alve (1995) from the study of foraminifera.

Silty clays in local basins along the coast of Norway are here interpreted as suspension and near-bottom suspension deposits transported by the Norwegian Coastal Current. Coarser-grained and poorly sorted sediments are thought to be locally derived erosion products from surrounding topographic highs, which may consist of bedrock as well as till and glaciomarine sediments. Due to the generally high current velocities of the Norwegian Coastal Current these sediments may locally be eroded and resedimented (Holtedahl 1989, Pederstad et al. 1993). Lag deposits may be present where erosion has occurred at the sea bottom, e.g. at Stations 3 and 11. Holtedahl (1989) and Van Weering (1981) also noticed this zone of winnowed sediments along the coast.

## Summary and conclusions

Grain size analysis has shown that the sea-bed sediments throughout large areas of the Norwegian Trench consist of silty clay with a clay content of 50-75% and generally less than 2% sand. Bioclastic gravel makes up less than 1% of the sediments, while carbonate and organic carbon contents reach 10% and 2.4%, respectively. These homogeneous sediments are transported into the Skagerrak by Atlantic water from the northwest, by the Jutland Current and the currents from the central and southern North Sea from the southwest and to a smaller degree by the Baltic Current from the southeast, and are interpreted as hemipelagic and near-bottom suspension deposits.

Sediments on the gently northward sloping plateau along the Norway-Denmark median line are dominated by fine and very fine, predominantly traction-transported sands that become coarser-grained at shallower water depths towards the southeast, where sand constitutes up to 80% of the sediments and silt and clay approximately 10% each. These sediments are transported into the Skagerrak mainly by the currents from the central and southern North Sea, including the Jutland Current, and originate by erosion of the sea floor in the North Sea, from rivers on the continent and in Britain, and from coastal erosion between Denmark and the English Channel.

Along the coast of Norway, areas of Holocene sediments alternate with areas of bedrock and glacial/glaciomarine deposits. Also on the southern slope of the Norwegian Trench, to the south of Kristiansand, and on the southeastern margin of the Arendal terrace, there are areas of erosion/non-deposition where glaciomarine and glacial deposits are exposed.

Sediment accumulation rates within the Norwegian Trench and on the plateau towards the Danish border are generally 10-20 cm/100 years, increasing to more than 30 cm/100 years in the southeastern parts of the investigated area and locally on the northwestern slope of the Norwegian Trench. Very high sediment accumulation rates (>50 cm/100 years) occur on the southeastern slope of the Norwegian Trench, and in the northeasternmost part of the Norwegian Trench. Areas of high accumulation rates generally coincide with areas of thick Holocene deposits, where there is a reduction in hydraulic energy and sediment transporting competency of the ocean currents. It is estimated that approximately 18.6 mill. tons of sediment (dry weight) accumulate in the Norwegian part of the Skagerrak annually.

Along the southern slope of the Norwegian Trench and on the plateau towards Denmark there is a general upward-coarsening trend in the uppermost 30 cm of the sediments on the sea bottom. This fits well with previously published data from long cores, indicating that 150-250 years ago there was a change in the direction and magnitude of the major current systems, leading to an increasing supply of coarse-grained material from the southwest.

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