

Late Cenozoic sediment drift complex, northeast Rockall Trough, North Atlantic

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Abstract. Seismic reflection profiles and two shallow cores have revealed a sediment drift complex in the northeastern Rockall Trough. The drift complex consists of an elongate drift with associated sediment waves, a broad sheeted drift with a larger field of sediment waves, and smaller, moat-related, isolated drifts. The internal reflection configuration of these features indicates consistent upslope migration throughout the late Cenozoic. The larger field of sediment waves has been described previously with a southerly migration; a reevaluation of these waves suggests a migration direction to the east, conforming with the other drift complex features. The most vigorous current activity probably occurred during the Miocene, with a more reduced current flow prevailing during the Pliocene to Holocene interval. Core evidence from the elongate drift and the moat has revealed upper Pleistocene and lower Holocene glaciomarine sediments reworked to produce muddy-silty and sandy contourites. Sedimentation rates for the early Holocene (pre-7.5 ka) are up to 4-times greater on the drift compared to the moat. It is suggested that the sediment drift complex has formed through the interaction of a northward flowing slope current, of North Atlantic Deep Water origin, with an area of complex bathymetry at the northeastern end of the Rockall Trough, where the Wyville-Thomson Ridge intersects the Hebridean Margin.

Introduction

Sediment drifts are a major depositional product of bottom-current activity in deepwater settings, particularly on slopes and basin plains within, and adjacent to, continental margins. They are large, elongate, or domed sediment accumulations that form positive features on the seabed. Fields of large-scale sediment waves are commonly developed in association with the drifts; the waves typically displaying marked undulations on the seabed. Where particularly strong, bottom currents may cause erosion of the seafloor and the formation of channels, moats and furrows. Consequently, the resultant deepwater physiography of the continental margin may be locally complex.

The continental margin off northwest Britain is an area of variable bathymetry, with the relatively shallow platform areas of the Hebrides Shelf and Rockall Plateau separated by the deeper water basin of the Rockall Trough (Figure 1). This basin receives an influx of bottom water from several sources and throughout the Neogene has experienced extensive redistribution of sediment through the activity of bottom currents [Kenyon, 1986; Richards *et al.*, 1987;

Huthnance, 1986; Booth and Ellett, 1983; Ellett *et al.*, 1986; Dickson and Kidd, 1986; Dickson *et al.*, 1986; Lonsdale and Hollister, 1979; Stoker *et al.*, 1993]. Sediment drifts and associated bedforms, together with an erosional moat, are well-preserved at the shallower, northeastern end of the Rockall Trough where the Wyville-Thomson Ridge intersects the Hebrides Shelf. The aim of this paper is to describe these deepwater depositional and erosional features in an attempt to determine the nature of the sediments, the processes of their deposition, and their palaeoceanographic implications.

Regional Setting

The Rockall Trough is a northeasterly trending basin separating the inner and outer margin platform areas of the Hebrides Shelf and the Rockall Plateau, respectively (Figure 1). The trough is bounded at its northeastern end by the Wyville-Thomson Ridge, a transverse bathymetric high that separates this basin from the Faeroe-Shetland Channel to the northeast. To the southwest, the Rockall Trough opens out and deepens into the Porcupine abyssal plain [Roberts *et al.*, 1979]. Water depths in the trough increase from 1000 m in the northeast to 4000 m in the southwest. The width of the trough (at the 1000-m isobath) is relatively uniform, between 200 and 250 km. The floor of the trough is predominantly flat-lying, albeit gently inclined to the southwest. However, the margins of the trough are more variable; a major depositional drift, the Feni Ridge, flanks the western side of the trough, whilst on its eastern side slope-front fans locally encroach onto the basin floor [Stoker *et al.*, 1993]. In the

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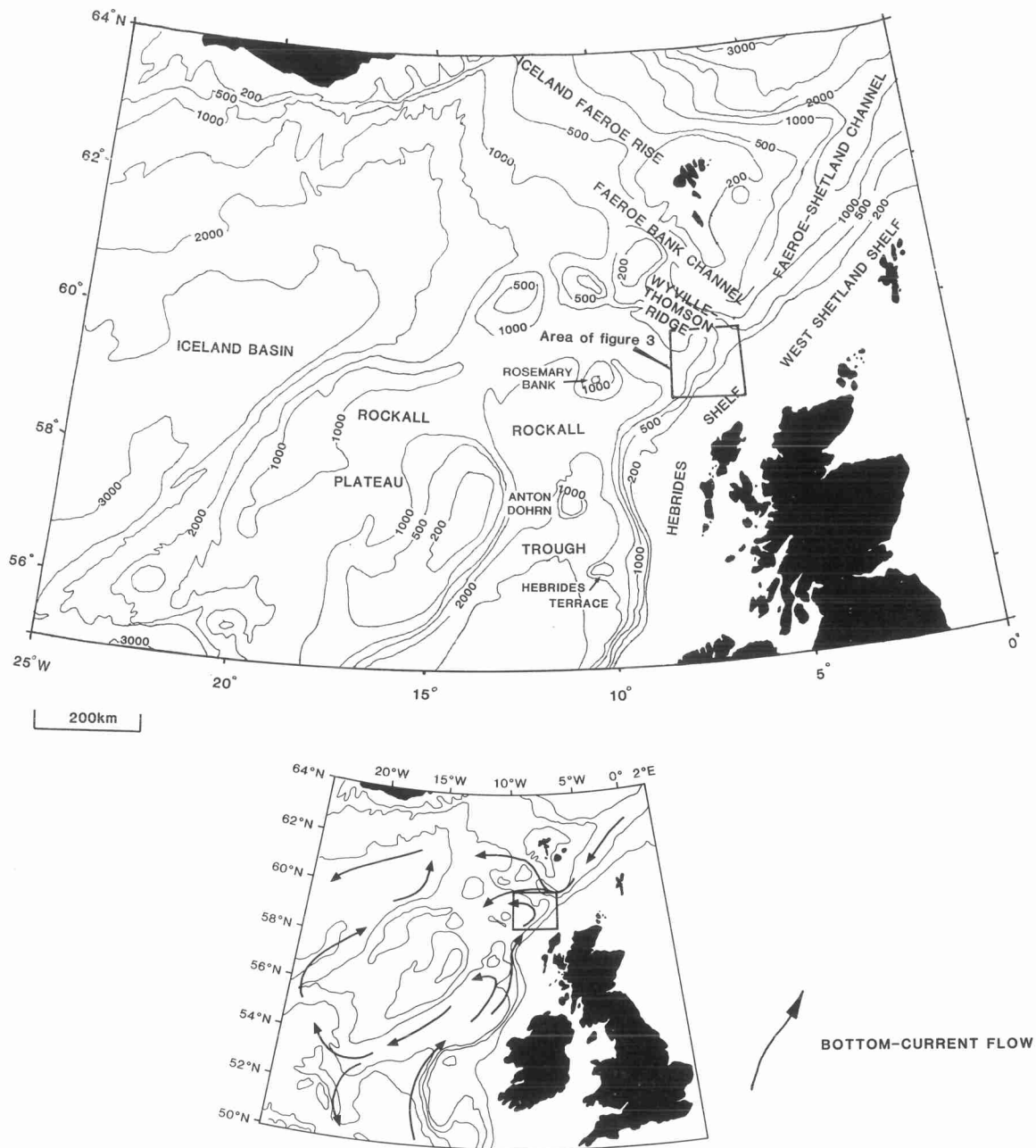


Figure 1. Regional bathymetric setting of the continental margin northwest of Britain: (Inset) Location of study area in northeastern Rockall Trough, which is expanded in Figure 3. Bathymetric contours in meters. Small map shows present-day bottom circulation pattern derived from a variety of sources, (see text for references).

central and northern part of the trough the continuity of the basin floor is interrupted by the isolated bathymetric highs of the Rosemary Bank, Anton Dohrn and Hebrides Terrace seamounts. Intense scouring of the sea floor has occurred around these obstructions. Although a depocenter may have existed in this area since the late Palaeozoic [Ziegler, 1982, 1988; Scrutton, 1986; Smythe, 1989], the current bathymetry largely reflects the Cenozoic evolution of the basin. During the Eocene the central and northern part of the Rockall Trough may have subsided by up to 3 km relative to the adjacent platforms [Stoker *et al.*, 1993]. During the Neogene, sedimentation in these areas has been dominated by the deposition, on its eastern margin, of a clastic wedge (including slope-front fans,

which passes downslope into basin plain deposits of the trough. The overall geometry of the Neogene succession displays a marked asymmetry, being locally in excess of 600 m thick on the eastern flank of the trough but thinning into the central part of the basin and pinching-out on its western margin.

The relatively restricted accumulation of Neogene sediment in the central and northern Rockall Trough suggests that sedimentation was controlled not by tectonics and subsidence, which influenced the development of the fringing slope-front fans, but by sediment availability linked to the oceanographic development of the northeast Atlantic. According to Miller and Tucholke [1983], bottom current activity has prevailed in this area since late Eocene/early Oligocene

time. At its inception, bottom circulation was very strong but current strength gradually decreased and stabilised during the early to mid-Miocene [Stow and Holbrook, 1984a]. In the northeast part of the Rockall Trough the onset of a vigorous late Palaeogene abyssal circulation pattern is manifest by a phase of cut-and-fill development adjacent to the Wyville-Thomson Ridge (Figure 2). In contrast, the sculpted drifts and sediment waves associated with the overlying Neogene strata (this paper) reflect more stable flow conditions.

The present deepwater circulation pattern in the Rockall Trough involves several different water masses, including the southward flowing Norwegian Sea Deep Water (NSDW), which enters the trough across the Wyville-Thomson Ridge [Dickson and Kidd, 1986]. This NSDW partially mixes with Labrador Sea Water and Antarctic Bottom Water to form North Atlantic Deep Water (NADW), which flows as a cyclonic loop within the southern part of the trough [Stow and Holbrook, 1984b; Dickson and Kidd, 1986]. The trough is also affected by a northward flowing slope current down to depths of about 1000 m [Kernon 1986; Booth and Ellett, 1983; Huthnance, 1986; D J Ellett, personal communication, 1992], although this may detach from the slope as the trough shallows to the north (especially where the current encounters the Wyville-Thomson Ridge), to flow westward and then southward along the western margin of the trough [Dickson and Kidd, 1986]. The slope current may be of NADW origin, flowing up the eastern margin of the Rockall Trough as a continuation of the cyclonic loop present in the southern Rockall Trough. The current, which contains elements of both separated NADW and some Mediterranean deep water, probably represents the most influential water mass at the

northeastern end of the trough. Maximum current velocities of 30 cm s⁻¹, increasing northward along the slope, have been recorded from the Sula Sgeir Fan area in 518-m water depth [Huthnance, 1986]. The contribution of NSDW remains uncertain.

Within the Neogene succession in the northeast Rockall Trough, Miocene and Plio-Pleistocene units are tentatively recognized on the basis of regional seismostratigraphical evidence [Stoker et al., 1993]. On the slope the Plio-Pleistocene has been further subdivided into the Pliocene to middle Pleistocene Lower MacLeod sequence, the middle to upper Pleistocene Upper MacLeod sequence, and the upper Pleistocene to lower Holocene MacAulay sequence (Figure 2). The Upper MacLeod sequence consists predominantly of ice-marginal slope deposits and is largely restricted to the Sula Sgeir Fan [Stoker, 1990b, 1994]. In the basal succession, the Lower MacLeod and MacAulay sequences may be separated by a hiatus or a condensed section, equivalent to the Upper MacLeod sequence, reflecting severe mid-Pleistocene to late Pleistocene glaciation. On available seismic profiles, the nature of the contact between these basal sequences is beyond the limit of seismic resolution. The Miocene deposits together with the Lower MacLeod and MacAulay sequences comprise the bulk of the drifted sediments.

Methods

This study uses both seismic data and core information collected by the British Geological Survey (BGS) as part of their offshore reconnaissance mapping program. The BGS survey utilized primarily low- to medium-frequency sources, such as 2 x 40 cubic inch airgun (up to 1500-m penetration, 20- to 50-m resolution) and

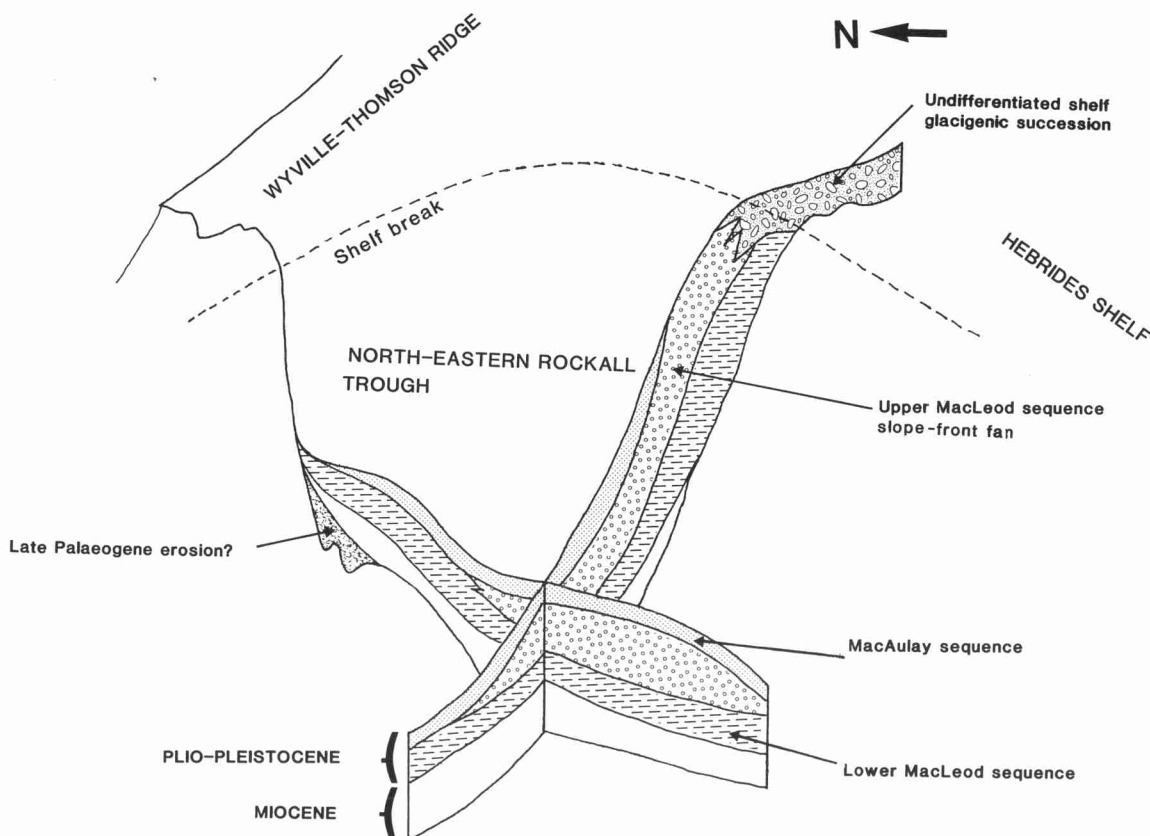


Figure 2. Schematic sections showing the general seismostratigraphical setting of the Neogene-Quaternary succession in the northeast Rockall Trough [modified after Stoker, 1990a].

1kJ sparker (up to 500-m penetration, 5- to 10-m resolution). Additionally, a high-frequency 6-kV deep-tow boomer (up to 100-m penetration, 0.25- to 1.0-m resolution) was deployed in specific areas of interest to improve resolution in the surficial section. Geological calibration of the seismic data used gravity core information: core 267, located at 59°34.9'N, 6°54.5'W, was taken in 1022 m of water and recovered 1.8 m of sediment, whereas core 269, located at 59°42.6'N, 6°39.8'W, was taken in 870 m of water and recovered 1.3 m of sediment. The cores were subjected to sedimentological analysis. Particle size analysis was conducted on five 50-100 g samples from core 267, and six from core 269. Percentages of clay (<9.0 phi) and silt (9.0-4.0 phi) were obtained using a Micrometrics Sedigraph 5000ET in the Department of Geography, University of Edinburgh. Sand and coarse-gravel percentages were obtained by sieving. X-radiographs of half cores were taken using a Scanray AC 120L at settings of 75 Kv and 5 mA for between 2 and 2.5 mins. The carbonate content of the cores was analysed by the use of a "Karbonate-Bombe" following the method of *Muller and Gastner* [1971]; samples were taken every 0.10 m for the entire length of both cores.

Sediment Drift Complex

The sediment drift complex is taken to include the main drifts, their associated bedforms, and adjacent moated area. The seismic and lithological characteristics of the drift complex are described below.

Seismic Characteristics

From detailed examination of the seismic profiles, three types of sediment drift have been identified: 1) Elongate drift and associated sediment waves; 2) broad "sheeted" drift; and 3) moat-related drifts.

An erosional moat is developed along the northeast margin of the drift complex. The moat-related drifts appear to be smaller scale and more transient features compared to the larger, more permanent, elongate and sheeted drifts. The distribution of these features is shown in Figure 3. Estimates of seabed relief are based on an acoustic velocity of water of 1.45 km s⁻¹; sediment thicknesses in the following descriptions are based on a measured acoustic velocity of 1.55 km s⁻¹ for the MacAulay sequence and on assumed velocities of 1.8 km s⁻¹ for the Lower MacLeod sequence, and 2.0 km s⁻¹ for the Miocene section. Actual unconsolidated sediment velocities may vary from 1.5 to 2.0 km s⁻¹ [e.g., *Hamilton*, 1985], so our gradation is an estimate based on increasing sound velocity as burial depth and hence compaction increases.

Elongate drift and sediment waves. The elongate drift is up to 300 m thick and has an asymmetrical cross section (Figures 4-7). It is 20 km in width, has a vertical relief (measured as the height from drift crest to the maximum depression of the moat) of up to 112 to 150 m (Figures 5 and 7), and can be traced along its length for up to 60 km before being obscured below the Sula Sgeir Fan (Figure 3). On the seismic profiles the drift displays a dominantly layered acoustic reflection pattern, the reflectors being parallel, continuous and of medium intensity. No truncated horizons are visible within the drift, although pinch-out and divergence of reflectors do occur (Figure 5). There appears to be slight upslope-migration of the reflections at the crest of the drift (Figures 4 and 5). A smaller, subsidiary drift is locally developed on the lee-side (west) of the main drift (Figures 3-5).

The high-resolution boomer profile displays well-developed sediment waves on the basinward side of the drift (Figures 3 and 5).

The waves in the MacAulay sequence have an apparent wavelength of about 2 km and a height of about 20 m (crest-to-trough). The waves can be identified on other profiles although their relief is more subdued with only slight surface expression. In Figure 5 the upslope migration of the waves can be traced with an apparent angle of climb of 1.3° in the Lower MacLeod sequence, and of 2.7° in the MacAulay sequence. The acoustic characteristics of the waves within the Lower MacLeod sequence consist of continuous, parallel reflections of medium intensity, which appear to converge on the northwestern flank of the waves but diverge on the southeastern flank (Figure 5).

The MacAulay sequence is dominantly an acoustically transparent unit, although discordant, irregular, semicontinuous reflectors are visible at the base of the unit. The uppermost part of the MacAulay sequence is also highly reflective, and on the sediment waves a greater sediment thicknesses appears to be present on the side of the waves facing the Hebrides Slope (Figure 5). The drift itself shows variation in thickness (<5 to 20 m) of the MacAulay sequence across the drift axis and the moated area (Figure 5).

Broad sheeted drift. A broad sediment body is observed in the northwestern part of the study area (Figures 3 and 7). This sediment accumulation is up to 490 m thick, is several tens of kilometers across, and displays a relief of up to 60 m above the general basin floor; for this reason the term sheeted drift is used to differentiate it from the other drift types. Its northwestern extent is unknown due to the limit of the data set; to the southeast, it is buried beneath the Sula Sgeir Fan.

On seismic profiles the sediments display parallel, low-angle, medium-intensity, laterally-continuous reflectors, with low-angle downlaps to the northeast observed at the base of the drift. This corresponds with a slopeward migration of the drift, with the broad crestal region of the drift having shifted approximately 10 km to the northeast during the late Cenozoic. A field of sediment waves occurs on the southwestern flank of the drift. These extend over an area of about 550 km² and form a sediment package of up to 200 m thick. *Richards et al.* [1987] divided the package into a basal climbing set, 105 m thick, passing into a transitional unit, followed by an upper unit characterized by sinusoidal waves of 18 m height and 1 km wavelength. Although *Richards et al.* [1987] inferred a southerly migration direction for the basal package, reexamination of the profiles indicates that the migration of the waves must be generally eastward, toward the slope. On Figure 7 the observed apparent angle-of-climb of the basal package is to the northeast, whereas an unpublished line perpendicular to this profile indicates apparent southeast migration. Consequently, the true migration direction must be eastward, toward the slope (Figure 3). This interpretation is more consistent with the absence of stoss-side laminae, as originally reported by *Richards et al.*, [1987], (hence the observed lamination represents leeside lamination) as well as the overall slopeward migration of the drift complex.

The sediment waves retain some surface expression except where locally overlain by debris flows (Figures 3 and 7). Their present sinusoidal morphology and partial burial by the Sula Sgeir Fan suggests that they are not currently active.

Moat-related drift. These features are a relatively small-scale component of the drift complex when compared to the other drift types (Figure 3). Drift-size and geometry range from small isolated asymmetric drifts on the slope-side of the moat, 30 m thick and 1 to 2 km wide (Figure 4), to larger multiple drifts, up to 100 m thick and 4 km wide, plastered on the flank of the elongate drift, on the basinward-side of the moat, and displaying a more subdued relief

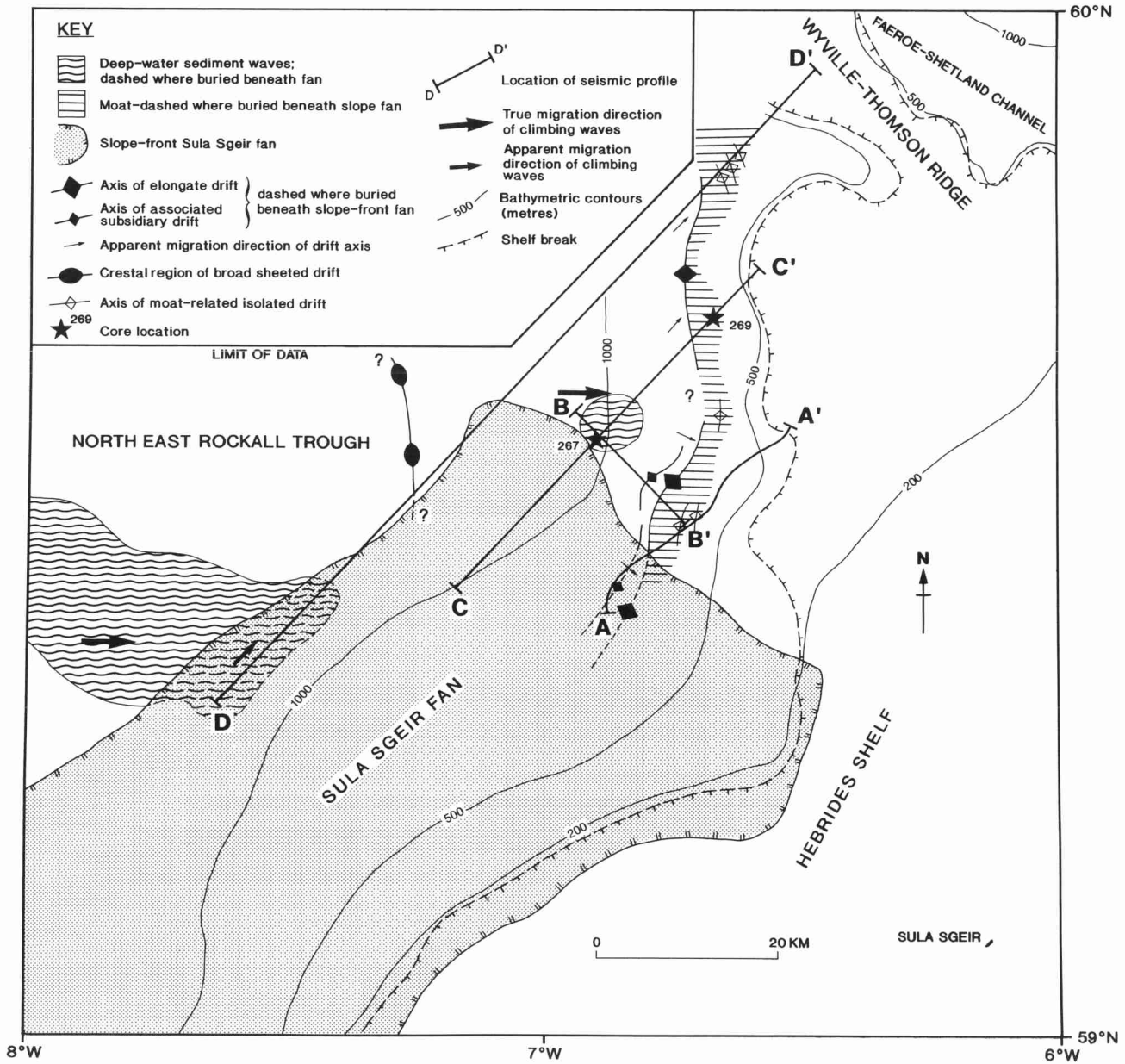


Figure 3. Map showing principal morphological features of sediment drift complex in the northeastern Rockall Trough and location of cores and seismic reflection profiles illustrated in other figures. Profile A-A' in Figure 4; B-B' in Figure 5; C-C' in Figure 6; D-D' in Figure 7. Area of map located in Figure 1.

(Figure 7). Acoustically, these drifts are well-layered and consist of regular, semicontinuous, parallel reflectors of low to medium intensity, but with some erosive horizons apparent within the drift.

Moat. The moat lies at the base of the slope and varies from a broad shallow depression in the southeast (Figure 4), to a deeper well-defined depression in the northwest of the area (Figure 7). Water depths are generally 800-900 m in the midmoat areas at the base of the Hebrides Slope, increasing to 850-950 m at the base of the Wyville-Thomson Ridge. The width of the moat varies from 2 to 6 km, with depths of up to 100 m relative to the relief of the adjacent elongate sediment drift.

Lithological Characteristics

Two cores were recovered from the northeastern end of the drift complex. Core 269 from the moat, and core 267 from the gentle western flank of the elongate drift in the vicinity of the sediment waves (Figure 6). These cores have been used to compare and contrast the sediments within the moat with those of the drift. The cores sampled only the uppermost part of the MacAulay sequence. Calcareous nannofossil analysis has revealed that the cores comprise upper Pleistocene and lower Holocene (pre-7.5 ka) glaciomarine sediments [Hine, 1993]. From detailed logging and examination of X-radiographs the cores can be subdivided into four main lithofacies

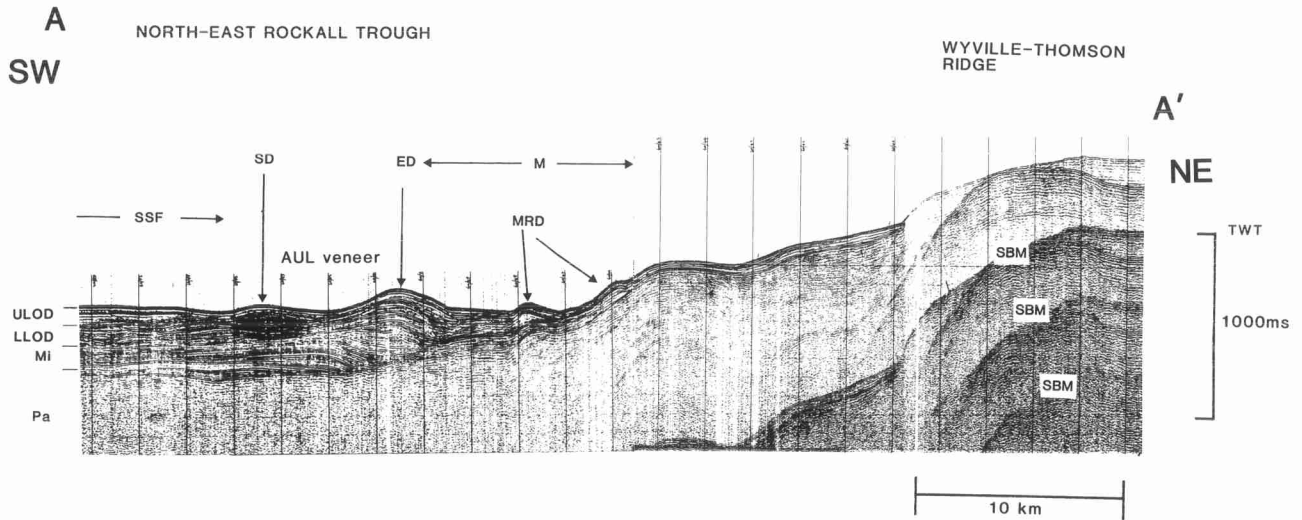


Figure 4. Single-channel airgun line 83/04-60, illustrating the seismic characteristics of the elongate, subsidiary and moat-related drifts adjacent to the Wyville-Thomson Ridge. The drift complex is partially buried below the distal edge of the Sula-Sgeir Fan. Abbreviations: ED, elongate drift; SD, subsidiary drift; MRD, moat-related drift; M, moat; SSF, Sula Sgeir Fan; AUL, MacAulay sequence; ULOD, Upper MacLeod sequence; LLOD, Lower MacLeod sequence; Mi, Miocene; Pa, Palaeogene; SBM, seabed multiple; TWT, two-way time; ms, milliseconds. Profile location shown as A-A' in Figure 3.

(1 to 4), based on lithology, occurrence of lithic clasts, bioturbation, coarsening/fining sequences, nature of the contacts, and internal structures and texture. Although lithofacies 1 to 3 largely comprise an admixture of mud, sand, and gravel, a distinction has been made on the degree of sorting of the sand component.

Lithofacies 1. This lithofacies is up to 28 cm thick and occurs at the top of both cores. It consists predominantly of a greyish yellow muddy sand comprising 30 to 80%, well-sorted, medium- to fine-grained sand, 10 to 45% mud, and some sporadic gravel (up to 30%) in the moated area. In core 269, lithofacies 1 has also been identified at 70 to 80 cm below seabed. Bioturbation is intense with most primary structures destroyed. A variety of burrow systems are

present, including *Zoophycos* and *Planolites*. Lithic clasts are common, and consist predominantly of high-grade metamorphic and igneous types. High concentrations of shelly material include comminuted bivalves and gastropods. The sediment is predominantly structureless, although core 267 locally displays cross-lamination visible in both the core section and in X-radiograph. Lithofacies 1 is always underlain by lithofacies 2, but the nature of the contact is variable; sharp and erosive in core 269 but gradational and irregular in core 267 due to intense bioturbation. In core 269, at depth, these sediments pass gradationally upwards into lithofacies 3.

Lithofacies 2. This lithofacies ranges from 10 to 55 cm thick and

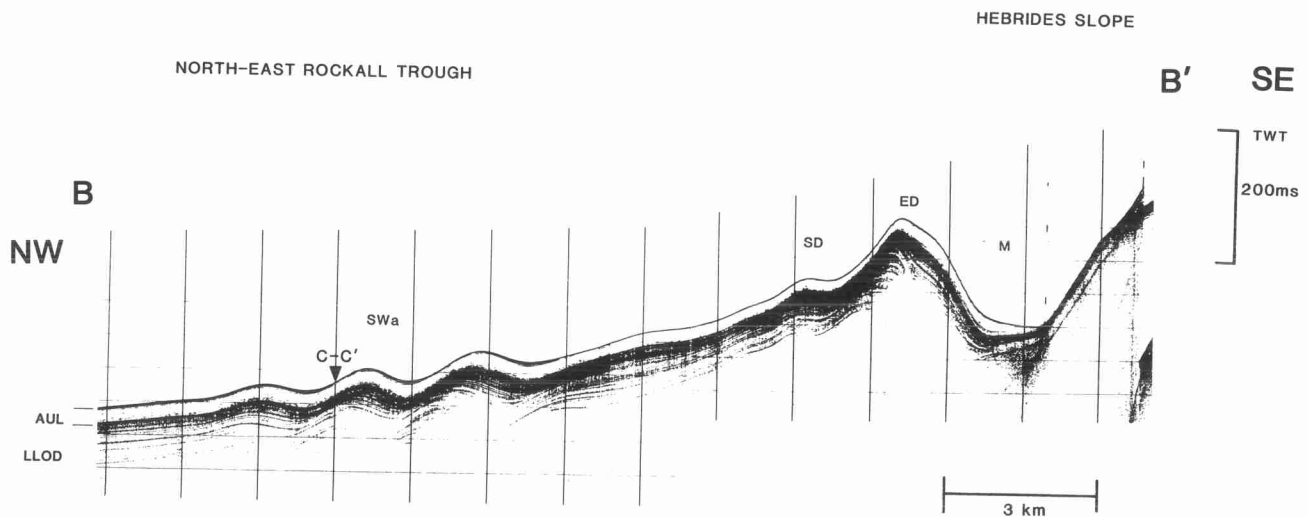


Figure 5. Deep-tow boomer profile 85/07-9, illustrating the high-resolution seismic characteristics of the elongate and subsidiary drifts, and associated sediment waves at the foot of the Hebrides Slope. Abbreviations as in Figure 4 except SWa, sediment waves. Intersection with profile C-C' (Figure 6) indicated. Profile location shown as B-B' in Figure 3.

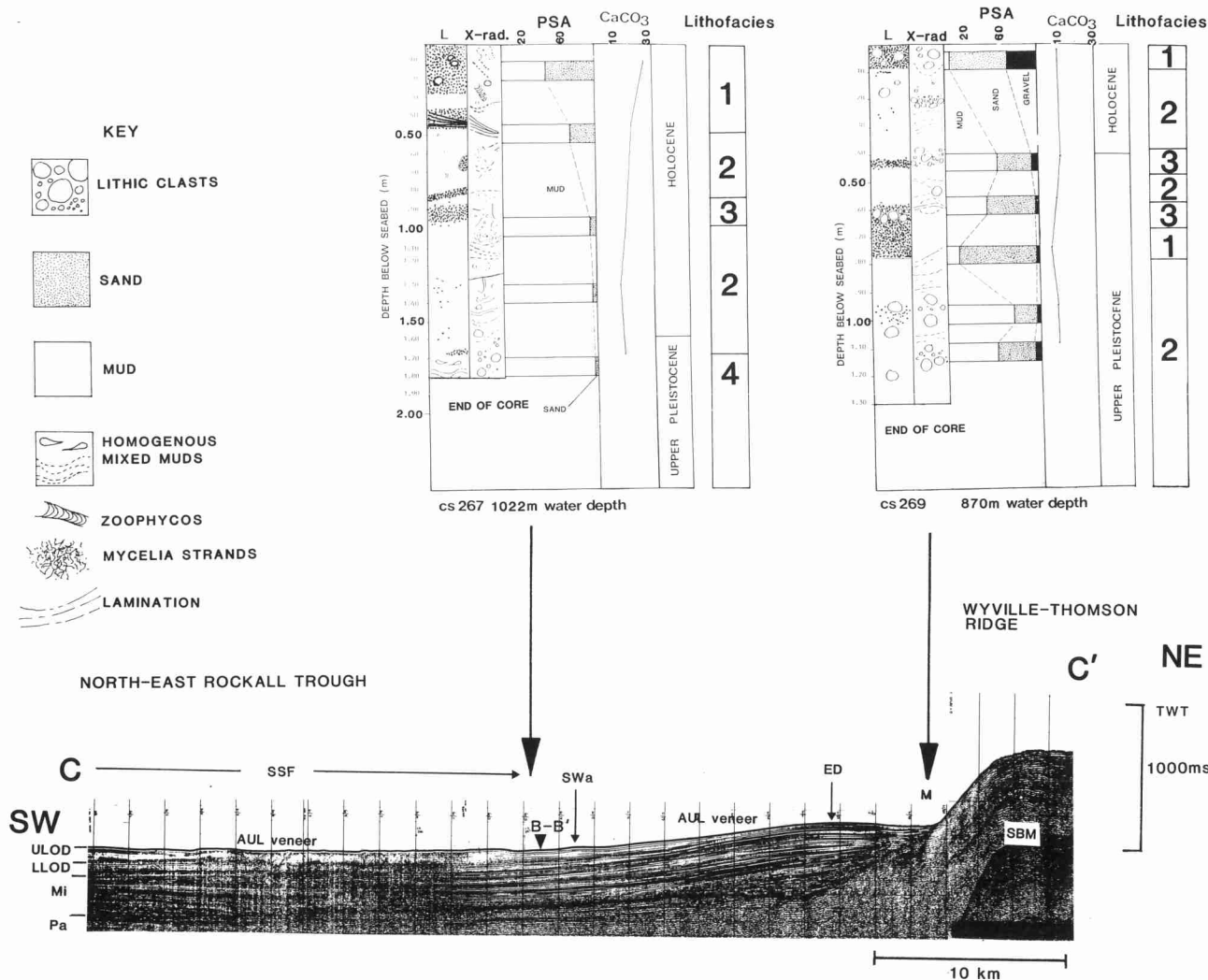


Figure 6. Single-channel airgun line 83/04-61, illustrating the seismic characteristics of the elongate drift and sediment waves adjacent to the Wyville-Thomson Ridge. The drift complex becomes buried below debris-flow deposits of the Sula Sgeir Fan to the southwest. Abbreviations as in Figures 4 and 5 except PSA, particle size analysis; L, lithology; X-Rad, X-radiograph. Profile location shown as C-C' in Figure 3. Locations of cores 267 and 269 are indicated; schematic graphic logs show the sedimentary characteristics of lithofacies 1-4 (see text for details).

consists predominantly of olive-brown sandy muds with <10 to 40% fine sand, up to 70% mud and with occasional gravel in the moat. Bioturbation is moderately intense with large, well-preserved burrow types; *Zoophycos*, *Chondrites* and *Trichichmus* are particularly evident. Smaller burrows are also common, with *Mycelia* strands visible in X-radiograph. Lithic clasts are common to abundant. Planar lamination is occasionally evident with small-scale (<5 cm) coarsening and fining upward sequences present. Minor truncations and erosive horizons are visible in X-radiograph.

Lithofacies 3. This lithofacies is <10 cm thick and consists of 10 to 40% poorly sorted yellow-brown sands and 50 to 90% muds, with occasional gravel in the moat area. There is little evidence of bioturbation although this may be due to the coarse-grained disorganized nature of the sediment. Shelly concentrations are common, particularly comminuted bivalve and gastropod debris. The unit is totally structureless and has gradational contacts with the surrounding units. These deposits occur more randomly within the sequence sandwiched between both lithofacies 1 and 2.

Lithofacies 4. This is only observed in the lower part of core 267, where it is at least 10 cm thick and consists dominantly of a dark brown homogeneous mud with <5% sands. The coarse fraction is reduced compared to the other lithofacies, although lithic clasts are randomly scattered throughout the deposit. Intense bioturbation has produced a structureless, totally homogenized sediment with no visible burrows being preserved. At some levels the bioturbation has “chumed” the muds producing lenticular, convoluted and flamelike structures. The contact with the overlying lithofacies 2 is gradational as a result of the bioturbation.

Interpretation and Discussion

Seismic Characteristics

Many authors have described the seismic reflection characteristics of sediment drifts and associated bedforms [Normark et al., 1980; R. A. Myers, Halifax Dalhousie University, unpublished thesis, 1986; Stow et al., 1986; Marani et al., 1993; Mezerais et al., 1993], and

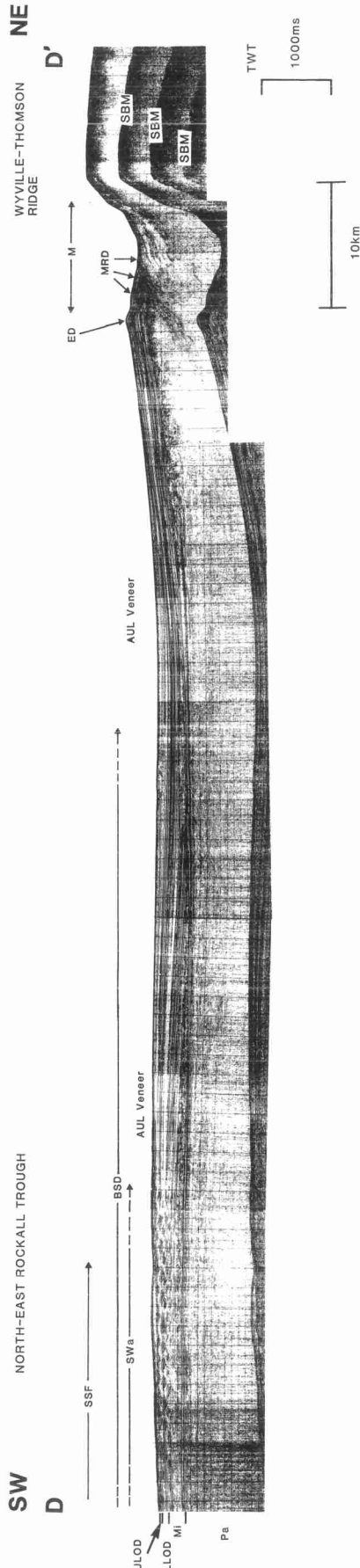


Figure 7. Single-channel airgun line 85/05-4 showing the seismic characteristics of the elongate and moat-related drifts adjacent to the Wyville-Thomson Ridge, together with the broad sheeted drift and associated sediment waves in the northeast Rockall Trough. Abbreviations as in Figures 4 and 5, except BSD, broad sheeted drift. Profile location shown as D-D' in Figure 3.

these studies show close similarities with the drifts documented in this study. The well-layered, semicontinuous reflections and the mounded asymmetric geometry of the drifts, subparallel to the Hebridean margin and separated from it by a moated area, are the clearest indications of bottom current activity influencing sediment deposition in the northeast Rockall Trough.

Downlapping and onlapping reflectors within the drifts, together with marked variation in thickness of the MacAulay sequence, indicate either meandering of the current "core" to produce areas of preferential and reduced deposition, or separation of the overall bottom current into several distinct flows.

Although drift development has been a semipermanent feature in the northeastern Rockall Trough, at least during the Neogene, there has clearly been much variation in the location and rate of contourite deposition. In general, drift growth has been both downcurrent, towards the north or northeast and partly across current, overstepping the moat to the east. Migration of the sediment waves, particularly the basal climbing set is more consistently oblique to the current direction. Adequate seismic coverage to determine the migration directions for the moat-related drifts is not available.

Thickness variation in the MacAulay sequence, from <5 m to about 30 m (Figure 5), illustrates some of this complexity. Deposition is absent, or below seismic resolution, on the slope-side of the moat, presumably reflecting the main high-velocity axis of bottom current flow. Deposition has been much greater on the drift-side of the moat and on the drift crest facing the moat. Upslope (updrift) migration of sediment waves on the western flank is also indicated by thickness variation in the MacAulay sequence.

Sediment wave fields in deepwater settings have been described by many authors, and are generally interpreted as being the product of either downslope or alongslope processes [Normark *et al.*, 1980; Tucholke and Laine, 1983; McCave and Tucholke, 1986; Richards *et al.*, 1987; Faugeres and Stow, 1993; Marani *et al.*, 1993]. In the northeastern Rockall Trough the sediment waves are closely associated with drift deposits, and we therefore prefer a bottom current interpretation for their origin. For reasons outlined earlier, we disagree with the southerly migration direction of Richards *et al.* [1987], preferring an easterly, slopeward migration direction. This is consistent with the migration direction of the drift complex. A fundamental flaw in the work by Richards *et al.* [1987] is to liken the waves to shallow-water sandy climbing ripples. However, the scale of these sediment waves is enormous, and in deepwater such waves dominantly consist of fine-grained sediment; this does not move by traction, as does sandy material, but by suspension fallout. The upcurrent/oblique current migration direction suggested in this paper for the waves is an antidune form. This maybe the result of migration beneath a single northward slope current, or possibly from interference between two parts of the same northward flowing current. This contrasts with the interpretation of Richards *et al.* [1987], who invoke an origin as a result of direct southerly overflow of NSDW across the Wyville-Thomson Ridge. However, we cannot discount the possibility that the waves developed within a zone of interference caused by southward flowing NSDW across the Ridge, and a northward flowing slope current.

Facies and Processes

The lithologies of the cores indicate that a variety of processes were active during the deposition of the MacAulay sequence. Lithofacies 1, which includes a well-sorted sand fraction, can be described as a sandy contourite [Stow and Holbrook, 1984b]. Where

it occurs at the sediment surface, it may be interpreted as the coarse-grained component of a coarsening upward (negative) sequence [Gonthier *et al.*, 1984]. This indicates an increasing or higher-velocity current able to transport coarser material as well as to winnow previously deposited sediment. The intense bioturbation is indicative of a persistent infauna keeping pace with deposition [Lovell and Stow, 1981].

The sandy mud of lithofacies 2 has features consistent with a muddy-silty contourite [Stow and Lovell, 1979]. Wetzel [1984] describes the *Zoophycos* ichnofacies as being typical of a stable environment with slowly accumulating sediment. Silty lamination and small-scale fining and coarsening upward sequences most likely represent fluctuations in the intensity of the current flow. Material for both facies 1 and 2 was supplied principally by hemipelagic and glaciomarine processes; this material was then subject to the influence of sluggish, slow-moving bottom currents [Akhurst, 1991].

Glaciomarine sedimentation particularly through ice rafting of detritus is believed to have been more dominant in the origin of the poorly sorted lithofacies 3. Similar deposits described by Pickering *et al.* [1989] (their facies A 1.3) are attributed to rain-out or overturning and unloading of icebergs.

The massive, homogenous nature, and high levels of bioturbation, suggest that lithofacies 4 is mainly a hemipelagic deposit. Any bottom current activity during its deposition was probably too weak to have a significant effect on the deposit, in terms of sediment reworking.

Calcareous nannofossil analysis has revealed the location of the Pleistocene/Holocene boundary within the two cores (Figure 6). According to Stoker *et al.* [1989], the changeover from a glacial to an interglacial regime in this area was accompanied by a strengthening of bottom current activity. This is consistent with our observations which record a general upward coarsening of the lower Holocene section. It is suggested that with the onset of deglaciation the bottom currents began to accelerate, initially producing muddy-silty contourites followed by the coarser sandy contourites. Sea ice and/or icebergs were still present as indicated by the lithic dropstone clasts found in the sandy Holocene contourites.

Sediment accumulation rates for the early Holocene can be estimated from the two cores, based on the Pleistocene/Holocene boundary taken at 10 ka and the seabed sediment layer no younger than 7.5 ka [Hine, 1993]. Core 269 from the moat has 40 cm of lower Holocene sediment, which indicates an accumulation rate of 16 cm/1000 years. Core 267 from the drift has 160 cm of lower Holocene sediment giving an accumulation rate of 64 cm/1000 years. These rates are average sediment accumulation rates for the lower Holocene section preserved in the cores; they do not take into account any preferential deposition within the section. These calculations indicate greater rates of deposition on the drift (at least 4 times greater) than in the moat, during the early Holocene.

Comparison between the two cores further demonstrates the coarser nature of the sediments preserved in the moat relative to the drift (Figure 6). This compositional variation may be due to the winnowing of fines from the moated area; the resuspended material possibly contributing to the buildup of the adjacent drift. Although these interpretations suggest that perhaps the highest-velocity "core" of current is channeled within the moat, the absence of upper Holocene deposits both within or outside the moat may be indicative of more widespread, presently ongoing, active erosion affecting the seabed in the Rockall Trough [Stoker *et al.*, 1993]. A similar erosive regime has been documented from the Faeroe-Shetland Channel [Akhurst, 1991].

The effect of climate on bottom current activity remains poorly understood, although there is mounting evidence to suggest that glaciation suppresses current flow. Our data support the view that climatic instability associated with the transition from glacial to interglacial conditions can lead to episodes of strongest current activity [Faugeres and Stow, 1993]. Moreover, recent work by Dowling and McCave [1993] on the Feni Drift has suggested current activity associated with a meltwater pulse in the northern Rockall Trough. This would lead to increasing density between the water masses, leading to greater thermohaline flow. Ruddiman and McIntyre [1981] describe surface water warming of up to 10°C between 40° and 65°N in the North Atlantic; such differences of temperature and salinity may contribute to increasing current activity during the changeover from glacial to interglacial regimes.

Drift Accumulation and Current Flow Relationships

The factors that influence bottom current drift accumulation are varied and include an active geostrophic circulation, topography to intensify activity, sediment supply, and nepheloid-layer turbidity [Faugeres *et al.*, 1993]. An active geostrophic circulation is needed to promote sediment transport. Density differences due to salinity and temperature can induce thermohaline geostrophic flows. Such conditions are prevalent during polar glacial episodes. High-energy, short-duration "benthic storms" can also be produced by areas of ocean surface instability as a result of global oceanic circulation [Hollister and McCave, 1984]. Topography can intensify activity by steepening of the slope angles to reduce the area of current influence and thereby to concentrate the flow or by restraining and changing flow direction. Narrow channels of deep straits between landmasses can be areas of strong localised current activity, for example, the Faro Drift, which is caused by the outflow of Mediterranean deepwater through the Straits of Gibraltar [Gonthier *et al.*, 1984]. Sediment supply and nepheloid layer turbidity are functions of sea level variation, tectonic activity, regional geology, climate and continental margin morphology. Material transported can be volcanoclastic, biogenic or terrigenous. Suspension of fines into a nepheloid layer is due to bottom current activity; generally, the greater the turbidity of the nepheloid layer the greater the potential for contourite accumulation.

The simple model of drift accumulation and current activity proposed by McCave and Tucholke [1986] needs some revision and modification in the northeastern Rockall Trough due to the presence of a series of features (sediment waves, elongate drifts, broad sheeted drifts and small isolated drifts) forming a drift complex. From seismic analysis it seems probable that single or multiple currents have been active across the trough.

The drift complex is best developed where the Hebrides Slope meets the Wyville-Thomson Ridge, and a number of factors may have contrived to promote drift development in this locality. In particular, a northward traveling slope current may have been intensified and concentrated by a steepening of slope angles from 1°-4° on the Hebrides Slope to 8°-10° on the Wyville-Thomson Ridge. The ridge itself may have acted as an obstacle to current flow accelerating and restraining flow to the northwest along the base of the ridge, causing erosion and/or nondeposition, and producing the moat.

Deposition of the drifts occurred with decreased current velocities away from the slope. Current velocities of 3-30 cm s⁻¹ have been recorded on the slope down to 2000-m water depth; such velocities may be due to downslope pressure changes caused by variations in

density, which drive the thermohaline, contour-following flow [Huthnance, 1986]. Additionally, Mediterranean Deep Water may also contribute to the slope current, providing increased salinity which increases the density differences between the surface and deepwater masses, therefore adding to the thermohaline flow (D. J. Ellett, personal communication, 1992).

The contribution of NSDW is uncertain. According to D. J. Ellett [personal communication, 1992], there is perhaps only seasonal and sporadic overflow across the Wyville-Thomson Ridge, predominantly at its northwest end. However, H. D. Dooley, personal communication [1984] as cited in the work by Dickson and Kidd [1986], suggests that NSDW does overflow across the entire length of the ridge into the northeastern Rockall Trough.

The influence of the slope current may extend out into the basinal area giving rise to the broader sheeted drift. Alternatively, a second bottom water mass is flowing in the basin as a slower, denser, deepwater mass compared to the slope current. A further suggestion is that the drift features themselves are causing eddies and small-scale perturbations in the flow to produce their own drift accumulations. An interaction of bottom current flows is feasible, as long as there are sufficient density differences between the water masses to prevent entrainment and mixing.

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