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Morphology and sedimentation on the Hebrides Slope and Barra Fan, NW UK continental margin

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Abstract: Rapidly deposited Neogene sands and Pleistocene glacigenic sediments originating from NW Britain were transported across the shelf and downslope to the Barra Fan depocentre. In contrast, the Holocene interglacial shelf environment is typified by sediment winnowing, sea-floor polishing and transport of relatively small volumes of sediment along the shelf to the northwest. Interpretation of swath bathymetry, 32 kHz side-scan sonar, 3.5 kHz pinger, sea-bed photography and near-bottom current survey data on the shelf edge and slope provides good morphological evidence for both downslope and alongslope sedimentary processes on this composite slope-front fan. On the northern fan a corrugated shelf edge gives rise to a network of channels on the upper slope, which incise into Pleistocene and older sediments and funnel sediment to middle and lower fan. An underpinning variable topography on the fan bulge originates from major and minor slide masses, sediment creep and debris flows. These are reworked by spatially and secularly variable strong-to-weak bottom currents and redistribute material across and down fan forming transverse and linear bedforms, draped sandy contourite sheets and moulded drifts.

The Barra Fan complex is a Neogene to Holocene sedimentary prism that extends oceanward adjacent to the Hebrides Terrace Seamount between the structural highs of the Geike Bulge in the north and the Donegal Platform to the south (Fig. 1). The Barra Fan north of the Hebrides Terrace Seamount and the Donegal Fan to the south are generally considered to be components of a single fan complex, which forms the largest sediment depocentre off NW Britain and covers an area of *c.* 6300 km^2. The oceanward boundary of the Barra Fan in the NE Rockall Trough exceeds 2000 m water depths. Sediments equivalent in age to the Barra Fan post-date the mid- to late Miocene unconformity on the shelf and thicken seaward in a prograding sediment wedge of late Miocene to Pleistocene age between 400 and 700 m thick (Stoker 1995; Holmes *et al.* this volume). These sediments correlate with the oldest fan–basinal sediments on the margin that post-date the regional Rockall Trough unconformity, itself dated at *c.* 14 Ma (Stoker this volume). Lower Pleistocene shelf sediments are unconformably overlain by a subhorizontal glacigenic erosional surface *c.* 250 m below modern sea level, which, in turn, is overlain by a sequence of mid-Pleistocene to Holocene sediments (Selby 1989; James & Hitchen 1992).

The immediate provenance of the sediments is evidenced by the modern shelf topography, which exhibits well-pronounced ridges adjacent to, and sub-parallel to, the shelfbreak. These sediments contain diamict lithofacies and are interpreted as submarine end-moraines deposited during the retreat of ice from the shelfbreak during the last regional shelf glaciation (Selby 1989). Middle- to inner-shelf basins formed from glacial overdeepening are filled with post-glacial sediments. These basins occur landward of the outer shelf ridges and have eroded into either glaciomarine sediments or Cenozoic–Palaeozoic bedrock (Holmes *et al.* this volume). Shoulder-to-axis relief of the basins is between 20 and 60 m.

The shelfbreak is sharply defined at 220 m within the shelf embayment of the Barra Fan at the southern limits of the study area but changes northward to a poorly defined convex-upward ramp shelfbreak on the southern Geike Bulge. The Barra Fan complex itself progrades westwards in the centre of the study area and encroaches on the Hebrides Terrace Seamount, which is enclosed to the east by the 1800 m isobath and to the west by the 2300 m isobath.

Previous regional studies with GLORIA of the northern Barra Fan and adjacent slope apron indicated that the principal mode of sediment supply was via turbidity currents associated with the gullied shelf edge and that large-scale downslope erosional processes were absent (James *et al.* 1990). However, more

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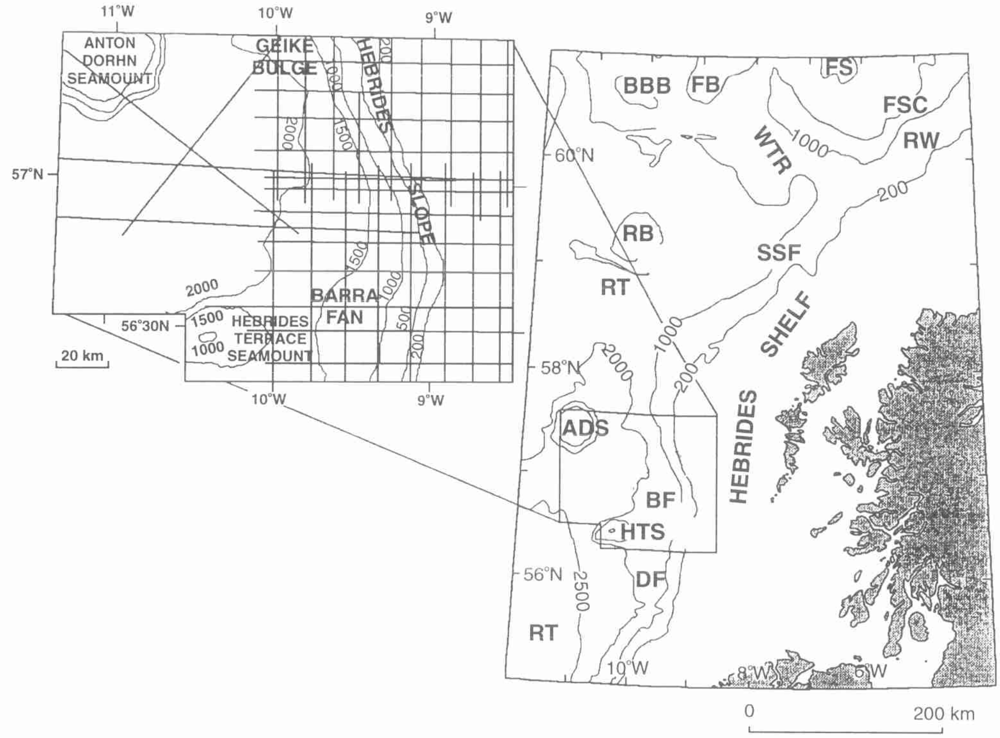


Fig. 1. Location of the study area, bathymetric setting (contours in metres) and track plots of regional airgun and sparker lines. South of *c.* 57°N, swath bathymetric data are available between 150 and 1900 m water depth for most of the study area. BBB, Bill Bailey's Bank; FB, Faeroe Bank; FS, Faeroe Shelf; WTR, Wyville-Thomson Ridge; RW, Rona Wedge; FSC, Faeroe–Shetland Channel; RT, Rockall Trough; RB, Rosemary Bank; SSF, Sula Sgeir Fan; ADS, Anton Dohrn Seamount; BF, Barra Fan; HTS, Hebrides Terrace Seamount; DF, Donegal Fan.

recent studies of the British Geological Survey (BGS) 3.5 kHz sonar dataset have shown mass-transport, where large segments on the North Barra Fan have been transported downslope into the mid-NE Rockall Trough in several slide events associated with a mega-slide known as the Peach Slide (Holmes 1994).

Physical oceanographers have known, since 1832, of a major surface current, the North Atlantic Drift, flowing northward along the coastal margins west of Ireland and Scotland (Deacon 1996). More than 130 years later, the impact of this current on sea-bed sediments began to be documented, when initial studies in the area of the Barra Fan complex began in the 1970s. Submersible operations described alongslope sediment transport in waters NW of Scotland in terms of E–W aligned sandy megaripples indicating a general northward current flow (Eden *et al.* 1971). Subsequently, a persistent current flowing along the edge of the continental shelf west of Britain, which represents a continuous mid-water filament of the North Atlantic Drift transport, and carrying water of mixed Atlantic origins was described by Ellett *et al.* (1986). Kenyon (1986) established a link between the bedforms and this strong northward-flowing current on the upper slope. He recognized an internally well-layered acoustic facies of linear slope-parallel bedforms with vertical relief of up to 10 m and wavelengths of several kilometres, which can be related to the acceleration of contour-parallel currents in areas where slope gradients range from 4° to 20° (Leslie 1992). Comparison of bedforms on the Barra Fan and on the Geike Bulge, just north of the region, may provide evidence for a more complex origin.

The objective of this paper is to explore the interaction between downslope gravitational and parallel-to-slope geostrophic processes on the North Barra Fan between 150 m and 1800 m water depths and 56°05′N and 57°15′N (Fig. 2). We attempt to interpret the modern sea-floor morphology and the underlying buried morphology in terms of sedimentary processes based primarily on high-resolution 12 kHz swath bathymetry, 32 kHz TOBI sidescan surveys, and 7.5 kHz and 3.5 kHz sonar data. A time series of

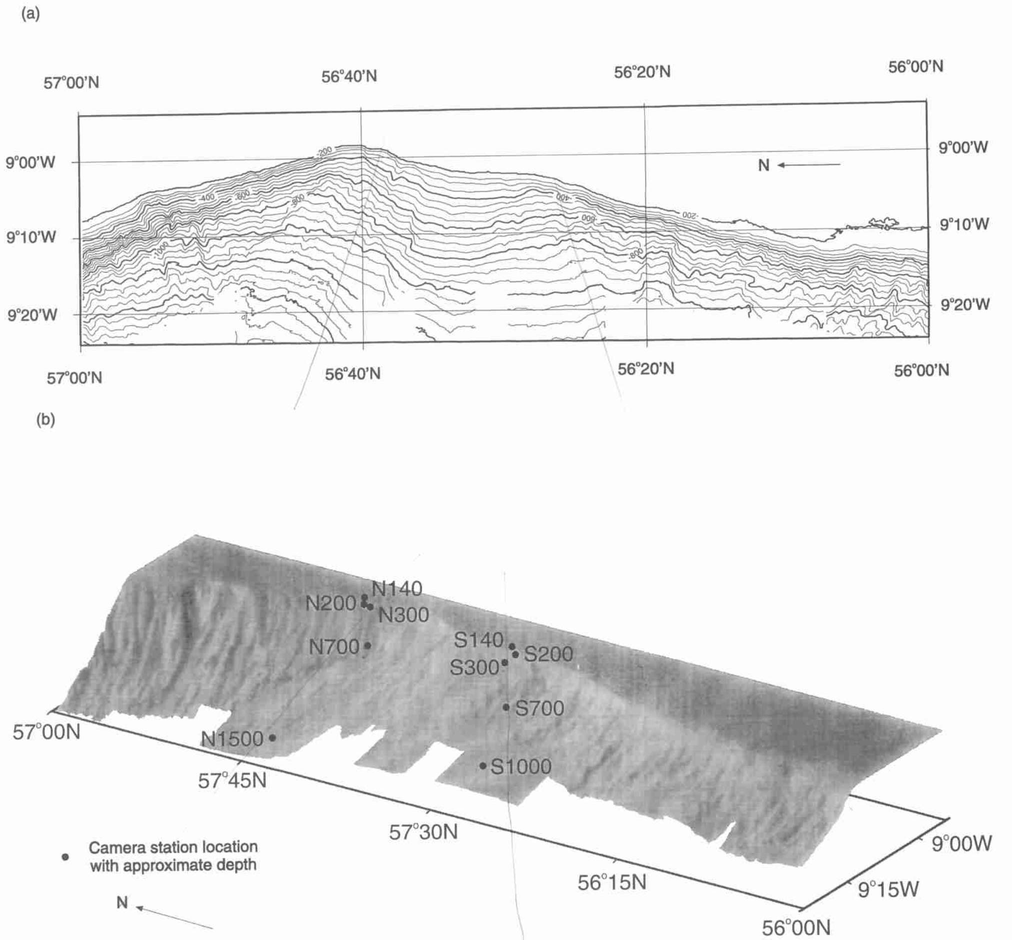
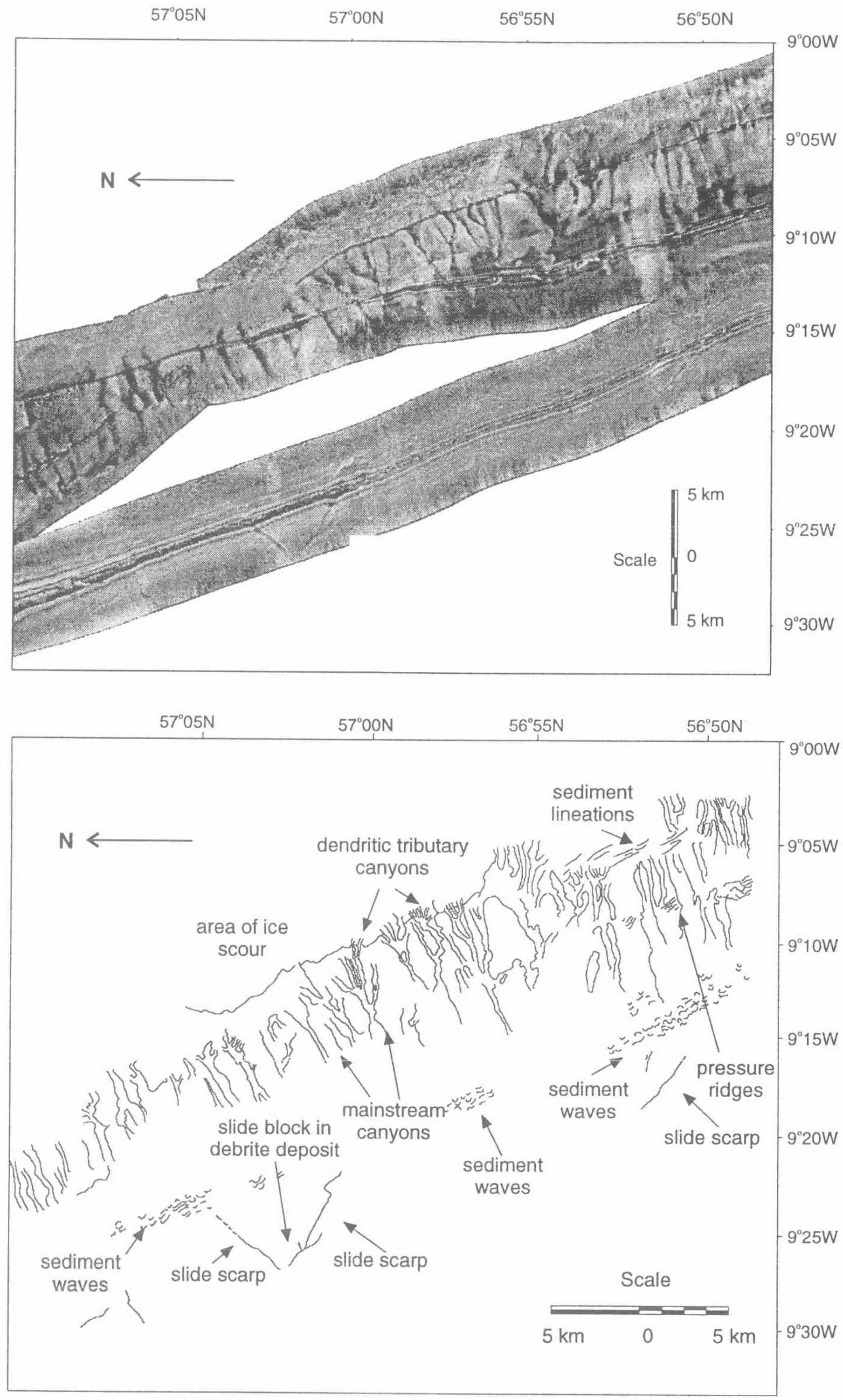


Fig. 2. (**a**) Bathymetry of the Hebrides Slope based on swath-bathymetric mapping. Contour intervals are 40 m spacing. (**b**) 3-D greyscale perspective image of the sea-bed topography derived from processed EM12-120 swath bathymetric survey data. The image is artificially truncated near the shelf edge at the 200 m isobath and at its westernmost downslope extent, corresponding to the 1500 m isobath. Artificial illumination of the sea-bed topography accentuates SE-facing scarps, which are in shadow, and conceals the lighter grey N-facing scarps. Areas of white within the frame are areas of no data. Data for the topographic model are courtesy of Pauline Weatherall of the British Oceanography Data Centre. Black dots mark the location of camera stations, with approximate depth.

bottom photographs taken during an 18 month period and combined with core samples allow calibration of the remotely sensed data, as well as observations on seasonal variation of sea-bed micromorphology.

Data and methods

The bathymetric chart (Fig. 2) of the region between 56°N and 57°N was obtained from the lines traversed during RRS *Charles Darwin* cruise 91, equipped with a Simrad EM12-120 (12 kHz) multibeam swath-bathymetry echosounder. This device consists of a hull-mounted echosounder, and provides an effective means to map in detail a swath of the ocean floor on either side of the ship's track. The EM12-120 system generates 81 stabilized beams, providing ±60° athwart coverage in water depths between 100 and 11,000 m, though depth coverage here ranges between 150 and 2000 m. Because of difficulties of following the desired survey lines in extreme weather conditions, the survey area was constructed by revisiting subareas several times during the cruise. This resulted in editing and repetition of the gridding process and produced charts on a 1:50,000 scale with a contour interval of 10 m.


57°05N
57°00N
56°55N
56°50N
9°00W
9°05W
9°10W
9°15W
9°20W
9°25W
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N
5 km
Scale
0
5 km
57°05N
57°00N
56°55N
56°50N
9°00W
9°05W
9°10W
9°15W
9°20W
9°25W
9°30W
N
sediment lineations
dendritic tributary canyons
area of ice scour
pressure ridges
sediment waves
mainstream canyons
slide block in debrite deposit
slide scarp
sediment waves
sediment waves
slide scarp
slide scarp
Scale
5 km
0
5 km

The geomorphic reconnaissance of the continental slope from 56°N to 57°20′N was conducted using the Institute of Oceanographic Sciences Deacon Lab TOBI side-scan sonar system, which has a neutrally buoyant fish towed 200 m horizontally behind a heavy depressor weight. The starboard and port side-scans operated at frequencies of 30 kHz and 32 kHz respectively, with a repetition rate of 4 s (Le Bas *et al.* 1995). Despite rough conditions restricting the direction of travel, a total of 85 hours of good, interpretable 6 km swath side-scan sonar and 7.5 kHz sub-bottom profiles was gathered. After reception and processing, signals were photographically anamorphosed to take into account the ship's speed over the sea floor and to correct for the horizontal scale, and the overlapping tracks were then mosaiced to produce the final copy maps (Figs 3–5).

Bottom photographs were obtained using the Proudman Oceanographic Laboratory UMEL deep-sea survey camera. A time series of shots were taken during a period of 18 months, between March 1994 and November 1996, to allow seasonally variable observations of sea-floor micromorphology to be monitored. The sea-bed area photographed is trapezoidal in shape and *c.* 3 m front to back. The width across the bottom of the frame is *c.* 120 cm and that across the top is *c.* 250 cm (J. Humphery, pers. comm.).

Classification and mapping of microtopography is based on the study of 3.5 kHz echograms taken during the BGS 85/06 survey in 1985. The principles of echo-character mapping and relationships of various echo types to sea-floor topography and near-bottom processes have been described in detail by J. Damuth and co-workers (Damuth 1975, 1978, 1980, Johnson & Damuth 1979; Damuth *et al.* 1983), and we use a modified version of his classification based on our own observations.

A total of 12 cores have now been collected from the study area (Fig. 2) and preliminary descriptions of these cores have been used to calibrate the remotely sensed data.

Bathymetry

The Hebrides Shelf east of the study area is broad and relatively smooth. It extends for about 150 km in width with shallow basins on the inner shelf and a broad smooth outer shelf (Fig. 1). The slope width in the study area ranges from about 50 km in the north to more than 100 km in the central area (including the Hebrides Terrace Seamount). The Barra Fan complex extends downslope both north and south of this seamount.

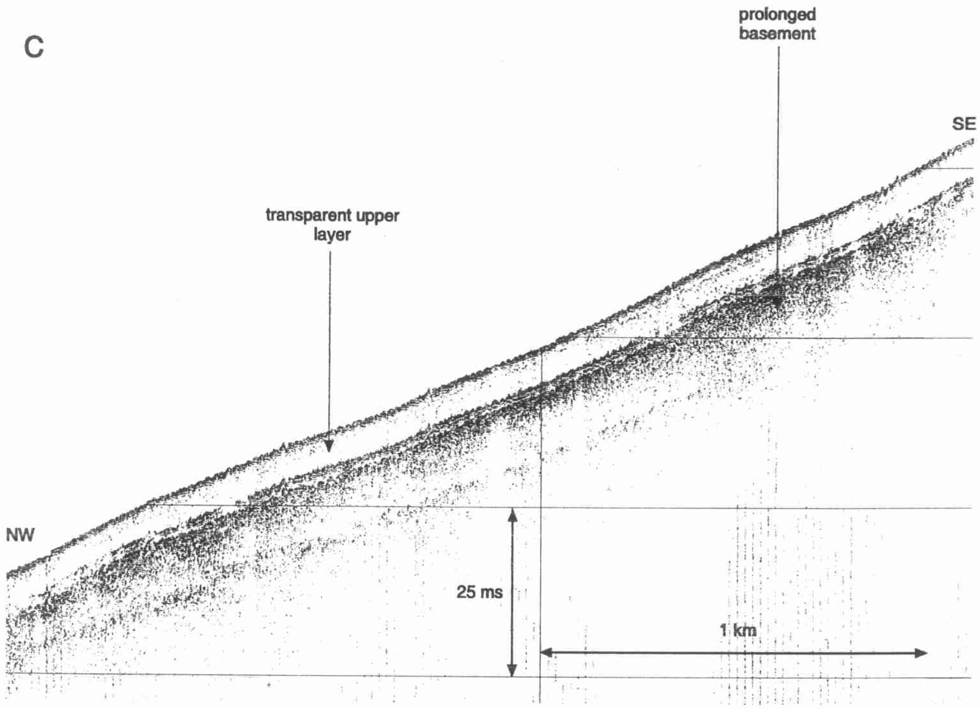
Based on recent data from EM12-120 swath bathymetry surveys (cruises CD91A and 91B, spring 1995) and IOSDL TOBI surveys, we have been able to produce a much more refined bathymetric map of the area than was previously available (Fig. 2). The 10 m spacing between isobaths permits the resolution of small-scale morphological features in four distinct zones based on marked changes in the slope gradient.

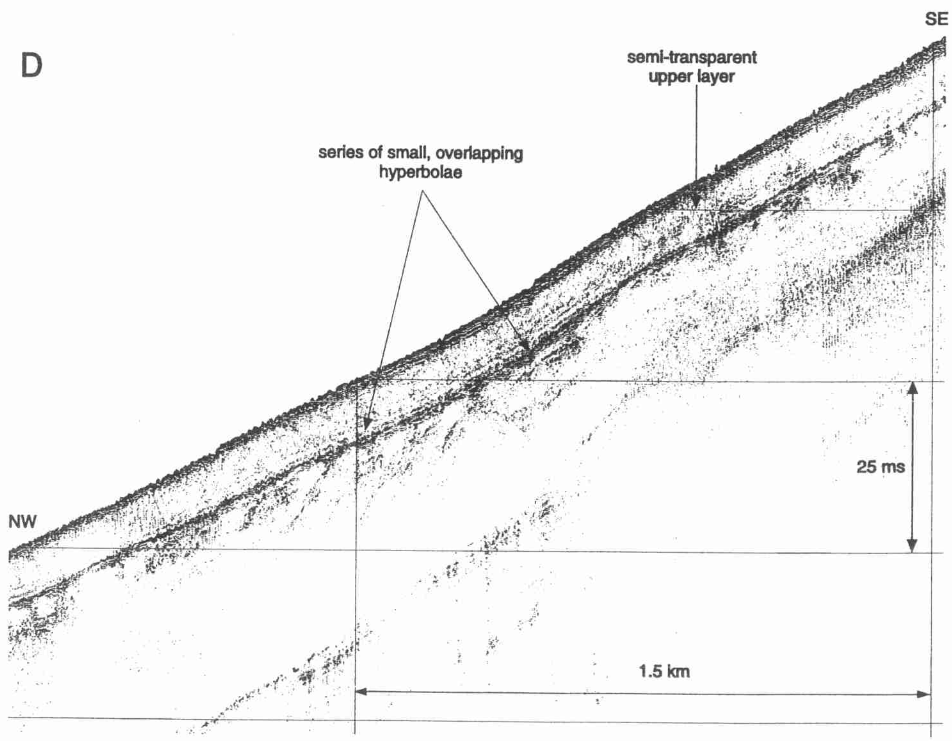
The outer shelf and shelfbreak. The outer shelf and shelfbreak are of interest to the present study as the immediate source of material for downslope resedimentation. The shelfbreak occurs between 150 m and 250 m below sea level (b.s.l.), but mainly ranges between 180 and 220 m. The average slope of the shelf ranges from less than 0.2° to 0.5°, and is characteristically smooth. The gently convex shelfbreak in the study area is often poorly defined, and is generally deeper where slope angles are lower. The shelfbreak is shallowest (150 m) where sliding and slumping have cut back into the shelf edge. Bathymetric features observed include iceberg scour marks, longitudinal furrows, sand streaks, sand ribbons, sand patches and sand waves. In areas where the shelfbreak is well defined, canyons produce a crenulated topography.

Upper slope. The upper slope (200 to 1000 m) is characteristically steep with angles ranging from 2.5° to 3.5°; however, a maximum slope of 16° occurs near slide escarpments. The upper part of the slope has a convex-upward profile, whereas the lower part of this zone tends to be concave. The upper slope has a characteristically steep and rugged terrain, with canyons, debris-flow deposits, contourite deposits, slides and fault scarps all well defined. Of particular note are the most recent boundaries of the Peach Slide, clearly visible as steep-sided curvilinear traces on the bathymetric chart and on TOBI images (Figs 2, 4 and 5).

Middle slope. The middle slope occurs between depths of 1000 m and about 2000 m b.s.l. Slope angles are lower than those of the upper slope, and vary between <0.1° and 1.6°, but may locally reach 3°. Slope profiles indicate that the slope is

Fig. 3. TOBI side-scan mosaic and interpretive map of the northern region of the Barra Fan. Location is shown in Fig. 1.


C
prolonged basement
SE
transparent upper layer
NW
25 ms
1 km


SE
D
semi-transparent upper layer
series of small, overlapping hyperbolae
25 ms
NW
1.5 km

hemipelagic sediment through the water column where no significant bottom currents are active (Damuth 1975; Chough & Hesse 1985; Yoon *et al.* 1991). In some areas the uppermost surface is composed of very small, regular, overlapping hyperbolae which may indicate the presence of weak bottom-current activity. Where the reflections are stronger we interpret the section as comprising interbedded hemipelagites and turbidites.

Type IB. Thin or thick, distinct acoustically well-layered sequences with numerous conformable sub-bottom reflectors similar to Type IA echoes, but they are classified separately on the basis of their different acoustic basement. Acoustic basement beneath Type IB echoes comprises either conformable or unconformable sequences of chaotic, irregular lensing sub-bottom echoes, or small regular single or overlapping hyperbolae (Fig. 6, profile B). The distribution of Type IB echoes is extensive (for tens of kilometres) throughout smooth lower-slope areas, mainly below 1200 m, and across areas where slope irregularities are more prominent than for Type IA echoes. Type IB echoes are also returned from small scarp faces and in areas of where upper-slope channels and gullies have dispersed into broad lower-slope channels or lobes. The upper layers, like Type IA echoes, are interpreted as slope hemipelagites and turbidites, whereas the underlying zone probably represents a slope system dominated by canyon dissection, slumping and debris flows.

Type IIA (Damuth et al. *1983, Type II).* Sharp bottom echo or echoes, underlain by an acoustically transparent to semi-transparent zone with an intermittent, discontinuous prolonged basement (Fig. 7, profile C). This basement layer, itself, may have parallel to sub-parallel sub-bottom reflections, may be topographically smooth or gently rolling, and is also widespread and generally found in upper- and mid-slope areas below 500 and 600 m where the sea-floor morphology is relatively steep, rugged and dissected by straight and meandering canyons. These well-layered and strong reflections at the surface or subsurface are interpreted as turbidites, whereas the transparent zones more probably indicate debris-flow deposits.

Type IIB. These echoes have an upper zone similar to that of type IIA echoes, but are classified separately because of their different acoustic basement. Acoustic basement is generally unconformable and it overlies a sequence of chaotic, irregular, wedging or truncated sequence of sub-bottom reflections. These reflections may be interspersed with parallel sub-bottom reflectors or single or overlapping small hyperbolae (Fig. 7, profile D). Echo Type IIB is observed in close association with Type IIA echoes. Both types are more prominent in the northern part of the area, as well as on the steeper upper-slope region (Fig. 5). Type IIB echoes are interpreted as turbidites and debrites, with the underlying zone being more indicative of extensive slope disruption by slides, slumps and debris flows.

Type III (Damuth et al. *1983, Type III).* Distinct to indistinct bottom echoes with intermittent to continuous zones of conformable, migrating, truncated or wedging sub-bottom reflectors, in some cases with zones of intermittent regular overlapping hyperbolae (Fig. 8, profiles E and F).These echoes are those that occur in areas of undulating sea-floor topography. For the most part, Type III echoes occur along the steep upper slope in areas of rugged terrain, but there is also one large mid-slope occurrence in the north over smooth gently rolling sea floor. In some cases the wavy or irregular topography appears to have formed by slope creep and slide processes and the overlying reflectors indicate bottom-current control of hemipelagic input (e.g. Fig. 8, profile E). In other cases, the sea-floor waves may be due to entirely bottom-current control (e.g. Fig. 8, profile F).

Type IV echoes. Irregular to more regular, overlapping hyperbolae commonly with greatly varying vertex elevations (Johnson & Damuth, 1979, Types IIIA and IIIB) (Fig. 9). Echoes are patchily distributed across the region. In most cases these are best interpreted as an irregular

Fig. 7. Echo Types IIA (profile C) and IIB (profile D). Sharp bottom echoes underlain by an acoustically transparent to semi-transparent zone, characteristic of flat or gently rolling sea-floor topography. These echoes are divided into two subtypes to distinguish regions with prolonged parallel to sub-parallel acoustic basements (echo Type IIA) and regions with more unconformable, chaotic, wedging, and truncated sub-bottom reflections interspersed with single or overlapping hyperbolae (echo Type IIB).

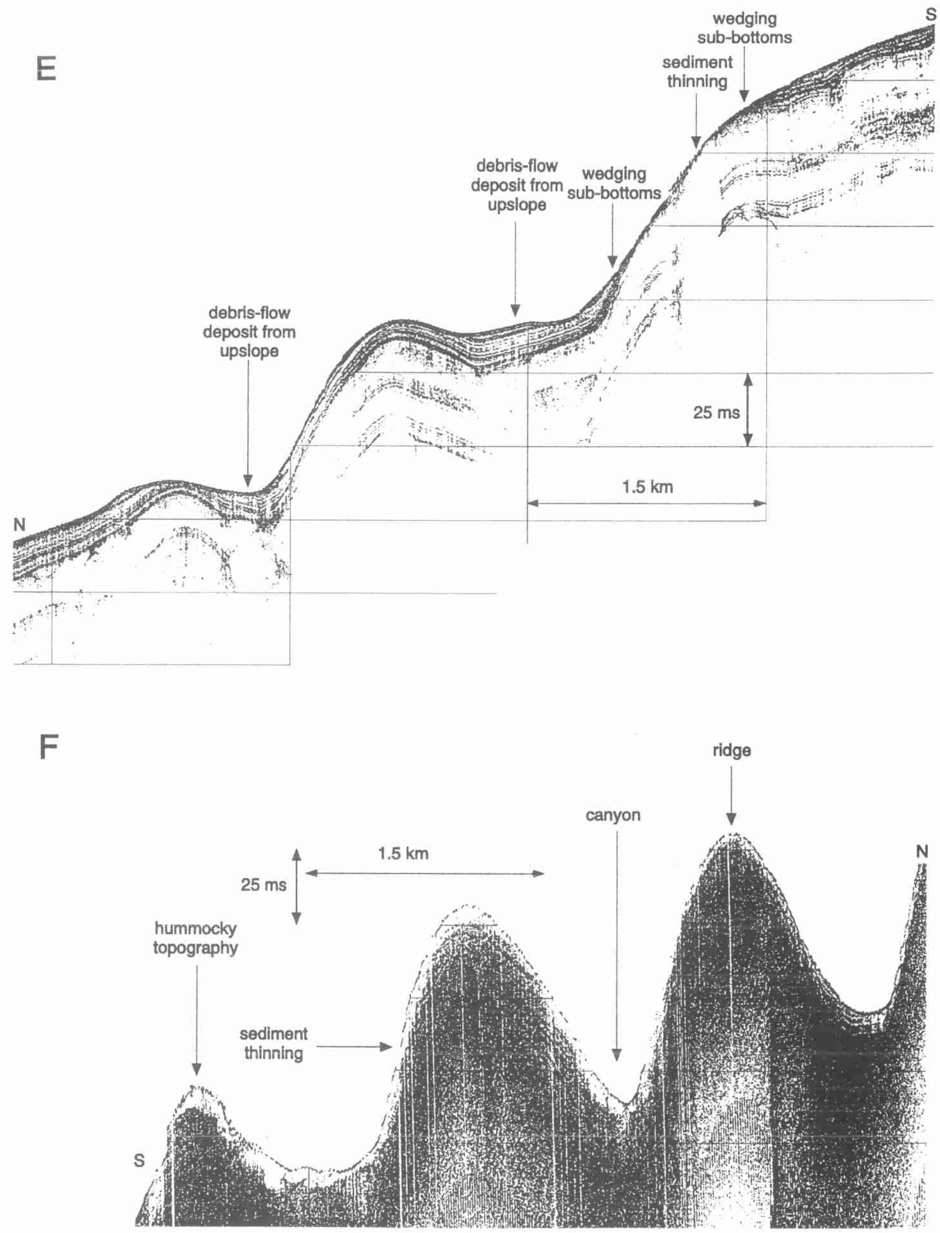


Fig. 8. Echo Type III (profiles E and F). Distinct to indistinct bottom echoes with intermittent to continuous zones of conformable, migrating or wedging sub-bottoms, or intermittent zones of regular single or overlapping hyperbolae.

sea-floor topography resulting from slump or slide masses. Type IV echoes occur on the steep upper slope, in association with the Peach Slide and near the foot of the Hebrides Terrace Seamount. The presence of smaller, more regular hyperbolae at some locations may indicate some bottom-current control.

Seabed photography

The Proudman Oceanography Laboratory deep-sea survey camera was deployed on several occasions on cruises between March 1995 and February 1996. Numerous bottom photographs were taken at each of five stations along a

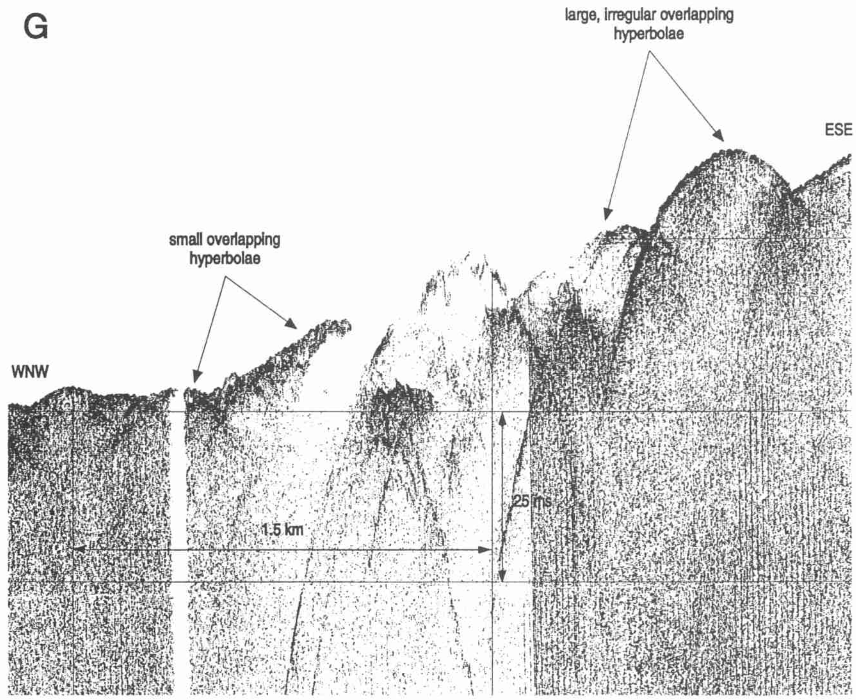


Fig. 9. Echo Type IV (profile G). Irregular, overlapping hyperbolae with large, often greatly varying vertex elevations.

southern transect running from 9°W to 9°25′W, between depths of 140 m and 1000 m, and at five stations along a northern array between 56°35′N and 56°45′N at depths between 140 m and 1500 m. All were taken on open slope sites. The photographs illustrate a variety of features attributable to current activity, normal marine hemipelagic sedimentation, and iceberg activity. Faunal (population type and density) and anthropogenic (trawl marks and relict core sites) indicators have been noted from several locations and are useful measures of current strength and the extent of sediment reworking.

Sediment texture

Both transects show a clear decrease in mean grain size of the surface sediment cover with depth downslope. The outer shelf and upper slope (140–300 m) have coarse cover with up to 25% cobbles and boulders (2–20 cm diameter, maximum 50 cm) (Figs 10–12). Sand cover persists, with less gravel, to a depth of *c.* 700 m (Fig. 13). From 700 m (Fig. 13) to 100 m (Fig. 14), the surface cover changes from mainly silty mud to mud, with both rare gravel patches and very rare cobbles and boulders (maximum 25 cm diameter). The deepest camera station, at 1500 m (Fig. 15), shows a muddy surface which is distinctly granular in parts.

Current-induced features

Current-induced features are characteristic of sites between 140 and 1000 m, including sand and silt ripples and obstacle marks such as crescents and sediment shadows (e.g. Lonsdale & Hollister 1979). Other indicators of current activity observed in the study area are crag-and-tail structures, which are often infilled with a coarser-grained lag deposit, current lineations and areas of smoothed sediment surface (Fig. 10).

One of the most common features across the slope are scour crescents, which typically exhibit an upstream moat partly infilled with coarse gravel-lag and a downstream sandy mound in the lee of the obstacle (Fig. 11b), commonly a large stone or boulder. Scour is observed at sites from 140 m (Fig. 10), where it clearly occurs around the southern faces of the obstacles, down to 700 m, where it is indistinct and most likely to be relict from previous current action (Fig. 13b). The strongest scouring is observed in mixed grain-size populations on the shelf and upper-slope regions (140–300 m) (Figs 10–12), where scours up to 10 cm deep and 20 cm × 30 cm in

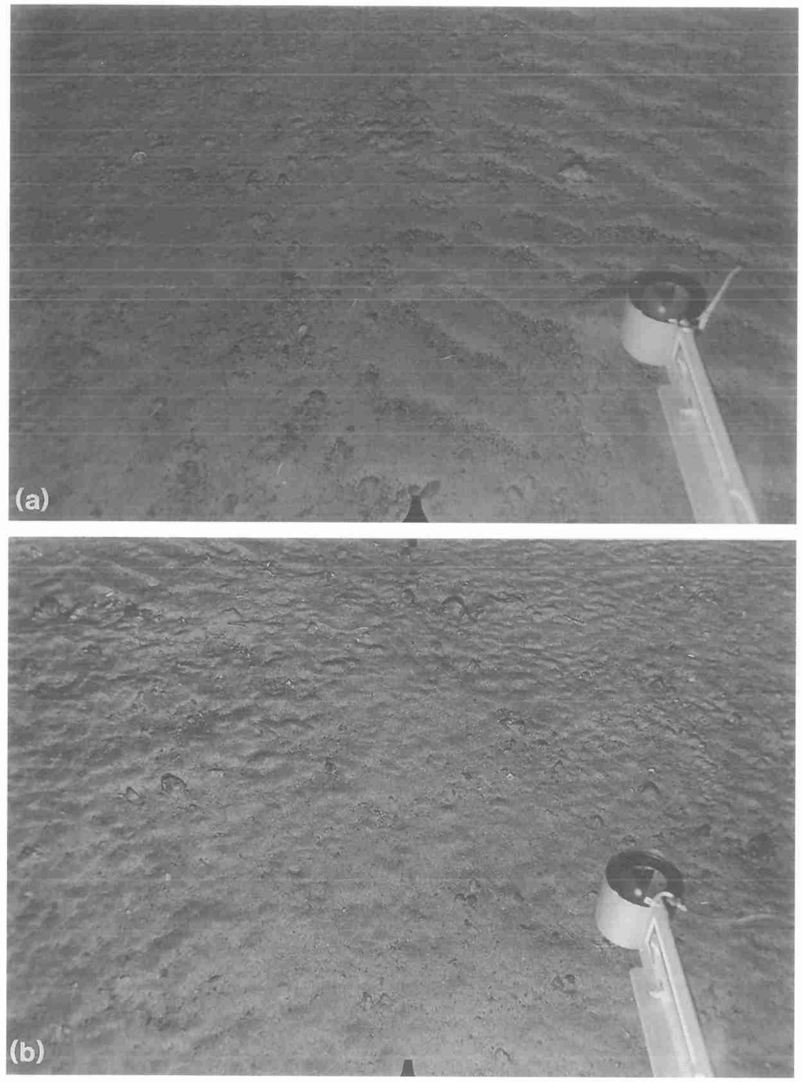
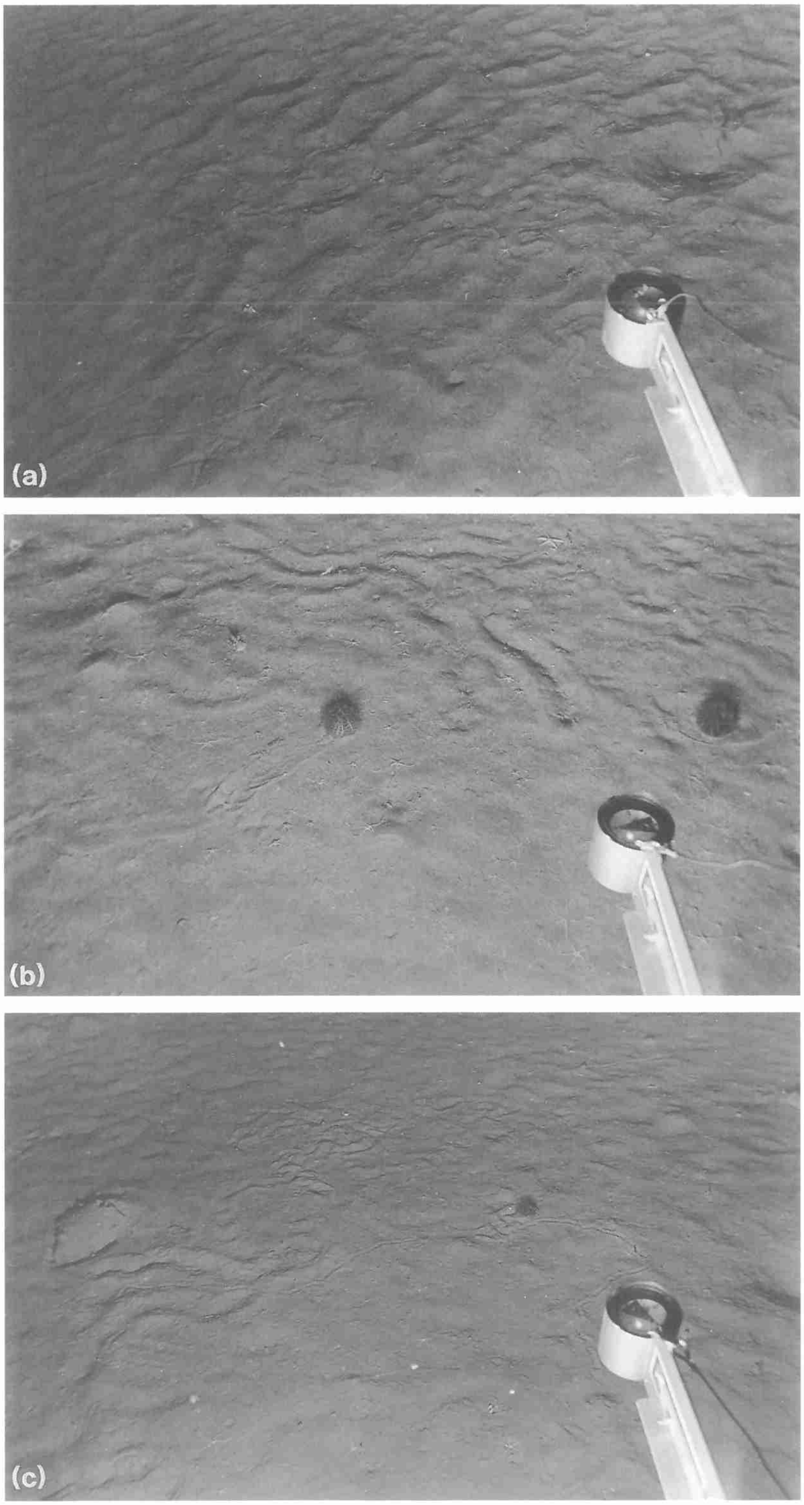


Fig. 12. Bottom photographs from camera stations N300 and S300 in *c*. 300 m of water. (**a**) March. Fields of small (1–2 cm) and larger (5–8 cm) stones (maximum 12 cm) with interstitial sand. Sand ripples advecting NNE over a stony pavement with the occasional appearance of N–S aligned streaky sand ribbons. Benthic community is small and is limited to larger stones. (**b**) August. Small stones (3–5 cm) interspersed in sand, which is thick enough to form a mobile pavement exhibiting small ripples showing movement to the NE. Scour development around a few of the larger (up to 35 cm) stones. The sea-bed area photographed is trapezoidal in shape and *c*. 120 cm across the bottom and *c*. 250 cm across the top of the frame (J. Humphery pers. comm.). Locations are shown in Fig. 2b.

Fig. 13. Bottom photographs from camera stations N700 and S700 in *c*. 700 m of water. (**a**) April. Sea floor composed of fine sand and silt which has been reworked by bottom-currents into symmetrical and confused bedforms and marked increase in benthic population, notably brittle-stars and echinoids. (**b**) August. Obliteration of coherent bedforms and marked increase in benthic population, notably brittle-stars and echinoids. (**c**) November. Soft mud and silty sea floor with a granular texture exhibiting limited occurrence of bedforms and small benthic population. The sea-bed area photographed is trapezoidal in shape and *c*. 120 cm across the bottom and *c*. 250 cm across the top of the frame (J. Humphery pers. comm.). Locations are shown in Fig. 2b.


(a)
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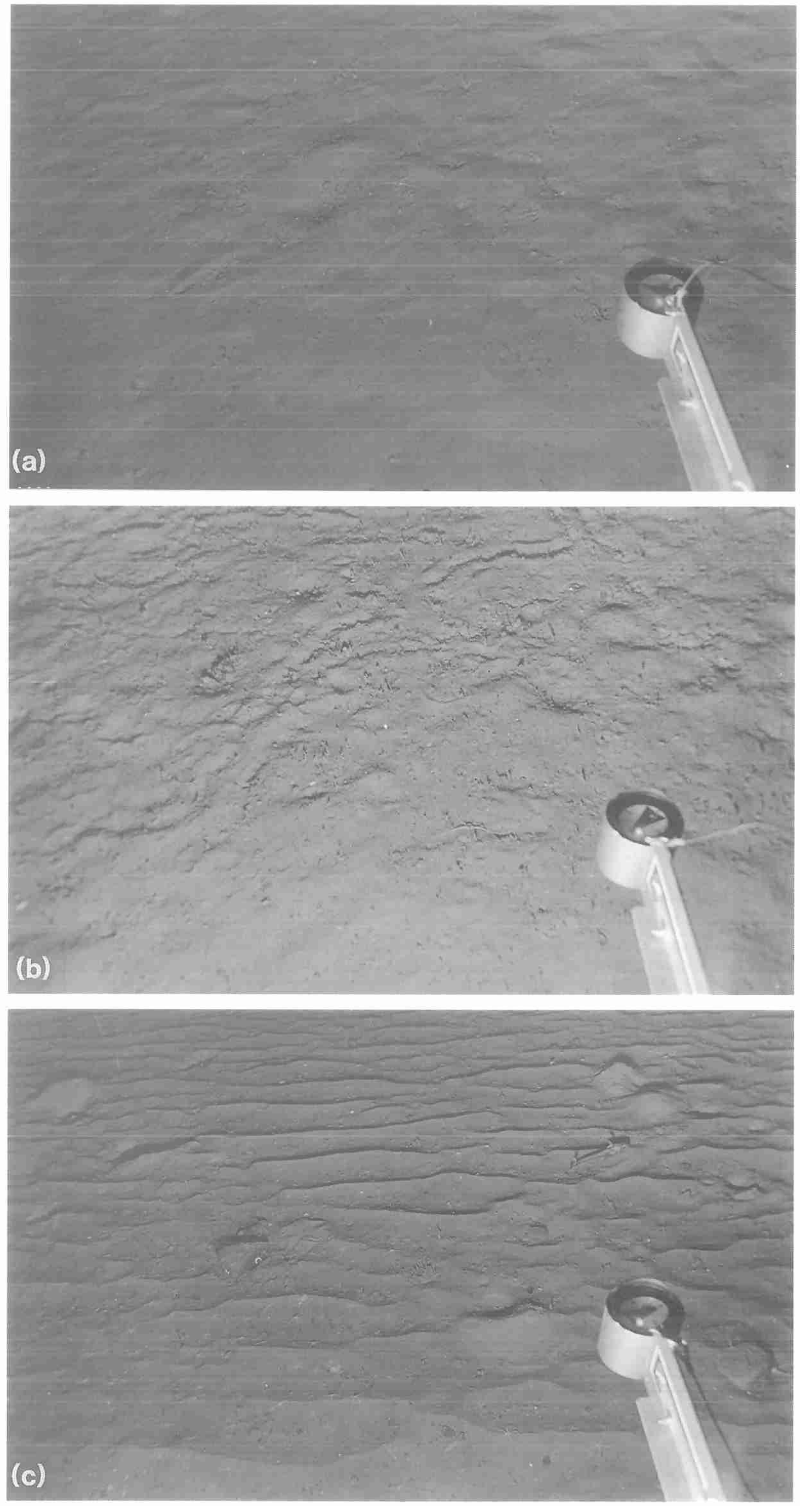
(a)
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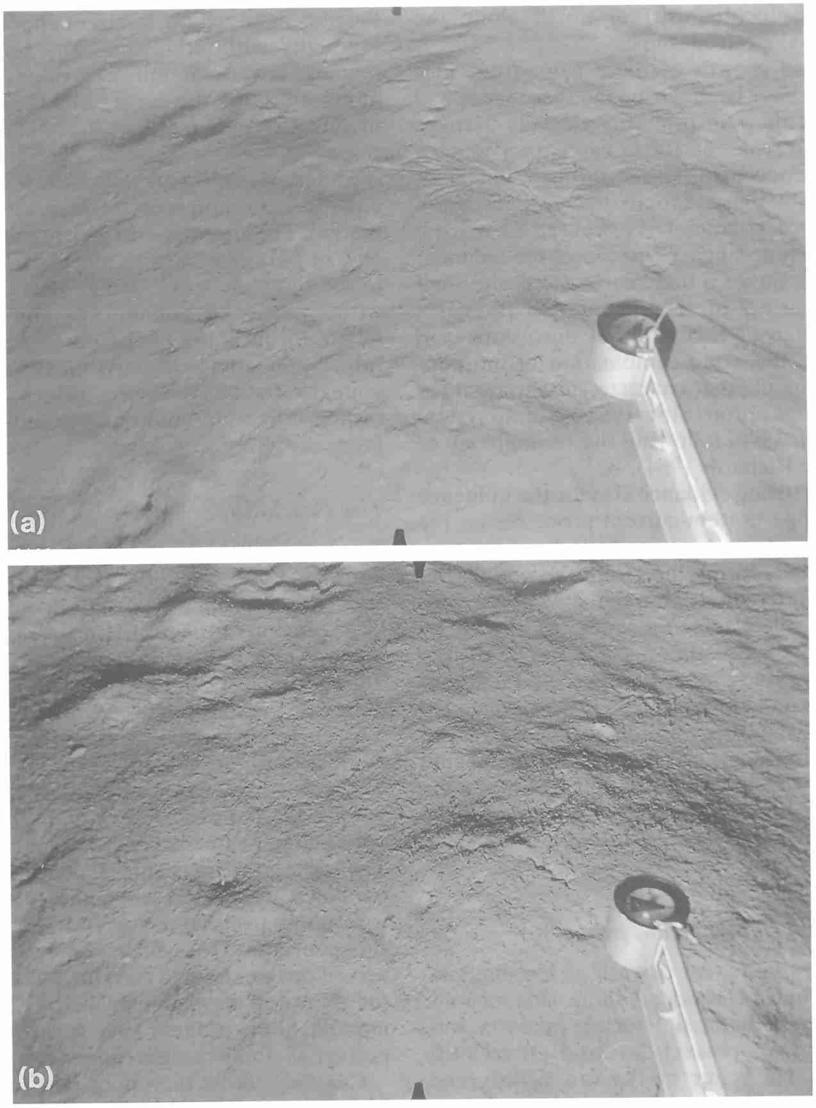

Fig. 15. Bottom photographs from camera station number N1500. (**a**) April. Silty to muddy sea floor with no current-induced bedforms. (**b**) August. Much modified sea floor, with the absence of any current-induced features. The sea-bed area photographed is trapezoidal in shape and *c.* 120 cm across the bottom and *c.* 250 cm across the top of the frame (J. Humphery pers. comm.). Location is shown in Fig. 2b.

Fig. 14. Bottom photographs from camera station S1000 in *c.* 1000 m of water. (a) April. Sea floor composed of fine sand and silt, with a scattering of small (1–5 cm) stones and few larger stones (up to 25 cm). Weak NW-flowing driving currents indicated by small-amplitude ripples. (**b**) August. Sea floor heavily reworked by a large benthic population, giving it a granular texture. Occasional presence of small (1–2 cm) stones. (**c**) November. Field of symmetrical, straight-crested and confused sand ripples, interspersed with small (1–3 cm) and large (up to 30 cm) stones, causing the development of crag-and-tail structures. The sea-bed area photographed is trapezoidal in shape and *c.* 120 cm across the bottom and *c.* 250 cm across the top of the frame (J. Humphery pers. comm.). Locations are shown in Fig. 2b.

Foula fans located further north along the margin, as slope-front fans.

The main growth of these slope-front fans appears to have been during the Pleistocene and the sediments were primarily glacially derived. On a broad scale the Barra Fan is very much a focused depocentre, either through fluvial or ice-stream activity, and in this respect has a point-source character. However, on a local scale there is no single point source for sediment supply but, rather a line source along the shelf edge. A variety of resedimentation processes then transferred this material downslope and resulted in the same combination of morphological elements that characterize a normal (or muddy) slope apron (Stow 1985) or ramp system (Stow *et al.* 1996, following the terminology of Reading & Richards 1994).

There is strong evidence also for the influence of alongslope bottom-current processes on the Barra Fan. These currents have been particularly effective during the Holocene period, but they also interacted with the downslope processes during glacial episodes, as shown by Howe (1996) for the margin north of the present-day study area. It is this interaction of downslope and alongslope processes, which led to the NW–NNW extension of the Barra Fan between the Hebrides Terrace Seamount and the Hebrides Shelf, that prompts us to term the Barra complex a composite slope-front fan. The different elements of this system are discussed below.

Downslope elements and processes

The primary source for downslope resedimentation is the outer Hebridean Shelf. This region is covered by a diamictite facies, in parts winnowed to give a present-day sand–gravel surficial layer. Ice scour marks are widespread, whereas the ridge and gully systems form a locally corrugated shelf edge and are interpreted as shelf channels developed in submarine end-moraines. Subsequent current action and slope steepening served to further deepen those channels to their present forms. Shelf spillover processes, perhaps mainly post-glacial, have transported the winnowed sands and gravels part way down the upper slope so that the mud line now lies at around 500–700 m.

The upper slope both below and above the mud line is heavily dissected by canyons. These are most numerous and have distinctive networks of tributary channels where the slope gradient is greatest (i.e. in the northern and southern sectors). In some cases, these canyon systems give rise to distributary channels across the mid-slope region, but most appear to die out gradually without feeding any terminal lobe system. Although minor levees are present along some of the larger channels, most are mainly erosional features dissecting a mud-rich slope.

Slides, slumps and debris-flow masses are equally commonplace throughout the whole margin. These give rise to an irregular morphology, in part erosive with steep scarps and hollowed-out slide scars, and in part depositional with a blocky–hummocky convex-upward lobate form. Some of the parallel wrinkled or ridged appearance of parts on the upper slope appears to be pressure ridges formed in response to slide-slump and/or sediment creep processes.

The Peach Slide

The largest slide mass identified in the area is known as the Peach Slide (Holmes 1994; Holmes *et al.* this volume). This slide has translated a large portion of the northern Barra Fan downslope towards the NE Rockall Trough, probably during the late Pleistocene although precise dating of the movement has not yet been possible. This slide represents a complex body with a number of different features.

The headwall can be traced as a curvilinear scarp edge between 150 m and 400 m on the upper slope, which has cut back into the shelf. The steepest relief is at least 50 m. Smaller subparallel scarps are present and may have formed in response to either retrogressive or progressive slump events. Downslope movement has also carved out steep scarp margins, which cut across the slope and show an en echelon displacement in parts. Some of these have subsequently been pirated as slump margin channels.

Canyons across the upper part of the Peach Slide are mostly original slope channels now cut off from their shelf-edge source. Further down the slide, the morphology is distinctly irregular, with interspersed blocks, lobes and depressions making up the surface of an overall convex-upward bulge. The area covered by this composite slide is *c.* 1600 km^2.

Alongslope elements and processes

Photographic evidence clearly supports the widely accepted view that there is a generally northerly advecting current on the Hebrides Slope (Booth & Ellett 1983; Huthnance 1986; Kenyon 1986; Howe & Humphery 1995) and that current strength and orientation fluctuates considerably, depending on depth and location on the slope. In general, current-induced bedforms disclose a shelf edge–upper-slope current that is advecting N to NNE and occasionally towards the NE (Fig. 11). Sites across the upper slope indicate a strong, continuous N- to NNE-flowing current throughout the year, although at some sites (during August), the occurrence of major WNW current ripples is superimposed upon ripples with a NE orientation, indicating current motion in two directions (Fig. 11b). Slightly further down the slope the current strength is significantly reduced.

A second area of current activity is observed on the lowermost part of the upper slope in the study area. This again supports the observations of Booth & Ellett (1983) for a northward current flow of 16 cm s^{-1} above the 1000 m depth contour over a 5 month period between May and September. From our photographs, taken at stations located at 700 m and 1000 m water depth (Fig. 13a–d), however, we would infer a seasonally affected current with a NNW–SSE oscillating flow during the winter and spring months and a much reduced flow during the summer. Ellett *et al.* (1986) suggested that the current to the west of Scotland broadens during the winter months, particularly under the influence of southeasterly and easterly winds, which may also cause the increase of the slope current transport in deeper waters (D. J. Ellett, pers. comm., 1995). The decrease of a slope current during the summer months may be explained by the notable lack of exchange between shelfedge waters and the slope current during summer and autumn (Booth & Ellett 1983). Water near the sea bed west of Scotland becomes isolated during the summer, and remains cool and dense until autumnal gales increase the mixing on the shelf (Edelsten *et al.* 1976), which may result in the confused and randomly orientated linguoid ripple bedforms seen at some stations (Fig. 11a).

Larger-scale morphological elements associated with alongslope bottom currents are present, but less readily observed on the Barra Fan. Sediment wave-like topography occurs along much of the upper slope, as well as in more restricted parts of the upper- to mid-slope region of the northern Barra Fan. However, some of these features, particularly those on steeper slopes, appear to have developed as pressure ridges from slump and creep processes, rather than as current bedforms. Furthermore, an area of true sediment waves on the northern edge of the Barra Fan has been interpreted as formed from turbidity-current flow (Howe 1996). Whereas unequivocal examples of sediment waves formed by bottom currents are elusive in the study area, the pattern of small-scale drift sedimentation associated with some of the wave fields, as well as with other topographic features (e.g. slide scarps and blocks), does suggest bottom-current moulding in two main depth zones: (a) from 150 to 300 m and (b) from 700 to 1100 m.

Bottom-current smoothing of the sediment by plastering over minor topographic irregularities is apparent over a rather broader depth range on the upper- to mid-slope region (i.e. *c.* 600–1200 m), particularly in the southern and central parts of the study area.

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