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A record of fluctuating bottom currents on the slopes west of the Porcupine Bank, offshore Ireland — implications for Late Quaternary climate forcing

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Abstract

Both local and regional controls on slope sedimentation west of Porcupine Bank are assessed using an array of 25 gravity cores, integrated with shallow seismic, TOBI side-scan and high-resolution bathymetry data. The cores were retrieved from an area of smooth, distally steepened slope (between 52° and 53°N) in water depths of 950 to 2750 m. The slope here is unmodified by gravity failures and is swept by bottom currents that flow from S to N along the margin. The cores reveal a coherent shallow stratigraphy that can be traced along and between transects at upper-, mid- and lower-slope levels. AMS ^{14}C dating, oxygen-isotopes and carbonate profiles suggest the cored record could extend as far back as 500 ka in the longest cores, with most cores providing details of the slope response to the last interglacial, last glacial and Holocene forcing. The facies indicate deposition was dominated by a combination of bottom currents, ice-rafting and hemipelagic settling, with carbonate-prone deposits during interglacials, and siliciclastic deposits during glacials. Inferred contourites imply that strong currents operated during interglacials, with weaker current reworking during glacial conditions. A pair of erosion surfaces record significant mid- and upper-slope scouring during Marine Isotope Stage (MIS 3) and in the Early Holocene. The lateral facies distribution implies stronger currents at shallower levels on the slope, although there is evidence that the core of the current migrated up and down the slope, and that sand might locally have spilt down-slope. The bathymetry influenced both the wider geometry of the condensed contourite sheet and the local thickness and facies variation across the slope. A significant result of the study is the identification of a pair of thin sand–mud contourite couplets that record enhanced bottom-current reworking corresponding to periods of interstadial warming during MIS 3. The couplets can be correlated to the terrestrial records onshore Ireland and imply that the NE Atlantic margin oceanographic and onshore climate records are strongly coupled at interstadial level.

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1. Introduction

Much work on contourites has been undertaken in areas of high sediment supply where large sediment drifts and extensive wave fields are developed (e.g. Cremer et al., 1993; Dowling and McCave, 1993; Masson et al., 2002; Stow and Holbrook, 1984; Stow et al., 2002; Wold, 1994). However, bottom currents are also important in areas of low sediment input. This paper assesses the history of bottom-current activity on the sediment-starved slopes to the west of the Porcupine Bank, on the Atlantic margin west of Ireland, against a backdrop of high-frequency Late Quaternary climate fluctuations. The slopes are close to the mouth of the trough and are exposed to a modern deep-water bottom-current system that sweeps the slopes from south to north. Significantly, the western flank of the Porcupine Bank has a large stretch of smooth and gentle upper slope (500 to 1200 m water depth) that is undisturbed by slope failures. This enables preservation of the background slope sedimentary succession without the complication of gravity remobilisation. The Porcupine Bank slope has also been extensively cored allowing a detailed reconstruction of the Late Quaternary shallow slope stratigraphy at different levels on the slope.

Both local and regional factors will potentially control sedimentation on an undersupplied ocean-facing slope system. Regional controls include changing sediment supply (both flux and type), variable current velocities and, during glaciation, episodes of ice-rafting. However, the presence of local factors such as slope failures and topographic irregularities can complicate the depositional signal produced by regional factors. To date, most studies addressing regional controls such as climate or ice-rafting flux are based on a single vertical core (e.g. Elliot et al., 2002; Knutz et al., 2001; Labeyrie et al., 1999; Lagerklint and Wright, 1999; Shackleton et al., 1984; van Kreveld et al., 1996). This, however, might not provide a complete picture, particularly in slope settings, as erosive and non-depositional hiatuses are often identified only through lateral correlations across an array of boreholes. The present study aims to identify and distinguish between local and regional controls on sedimentation using a large number of correlated cores on the Porcupine Bank slope. The spacing of the cores varies from grids of cores spaced 1 km apart to isolated cores spaced tens of kilometres apart. This allows both short- and long-scale correlations to be built and validated, and the wider 3D structure of the slope deposits to be reconstructed.

2. Regional setting

The Rockall Trough (Fig. 1), offshore western Ireland, is an elongate bathymetric depression trending approximately NNE–SSW. It is 1000 km long and 250 km wide with narrow marginal slopes (10–40 km wide) with gradients ranging from 2° to $>20^{\circ}$. The trough extends from the Porcupine Abyssal Plain in the southwest (c. 52°N) to the Wyville–Thomson Ridge in the northeast (60°N). It is flanked to the west by the Rockall Bank and to the southeast by the Porcupine Bank. The water depths along the axes of the trough increase southwards from 1200 m in the north to 4500 m in the south.

The bathymetric configuration of the Rockall Trough has changed little since the mid-Cenozoic when late Eocene–Oligocene differential subsidence deepened the trough, forming the marginal slopes (Stoker et al., 2005). This deepening was associated with the onset of bottom-current circulation in the region (Stoker, 1997; Stoker et al., 2001). By the early Miocene, the Greenland–Scotland Ridge (including the Wyville–Thomson Ridge) was submerged and deep-water exchange between the Arctic and North Atlantic oceans was established (Boldreel and Andersen, 1995; Tucholke and Mountain, 1986) allowing northerly-derived water masses (*Norwegian Sea Deep Water*; NSDW) to enter the Rockall Trough. Davies et al. (2001) suggested an early Oligocene initiation of *North Atlantic Deep Water* (NADW) formation, which is the result of mixing of NSDW with surrounding water masses. The early Miocene to the early Pliocene was thus characterised by strong deep-water bottom-current circulation resulting in the accumulation and development of contourite sediment drifts and waves in the region (Stoker et al., 2001). The Plio-Pleistocene transition was marked by a period of major cooling in the North Atlantic and the initiation of Northern Hemisphere glaciation. Early Pliocene to Holocene sedimentation was influenced by climatic changes and sea-level fluctuations, and was characterised by further drift accumulation.

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