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Marine geophysical evidence for ice sheet extension and recession on the Malin Shelf: New evidence for the western limits of the British Irish Ice Sheet

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ABSTRACT

Multibeam swath bathymetry and backscatter data collected as part of the Irish National Seabed Survey and Integrated Mapping for the Sustainable Development of Ireland's Marine Resource programmes is used to investigate the glacial geomorphology of the Malin Shelf. The data provides direct evidence that the former British Irish Ice Sheet was grounded as far out as the shelf break in this sector on more than one occasion. Drumlins on the outer shelf indicate the region was a zone of confluence where ice flowing onto the shelf from northwest Ireland converged with ice flowing across the shelf from western Scotland. Ice berg furrows located on the outer shelf record ice sheet break up by a calving event that may have been triggered by rising sea levels and northwest–southeast aligned moraines indicate the ice retreated north-eastwards across the shelf towards Scotland. The absence of direct dating control from moraines on the Malin Shelf precludes a definitive assessment of the timing of ice sheet events. However, consideration of the stratigraphic relationship of the glacial landforms on the shelf with age constrained ice sheet events in the wider region indicates that the former British Irish Ice Sheet reached the outer shelf in this region on at least two occasions during the last cold stage. Moraines that have been overprinted by drumlins may possibly belong to an early phase of glaciation that occurred c 45 ka B. This was subsequently followed by another episode of shelf extensive glaciation where converging ice flow from northwest Ireland and western Scotland reached the shelf break during the LGM that subsequently retreated from the shelf edge around 23 ka BP.

1. Introduction

Over a century of investigating the glacial record has lead to major advances in our understanding of the nature and importance of glaciation in the global climate system (e.g. Broecker, 2002). However, our knowledge of the submerged record has been somewhat constrained due to the difficulties involved in surveying offshore. Until recently, the submerged glacial record has been gleaned from low-frequency seismic surveys and deep-sea cores (e.g. Belderson et al., 1973; Bailey et al., 1974) and although this approach has yielded important insights on the nature and extent of Pleistocene glaciation it does not provide data coverage on the scale mirroring the entire glacial system; thus inhibiting regional-scale reconstructions. Recent advances in acoustic methods are now rapidly improving our understanding of the nature and extent of glaciation along continental margins. An example is the development of multibeam echo sounders which allow the seabed to be imaged at a scale and resolution comparable to terrestrial remote sensing systems. The position and orientation of bedforms can be mapped in detail and information on subtle aspects of sedimentation and erosion can be enhanced by digital processing techniques. The characteristics of features identified on multibeam imagery can be mapped in detail and investigated further using backscatter and sub-bottom profile data. Marine surveys that use these techniques have provided new insights on the extent and inferred dynamics of former ice masses in the polar and sub-polar regions and on the Antarctic continental shelf (e.g. O'Cofaigh et al., 2002; Evans et al., 2006; Bradwell et al., 2007, 2008).

The Irish National Seabed Survey (INSS) and Integrated Mapping for the Sustainable Development of Ireland's Marine Resource (INFOMAR) programmes were initiated in 1999 by the Geological Survey of Ireland and the Irish Marine Institute to survey Ireland's territorial waters. They involve the acquisition and processing of 850,000 km^2 of multibeam bathymetry, backscatter, sub-bottom seismic reflection, ancillary geological and water column data in water depths from 50 to 400 m. As one of the most comprehensive surveys of its kind, the INSS/INFOMAR programmes have opened up the possibility for new research to begin on the glacial record around the Irish continental shelf (Benetti et al., 2010; O'Cofaigh et al., in press). This study uses multibeam bathymetric and backscatter data from these surveys to conduct the first detailed investigation of the glacial geomorphological record of the Malin Shelf in Irish territorial waters between 55° 29′ N and 56° 17′ N (Fig. 1). Our motivation is that by unravelling the submerged glacial record here we can provide a wider context to the glacial record onshore

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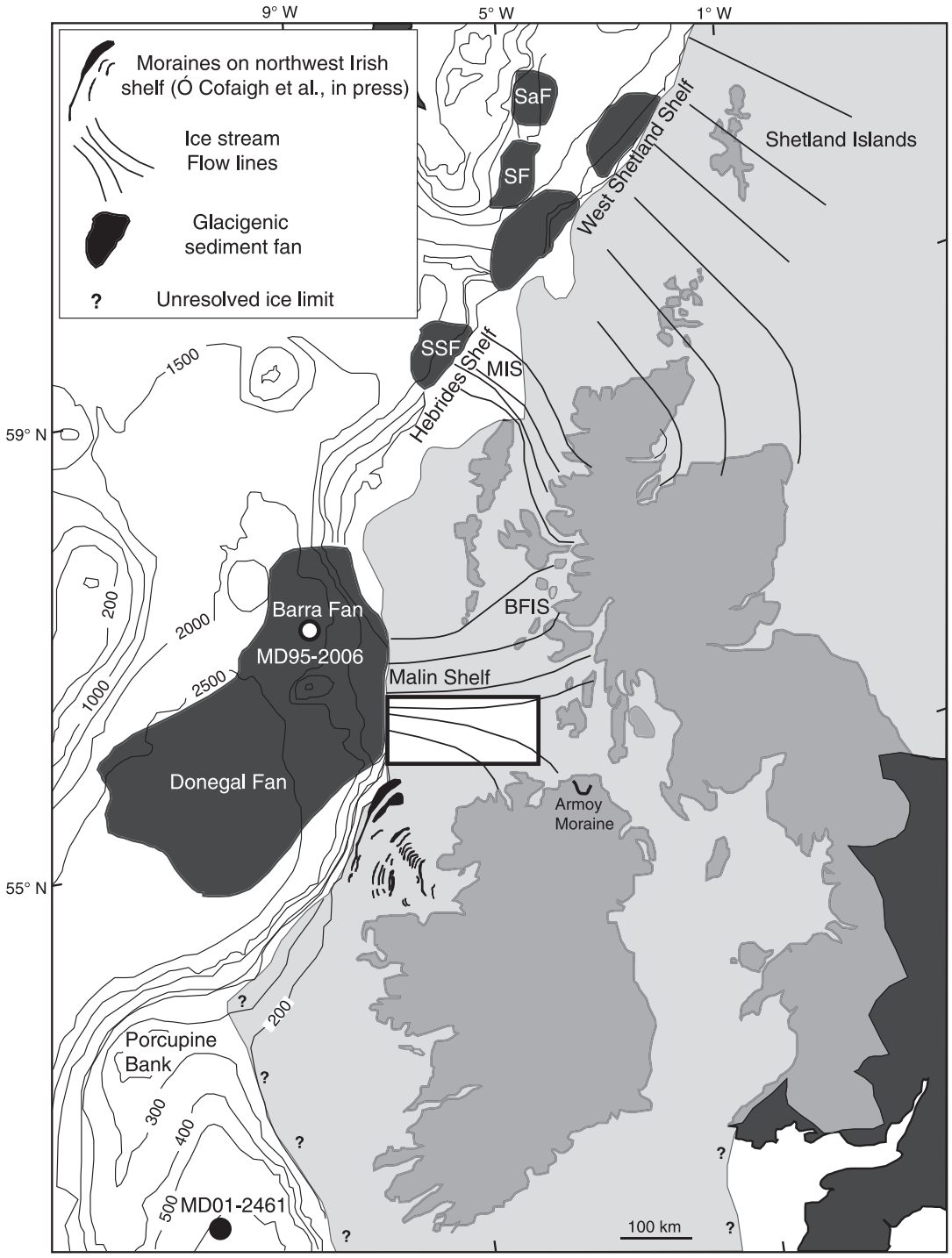

Fig. 1. Location map showing the position of study area in relation to the bathymetry and major morphological features of the southern part of the northwest European continental margin. Also shown is the inferred maximum extent of the last British–Irish Ice Sheet (light grey shading), major ice streams (BFIS: Barra Fan Ice Stream; MIS: Minch Ice Stream), trough mouth fans (Donegal and Barra Fans and the SSF: Sula Sgeir Fan; SF: Suderoy Fan; SaF: Sandoy Fan) and selected marine sediment core locations discussed in the text. After Sejrup et al. (2005) and Scourse et al. (2009).

and build a more spatially consistent understanding of the climatically sensitive British Irish Ice Sheet (BIIS) in this region (McCabe and Clark, 1998; McCabe and Dunlop, 2006).

2. Regional setting and background

2.1. Geology and glacial history

The study area is situated in the south-western region of the Malin Shelf north of County Donegal, Ireland and covers an area approximately 9652 km^2 in extent, in water depths ranging from 50 to 200 m (Fig. 1). The geological structure of the shelf in this region is dominated by northeast trending basement blocks and sedimentary basins. Basin distribution is largely controlled by major northeast–southwest oriented Caledonian faults and faults systems that cut across the area. These are the Skerryvore Fault, which runs from the shelf break north of 55° 30′ N in the direction of the Stanton Banks, the Great Glen Fault which runs through the centre of the study area and the Leannan–Loch Gruinart Fault, which extends onto the shelf northeast of Malin Head (Dobson and Evans, 1974; Riddihough and