Filling the gaps: ice-streaming and ice-sheet readvance in the western North Sea Basin

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I. Research project

The aim of this research is to study the impact of glacial and interglacial cycles and ice streaming on the sediments of the North Sea Basin. An improved understanding of the past cycles of glaciation, timing and extent, has far reaching implications for better understanding global climate change and ice-sheet behaviour. The 1000 metre-thick Quaternary sediment sequence of the North Sea Basin forms the overburden and geological seals to underlying CO2 storage complexes and migration pathways (e.g. thief zones) for fluids. These Quaternary strata also form the foundations for offshore renewable installations and infrastructure for hydrocarbon exploration and extraction. The impact on geotechnical properties of glacial loading and unloading and lateral variation in these deposits is an important consideration for offshore development. Glacial geomorphology shapes the current sea-bed topography and glacial deposits determine sea-bed composition which impacts on the benthic community composition and distribution.

II. Data

Multibeam echosounder datasets have been combined with high-resolution topographic digital surface models (NEXTMap) (Fig. 1), 2D seismic reflection profiles, shallow vibrocore and borehole samples. It is anticipated that during the course of this research high-resolution 3D seismic data volumes may also be incorporated into this study.

To describe the geomorphology of the region, both the sea-bed imagery and the seismic reflection profile data will be studied.

III. Methodology

Multibeam bathymetry and backscatter data (Fig. 1 and 2a) were collected during 2004-2009 as part of the Civil Hydrography Programme (CHP) on behalf of the Maritime and Coastguard Agency (MCA) (Fig. 1). Onshore hill-shaded surface models derived from the NextMap Britain elevation dataset (Intermap Technologies) with a vertical resolution of 1.5 m and a horizontal resolution of 5 m were utilised.

ArcGrids of the processed data were produced at the best possible resolution of between 4 and 8 m dependent on the individual survey area. Additional layers of slope, rugosity, aspect and bathymetric position index were derived from the multibeam bathymetry data and were generated in ArcGIS using the Spatial Analyst extension. The original raw data were also processed using FM Geocoder (Fonseca and Calder, 2005) by the BGS which corrects the backscatter intensities registered by the acquisition system, and then geometrically corrects and positions each acoustic sample in a backscatter mosaic. The backscatter intensity data were gridded between 2 and 5 m (Fig. 2a).

Geomorphological classification and interpretation of sea-bed composition (Fig. 2b) were mapped within ArcGIS via direct digitisation of features. Over smaller areas a semi-automated classification of the backscatter intensity data was undertaken (Fig. 3) whereby reducing potential interpreter bias.

Single-channel seismic data acquired by the BGS were used to map the shallow sub-surface geology. These data reveal multiple seismo-stratigraphic units that have been previously interpreted to represent sediments derived from a number of glacial cycles, including the Last Glacial Maximum through to the present. This study will attempt to reconcile the previously described seismic stratigraphy with the recently acquired sea-bed imagery.

IV. Interpretation thus far and initial conclusions

These datasets reveal strong evidence for onshore-offshore palaeo-ice streaming in the western North Sea Basin. The study area includes the catchments of the previously proposed, but only partly mapped, Strathmore, Forth–Tay, and Tweed palaeo-ice streams. Long suspected to terminate offshore, the full flow path and dimensions of this palaeo-ice stream system can now be reconstructed with some certainty using these new data including the backscatter intensity data that is often overlooked.

The ice sheet glacial landsystem is extremely well preserved on the seabed with four main types of subglacial and ice marginal morphology present: 1) highly elongate flow-parallel ridges and grooves strongly suggestive of ice streaming; 2) shorter-elongation flow aligned drumlins and crag and tails indicative of fast-flowing and persistent ice-sheet flow configurations; 3) large arcuate moraine ridges marking frontal stillstands or readvances of the ice sheet margin; and 4) tunnel valleys and deeply incised meltwater channels probably associated with retreat phases of the British Ice Sheet (BIS) following Last Glacial Maximum.

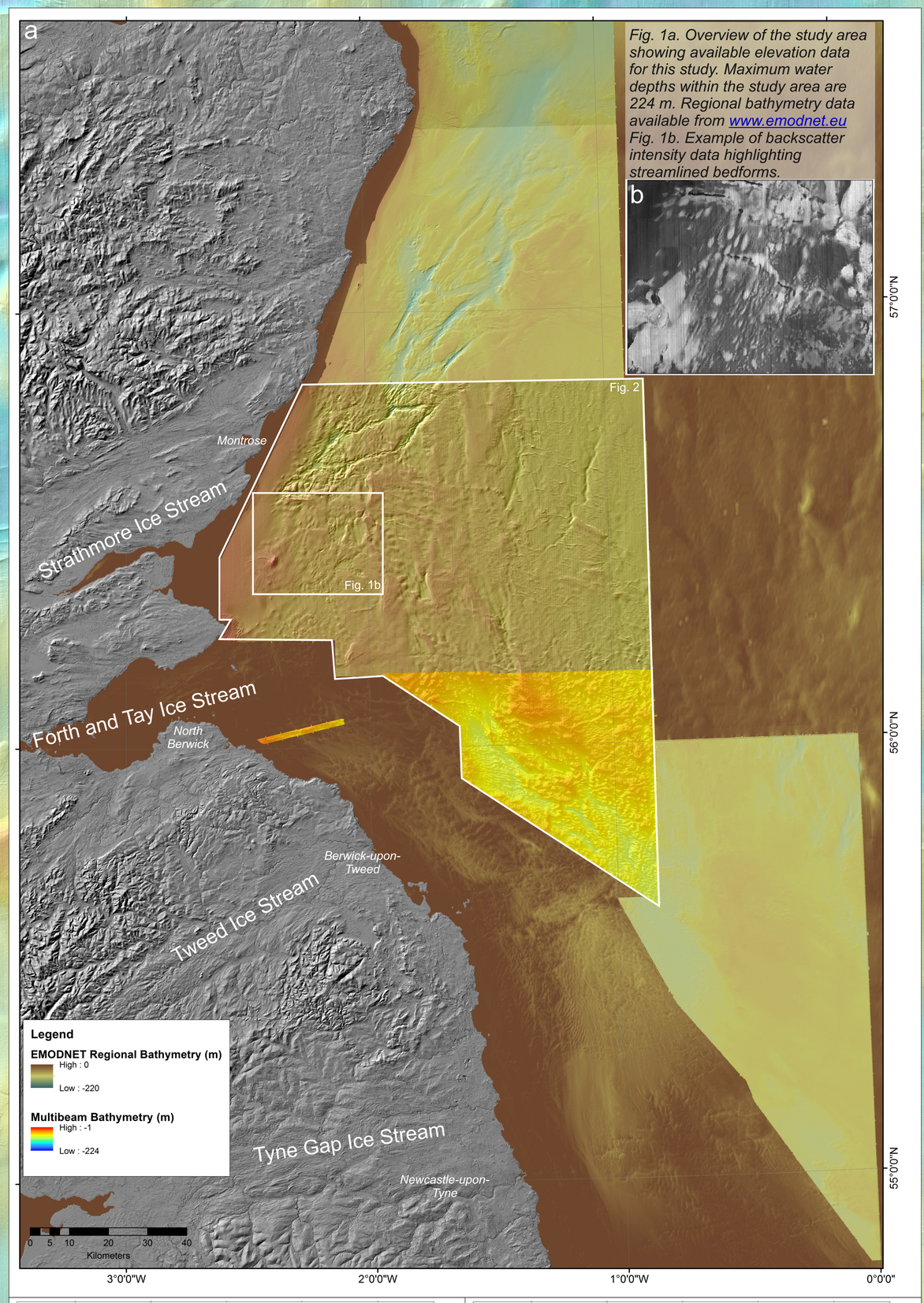

Fig. 1a. Overview of the study area showing available elevation data for this study. Maximum water depths within the study area are 224 m. Regional bathymetry data available from www.emodnet.eu
Fig. 1b. Example of backscatter intensity data highlighting streamlined bedforms.

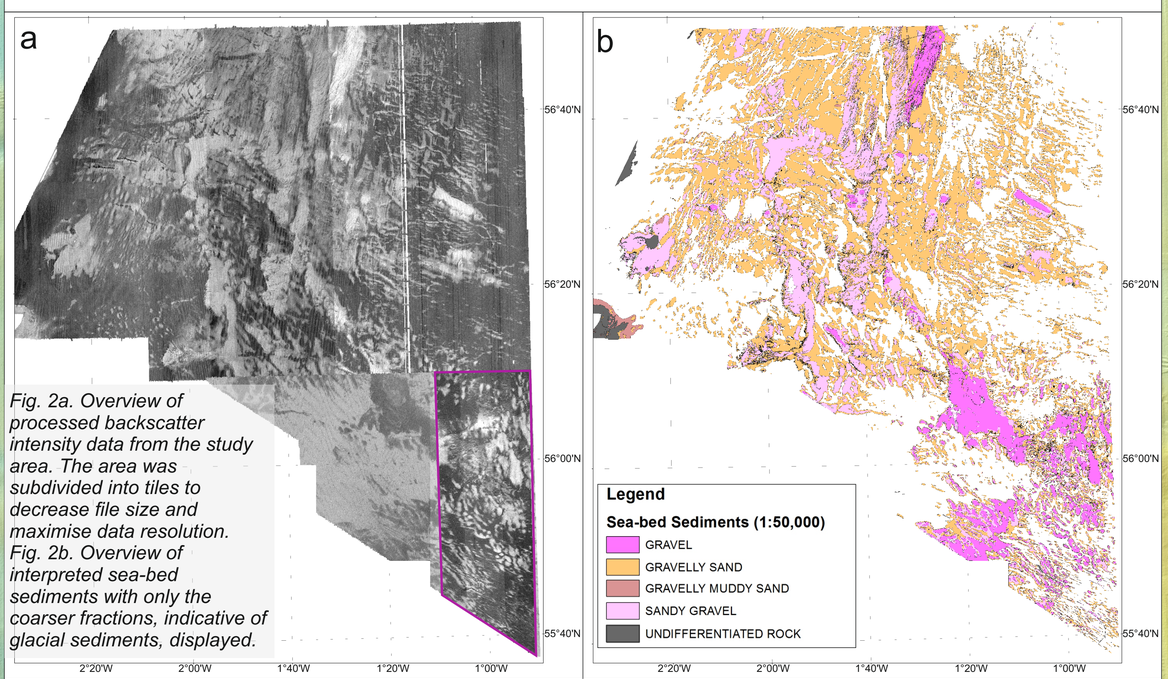

Fig. 2a. Overview of processed backscatter intensity data from the study area. The area was subdivided into tiles to decrease file size and maximise data resolution.
Fig. 2b. Overview of interpreted sea-bed sediments with only the coarser fractions, indicative of glacial sediments, displayed.

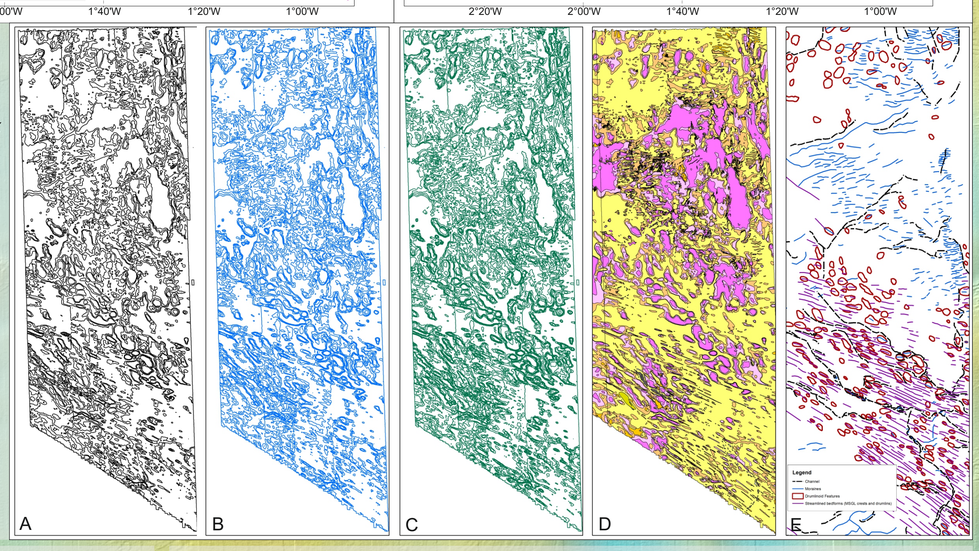

Fig. 3. Example of semi-automated classification of backscatter intensity data (See purple box on Fig. 2a for location).

Polygons generated with 4 classes (A); 5 classes (B); and 6 classes ©.

Resultant sea-bed sediment interpretation (D).

Glacial geomorphological interpretation (E).

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Fonseca, L., and Calder, B.R., 2005. Geocoder: An efficient backscatter map constructor. U.S. Hydrogr. Conf. (US HYDRO). San Diego, CA., USA. 29-31 March. Conf. Proc. (www.thsoa.org/hy05/08_3.pdf)