Exploring for extended continental shelf claims off Greenland and the Faroe Islands – geological perspectives

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Following the expected ratification in 2004 of the United Nations Convention on the Law of the Sea (UNCLOS from 1982), Denmark, Greenland and the Faroe Islands have a period of maximum 10 years to make claims beyond 200 nautical miles (NM) in five potential areas off Greenland and the Faroe Islands (Fig. 1). In order to provide the necessary database, the Danish Continental Shelf Project has been launched by the Ministry for Science, Technology and Innovation in cooperation with the Faroese and Greenland Home Rule governments. Several institutions are participating in this project, with the Geological Survey of Denmark and Greenland (GEUS) as the coordinator of the technical work for the Greenland part of the project, and sharing the responsibility for coordination of the Faroese part with the Faroese Geological Survey (JFS).

Background

Article 76 of UNCLOS is the key to future jurisdiction over resources on and below the seabed beyond 200 NM. The right to explore and exploit these resources, which include both non-living resources (hydrocarbons and minerals) and bottom-dwelling living resources, may have significant economic implications. Furthermore, jurisdiction of the extended continental shelf gives the right to regulate transport, environment and research. The technical data needed for a submission to the Commission on the Limits of the Continental Shelf (CLCS) include geodetic, bathymetric, geophysical and geological data. The most critical issue is to be able to demonstrate a natural prolongation of the submerged land territory based on geological and geomorphological factors, and later to document claims in detail by using the various formulas and constraint lines of Article 76 (Commission on the Limits of the Continental Shelf (CLCS) 1999; Cook & Carleton 2000). For construction of these lines it is necessary to know distances from territorial sea base lines (+ 200 and 350 NM), to define the location of the foot of the continental slope and the 2500 m isobath, and to know the sediment thickness beyond the foot of the slope. The foot of the continental slope (FOS) is defined as the point of maximum change of gradient at the base of the continental slope.

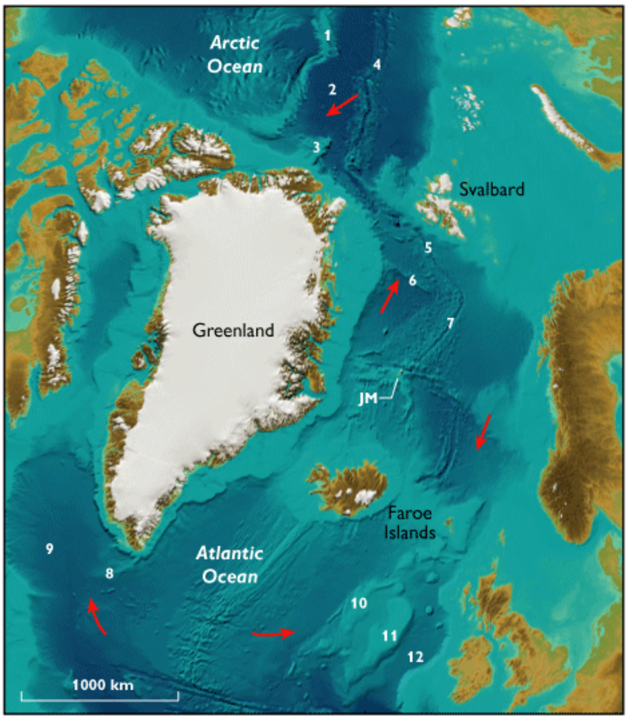

Fig. 1. Map of the North Atlantic region. **Arrows** indicate the five potential claim areas of interest. **1**: Lomonosov Ridge, **2**: Amundsen Basin, **3**: Morris Jesup Rise, **4**: Gakkel Ridge, **5**: Knipovitch Ridge, **6**: East Greenland Ridge, **7**: Mohns Ridge, **8**: Eiriks Ridge, **9**: Labrador Sea, **10**: Hatton Bank, **11**: Rockall Bank, **12**: Rockall Trough. **JM**, Jan Mayen.

Areas of interest around Greenland

There are three potential claim areas off Greenland. One south of Greenland is outlined by the 200 NM limit, a yet to be established boundary with Canada, and the new outer limit. The second area north-east of Greenland is outlined by the 200 NM line from Greenland, Jan Mayen (Norway) and Svalbard (Norway) and the new outer limit. The third is north of Greenland, outlined by the 200 NM limit and yet to be established boundaries with Canada and possibly also Russia and/or Norway, and a new outer limit. All three areas are situated along margins of mixed rifted and strike-slip nature, and contain significant successions of volcanic and sedimentary rocks.

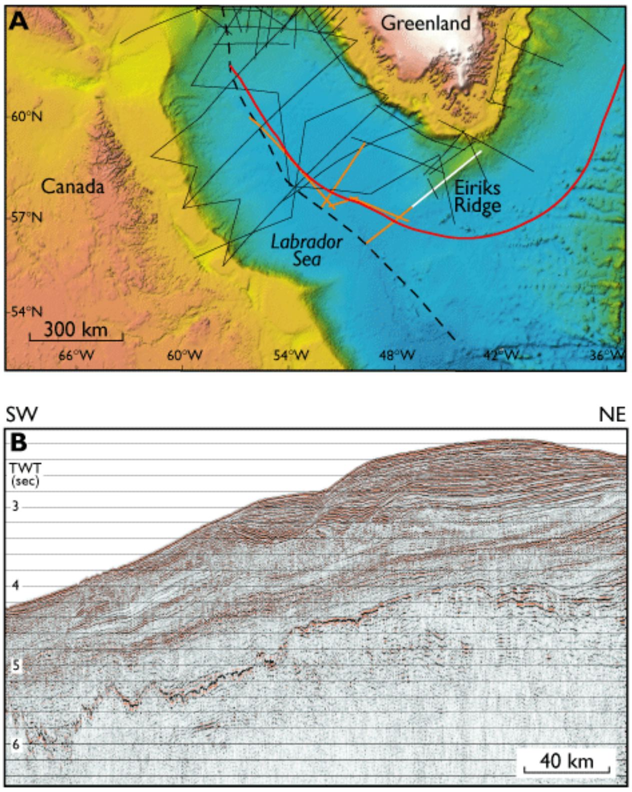

Fig. 2. **A**: Map of the South Greenland region showing seismic lines acquired in 2003 (**orange** and **white**) and older seismic lines (**black**). **Stippled line** is the unofficial median line with Canada; 200 NM **line in red**. **B**: Seismic line along the Eiriks Ridge. Position indicated in Fig. 2A (white line).

South of Greenland

The Eiriks Ridge is assumed to be a natural prolongation of southern Greenland with the foot of slope on the deep-water side of the ridge (Fig. 2). The existence of very thick sedimentary successions between Greenland and Canada, especially within the extinct spreading zone, may form the basis for a claim far out into the Labrador Sea. There is a general consensus on a tectonic model with sea-floor spreading in the Labrador Sea in Paleocene–Eocene time, possibly continuing into the Miocene. Models have changed considerably with time, since the early work by Srivastava and co-workers suggested large areas were underlain by oceanic crust of Late Cretaceous to Miocene age, anomaly 33–20 time (e.g. Srivastava 1978; Roest & Srivastava 1989). These models were revised by Chalmers & Pulvertaft (2001), who suggest spreading from anomaly 27–20 time.

The 2003 geophysical programme focused on data acquisition along the Eiriks Ridge, and within and across the extinct spreading zone, to document and correlate thick sedimentary successions. A total of 1500 km reflection seismic data were acquired. The new seismic data confirm the sedimentary nature of the Eiriks Ridge (Fig. 2) and furthermore show that sediment thicknesses are a potential factor for a future claim beyond 200 NM.

North-east of Greenland

The East Greenland Ridge is assumed to be a natural prolongation of north-eastern Greenland, and the foot of the slope extends around the ridge (Fig. 3). The thick sedimentary suc-

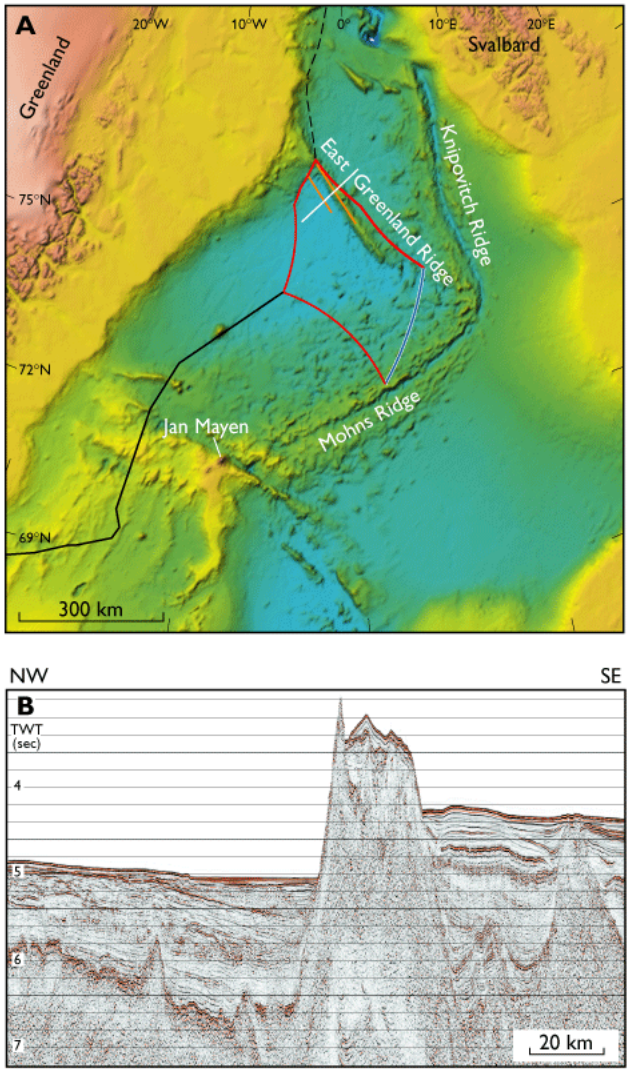

Fig. 3. **A**: Map of the East Greenland Ridge region. The seismic lines acquired in 2002 are shown in **orange** and **white**, the 200 NM limits of Greenland, Svalbard and Jan Mayen in **red**, and the 350 NM limit of Greenland in **blue**. The **stippled black line** is the unofficial median line between Greenland and Svalbard; the **full black line** is the official border between Greenland and Norway (Jan Mayen), and Greenland and Iceland. **B**: Seismic section across the East Greenland Ridge. Position indicated in Fig. 3A (white line).

cessions that exist both north and south of the ridge are likely to contribute to the claim area. Although there is general consensus on the opening history of the North Atlantic, problems with details of the structural elements are apparent, especially north of the East Greenland Ridge where major strike-slip movements occur in the region between the shelf break and the Knipovitch Ridge. A simpler spreading pattern is observed south of the ridge since anomaly 24 B time, with active spreading along the Mohns Ridge (Mosar *et al.* 2002; Tsikalas *et al.* 2002).

In the summer of 2002 GEUS and the University of Bergen carried out a joint refraction and reflection seismic survey over the East Greenland Ridge. There is a marked difference in water depth and subsurface structure north and south of the ridge (Fig. 3). The preliminary wide-angle velocity model shows standard oceanic crust to the south, while the northern side of the ridge and the crust further north may be stretched continental crust.

North of Greenland

The Lomonosov Ridge and the Morris Jesup Rise are assumed natural prolongations of northern Greenland. If relatively thick sedimentary successions can be demonstrated in the Amundsen Basin it may be possible to enlarge the potential claim area (Fig. 1). The existing data coverage from the Arctic Ocean north of Greenland is very sparse, due to the adverse physical conditions with metre-thick sea ice and many pressure ridges. There is, however, general consensus on a tectonic model with active spreading since Paleocene time along the Gakkel Ridge, and with the Lomonosov Ridge most likely consisting of continental crust separated from the Barents–Kara shelf (Jokat *et al.* 1995; Lawver *et al.* 2002). Preliminary studies in 2004 will focus on testing data acquisition methods on the sea ice, and on a passive earthquake seismological experiment for the crustal structure of North Greenland. Subsequent studies will include acquisition of refraction seismic data on the sea ice along the innermost parts of the Lomonosov Ridge, followed by data acquisition from ice breakers across the Lomonosov Ridge and in the Amundsen Basin.

Areas of interest around the Faroe Islands

The Faroe Islands consist of basaltic rocks with a cumulative stratigraphic thickness of more than 6.5 km resting on top of presumed Precambrian basement (Ellis *et al.* 2002). During the initial phases of continental break-up between Europe and Greenland, the Faroe Islands and the Hatton–Rockall area (the Faroe–Rockall Plateau) were partly isolated from the main European continent. Subsequent shift of the break-up

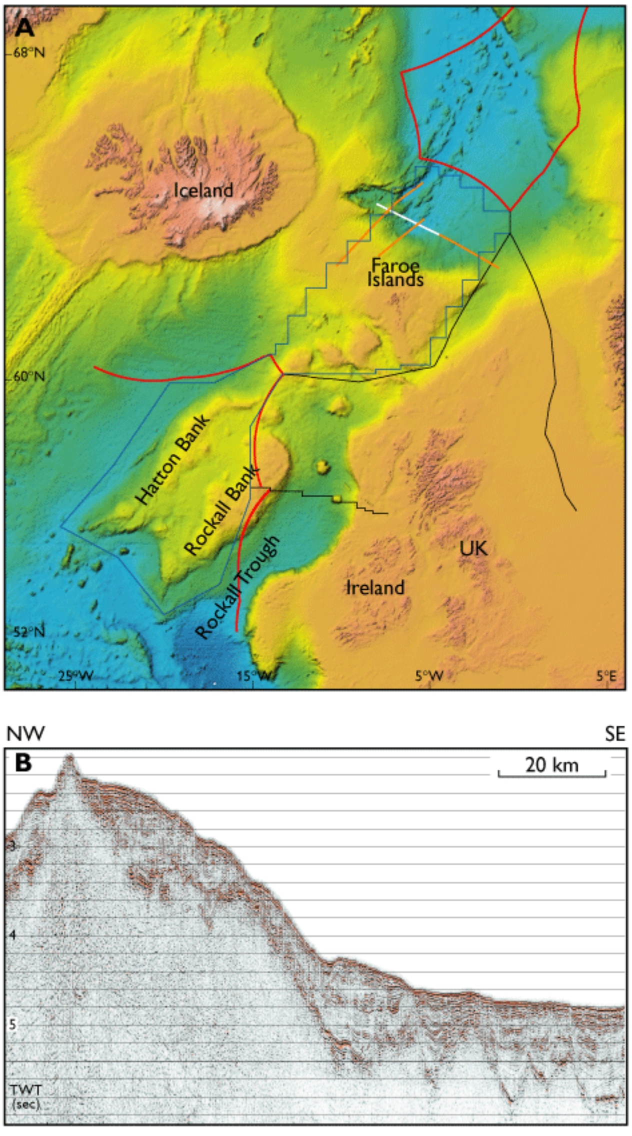

Fig. 4. **A**: Map of the Faroe Islands region. The designated area is outlined with **blue lines**. The **red lines** indicate the 200 NM limits of the surrounding coastal states. Continental shelf median lines are drawn in **black**. The position of the three seismic lines acquired in 2003 are shown in **orange** and **white**. **B**: Seismic line LOS_FO_03-1. Position indicated in Fig. 4A (white line).

axis to the west of the plateau resulted in extensive (basaltic) volcanism, seafloor spreading and the creation of the northeast Atlantic Ocean between Europe and Greenland. The two potential claim areas off the Faroe Islands are an area northeast of the islands, and the Hatton–Rockall area to the southwest (Fig. 4).

The north-eastern area

The basaltic rocks that form the Faroe Islands reach far offshore on the continental shelf and continue onto the continental margins to the north of the islands (Boldreel & Andersen 1994). In the central part of this region the slope beyond the shelf break is steep and the transition from shelf to deep ocean sea floor is narrow. Elsewhere, the slope is more gentle (Fig. 4).

Thick sediment accumulations in the deep-water areas favour claims extending beyond the 200 NM limit. Three seismic lines were acquired in 2003 (Fig. 4) to study the continent–ocean transition (COT) and to assess the sediment thickness along the continental shelf margin.

The south-western area

Based on UNCLOS, Article 76, and on the assumption that the Faroe–Rockall Plateau constitutes a micro-continent, the Danish authorities designated a large continental shelf area to the south-west of the Faroe Islands in 1985 (Fig. 4). This area includes the parts of the Hatton and Rockall Banks situated outside the 200 NM limits of the neighbouring states (Great Britain, Ireland and Iceland), who in their turn have made individual designations for the same area.

The basaltic rocks that form the Faroe Islands continue and thin south-westwards, and disappear at several locations at the Hatton and Rockall Banks where the underlying rocks are exposed at seabed. The plateau margin to the west is relatively simple with a well-defined slope area (Fig. 4). Different volcanic and tectonic features to the south of the plateau complicate the marginal area in this region. Towards the east the plateau borders the Rockall Trough, which reaches water depths of 3–4 km in its southernmost part. Work planned for 2004 includes a deep reflection and refraction seismic programme and a geochemical study.

Conclusion

The Danish Continental Shelf Project has so far acquired new data in three out of five potential claim areas off Greenland and the Faroe Islands, and much more data acquisition and interpretation will follow in the next few years. The results of the project, together with similar projects by neighbouring countries, will create new focus on the geology and tectonics of the North Atlantic and Arctic regions.

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