Structure and Evolution of the Atlantic Floor between Northern Scotland and Iceland

M. H. P. BOTT

Bott, M. H. P. 1975: Structure and evolution of the Atlantic floor between northern Scotland and Iceland. *Norges geol. Unders. 316*, 195–199.

The continental shelf west of the Shetland and Orkney Islands is a region of varied geology traversed by the Caledonian front, including some areas of shallow basement and some partially fault-bounded Mesozoic basins such as the west Shetland basin; Tertiary strata appear to be absent except on the slope and near it. At the other extremity of the region, the Iceland–Faeroe Ridge is formed by anomalously thick 'Icelandic-type' oceanic crust probably originating between 60 and 45 m.y. ago. Recent evidence confirms that the shelf region around the Faeroe Islands is underlain by continental crust, but the origin of the Faeroe–Shetland Channel is problematical.

M. H. P. Bott, Department of Geological Sciences, University of Durham, England

Introduction

This paper briefly summarises the deep structure of the region between the North Scottish continental shelf and the Iceland–Faeroe Ridge (Fig. 1). The region forms the southeastern end of the highly anomalous strip of the North Atlantic extending from the Denmark Strait through Iceland to North Scotland, and can be subdivided into the following four main structural units: the North Scottish continental shelf, the Faeroe–Shetland Channel, the Faeroe Block and the Iceland–Faeroe Ridge.

Continental shelf west of the Shetland and Orkney Islands

The aeromagnetic map of the Institute of Geological Sciences, London, was the first geophysical evidence on the deep structure of this shelf region. A qualitative interpretation of the depth and character of the basement using this map was made by Flinn (1969). This was soon followed by a regional marine geophysical investigation of the area by Durham University, using gravity, magnetic, shallow seismic reflection and seismic refraction methods (Bott & Watts 1970, 1971; Watts 1971; Browitt 1972; Bott & Browitt 1975). These early investigations led to a broad understanding of the deep geological structure of the region and outlined the regions of thick sediments.

The basement rocks of this shelf are cut by the Caledonian front, which would be expected to separate the foreland Lewisian and Torridonian basement rocks to the west from the Moinian and Dalradian Caledonian rocks to the east. The Great Glen fault may traverse the eastern extremity of the region, possibly occurring in the Shetland Islands along the line of the Walls boundary fault (Flinn 1961). Old Red Sandstone rocks probably occur

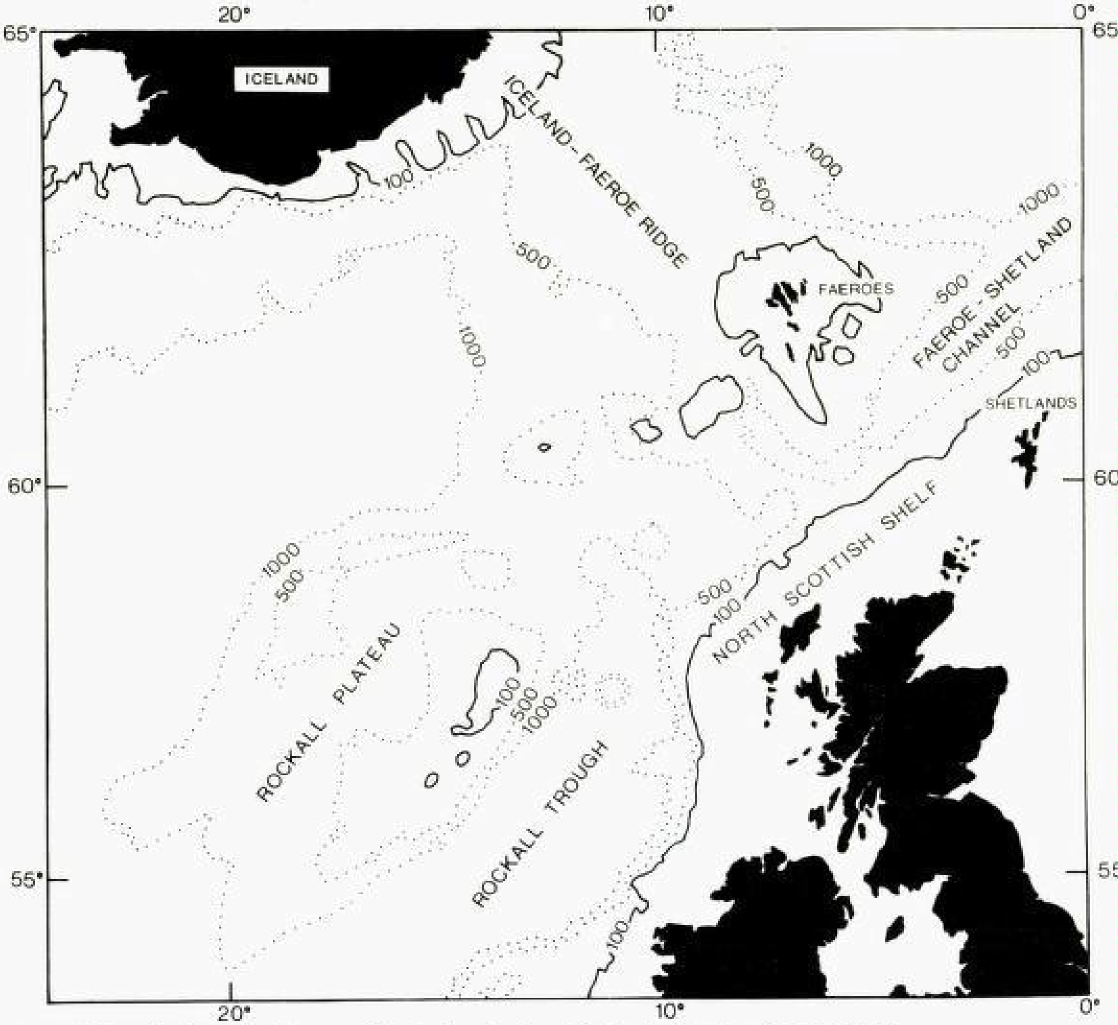

Fig. 1. Map of the region between North Scotland and Iceland showing the structural regions discussed in the text.

extensively in the east of the region but the presence of Carboniferous rocks is conjectural. A series of well-defined sedimentary basins of Mesozoic age occur on the shelf. Tertiary strata probably do not occur on the shelf except near the slope and on it, where a prograding sequence extends into the Shetland–Faeroe trough.

A conspicuous Bouguer anomaly high reaching 94 mgal occurs west of the Shetland Islands. It is about 250 km long and has a NNE strike which gently transgresses the margin. With support from sparker and magnetic observations, this has been interpreted as a region of shallow or outcropping Lewisian rocks of high density, probably of granulites. Other regions of shallow or outcropping basement rocks further south are recognised by their high local gravity and short-wavelength magnetic anomalies.

The Shetland–Orkney shelf is notable for a series of fairly deep and local sedimentary basins which are probably mainly filled by Mesozoic sediments. These are clearly visible on the Bouguer anomaly map, and characteristically steep gravity gradients indicate that they are partially fault-bounded, particularly along their eastern margins. The largest and most spectacular of these is the west Shetland basin, which runs along the west side of the above-mentioned gravity high, being separated from the shallow basement rocks by a normal fault or fault zone. This basin causes Bouguer anomalies of about 70 mgal below those of the adjacent high, and the intervening gradient attributed to the fault is particularly steep. A ridge of basement uplift occurs along the west side of the west Shetland basin. According to gravity and seismic refraction observations, the basement is about 6 km deep beneath the basin, but the deeper sedimentary rocks within it are possibly of pre-Mesozoic age.

The Iceland—Faeroe Ridge

The Iceland–Faeroe Ridge occurs at the other extremity of our region. It is an aseismic ridge of relatively smooth bathymetry and north-westerly trend which joins Iceland and the shelf region around the Faeroe Islands. The depth to the crest is about 400 m along the length, and the ridge is separated from the Icelandic and Faeroe shelf regions by small but steep bathymetric scarps. The deep structure and affinity of this problematical quasi-continental feature have been clarified in recent years by geophysical investigations (Bott et al. 1971; Fleischer 1971; Johnson & Tanner 1972).

It is widely believed that the north-eastern branch of the North Atlantic formed over the last 65 m.y. by ocean-floor spreading as Greenland separated from North Europe. If correct, this implies that the Iceland–Faeroe Ridge also formed by the ocean-floor spreading mechanism, probably over the period 60–45 m.y. ago, despite its shallow bathymetry. Seismic investigations indicate that the Ridge is underlain by a type of crust similar to that beneath Iceland, although of greater thickness. Such thick crust is probably produced as a result of intense differentiation from the underlying mantle because of its local high temperature (hot spot theory).

Sediments are generally thin or absent from the crestal region of the Iceland–Faeroe Ridge, except for local pockets, some of which are probably volcanic in origin. The upper crust extends to a depth of about 8 km and it is formed of highly magnetic igneous rocks. It is unlikely that significant hydrocarbon deposits will be found here.

The Faeroe Block

The region of relatively shallow shelf bathymetry surrounding the Faeroe Islands is referred to as the Faeroe Block. The Faeroe Islands themselves are formed by nearly horizontal basaltic lavas of early Tertiary age. The nature of the underlying crustal structure has been a subject of controversy, but has recently been clarified.

Early seismic refraction lines reaching the basement beneath the lavas (Pálmason 1965) suggested a similar upper crustal structure to that of Iceland, indicating oceanic rather than continental affinities. More recently, this conclusion has been reversed. The observed gravity gradient between the Iceland–Faeroe Ridge and the Faeroe Block indicated that these regions are underlain by different types of crust (Bott et al. 1971) and a pre-Tertiary continental reconstruction including the Rockall Plateau indicates that the Faeroe Block itself is probably continental. The most definite evidence comes from a recent crustal seismic project which indicates absence of the characteristics 6.4–6.7 km s^{-1} layer of Iceland and the Ridge, and a crustal thickness of over about 30 km (Bott et al. 1974). Thus continental crust is now believed to underlie the Faeroe Block.

Although some pre-Tertiary sediments may be sandwiched between the Faeroe lavas and the basement, the geophysical evidence indicates that they are unlikely to be more than about 1 km thick. Some thicker sediments may occur on the Faeroes shelf, particularly in the east.

The Faeroe—Shetland Channel

The Faeroe–Shetland Channel forms a north-easterly extension of the Rockall Trough, being separated from it by the transverse Wyville–Thomson Ridge. It is about 1200 m deep and opens at its north-eastern end into the Norwegian Sea. Flat-lying sediments overlie the magnetic basement and these generally thicken towards the north-east. Gravity investigations (Bott & Watts 1971) indicate that the Channel is underlain by slightly thinner crust than that beneath the adjacent continental regions of the North Scottish shelf and Faeroe Block.

The origin of the Channel is problematical. One view, taken for example by Talwani & Eldholm (1972), is that it was formed by subsidence of continental crust. The alternative view, which the author favours, is that the Channel originated as oceanic crust during a preliminary stage of opening of the Atlantic in the Mesozoic when the Rockall Trough also formed. If such a preliminary opening occurred, then one would expect it to extend further north for a considerable distance; a suggestion is that this extension may form the trough of thick sediments beneath the eastern part of the Vøring Plateau, which has been mapped by Talwani & Eldholm (1972).

REFERENCES

Bott, M. H. P. & Browitt, C. W. A. 1975: Interpretation of geophysical observations between the Orkney and Shetland Islands. *Jl. geol. Soc. Lond.* (in press).

Bott, M. H. P., Browitt, C. W. A. & Stacey, A. P. 1971: The deep structure of the Iceland–Faeroe Ridge. *Marine Geophys. Res. 1*, 328–351.

Bott, M. H. P., Sunderland, J., Smith, P. J., Casten, U. & Saxov, S. 1974: Evidence for continental crust beneath the Faeroe Islands. *Nature (Lond.) 248*, 202–204.

Bott, M. H. P. & Watts, A. B. 1970: Deep sedimentary basins proved in the Shetland–Hebridean continental shelf and margin. *Nature (Lond.) 225*, 265–268.

Bott, M. H. P. & Watts, A. B. 1971: Deep structure of the continental margin adjacent to the British Isles. *Inst. Geol. Sci.* Rep No. 70/14, 89–109.

Browitt, C. W. A. 1972: Seismic refraction investigation of deep sedimentary basin in the continental shelf west of Shetlands. *Nature (Lond.) 236*, 161—163.

Fleischer, U. 1971: Gravity surveys over the Reykjanes Ridge and between Iceland and the Faeroe Islands. *Marine Geophys. Res. 1*, 314–327.

Flinn, D. 1961: Continuation of the Great Glen fault beyond the Moray Firth. *Nature (Lond.) 191*, 589–591.

Flinn, D. 1969: A geological interpretation of the aeromagnetic maps of the continental shelf around Orkney and Shetland. *Geol. Jl. 6*, 279–292.

Johnson, G. L. & Tanner, B. 1972: Geophysical observations on the Iceland–Faeroe Ridge. *Jøkull 21*, 45–52.

Pálmason, G. 1965: Seismic refraction measurements of the basalt lavas of the Faeroe Islands. *Tectonophysics 2*, 475–482.

Talwani, M. & Eldholm, O. 1972: Continental margin off Norway: a geophysical study. *Bull. geol. Soc. Am. 83*, 3575–3606.

Watts, A. B. 1971: Geophysical investigations on the continental shelf and slope north of Scotland. *Scott. Jl. Geol. 7*, 189—218.