EVIDENCE FOR AN EARLY PERMIAN OCEANIC RIFT IN THE NORTHERN NORTH ATLANTIC

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ABSTRACT. The Greenland-Svalbard and Proto-Bay of Biscay fault zones are small circles to a common pole, and it can be shown that transform motion on these faults opens the Rockall Trough and the eastern Norwegian Sea. Arthaud and Matte calculate a dextral movement along the Proto-Bay of Biscay fault of more than 100 km. This movement took place between the emplacement of the Variscan granites and the beginning of the Triassic, and we argue here that this was one of the results of ocean floor spreading in Rockall Trough and the eastern Norwegian Sea. Widespread intrusions of dolerite in Sweden, Norway, England and Scotland c. 290 Ma imply that the lithosphere had reached its limit of strength in relative tension and it is surmised that this is the time that the lithosphere began to separate between Greenland and Northwest Europe. Magmatism continued in the Early Permian as evidenced by the Oslo extrusives and fluorite deposits of magmatic derivation in England. Rosemary Bank is an extinct volcano in the northern Rockall Trough, and judging from the remanent magnetic vector, this seamount was probably active during the Permian.

In mid Permian times the Zechstein Sea, which presumably occupied Rockall Trough and the Faeroe-Shetland Channel, as well as the eastern Norwegian Sea, flooded parts of East Greenland, Ireland, England, the North Sea and north-central Europe.

1. INTRODUCTION

The Rockall Trough, the Faeroe-Shetland Channel and the eastern

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Norwegian Sea comprise a contiguous pre-anomaly 24 rift (the Proto northern North Atlantic) probably floored by oceanic basalts [1,2]. The Moho is about 14 km deep in the Rockall Trough [3] and the Vøring Plateau [4]. Here we provide evidence to support the proposal that the Proto northern North Atlantic Rift began to form at the beginning of the Permian [5,1].

2. GEOMETRY

The margins of the pre-anomaly 24 rift are remarkably parallel and a little over 200 km apart [6]. There is a generally held assumption [7] that the Rockall Trough opened as a northerly propagation of the central North Atlantic. The northern limit of this rift must have been a transform fault between Svalbard and Greenland. Roberts [8] has argued that the Rockall Trough opened at the same time as the Bay of Biscay, but since the proto-Bay of Biscay Fault trace is a small circle with a common pole to the Greenland-Svalbard Fault (which is presumably more than coincidental), we suggest instead that the Proto northern North Atlantic opened before the Bay of Biscay, and that the northern and southern limits of the rift were these transform faults. Furthermore, a rotation of Greenland-North America, relative to Europe of 2.4°, about this pole, opens the Rockall Trough to its present configuration [2].

A test of this geometrical hypothesis would be demonstrable dextral movement along these faults.

As the Svalbard-Greenland Fault parallels the orogenic grain the theory is as yet untestable in the north. However, Hercynian structures do cross the proto-Bay of Biscay Fault, and Arthaud and Matte [9] have shown that the Variscan leucogranites provide a good marker. When Iberia and Brittany are reassembled [10] it is clear that there has been a dextral offset along the proto-Bay of Biscay Fault of at least 100 km and possibly about 200 km (Figure 1).

Arthaud and Matte [9] argue that this movement took place after the intrusion of the leucogranites (c. 300 Ma) but before the Triassic, since associated faults do not affect overlying Triassic basin sediments. Their preferred age for this lateral movement is Early Permian. The proto-Bay of Biscay Fault cannot continue between Greenland and Labrador as demonstrated by the contiguous margin to the Superior chelozone [11], (Figure 1).

From the refit of Figure 1 (amended from Bullard et al [12]) we can see that this significant dextral motion along the proto-Bay of Biscay Fault must therefore have opened the Rockall Trough.

3. TECTONICS

Immediately preceding a period of rifting the crust normally upwarps to form a dome or series of domes [13]. It is known that domes did form around the time of the Carboniferous-Permian boundary in the Oslo region [14] and in the Northern Pennines [15]. We know also that there was uplift at this time in Scotland where there is a non-sequence between probable upper Stephanian red beds and the underlying Westphalian containing marine bands [16]. The Westphalian sediments have been oxidised down to a maximum depth of half a kilometre [17]. There was also a period of non deposition in East Greenland at about the same time [18].

The dome in the Oslo region finally collapsed to form a lower Permian rift, and we argue that this was a microcosm of what was happening on the site of Proto northern North Atlantic at the beginning of the Permian.

McLean [19], elaborating on the earlier views of Bott [20] argues that the belt of Permo-Triassic basins parallelling and within 150 km of the continental margin northwest of Britain is best explained in terms of flow of ductile lower lithosphere towards an Early Permian ocean.

4. MAGMATISM

About 290 Ma there was sudden intrusion and extrusion of basic magma in northern Britain, Norway and southern Sweden (Figure 1) [21-25]. In Britain and southern Sweden the magmatism comprised a short lived episode of dolerite and quartz dolerite intrusion. In Norway volcanic activity was of an alkaline type and significant magmatism continued for about 20 Ma, accompanying rifting.

Dolerite dyke swarms are often associated with the onset of rifting [26] and we suggest that 290 Ma is the date when the lithosphere reached its limits of strength in relative tension and began to separate.

It may be that towards the end of this phase of ocean floor spreading, Rosemary Bank formed as a large volcano. This conjecture is based on Scrutton's [27] calculation of the remanent magnetic vector, which suggests that the latitude of formation was about 16° ($\pm$ 20°)N. A 16°N position would place the formation of the Bank in the Permian [28].

5. MINERALISATION

There was a significant period of mineralisation c. 280 Ma in Britain, Norway and southern Sweden [29]. Most of the ores

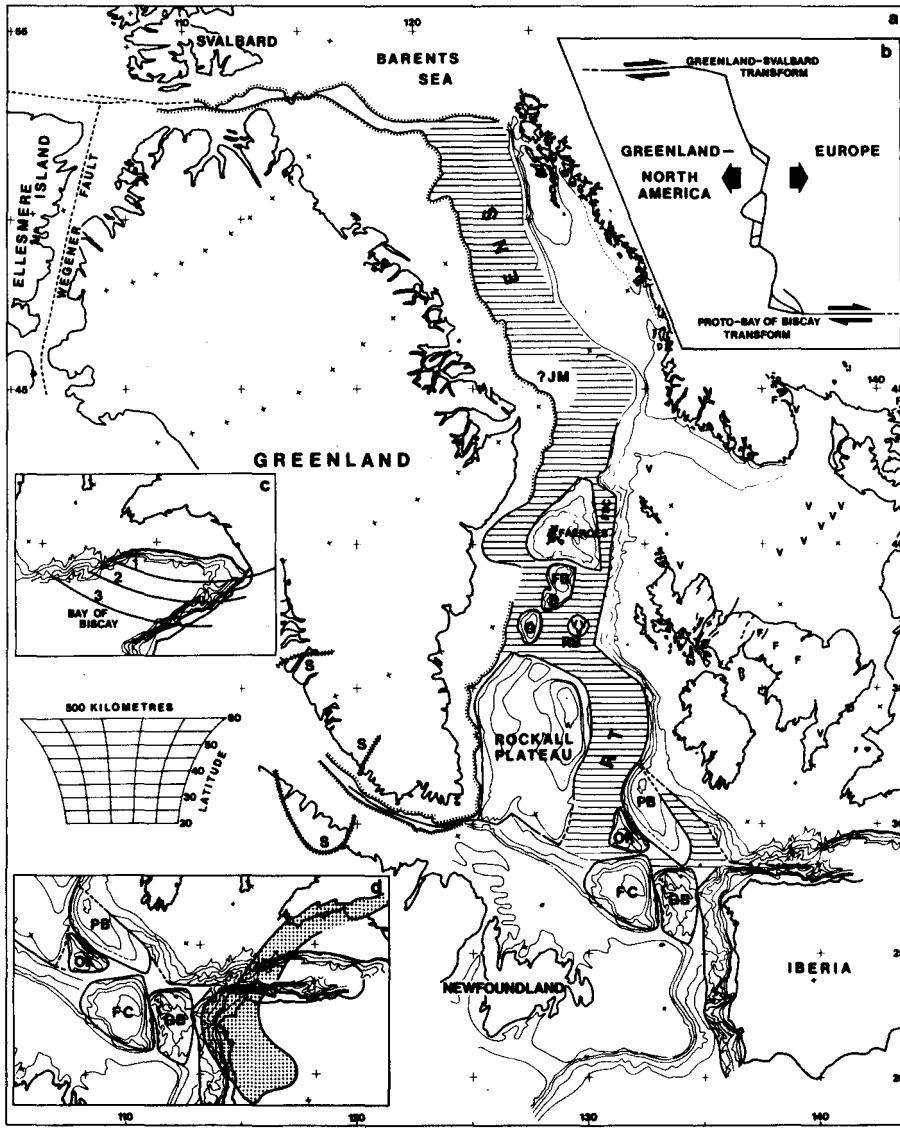

Fig. 1. a, Pre-anomaly 32 northern North Atlantic reconstruction on an oblique Mercator projection. The north pole of the oblique aspect is at 55°N, 100°E, with Europe in its modern position (basic intrusive and extrusive ∿ 290 Ma in black). b, The projection pole is the pole of rotation of Europe away from Greenland - North America; transform faults should then approximate to parallels of latitude. c, transform fault traces in the Bay of Biscay. d, Variscan leucogranite belt (crosses) on a pre-drift reconstruction.

include fluorite. For example fluorite occurs as a primary mineral in the border zones of the alkali granite in the Ramnes cauldron of the Oslo Graben [30]. Fluorite deposits also occur to the west and southwest of the Graben at Lassedalen and Gjerpenfeltet respectively [31,32].

Smith [33] has shown that the yttrium content of fluorite in the North Pennines, England, is in the range of 120 to 815 ppm, and so supports Sawkins [34] in considering that the ores have an igneous source. Fluorite in the Central Pennines probably has a similar origin, and we may assume that the fluorite distribution represents the extent of partial melting of the upper mantle in the Early Permian [29].

Vokes [35] and Sawkins [36] have previously pointed out the apparent association between this mineralisation and rifting.

6. STRATIGRAPHY

The Zechstein and Bakevellian Seas of mid Permian age supported a Boreal fauna, and are best explained as incursions from a Permian ocean in the Proto northern North Atlantic [1]. Talwani and Eldholm [37] have suggested that Zechstein strata may occur near the base of the sedimentary pile in the eastern Vøring Plateau, although they assume the basement to consist of subsided continental crust rather than the ocean floor postulated by us [1,2].

7. PREDICTIONS

Drilling in the Rockall Trough, the Faeroe-Shetland Channel and the

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Closure of the Bay of Biscay along the best fit transforms 1-3 (1c) corresponds closely to the position of Iberia relative to Europe (1a) after the Rockall Trough has opened, whereas continuity of the Variscan leucogranite belt is achieved on the pre-drift reconstruction (1d). Geological arguments (see text) place the opening of the Proto northern North Atlanitic (viz. from the configuration shown in 1b,d to that of 1a) in the Early Permian.

ENS; eastern Norwegian Sea. FSC; Faeroe-Shetland Channel.
RT; Rockall Trough. JM; Jan Mayen continental fragment.
FB; Faeroe Bank. B; Bill Bailey Bank. O; Outer Bailey Bank.
RB; Rosemary Bank. PB; Porcupine Bank. OK; Orphan Knoll.
FC; Flemish Cap. GB; Galicia Bank. S; Superior chelozone.
V; Permian volcanics. F; Permian fluorite deposits.

Sources: 1,2,9-12,15,21,25,29-33,38-41.

Eastern Norwegian Sea will intersect sediments down to Permian age and then pass into Lower Permian ocean floor basalts. Jurassic sediments will be present and may be oil-bearing [2].

Fluorite and metalliferous deposits may be found spatially associated with 290 Ma intrusives.

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