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The Norwegian Sea, A Meeting Place For Opposed And Overlapping Arctic And Atlantic Rifts; Implications For Magmatism

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Within the well-established plate tectonic framework for the North Atlantic, characterized by progressive northward opening, we have reinterpreted the boundaries and ages of oceanic seafloor in the complicated area surrounding the Aegir and Kolbeinsey Ridges (e.g. Talwani & Eldholm, 1977; Vogt et al., 1980). Our interpretation suggests that the proto-Aegir and Kolbeinsey Ridges represent the tips of opposed and overlapping rifts, whereby a southward-propagating Arctic rift system attempted to link with a northward-propagating Atlantic rift system. The Arctic rift system consisted of the proto-Nansen, Mohns, and Aegir Ridges, and experienced left-stepping shifts to avoid intersecting the resistant Greenland craton. The Atlantic rift system consisted of the proto-Reykjanes and Kolbeinsey Ridges and stepped right around Greenland for the same reason. Following break-up at Chron 24 (54 Ma), the tips of the Aegir and Kolbeinsey Ridges remained overlapping and propagated in opposite directions, approximately until Chron 12 (30 Ma) when spreading stopped along the Aegir Ridge (Jung & Vogt, 1997). Overall, the overlap configuration resembles that seen for microcracks, mode 1 fractures, normal faults, and minor offsets along spreading axes (Macdonald & Sempere, 1984), a phenomenon that may be dictated by fracture mechanics (Pollard & Aydin, 1984). Regardless of origin, we argue that the Aegir and Kolbeinsey Ridges worked in concert and compensated for each other, a concept also discussed by Vogt (1986).

As a result of the overlapping tips of the Aegir and Kolbeinsey Ridges, the Jan Mayen microcontinent gradually became separated from East Greenland and rotated c. 50° counterclockwise in the process. The separation and rotation started near break-up and ended when the Aegir Ridge became extinct. During its rotation, the highly segmented Jan Mayen microcontinent formed a bridge between NW Europe (the Faroes area) and southern East Greenland, analogous to the way the Danakil Block bridged the Arabian and African plates in the Afar region (e.g. Collet et al., 2000). Clearly, the presence of the Jan Mayen continental sliver must have influenced oceanic circulation patterns between the NE Atlantic and Norwegian Sea.

It is generally accepted that the Kolbeinsey Ridge became connected with the Mohns Ridge near Chron 7 (25 Ma) along the West Jan Mayen Fracture Zone (WJMFZ). However, the WJMFZ extends eastward to oceanic seafloor of Chron 13 age (35 Ma), implying that linkage must have been achieved already by this time. We propose that this connection made spreading along the Aegir Ridge unnecessary, and likewise, may have been the reason for terminating spreading in the Labrador Sea; this marks the definitive linkage between the Arctic and Atlantic spreading systems, as well as the final touch to break-up of Pangea. By analogy with normal faults, the

Aegir and Kolbeinsey Ridges can be viewed as "soft linked" prior to development of the WJMFZ, i.e. the two overlapped but lacked a hard link in the form of a transform fault.

With respect to magmatism, we observe that where prolonged impingement of spreading axes has taken place against shear margins, magmatism has been more vigorous. This is observed for the subaerial construction of the oceanic Spur Ridge south of Grand Banks and the conjugate Madeira-Tore Rise (Chron M0-M4, c. 120-125 Ma), prior to northward propagation of the Mid-Atlantic spreading axis between Grand Banks and Iberia (Tucholke & Ludwig, 1982). An example in the Arctic is provided by the Yermak and Morris Jesup Plateaus, two conjugate and oceanic magmatic massifs interpreted to have formed between Chron 18 and 13 (39 and 35 Ma) (Feden et al, 1979). We interpret that this magmatism started as early as Chron 24 (54 Ma); the outer boundaries of the plateaus lie on strike with Chron 24 in the Eurasia Basin to the north. The termination of this magmatism coincides with the change in relative plate motions at Chron 13 (35 Ma), which initiated oblique opening of the former SW Barents Sea transform margin. The event marks the initiation of the NE Atlantic-Arctic gateway, a change of major importance to oceanic circulation (Thiede & Myhre, 1996).

It was the thick and strong Greenland lithosphere that stood in the way of the evolving Atlantic and Arctic rift systems In contrast, areas already thinned by rifting seem to have made little difference to the direction of rifting. Rather, the far field stresses can be inferred to have dominated the trend of break-up; only where the structural grain was conveniently oriented with respect to the far field stresses did the break-up follow pre-existing weaknesses. This is exemplified by the NE Greenland margin, where the pre-existing rift grain was cut at a c. 45° angle.

While the Iceland plume was instrumental for magmatism in the North Atlantic Igneous Province, it is questionable if the radius of influence of this plume reached the southern tip of the Arctic spreading system, affecting magmatism at Yermak-Morris Jesup Plateaus. Feden et al (1979) proposed the existence of a separate Yermak hotspot. However, we question the likelihood of such a plume's existence since its life span coincided with onset of spreading along the Nansen Ridge and subsequent linkage with the Mohns Ridge. Likewise, Tucholke & Ludwig (1982) proposed a local plume beneath the Spur Ridge and Madeira-Tore Rise. Activity of this plume apparently ended when spreading propagated into the North Atlantic. Alternatively, magmatism at the mentioned locations could relate to relatively long-lived impingement of spreading axes against shear margins, preceding ridge propagation.

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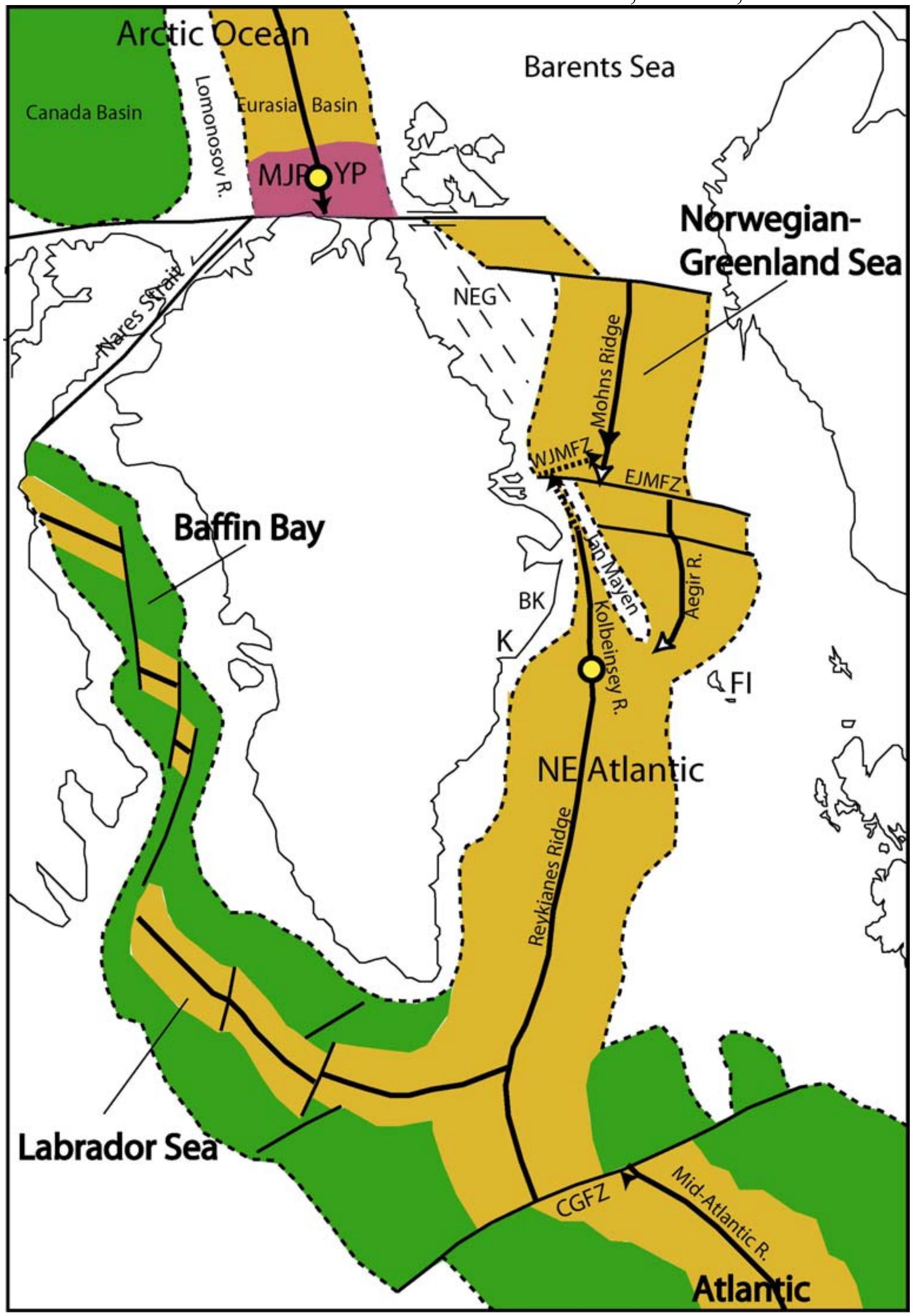

Scematic reconstruction of Arctic and NE Atlantic to Chron 13 (c. 35 Ma, earliest Oligocene).
Dotted line at tip of Kolbeinsey Ridge marks linkage between the Arctic and Atlantic spreading axes. Black arrowheads = ongoing propagation. White arrowheads = ceasing propagation/ spreading. Thin lines in NE Greenland margin mark structural grain. Green = seafloor of Chron 33 to 24 age (c. 81-54 Ma), Yellow = seafloor of Chron 24-13 age (c. 54-35 Ma). Yellow dot in south = position of Iceland plume center. Northerly yellow dot marks the position of the presumed Yermak hostspot (argued against here). Dashed lin e= approximate COB. Abbreviations: CGFZ = Charlie Gibbs Fracture Zone, EJMFZ = East Jan Mayen Fracture Zone, FI= Faroe Islands, K = Kangerlussuaq, MJP= Morris Jesup Plateau, NEG = NE Greenland margin, WJMFZ= West Jan Mayen Fracture Zone, YP = Yermak Plateau