

On the apparent eastward migration of the spreading ridge in Iceland

G. R. Foulger

U.S. Geological Survey, 345 Middlefield Rd., MS 910, Menlo Park, CA 94025, U.S.A. (gfoulger@usgs.gov) & Dept. Geological Sciences, University of Durham, Durham DH1 3LE, U.K. (g.r.foulger@durham.ac.uk)

The part of the north Atlantic where Iceland is currently forming has functioned as a tectonic divide since the opening of the ocean, and has persistently featured paired spreading ridges and intervening microplates.

At the time of ocean opening a ~ 100-km long, right-stepping transform fault, the Faeroe transform fault (FTF), formed where the new spreading ridge crossed the Caledonian suture [Bott, 1985] (Figure 1a). Tectonic complexities subsequently rafted several continental blocks into the ocean, including Jan Mayen, the Jan Mayen microcontinent (JMM) and the Faeroe block.

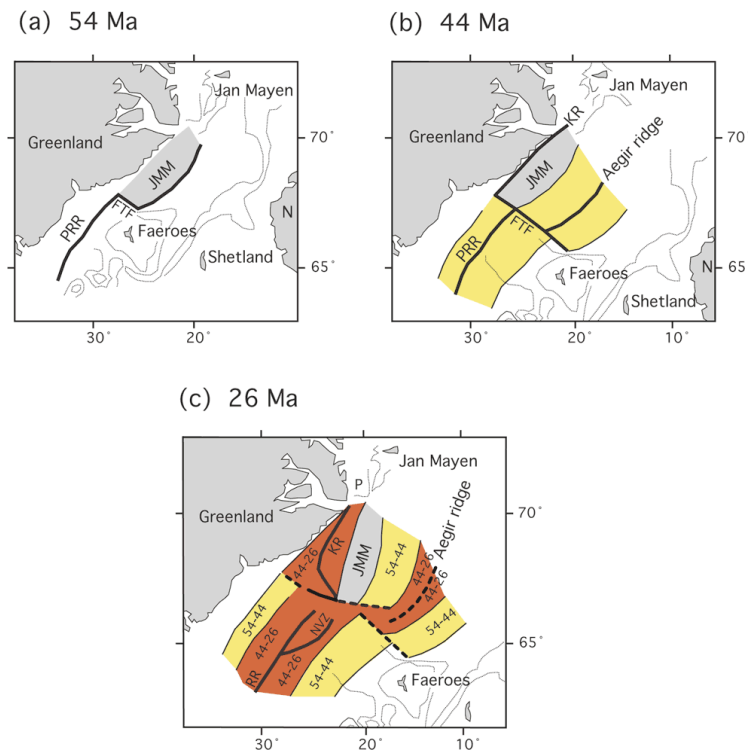


Figure 1: Tectonic evolution of the Iceland region at 54, 44 and 26 Ma [from Bott, 1985]. Gray: continental crust, heavy solid lines: active plate boundaries, heavy dashed lines: extinct plate boundaries, thin lines: bathymetric contours, FTF: Faeroe transform fault, KR, PRR, RR: Kolbeinsey, proto-Reykjanes, Reykjanes ridges, NVZ: Northern volcanic zone, JMM: Jan Mayen microcontinent, N: Norway, P: pole of rotation of JMM 44 – 26 Ma, numbers: sea floor age in Myr.

Spreading proceeded relatively simply for the first ~ 10 Myr following opening, but at ~ 44 Ma, a major reorganization occurred north of the FTF. A second spreading center, the Kolbeinsey ridge, developed within the Greenland craton (Figure 1b). Complimentary fan-shaped spreading then occurred along both the original Aegir ridge and the Kolbeinsey ridge during the period 44 - 26 Ma, causing ~ 32° of counterclockwise rotation of the intervening, continental JMM (Figure 1c). This resulted in up to ~ 60 km of transtensional extension across the FTF, which corresponds to opening at up to ~ 15% of the local full spreading rate of 1.9 cm/a. The onset of this phase of transtensional extension coincides with a time when the magmatic production rate increased greatly, and formation of the ~ 250-km-wide Iceland-Faeroe ridge of thickened crust gave way to formation of the ~ 600-km-wide Iceland volcanic plateau. This increased magmatism may have been permitted by the transtensional opening across the FTF.

In the neighborhood of Iceland spreading continued about a pair of parallel centers that progressively migrated south through the repeated extinction of old rifts and the opening of new. At ~ 26 Ma the Aegir ridge became extinct, spreading became confined to the Kolbeinsey ridge, and a second parallel spreading center formed to the immediate south (Figure 1c). The eastern center developed into the currently active Northern Volcanic Zone (NVZ) (c.f., Figures 1c and 2a). Continuity of the lava succession in eastern Iceland, and the absence of an eastward extension of the Tjornes fracture zone beyond the NVZ shows that the eastern center has been long-lived and has remained approximately fixed with respect to the Kolbeinsey ridge [Jancin *et al.*, 1985; Saemundsson, 1979].

As a consequence of the fixed spatial relationship of the eastern spreading center with the Kolbeinsey ridge, the western center was progressively transported west relative to the Kolbeinsey ridge. This center experienced at least two rift extinctions, accompanied by the opening of new rifts further east with better colinearity with the Kolbeinsey ridge. At ~ 15 Ma the western rift became extinct and a new rift opened ~ 80 km further east (Figure 2a), and at ~ 7 Ma this new rift in turn became largely extinct and the presently active Western Volcanic Zone (WVZ) formed (Figure 2c). Extension across a pair of parallel spreading centers has occurred in south Iceland since ~ 2 Ma when the Eastern Volcanic Zone (EVZ) formed [Saemundsson, 1979] (Figure 2d).

The continually evolving, parallel-pair spreading center configuration has resulted in a jigsaw of ephemeral microplates. These include the JMM and two microplates in Iceland. One lay between the northern pair of parallel spreading centers (the Trollaskagi microplate) and one between the southern pair (the Hreppar microplate). The palinspastic reconstruction (Figure 2) shows that oceanic crust up to ~ 30 Myr old has been trapped beneath central and southeast Iceland as a consequence of the complex history of spreading. Recent ancient ages determined for zircons from basalts in southeast Iceland suggest the presence of continental crust beneath that area, suggesting that the JMM may have continued further south than shown in Figure 1c [Amundsen *et al.*, 2002]. In this case, a sliver of continental crust might have been captured between the parallel pair of spreading centers that formed at ~ 26 Ma, and currently underlie central and southeastern Iceland. The presence of such a sliver may have been influential in the formation of the parallel spreading-center pair.

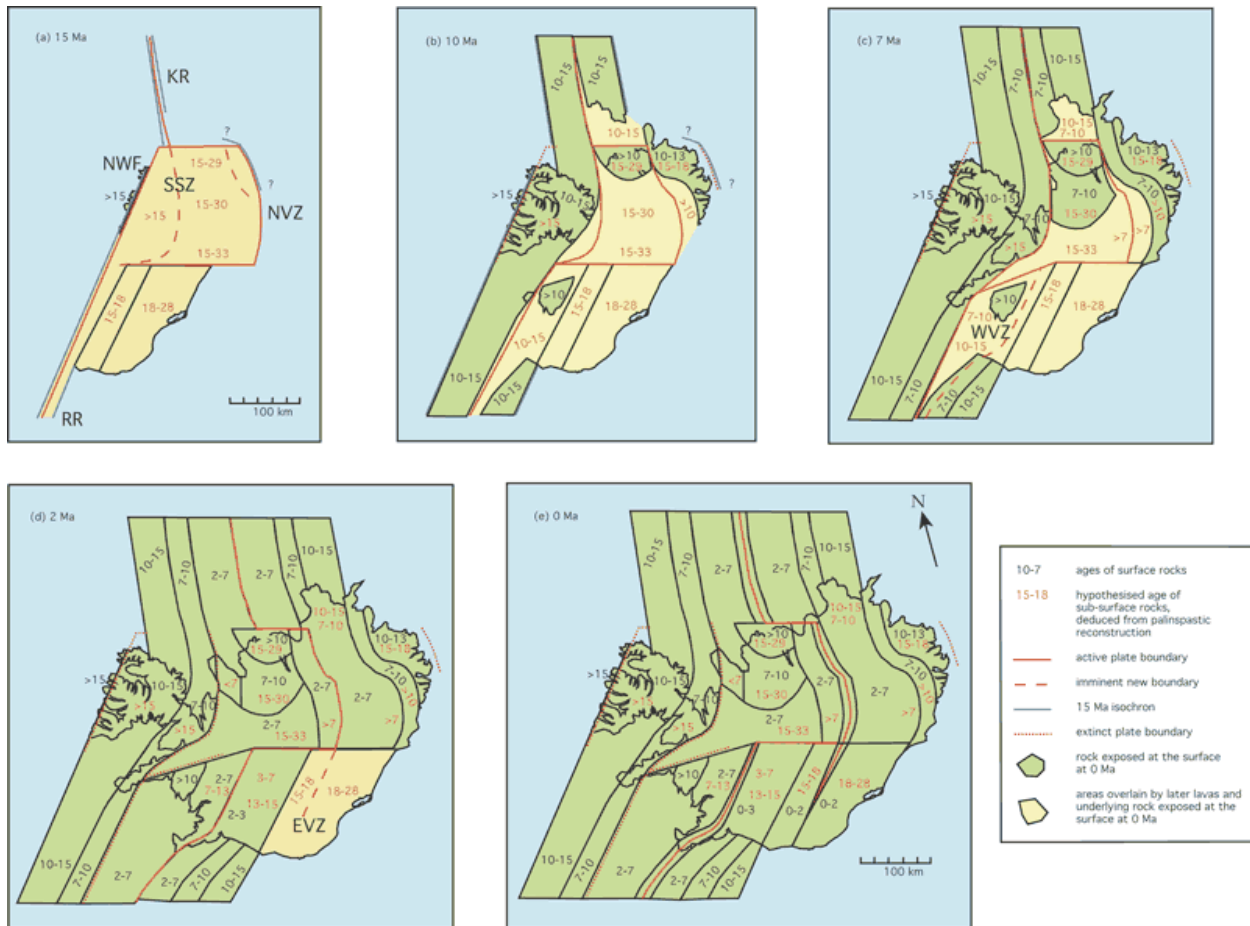


Figure 2: Tectonic evolution of Iceland at 15, 10, 7, 2 and 0 Ma. Black lines indicate the boundaries of modeled blocks. The oldest rocks exposed in Iceland are 17 Myr old. Blue: unmodeled oceanic areas, yellow: areas that are part of present-day Iceland but are now covered with later lavas, green: rock currently exposed at the surface, solid, dashed and dotted red lines: active, imminent and extinct plate boundaries, blue lines: inferred position of the 15 Ma isochron, red and black numbers: ages of rock in Myr, red: ages of rocks currently covered with younger lavas, black: ages of surface rocks. Where ages are shown in both black and red for blocks in later panels, older rock underlies younger surface rock. The extent of rock in a given age range offshore is inferred assuming a spreading rate of 1.9 cm/a about the KR and the RR. On land, the possible age range of rocks in a given block is deduced assuming spreading is equally distributed between parallel spreading center pairs, where these exist. The ages of rocks onland are taken from the published literature. The positions of the extinct NWF (Northwest Fjords) and SSZ (Snaefellsnes-Skagi zone) rifts are taken from Saemundsson [1979]. Other extinct rifts are required by space considerations, given the ages of surface rocks.

Eastward migration of spreading in Iceland is often cited as evidence in support of an eastward-migrating plume. The palinspastic reconstruction (Figure 2) shows, however that the locus of spreading has not migrated east. The regular progression of basalts extending from the NVZ to

the east coast shows that spreading has proceeded about the eastern center since at least ~ 15 Ma [Bott, 1985; Jancin *et al.*, 1985; Saemundsson, 1979] and marine observations suggest that this situation has probably been relatively stable since ~ 26 Ma [Bott, 1985]. Spreading about a parallel pair of ridges is unstable and, given the fixed location of the eastern rift relative to the Kolbeinsey ridge, the western rift has been required to re-equilibrate by repeated relocations to the east or else be rafted away with the north American plate. These relocations do not represent an eastward migration of the general locus of melt extraction in the region, which has remained fixed relative to the Kolbeinsey ridge. Indeed, southerly ridge migration is a more prominent characteristic of the Iceland region than easterly migration.

References

- Amundsen, H.E.F., U. Schaltegger, B. Jamtveit, W.L. Griffin, Y.Y. Podladchikov, T. Torsvik, and K. Gronvold, Reading the LIPs of Iceland and Mauritius, in *15th Kongsberg Seminar*, edited by B. Jamtveit, and H.E.F. Amundsen, Kongsberg, Norway, 2002.
- Bott, M.H.P., Plate tectonic evolution of the Icelandic transverse ridge and adjacent regions, *J. geophys. Res.*, **90**, 9953-9960, 1985.
- Jancin, M., K.D. Young, B. Voight, J.L. Aronson, and K. Saemundsson, Stratigraphy and K/Ar ages across the west flank of the northeast Iceland axial rift zone, in relation to the 7 Ma volcano-tectonic reorganization of Iceland, *J. geophys. Res.*, **90**, 9961-9985, 1985.
- Saemundsson, K., Outline of the geology of Iceland, *Jokull*, **29**, 7-28, 1979.