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A source for Icelandic magmas in remelted Iapetus crust

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Abstract

The geochemistry and large melt volume in the Iceland region, along with the paucity of evidence for high, plume-like temperatures in the mantle source, are consistent with a source in the extensive remelting of subducted Iapetus crust. This may have been trapped in the Laurasian continental mantle lithosphere during continental collision in the Caledonian orogeny at ~420–410 Ma, and recycled locally back into the asthenosphere beneath the mid-Atlantic ridge by lithospheric delamination when the north Atlantic opened. Fractional remelting of abyssal gabbro can explain the major-, trace- and rare-earth-element compositions, and the isotopic characteristics of primitive Icelandic tholeiite. An enriched component already present in the recycled crustal section in the form of enriched mid-ocean-ridge basalt, alkalic olivine basalt and/or related differentiates could contribute to the diversity of Icelandic basalts. Compositions ranging from ferrobasalt to olivine tholeiite are produced by various degrees of partial melting in eclogite, and the crystallization of ferrobasalt as oxide gabbro, i.e., containing the magmatic Fe–Ti oxide minerals, ilmenite and magnetite, may explain the anomalously high density of the Icelandic lower crust. The very high $^3He/^4He$ ratios observed in some Icelandic basalts may derive from old helium preserved in U+Th-poor residual Caledonian oceanic mantle lithosphere or olivine-rich cumulates in the crustal section. The persistence of anomalous volcanism at the mid-Atlantic ridge in the neighborhood of Iceland suggests that in the presence of lateral ridge migration, the shallow fertility anomaly must be oriented transverse to the mid-Atlantic ridge. The Greenland–Iceland–Faeroe ridge is co-linear with the western frontal thrust of the Caledonian collision zone, which may thus be associated with the fertility source. The fertile material beneath the Iceland region must lie at a steep angle or be thickened by deformation or imbrication to supply the large volumes of basalt required to build the thick crust there. "Hot spot" volcanism and large-igneous-province emplacement often occurs within or near to old suture zones and similar processes may thus explain anomalous magmatism elsewhere that is traditionally attributed to plumes.

Keywords: Iceland; plume; hotspot; plate tectonics; recycled crust

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1. Introduction

The Greenland–Iceland–Faeroe ridge comprises a belt of anomalously thick crust that varies from ~250 to 600 km in north–south extent and spans the entire North Atlantic ocean (Fig. 1a). It formed as a result of chronic, locally enhanced magmatism at the mid-Atlantic ridge (MAR). The typical seismic crustal thickness of ~30 km (Foulger et al., 2003) suggests that melt has been extracted at a rate up to three times greater than on the neighboring Kolbeinsey and Reykjanes ridges, where the seismic crust is only ~10 km thick (Foulger et al., 2003). This large-volume melting anomaly is usually explained as the result of a hot mantle plume.

Foulger and Anderson (in press) describe several primary geophysical and tectonic observations from the Iceland region that require special adaptions of the classical plume model, thereby detracting from its credibility. These include the geographical distribution

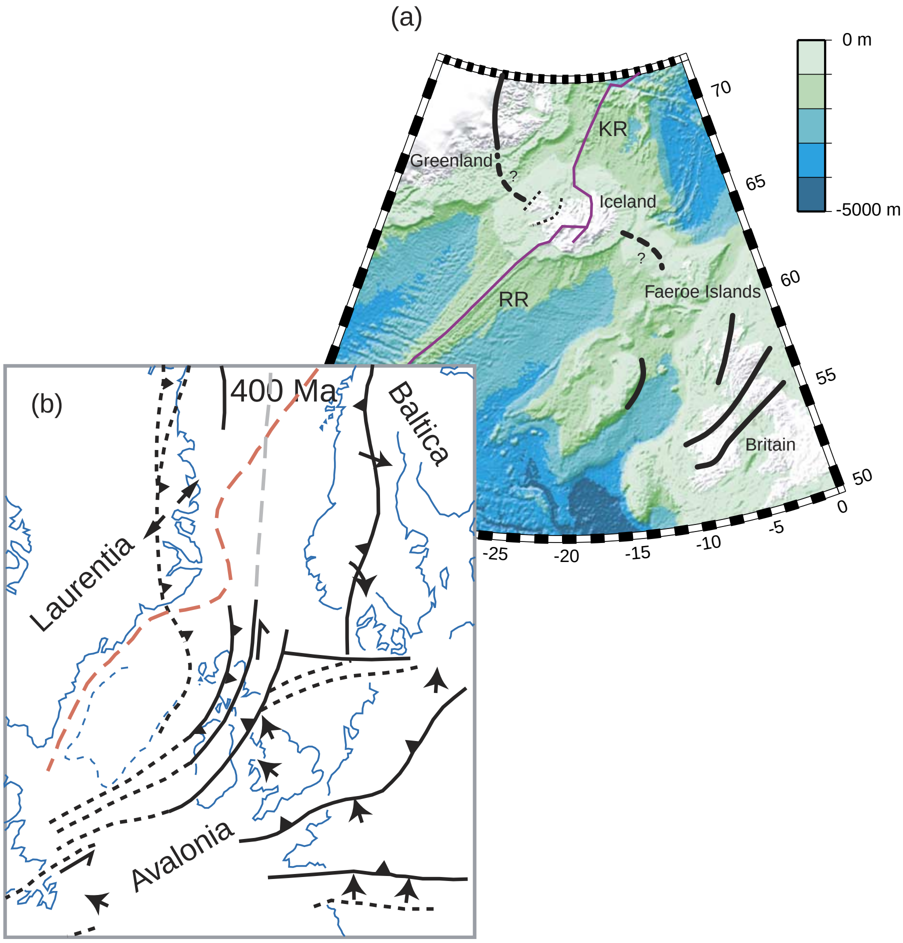

Fig. 1. (a) Bathymetry of the North Atlantic, showing the Greenland–Iceland–Faeroe bathymetric ridge which is underlain by crust with a seismic thickness of ~30 km. Other shallow areas are blocks of stretched continental crust. Thin black line: MAR; thin dashed black lines: extinct ridges; thick lines: faults of the Caledonian collision belt (Soper et al., 1992); thick dashed line: inferred trend of the western Caledonian frontal thrust crossing the Atlantic Ocean (Bott, 1985). RR: Reykjanes Ridge, KR: Kolbeinsey Ridge (adapted from Foulger and Anderson, in press). (b) Closure of the Iapetus Ocean at 420–410 Ma by convergence of Laurentia, Baltica and Avalonia. Arrows: convergence directions; thick lines: faults and orogenic fronts, gray dashed line: inferred line of the Caledonian suture. Black triangles indicate sense of thrust faults and fronts. Slabs are thought to have been subducted beneath Greenland, Baltica and Britain. Bold dashed line: inferred line of opening of MAR at ~54 Ma (from Soper et al., 1992; Skogseid et al., 2005; Roberts, 2003).