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Iceland: What we know and what we don't

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The term "hotspot" implies that excess magma is produced as a result of high potential temperature in the mantle ("hot"), and that the source is localised (a "spot"). A considerable body of evidence suggests that both these assumptions are wrong. There is no unequivocal evidence for temperature anomalies associated with the North Atlantic Igneous Province or Iceland higher than a few 10s of ˚C, which is within normal mantle variations (Foulger et al., 2005; Vinnik et al., 2005). Furthermore, there is no evidence that the source of magma at Iceland is a localised conduit beneath SE Iceland. Numerical models of such a system can be made to fit some observations, but such models predict poorly many other observations e.g., geochemistry, for which they require *ad hoc* adaptations. Only rarely do they predict features that are later confirmed by observation.

We have to stop saying "hotspot" if we are to clear our minds of prejudice and make progress.

A measure of the weakness of models that assume high temperatures is that, despite several decades of increasingly sophisticated and ambitious study of the Iceland region, many first order problems remain unsolved. Spreading there has been complex for at least 20 Ma and perhaps longer. Two parallel rift zones existing simultaneously is the norm. The distance between isochrons in Iceland *requires* there to be older, captured crust there, submerged beneath younger lavas. The captured crust may be an oceanic block analogous to the Easter microplate, whole or fragmented, and some or all of it may be continental, possibly a southerly continuation of the Jan Mayen microcontinent (Foulger, 2006). Recent reports of Mesozoic, or even older, zircons in Icelandic lavas support this (Paquette et al., 2006; Sigmarsson et al., 2007).

This complex tectonic behaviour occurs in the context of a crust that is extraordinarily poorly understood, considering the massive amount of study to which it has been subject in recent years. Numerous seismic and other experiments have been conducted by several groups, on many scales, and using diverse methodologies (see Foulger et al., 2003 for a summary). Nevertheless, estimates of crustal thickness beneath central Iceland today vary from ~ 15 km to > 40 km (Björnsson et al., 2005; Foulger et al., 2003). The crust-mantle boundary is obscure, and structure is gradational and much less compliant to seismic study than normal oceanic crust. Most troubling is the fact that the composition of Icelandic-type crust is still not understood, and the thickness of melt that it represents is unknown (Gudmundsson, 2003; Menke, 1999). Crustal thickness on the Reykjanes ridge probably corresponds to the amount of melt, and is ~ 10 km. But does the melt thickness surge to 40 km beneath central Iceland, a distance of only ~ 200 km along the ridge, with a topographic elevation increase of only ~ 1 km?

Fresh ideas are needed, and commitment to address the problems rather than reiterating models that cannot account for the observations ignoring the elephants in the living room. It

is now generally accepted that the mantle is compositionally heterogeneous, and contains recycled materials such as subducted slabs, delaminated continental mantle lithosphere and possibly delaminated lower crust. An intriguing question is its degree of structural heterogeneity, and whether this influences surface tectonics. The North Atlantic is young, narrow, and contains several continental microcontinents. If we are to understand the tectonic history and current behaviour of the region, we may need to abandon the simple model of a rigid lithosphere floating like a layer of cork above a rheologically uniform asthenosphere.

The surface area of the shallow offshore Icelandic shelf is ~ 2 x the area of Iceland itself. Exploring this shelf must inevitably yield entirely new information about evolution of the region, and possibly also information of economic importance. There is little information available at present on which to build a case for such study, which is, ironically, both a virtue and an Achilles heel of such a project. Fresh, new approaches have the potential to bring radical and unexpected new insights, but scientific research approaches are typically conservative, safe, and limited to work that guarantees small, predictable steps forward rather than risks great leaps forward. Nevertheless, the Icelandic shelf remains comparatively unexplored and will very likely yield significant new insights when it is finally surveyed in detail.

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