Geographical variations of mantle source fertility beneath Iceland

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The nature of mantle sources is partially recorded in the composition of oceanic island basalts. The record is, however, not always straightforward to decipher. The only direct evidences of mantle composition and lithology, which upon melting can produce mafic magmas, are the orogenic peridotitic massifs and mantle xenoliths. These samples suggest that the non-refractory mantle is principally composed of lherzolite with small but significant proportions of fertile pyroxenites. During upwelling of such a lithologically heterogeneous mantle, the pyroxenites should melt first and probably to a larger extent, because they would reach their solidus at a greater depth than the enveloping lherzolites. Preferential melting of garnet pyroxenite would produce melts characterised by high La/Yb and ($^{230}Th/^{238}U$) since garnet retains Yb and U relative to La and Th, respectively. Mixing of such melts with those generated from spinel lherzolite would result in lower La/Yb and ($^{230}Th/^{238}U$) in the mixture. If mantle plumes have hotter centre than their periphery then lower proportions of garnet pyroxenite melts may be expected in mantle derived basalts from the centre of the hot spots.

Recent basalts from the off-rift volcanic zone on the Snæfellsnes peninsula in western Iceland offer the possibility of investigating over 100 km, lateral compositional variability in a presumed mantle plume head if the magmas ascend vertically from their source region. The alkalinity of these basalts, as well as La/Yb, ($^{230}Th/^{238}U$) and $^{87}Sr/^{86}Sr$, decreases along the volcanic zone, from west to east, towards the centre of Iceland. These geochemical variations, therefore, are also correlated with the SiO_2 contents of the basalts, suggesting a link between major and trace elements and isotope ratios in their mantle source. These compositional variations are taken to indicate that melting of garnet pyroxenites generates a significant component of the basalts, in the Snæfellsnes volcanic zone. This component appears to decrease towards the centre of Iceland. There, the composition of primitive basalts in the rift zones may be dominated by melts of overwhelming lherzolitic source. This could be the result from a large extent of melting due to a higher temperature in the core of the presumed mantle plume.

The alkali basalts furthest to the west in the Snæfellsnes volcanic zone, having the highest La/Yb and ($^{230}Th/^{238}U$), or garnet signature, also have the highest $^{87}Sr/^{86}Sr$ and $^{3}He/^{4}He$ lower than 8 (R/Ra). These isotope ratios are compatible with the hypothetical garnet pyroxenites in the periphery of the Icelandic plume being recycled oceanic crust. The inference from this study is that garnet pyroxenite melts are likely to be involved in the genesis of most oceanic island basalts, but are most readily identified in basalts from regions such as fracture zones or off-rift volcanic zones where geothermal gradient is likely to vary significantly. Finally, elevated ratios of Sr isotopes and La/Yb are better tracers for mapping mantle fertility than possible centres of plumes.