A lithospheric mantle source for the Cape Verde Island magmatism: Trace element and isotopic evidence from the Island of Fogo

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Young silica undersaturated rocks from the island of Fogo, in the southern Cape Verde islands, show striking correlations between rocks types, incompatible trace element (ITE) ratios and Pb-Sr-Nd isotopic compositions that provide new insights into the generation of the HIMU source. The Cape Verde islands are situated on relatively old and thick oceanic lithosphere that, unlike most hotspots world-wide, has remained relatively steady compared to the underlying mantle plume for a considerable period of time. The magmatism has resulted in highly silica undersaturated rocks, including some of the rare cases, globally, of oceanic carbonatites. The lavas studied are mainly primitive (MgO = 5–12%) nephelinites and tephrites, with less silica undersaturation characterising the historic volcanism. ITE ratios range widely, with Zr/Hf = 37–60, Nb/U = 33–92 and Th/U = 2.7–4.2, whereas Nd and Sr isotopic compositions show a restricted range with $^{143}Nd/^{144}Nd$ = 0.51272–0.51282 and $^{87}Sr/^{86}Sr$ = 0.7034–0.7038. Pb isotope compositions are within the typical range of 'young HIMU' OIB: $^{206}Pb/^{204}Pb$ = 18.8–19.4, $^{207}Pb/^{204}Pb$ = 15.52–15.59, $^{208}Pb/^{204}Pb$ = 38.7–39.1. The isotopic data agree well with previously published results (Gerlach *et al.*, 1988), albeit with tighter arrays. Measured oxidation states of iron vary by a factor of two, and show good correlations with rock types and degrees of silica undersaturation, but also with isotopic and ITE ratios.

The Fogo arrays are in accordance with a model of binary mixing between two dominating source components beneath the Cape Verde islands, a HIMU and a EMI-type source. The most distinctive feature of the EMI-type source is its low $^{143}Nd/^{144}Nd$ ~0.51260 and high Ba/La ratios, and it is interpreted to represent delaminated subcontinental lithosphere. The HIMU component in the Cape Verde islands is characterised by high oxygen fugacity and high ratios of U/Pb, U/Th, Zr/Hf and *LREE*/HFSE, features that are shared with many carbonatites. It also has high present-day $^{143}Nd/^{144}Nd$, ~0.51305 and negative Δ7/4 values (down to −5.5), the latter indicating it to be much younger than the 1.5–2 Ga source age, typically inferred for the HIMU source.

There are well-defined arrays in diagrams of $^{206}Pb/^{204}Pb$ versus μ ($^{238}U/^{204}Pb$), and of $^{208}Pb/^{204}Pb$ versus ($^{232}Th/^{204}Pb$) that imply concordant ages of ~120 Ma for the two systems (Fig. 1). No such good correlations exist for the Sm-Nd and Rb-Sr systems, so mixing is restricted to the source regions. For the U-Th-Pb arrays to have preserved significant source age information, provides tight constraints on aspects of the melt generation models. The preferred model includes the derivation of the HIMU component from DMM by mantle degassing (due to the high $^{143}Nd/^{144}Nd$ in the HIMU endmember), and the best-fit model ages for the HIMU component of ~200 Ma broadly overlap the timing of Pangea break-up at this latitude. In such a model, the source region is situated within the oceanic lithosphere, and the contribution from the plume itself is limited. Geophysically, the model is consistent with (1) the considerable thickness of the Cape Verde plate (100–125 km) which would diminish the probability of any extensive melting in the plume, and (2) the fixed position of the ocean plate, that would allow for heat to be conducted from the plume into the lithosphere. The temporal variations are attributed to exhaustion of the HIMU component, possibly combined with progressive thermal erosion of the lithosphere by the rising plume, causing melting to proceed at higher levels in the oceanic lithosphere.

The presented model suggests that 'young HIMU'

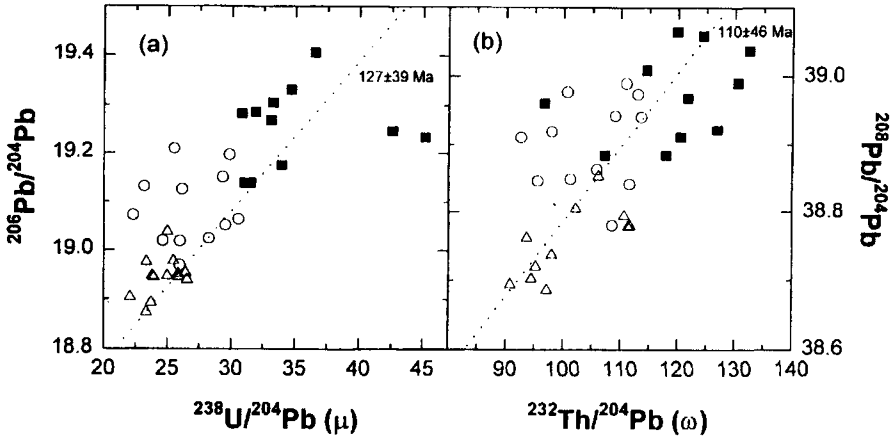

FIG. 1.

source regions are continuously generated through episodic mantle devolatilisation and it appears to have profound consequences for the debate about shallow versus deep sources for OIB.

Currently, it is debated whether OIB with typical 'HIMU' (high-μ; high $^{238}U/^{204}Pb$) trace element characteristics, but without having evolved extreme Pb isotope ratios, reflect shallow lithospheric contributions, or whether they are generated from deeper asthenospheric mantle sources (e.g. Hart *et al.*, 1992; Hoernle *et al.*, 1995; Thirlwall, 1997; Class and Goldstein, 1997). Such 'young HIMU' OIB are particularly abundant in the Atlantic Ocean, and in addition to the Cape Verde islands, such basalts are also found in the Canaries, Madeira, parts of the Azores and the Cameroon line (see also Thirlwall, 1997). The basalts tend to be silica undersaturated and isotopically they are constrained to have $^{87}Sr/^{86}Sr$ = 0.7029–0.7035, $^{143}Nd/^{144}Nd$ = 0.51275–0.51308, $^{206}Pb/^{204}Pb$ = 19.0–20.0. A distinctive feature of these OIB is that they often have negative Δ7/4 values, indicating their source regions to be relatively young, compared to the 1.8 Ga source age suggested for 'typical' HIMU OIB, such as St. Helena and Tubuaii (e.g. Chauvel *et al.*, 1992). The assessment of source ages is particularly relevant to resolving the nature of the 'young HIMU' source, because very young source ages (in the order of less 0.1–0.3 Ga) would make deep asthenospheric recycling less feasible, due to insufficient time.

In isotopic space (e.g. $^{87}Sr/^{86}Sr$ *vs* $^{206}Pb/^{204}Pb$) many of the 'young HIMU' OIB define a focal zone (forming a fan shape), which provoked different workers to propose the existence of a commonly sampled deep asthenospheric mantle component. Hart *et al.* (1992) termed this component FOZO (focal zone), whereas Hoernle *et al.* (1995) in their combined seismic and geophysical study of the eastern Atlantic and western and central Europe defined it as a low velocity component (LVC). We agree with the view of Hart *et al.* (1992) and Hoernle *et al.* (1995), that the convergence of many OIB (and particularly 'young HIMU' OIB from the Atlantic Ocean) in Sr, Nd, Pb isotopic space, indicates a common source for many of these rocks. However, in the present model such a source is readily provided for within the older parts of the oceanic lithosphere as shallow (60–100 km) carbonatitic vein-material, hosted within older delaminated rafts of the Pangean lithosphere. The proposed model would also predicts a close spatial relationship between EMI and 'young HIMU' sources in areas of relatively old oceanic lithosphere, in general, a feature that seems unlikely to be unique for the Atlantic Ocean.

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