Multistage evolution of HIMU sources with its main stage in the continental lithospheric mantle

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HIMU (high μ=^{238}U/^{204}Pb) basalts represent the highest Pb isotopic compositions of oceanic basalts. HIMU sources have generally been interpreted as recycled oceanic crust free of additional contaminants that has preferentially lost fluid-mobile trace elements. Recent measurements of sulfur isotopes in HIMU basalts show mass-independent fractionation [1], indicating recycling of >2.4 Ga-old surface material. However, olivine compositions do not indicate the expected pyroxenitic source lithology for HIMU [2].

Here we present new high precision trace element data on olivine phenocrysts from the HIMU endmember ocean islands Mangaia and Tubuai showing very high Ca contents up to 3200 ppm and associated low Al at 80-180 ppm. The resulting distinct high-Ca/Al ratios are outside the range previously reported for olivines from MORB or Icelandic and Hawaiian OIB. Unlike Ni [3], the elevated Ca/Al ratios in these olivines cannot be explained by differences in temperature, rather they reflect the combination of CaO enrichment - Al_2O_3 depletion in in the source of HIMU lavas compared to other OIBs. The low Al abundances go along with high Mn/Fe ratios in the phenocrysts, indicating a peridotite source with low garnet content (or any Al phase), likely the consequence of a previous melt extraction episode. However, the very high Ca in these olivines points towards an enrichment process, which must have involved carbonatitic melt/fluid (low in SiO_2 and Al_2O_3) to prevent the formation of pyroxene by olivine consumption and preserve the low-Al content in the HIMU peridotite source.

Similarities in incompatible trace element patterns between HIMU lavas and deep high-Mg carbonatitic melts captured in diamond fluid inclusions suggest that this metasomatism occurs in a deep continental lithospheric source region, likely a cratonic root. Thus, a multi-stage evolution of the HIMU-source over more than half of Earth's history is revealed as old, subduction-related, carbonatite-metasomatized, recycled continental lithospheric mantle.

[1] Cabral *et al*. (2013) *Nature* **496**, 490-493. [2] Herzberg *et al*. (2014) *EPSL* **396**, 97-10. [3] Matzen *et al*. (2013) *J. Pet*. **54**, 2521-2545.