HIMU signature trapped in a diamond from the mantle transition zone

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Mantle plumes sample the deep mantle. A limited number of geochemical endmember components can describe the isotopic and compositional variations in the ocean island basalts (OIBs), which are produced by plume volcanism. The endmembers are correlated to compositions in the OIB source regions or represent incorporation of material upon ascent. However, their actual nature and origins are still highly debated. The depths of plume sources have been proposed to be anywhere between the core-mantle boundary and the upper mantle, and need not be the same for all plume-related volcanic activities.

Using a combination of synchrotron micro-X ray fluorescence and -diffraction mapping, and in-situ Laser Ablation Inductively Coupled Plasma Mass Spectrometry, we show that the elemental features of HIMU-rich OIBs, such as Bermuda, St Helena, and Cook-Austral, exactly match the geochemical signature of a multiphase inclusion in a diamond. The geochemical signature in our studied diamond inclusion is markedly different from that of inclusions in lithospheric diamonds. The phases identified in the inclusion are majorite-rich garnet, ilmenite, the sodic 10Å-phase (TAP), and liebermannite.

Furthermore, we show that this inclusion was entrapped at 14.5 ± 0.5 GPa (420-440 km) and 1450 ± 50 K. At the conditions of entrapment, the diamond inclusion phase assembly was garnet + ilmenite + liebermannite + clinopyroxene + stishovite + fluid. Sodic TAP is a retrograde product of reaction between clinopyroxene, stishovite, and fluid upon ascent. Its presence shows that the HIMU source is water-saturated. Entrapment in diamond indicates that the fluid also contained carbonate. The conditions of 14.5 ± 0.5 GPa and 1450 ± 50 K plot right on top of the alkaline carbonatite solidus, and match the formation of carbonatitic melt from subducted slabs plus diamond formation from reaction of carbonate with iron.

In summary, our data show that the transition zone source accounts for the global HIMU endmember.

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