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Constraints on the source of mantle plumes from the geochemistry of the first picrites erupted Ethiopian flood basalt province

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The earliest basalts erupted by largest mantle plumes are typically hotter than those derived from convecting upper mantle at mid-ocean ridges. They originate from a thermal boundary layer deep in Earth that is assumed to be the core-mantle boundary. Consequently the first plume-derived basalts provide constraints on Earth structure and differentiation history. The first picrites erupted by the Iceland plume have a high proportion of primordial He (3He/4He $\sim$ 50 Ra) yet a range in radiogenic isotope and incompatible trace element ratios that overlap mid-ocean ridge basalts. This is difficult to reconcile with pristine mantle dominating the plume head. The simplest interpretation is that the convecting mantle has been polluted by primordial He either at the core-mantle boundary or during ascent to upper mantle. Importantly, this explanation requires the existence of primordial volatile-rich reservoir at depth.

In an attempt to provide better constraints on the deep mantle source of plumes we have analysed the He-Sr-Nd-Pb isotopic composition of the earliest picrites from the Dilb section of the $\sim$30 Ma Ethiopian flood basalt province. The basalts are characterized by high Fe and Ti contents for MgO = 14-15% that implies that the parent magma was derived from a high temperature small melt fraction, likely from the plume head. The basalts are characterized by a narrow range of 87Sr/86Sr (0.70396–0.70412) and 206Pb/204Pb (18.82-19.01), and 3He/4He of olivine phenocrysts that never exceed 21 Ra. Thus the Afar plume was sourced in a discrete mantle reservoir that is less degassed and more enriched than the convecting upper mantle. The source region is more degassed than the mantle brought up by the proto-Iceland plume and appears to be significantly more homogenous. Although it is still in the study of the geochemistry of early plume basalts, this study suggests that the largest mantle plumes are not initiated in a single deep mantle domain with the same depletion history, and they do not mix with convecting mantle to the same extent.