Geophysical Research Abstracts
Vol. 18, EGU2016-17009, 2016
EGU General Assembly 2016

The He isotope composition of the earliest picrites erupted by the Ethiopia plume, implications for mantle plume source

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The earliest basalts erupted by mantle plumes are Mg-rich, and typically derived from mantle with higher potential temperature than those derived from the convecting upper mantle at mid-ocean ridges and ocean islands. The chemistry and isotopic composition of picrites from CFB provide constraints on the composition of deep Earth and thus the origin and differentiation history. We report new He-Sr-Nd-Pb isotopic composition of the picrites from the Ethiopian flood basalt province from the Dilb (Chinese Road) section. They are characterized by high Fe and Ti contents for MgO = 10-22 wt. % implying that the parent magma was derived from a high temperature low melt fraction, most probably from the Afar plume head. The picrite 3He/4He does not exceed 21 Ra, and there is a negative correlation with MgO, the highest 3He/4He corresponding to MgO = 15.4 wt. %. Age-corrected 87Sr/86Sr (0.70392–0.70408) and 143Nd/144Nd (0.512912-0.512987) display little variation and are distinct from MORB and OIB. Age-corrected Pb isotopes display a significant range (e.g. 206Pb/204Pb = 18.70-19.04) and plot above the NHRL. These values contrast with estimates of the modern Afar mantle plume which has lower 3He/4He and Sr, Nd and Pb isotope ratios that are more comparable with typical OIB. These results imply either interaction between melts derived from the Afar mantle plume and a lithospheric component, or that the original Afar mantle plume had a rather unique radiogenic isotope composition. Regardless of the details of the origins of this unusual signal, our observations place a minimum 3He/4He value of 21 Ra for the Afar mantle plume, significantly greater than the present day value of 16 Ra, implying a significant reduction over 30 Myr. In addition the Afar source was less degassed than convecting mantle but more degassed than mantle sampled by the proto-Iceland plume (3He/4He ∼50 Ra). This suggests that the largest mantle plumes are not sourced in a single deep mantle domain with a common depletion history and that they do not mix with shallower mantle reservoirs to the same extent.