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Helium isotopes and melt temperature of Miocene basalts from NW Iceland: Constraints on the evolution of the heat and primordial He flux from the Iceland mantle plume

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Basalts with 3He/4He > 10 Ra provide crucial evidence that the Earth still contains primordial volatiles that were trapped during accretion. Increasingly evidnce shows that these basalts are hotter than those generated in the convecting upper mantle supporting the contention that they are sourced at the core-mantle boundary and brought to surface in upwelling mantle plumes. Understanding how primordial He and heat in mantle plumes varies with time provides insight into the nature of the deep mantle and the source of primordial terrestrial volatiles.
Picrites from the proto-Iceland plume (PIP) (∼60 Ma) have the highest 3He/4He (50 Ra) and melt temperatures (1500°C). Modern Iceland basalts have a maximum 3He/4He of ∼32 Ra and maximum temperatures of 1370°C, attesting to a decrease in the flux of both heat and primordial 3He with time. As part of a larger geochemical study we have made new 3He/4He and temperature measurements from a suite of Miocene basalts from NW Iceland in order to determine how the Iceland plume has evolved.
The highest 3He/4He (42 Ra) is midway between the best estimate of the starting and modern Iceland plume, demonstrating that 3He/4He appears to have decreased (monotonically) with time. The high 3He/4He Vestfirdir basalts have a large range of Nb/Zr, as also seen in the PIP picrites, implying that there is no compositionally-unique mantle source for the high 3He/4He component in the Miocene Iceland plume. Al-in-olivine data from high 3He/4He Vestfirdir basalts yield crystallisation temperatures of 1138-1350°C. These are significantly less than the highest crystallisation temperature of the PIP picrites and modern Iceland picrites. The apparent 50°C increase of the Iceland plume temperature in the last 15 million years contrasts strongly with the decrease of 3He/4He. This suggests that the heat and primordial 3He are decoupled in the Iceland plume. This may reflect the different sources (i.e. heat from the core, primordial He from the deep mantle) or the different diffusion rate of heat and He across the core-mantle boundary. Either way, the apparent lack of covariance implies that using fluctuations in mantle plume temperature or 3He/4He with time to record the mantle plume flux must be treated with caution.