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The role of mantle plumes in the formation of Large Igneous Provinces: A noble gas isotope study from the Etendeka province of Namibia

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The magmatic history of the Earth is characterised by the episodic appearance of enormous magmatic events, during which large volumes of mainly mafic magmas are generated and emplaced by processes distinct from seafloor spreading or subduction. The so-called Large Igneous Provinces (LIPs) produced during these events are mainly created within less than 10 Ma, with the bulk of magmatism occurring in the first Ma. The favoured explanation for LIP formation is magmatism resulting from plume head decompressional melting. However, the evidence for this theory is mixed and has been challenged lately. Conventional geochemical tracers (Sr, Nd or Pb isotopes or trace elements) generally used to characterise the mantle sources of a magmatic sample are relatively ambiguous in this context, because (1) various mantle reservoirs can contribute to LIP formation and it is unclear which of them are located in the deep mantle, (2) magmas can be contaminated during their ascent through the lithosphere and crust and (3) trace element patterns are also controlled by the degree and depth of melting. In this respect, the principal advantages of noble gases as geochemical tracers for magmatic processes are related to (1) their chemical inertness - they are only modified by nuclear, melting and degassing processes, (2) the large and indicative isotope variations between the various terrestrial reservoirs and (3) their relatively low abundance in the solid Earth.

Here we present He, Ne, and O-isotope data from fresh olivines as well as REE and Sr, Nd, and Pb isotope whole rock data derived from dolerite dykes and related rocks from the southern Etendeka province of Namibia. The He-isotope data show a range from radiogenic values of 0.15 ± 0.01 $R_A$to mantle values of 12.03 ± 0.28 R_A. The radiogenic He isotope ratios are indicative of crustal contamination during magmatic evolution, which is generally supported by the Ne and O isotope data. The upper range of the He isotope data is higher than the typical MORB value (8 ± 1 R_A), indicating the involvement of a more primitive mantle source in the formation of the investigated magmas. Such an involvement is also supported by the observed co-variations between the He isotopes and the Sr and Pb isotopes as well as the REEs.