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Calcium isotope constraints on the mantle sources of volatile-rich alkaline magmas

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Considerable Ca isotope differences have been observed between the mantle minerals carbonate, clinopyroxene, garnet, and orthopyroxene, indicating that Ca isotopes are a promising tracer of mineralogical heterogeneity in the mantle. To further explore the effects of lithological heterogeneity in the upper mantle on the Caisotope systematics of deep-sourced magmas, we present stable Ca isotope data for ca. 1.4 Ga lamproites, 590-555 Ma ultramafic lamprophyres and carbonatites, and 142 Ma nephelinites from Aillik Bay in Labrador, eastern Canada. These primitive alkaline rock suites are the products of three main stages of magmatism that accompanied lithospheric thinning and rifting of the North Atlantic craton. The three discrete events of deep-sourced volatile-rich alkaline magmatism formed by melting of different lithologies in a metasomatised lithospheric mantle column at various depths: (1) MARID-like components were involved in the origin of the lamproites; (2) phlogopite-carbonate veins are an additional source component to the ultramafic lamprophyres during the second event; and (3) amphibole wehrlites at shallower depths are a source component to the nephelinites during the final event.

The 1.4 Ga lamproites show lower $\delta^{44/40}$Ca values (0.58 to 0.66 ‰) than MORBs (0.85‰), which can be explained by the MARID source containing K-richterite with low $\delta^{44/40}$Ca. The $\delta^{44/40}$Ca values of the 590-555 Ma ultramafic lamprophyres are relatively uniform (0.67 to 0.75 ‰), similar to those of the carbonatites (0.71 to 0.82 ‰), suggesting limited Ca isotope fractionation during liquid immiscibility of carbonated silicate melt. The average $\delta^{44/40}$Ca value of the carbonate-bearing magmas is slightly lower than MORB compositions. The $\delta^{44/40}$Ca values of the 142 Ma nephelinites (0.72 to 0.78 ‰) are similar to those of the 590-555 Ma ultramafic lamprophyres, which may indicate that their ‘shallow’ wehrlitic metasomatic source formed by interactions with rising carbonated silicate magmas during the Neoproterozoic rifting stage. The new data highlight that either K-richterite or carbonate components in the mantle source could result in systematically low $\delta^{44/40}$Ca values in the alkaline melts produced, suggesting that Ca isotopes are a robust tracer of lithological variation caused by volatiles in the Earth’s upper mantle.