Origin of carbonatites and associated silicate rocks revealed by Ca stable isotopes

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The enigmatic source and igneous origin of carbonatites is an outstanding major challenge in geoscience. Models for carbonatite genesis invoke either solely low-degree partial melting or, alternatively, involvement of crustal recycling. High-precision Ca isotope measurements can provide insights into carbonatite petrogenesis, including the identification of recycled crustal material in their source region. We report high-precision mass dependent and mass-independent Ca isotope data for 80 Ca- and Mg-rich carbonatites and associated silicate rocks from various localities and with ages ranging from 2610 to 67 Ma. These data reveal a wide range of stable Ca isotope compositions from $\delta^{44/42}Ca_{SRM915b}$= +0.33‰ to –0.20‰. Carbonatites are typically enriched in their light Ca isotopes relative to the Bulk Silicate Earth (BSE; ~+0.15‰). We observe that the lightest samples also record positive residual anomalies in the kinetically mass fractionated data. This observation established that a component of the Ca present in these samples has been fractionated by mass dependent equilibrium processes. Equilibrium isotope fractionation is expected to dominate at low temperature and, moreover, marine carbonates are enriched in light Ca isotopes relative to BSE. As such, the observation of an equilibrium fractionation component in carbonatites provides clear evidence for the contribution of recycled Ca from the Earth's surface in the mantle source of Ca- and Mg-rich carbonatites and their associated alkali silicate rocks.