Significant variability in the $\delta^{44/40}$Ca of global carbonatites: implications for carbonate recycling, magma differentiation and source-mantle mineralogy

Anupam Banerjee$^1$, Ramananda Chakrabarti$^1$, and Antonio Simonetti$^2$

$^1$Indian Institute of Science
$^2$University of Notre Dame

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Abstract

Stable Ca isotopic composition ($\delta^{44/40}$Ca) of crustal carbonates are typically lighter than that of the bulk silicate Earth value (~1.05 potentially trace recycled crustal carbonates into the mantle. We report the Ca isotopic compositions of globally distributed carbonatites ($n = 46$), which are unique igneous rocks with more than 50% modal carbonate minerals, with eruption ages ranging from Precambrian until recent. The $\delta^{44/40}$Ca (w.r.t. SRM915a) of these carbonatites show a large range (0.35 uncertainty (0.08IISc. These samples are well-characterized in terms of their major and trace element geochemistry as well as Nd, Sr, B, C, and O isotopic compositions for selected samples. No systematic trend is observed between $\delta^{44/40}$Ca of the carbonatites and their eruption ages. Significant variability is observed in $\delta^{44/40}$Ca values in samples from individual provinces including those from the Oka complex in Canada (0.44 Newania complexes (0.44 South Indian carbonatites (0.65 the Palabora complex in South Africa (0.35 $\delta^{44/40}$Ca of carbonatites from Oka, Newania and the Ambadongar show strong correlations with Ca/Mg, Ca/Fe as well as CaO and MgO contents. The $\delta^{44/40}$Ca of the Oka and Ambadongar carbonatites show correlated variations with their Mg# and K/Rb ratios, respectively. The large variability in $\delta^{44/40}$Ca of global carbonatites is explained in terms of: (1) presence of isotopically lighter ancient subducted carbonates in the mantle-source regions and carbonate metasomatism of the mantle, (2) partial melting and differentiation of the carbonatite magma and (3) heterogeneity in the source-mantle mineralogy of carbonatites.
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Anupam Banerjee (anupam.gg.2006@gmail.com)¹, Ramananda Chakrabarti¹ and Antonio Simonetti²

¹Centre for Earth Sciences, Indian Institute of Science, Bangalore, India
²Department of Civil and Environmental Engineering and Earth Sciences, University of Notre Dame, USA

Classification of carbonatites: location and ages

Introduction
Stable Ca isotopic compositions ($\delta^{44/40}$Ca) of crustal carbonates are typically lighter (typically 0.2% or lower, Huang et al., 2011; DePaolo, 2004) than the bulk silicate Earth (BSE) or upper mantle compositions (0.94–1.05‰) (Huang et al., 2010; Kang et al., 2011; DePaolo, 2004). Carbonates are unique igneous rocks with more than 50% modal carbonate minerals. Hence, these unique igneous rocks provide ideal opportunity to study the role of recycled carbonates in their mantle sources. In this study, we report major and trace element concentrations and Sr isotopic compositions of WR carbonatites of different ages (from the Precambrian to recent) and exposed in different geographical locations of the world to understand their origin as well as explaining the reason of variability of $\delta^{44/40}$Ca in such unique igneous rocks.

Sampling of carbonatites: location and ages

Mass-dependent isotopic fractionation

$\delta^{44/40}$Ca, $\delta^{44}$B and $\delta^{87}$Sr/$\delta^{86}$Sr of global carbonatites

OKA carbonatite complex, Canada (~120 Ma)

South Indian Carbonatites (~800 Ma)

Ambadongar carbonatite complex, India (~65 Ma)

Conclusions
(1) No variability of $\delta^{44/40}$Ca of global carbonatites with their age of eruption.
(2) Variability in $\delta^{44/40}$Ca of carbonatites from a particular complex can vary as a result of (i) presence of isotopically lighter ancient subducted carbonates in the mantle-sourced region, (ii) degree of differentiation of magma and (iii) mineralogical compositions.

Hence, a comprehensive study of carbonatites from a particular complex is required to explain the variability in $\delta^{44/40}$Ca of these rocks.