

Bulk rock Nd-Sr and multiple-sulfur isotope compositions of carbonatites from the Phalaborwa complex, South Africa

*Anupam Banerjee¹, Madhusoodhan Satish-Kumar¹

1. Niigata University

Carbonatites are unique mantle-derived rocks with more than 50% modal abundance of igneous carbonates and they mostly occur in association with alkaline silicate rocks. Since carbonatites and alkaline silicate rocks are highly enriched in Sr, Nd and S concentrations than any other terrestrial igneous rocks, they are less susceptible to crustal contamination. Therefore, such igneous rock suites provide an ideal opportunity to trace crust-mantle interaction through recycling and mantle heterogeneity. While $^{143}\text{Nd}/^{144}\text{Nd}$ and $^{87}\text{Sr}/^{86}\text{Sr}$ of any magmatic rocks are suitable tracers for distinguishing depleted versus enriched mantle source regions, sulfur isotopic compositions of these rocks are also useful in delineating crustal recycling owing to the higher $\delta^{34}\text{S}$ of crustal sediments than primitive and/or depleted mantle¹. Additionally, $\Delta^{33}\text{S}$ of these rock samples would indicate the relative timing of crustal sources since only Archean sediments could possess a non-zero $\Delta^{33}\text{S}$ value². A recent study, based on the combined S and Pb isotopic compositions of bulk rock carbonatites and in-situ measurements of sulfide minerals, from the ~2.06 Ga Phalaborwa complex of South Africa suggests a possible role of Archean sediments in their mantle source regions³. However, this study is limited to only three carbonatites and their constituent sulfur-bearing minerals. Thorough multiple isotopic investigations are required on multiple samples from this peculiar carbonatite occurrence to characterize the mantle source region of this igneous suite and its interaction with recycled components.

Here we report multiple-sulfur isotopic compositions of whole-rock carbonatites and associated alkaline silicate rocks along with their $^{87}\text{Sr}/^{86}\text{Sr}$ and $^{143}\text{Nd}/^{144}\text{Nd}$ from the Phalaborwa carbonatite complex of South Africa. Whole-rock sulfur isotopic compositions of these rocks have been measured with SF_6 method using Thermo Scientific MAT 253 gas source Ion Ratio Mass Spectrometer at Niigata University. The analytical uncertainty of $\delta^{34}\text{S}$, based on long-term measurements of sulfur isotope standards S-1 and S-2, is better than 0.5‰. Radiogenic Nd and Sr isotopic compositions of the carbonatites and the associated silicate rocks have been measured using MAT 251 Thermal Ionization Mass Spectrometer at Niigata University. Preliminary results obtained from these samples show a wide range in $\delta^{34}\text{S}$ for carbonatites and alkaline silicate rocks (-0.8 to 4.2‰ and -4.0 to 12‰, respectively). Mass independent fractionation (MIF) of sulfur isotopes is observed for most of the samples, as revealed by their positive $\Delta^{33}\text{S}$ values. On the contrary, two silicate rocks show no significant MIF S isotopes. The initial (calculated at 2.06 Ga) $^{87}\text{Sr}/^{86}\text{Sr}_{(t)}$ and $\epsilon_{\text{Nd}(t)}$ of carbonatites and some silicate rocks show overlapping values, ranging from 0.703665 to 0.707879 and -6.6 to -8.3, respectively. Two silicate rocks, those showing mass-dependent fractionation of S isotopes, have extremely non-radiogenic $^{87}\text{Sr}/^{86}\text{Sr}_{(t)}$ (0.693161 and 0.698217) and CHUR like $\epsilon_{\text{Nd}(t)}$ (-0.3 and 0.4) isotopic compositions. Based on the radiogenic Sr and Nd isotopic compositions of these rocks, we suggest that parent magma for this carbonatite complex is derived from an enriched mantle reservoir. Such enrichment of the mantle source region is perhaps the result of recycling of crustal sediments. This result is also consistent with the $\delta^{44/40}\text{Ca}$ of a different set of carbonatite samples from this location suggesting a possible role of crustal recycling process⁴. Since most of the rock samples used in this study show a large range in $\delta^{34}\text{S}$ and MIF $\Delta^{33}\text{S}$ isotopic composition, we suggest that such enrichment of mantle source must have happened prior to the global oxidation event at ~2.45 Ga.

References: ¹Labidi et al. (2013) *Nature*, **501**(7466), 208-211; ²Farquhar et al. (2000) *Science*, **289**, 756–758; ³Bolhar et al. (2020) *Earth Planet. Sc. Lett.*, **530**, 115939; ⁴Chakrabarti & Banerjee (2019), *AGU Fall Meeting*, Abstract ID: V51E-0093.

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