# Sr-Nd-C-O isotope composition of carbonatites of the Petyayan-Vara REE deposit (Vuoriyarvi, Kola Region, NW Russia): Insight to the origin



Evgeniy Kozlov and Ekaterina Fomina
Kola Science Centre of Russian Academy of Sciences, Geological Institute, Russian Federation (kozlov_e.n@mail.ru)

Russian Science Foundation

## INTRODUCTION

Our studies (Kozlov et al., 2020) have shown that rare earth (REE) carbonatites of the Petyayan-Vara area in the Vuoriyarvi massif have an extraordinarily complex history of formation and, as a result, a complex geological structure. In many geological characteristics, carbonatites of Petyayan-Vara are similar to REE carbonatites of the Bear Lodge complex in USA (Moore et al., 2015; Chakhmouradian et al., 2017; Andersen et al., 2017). Recently, it was shown (Andersen et al., 2019) that in Bear Lodge, carbonatites could have formed during several stages related to the influx of fluids from several independent sources. We examined the Sr-Nd-C-O isotope composition of Petyayan-Vara carbonatites to find out which sources of matter have contributed to their formation.

## GEOLOGICAL SETTING

The Petyayan-Vara area of the Devonian (ca. 370 Ma) alkaline-ultramafic carbonatite complex Vuoriyarvi, located in Kola region (NW Russia; N 66°47', E 30°05'), hosts abundant REE-Sr-Ba-rich magnesiocarbonatite veins. Magnesiocarbonatites containing burbankite are primary magmatic (Figure 1a). These rocks underwent alterations during several magmatic-metasomatic events, which resulted in the formation of other varieties of carbonatites, including ancylite-dominant and bastnäsite-dominant magnesiocarbonatites (ores) (Figures 1b,c). We studied the Sr-Nd-C-O isotopic characteristics of both the most common varieties of carbonatites of the Petyayan-Vara area and calciocarbonatites (søvites) of its nearest surroundings.

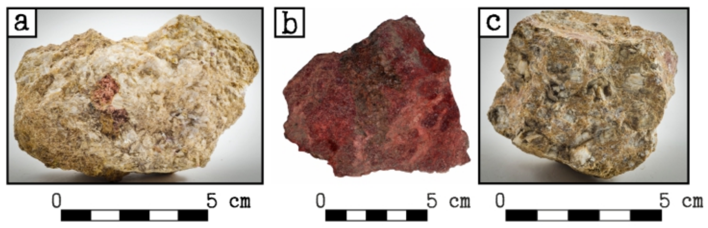


Figure 1. Some varieties of Petyayan-Vara carbonatites: (a) Magnesiocarbonatites containing burbankite; (b) "Ancylite ores"; (c) "Bastnäsite ores"

## RESULTS

The isotopic composition of the least altered magnesiocarbonatites ($\varepsilon Sr_{370}$=-13.9, $\varepsilon Nd_{370}$=5.2, $\delta^{13}C_{PDB}$=-3.8‰, $\delta^{18}O_{SMOW}$=9.9‰) is close to that of søvites ($\varepsilon Sr_{370}$=-13.5±0.1, $\varepsilon Nd_{370}$=4.95±0.05, $\delta^{13}C_{PDB}$=-3.85±0.25‰, $\delta^{18}O_{SMOW}$=7.9±0.7‰) (Figures 2a,b). Analysis of other Petyayan-Vara carbonatites (including ancylite and bastnäsite ores) showed wide variations in signatures of all studied isotopic systematics. All altered carbonatites are enriched with crustal strontium ($\varepsilon Sr_{370}$ of -12.8 to -2.0), and an increase in $\varepsilon Sr_{370}$ is accompanied by an increase in the content of heavy isotopes of carbon (up to -1.0‰) and oxygen (up to 23.8‰). Most Petyayan-Vara carbonatites (including ancylite ores) have close values of $\varepsilon Nd_{370}$=5.1±0.2. Isochron dating based on the figurative points of these rocks yielded an age of 365 Ma (Figure 2c), indicating that the Sm-Nd radiogenic isotope system in the studied samples was unperturbed after carbonatites were crystallized. The similarity of the obtained $\varepsilon Nd_{370}$ value with estimates of this parameter for different (both carbonate and silicate) rocks of the Vuoriyarvi complex (Balaganskaya et al., 2001) indicates the isotopic homogeneity of the mantle source and its small contamination with the crustal material. Samples with a disturbed Sm-Nd system ($\varepsilon Nd_{370}$ of -1.1 to 4.7) have petrographic signs of alterations during later processes (e.g., superimposed silicification, crystallization of the late strontianite, etc.). Bastnäsite ores also exhibit severely disturbed Sm-Nd system ($\varepsilon Nd_{370}$=2.9). The change in $\varepsilon Nd_{370}$ can be explained by either (1) an addition of crustal Nd or (2) chemical fractionation of Sm and Nd during events that occurred much later than the crystallization of Petyayan-Vara carbonatites.

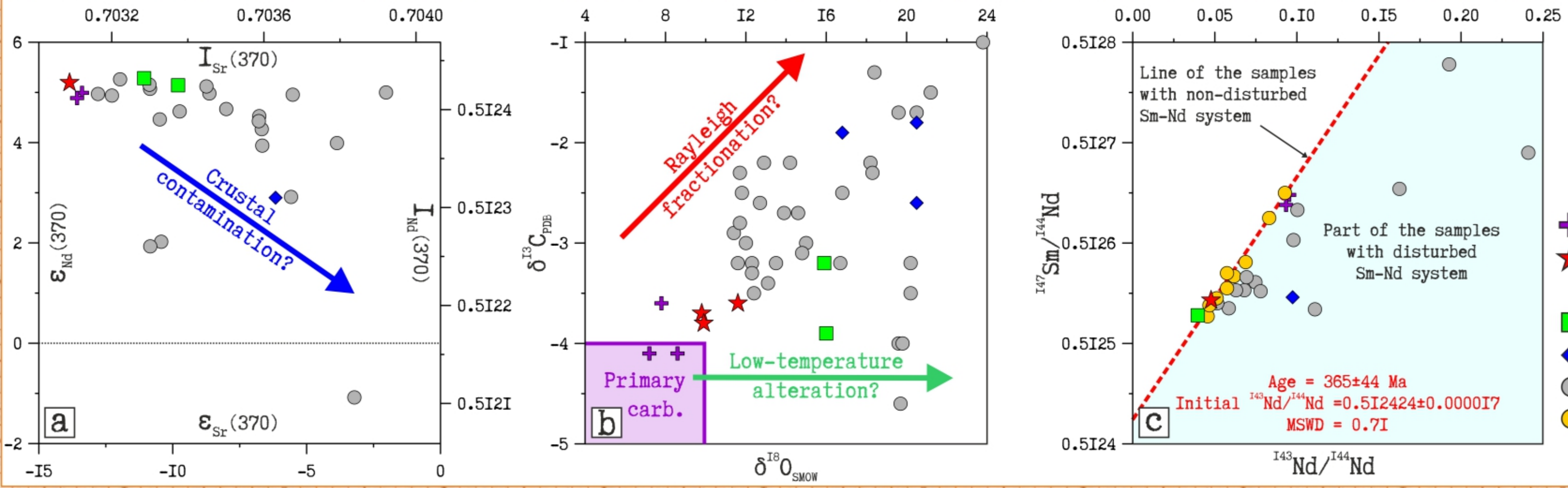


Figure 2. The isotopic composition of Petyayan-Vara carbonatites:
(a) $\varepsilon Nd_{370}$-$\varepsilon Sr_{370}$;
(b) $\delta^{13}C_{PDB}$-$\delta^{18}O_{SMOW}$, ‰;
(c) $^{147}Sm/^{144}Nd$-$^{143}Nd/^{144}Nd$.

Legend:
- Calciocarbonatites;
- Magnesiocarbonatites containing burbankite;
- "Ancylite ores";
- "Bastnäsite ores";
- Other carbonatites;
- The samples used to construct the isochrons in Figure (c)

## CONCLUSION

1) The burbankite-containing magnesiocarbonatites are primarily igneous rocks and have the same isotopic signatures as other igneous rocks of the massif (including primitive calciocarbonatites);
2) Ancylite ores formed at the late magmatic stage of the massif and did not undergo later restructuring of the Sr-Nd system;
3) Bastnäsite ores are the products of post-magmatic processes that caused the remobilization and redeposition of REEs.

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