Geochemistry of the komatiite-tholeiite rock association in the vedlozero-segozero archean greenstone belt, Central Karelia

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Doklady Earth Sciences, Vol. 369, No. 8, 1999, pp. 1204–1206. Translated from Doklady Akademii Nauk, Vol. 369, No. 2, 1999, pp. 261–263.

Geochemistry and Sm–Nd Systematics of the Archean Komatiitic–Tholeiitic Associations of the Vedlozero–Segozero Greenstone Belt, Central Karelia

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Presented by Academician O.A. Bogatikov December 23, 1997

Received December 29, 1997

The komatiitic–tholeiitic associations are characteristic of the Archean greenstone belt sequences of Karelia and serve as an important source of information on geodynamic and physicochemical conditions of magma generation in these ancient structures.

The Vedlozero–Segozero greenstone belt is located in Central Karelia and is submeridionally traced from Lake Vedlozero to Lake Segozero over a distance of 300 km; its width ranges from 50 to 60 km. The Lopian volcano sedimentary rocks within the belt are developed in several local structures (Khautaavara, Koikary, Palasel'ga, Semchen, Sovdozero, and others), which form subparallel zones separated by granite gneiss microblocks. As geophysical data indicate, the Vedlozero–Segozero greenstone belt is confined to the Khautavaara–Koikary mobile permeable zone, which divides the Karelian megablock into the Central Karelian and Onega segments [2].

The Koikary sequence consists of a komatiitic–tholeiitic association (2800 m thick) ascribed to the Pitkilampa Formation, which is overlain by acid volcanics and terrigenous rocks (about 900 m thick) of the Kivilampa Formation. The Palasel'ga structure consists of komatiitic–tholeiitic rocks (up to 1500–1800 m thick) of the Pitkilampa (Koikary) Formation. The upper age limit of the considered volcanics of 2935 ± 20 Ma was

Sm–Nd whole-rock data and rock description

Sample no.	Rock	Sm, ppm	Nd, ppm	$^{147}Sm/^{144}Nd$	$^{143}Nd/^{144}Nd$	$2m$	ε_{Nd} (2940)
Komatiitic–tholeiitic association of the Palasel'ga structure							
5410-6	PK, flow top	0.30	0.75	0.2449	0.513603	21	0.5
275-16	PK, cumulative zone	0.38	0.95	0.2414	0.513395	15	–2.3
60-8a	PxK, spinifex texture	0.82	2.18	0.2268	0.513297	13	1.4
60-9	PxK, spinifex texture	0.83	2.16	0.2319	0.513340	20	0.3
5460-5	B, from chilled zone the in pillow	5.97	27.87	0.1295	0.511430	10	1.8
5414-1	flow top	5.04	24.25	0.1256	0.511321	10	1.2
Komatiitic–tholeiitic association of the Koikary structure							
9-50	PxK, spinifex texture	1.15	3.04	0.2291	0.513343	10	1.4
350-61	PxK, spinifex texture	0.87	2.33	0.2243	0.513256	13	1.5
90-1	PxK, massive top	0.83	2.30	0.2176	0.513288	12	4.7
2-1	PxK, spinifex texture	0.78	2.02	0.2322	0.513424	22	1.8
847-1	Mg-B, massive bottom	1.37	4.35	0.1898	0.512573	11	1.3
849-1	Mg-B, massive top	1.64	5.20	0.1910	0.512624	10	1.8

Note: (PK) peridotite komatiites, (PxK) pyroxenite komatiites, (B) basalts, (Mg-B) high-Mg basalts

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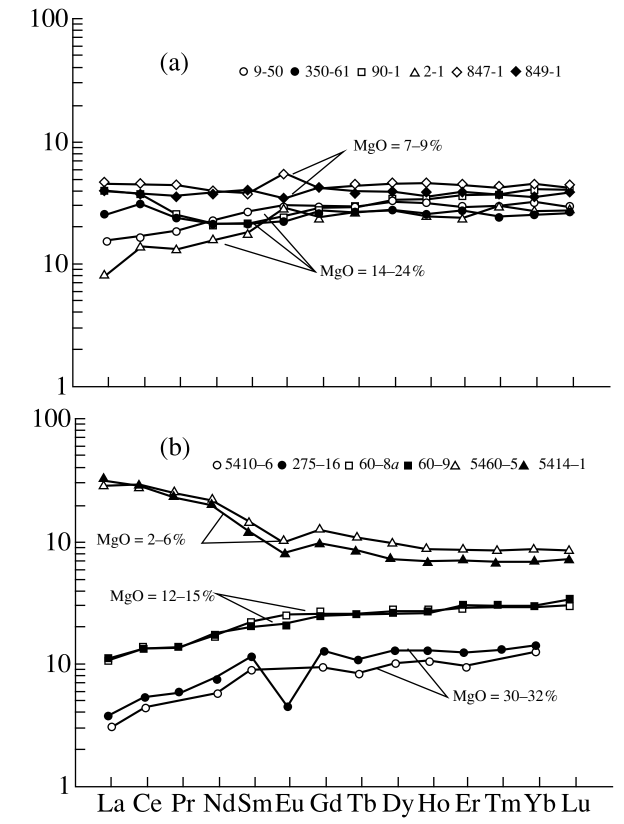

Fig. 1. Primitive mantle-normalized [8] REE in komatiitic associations of the (a) Koikary and (b) Palasel'ga Vedlozero–Segozero greenstone belt.

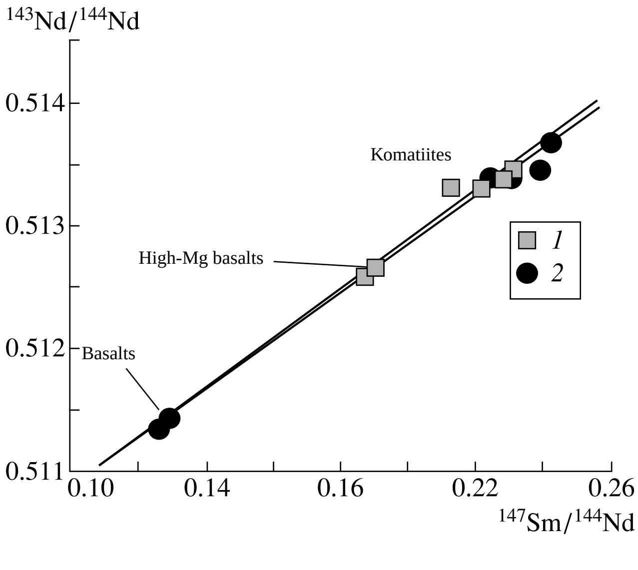

Fig. 2. Sm–Nd evolution diagram for komatiitic associations of the Vedlozero–Segozero greenstone belt. (*1*) Koikary structure (2944 ± 170 Ma, ε_{Nd} = + 1.7, MSWD = 2, n = 5), (*2*) Palasel'ga structure (2893 ± 110 Ma, ε_{Nd} = + 1.2, MSWD = 7, n = 5).

obtained by the U–Pb zircon method for dacite dikes [1, 4].

The Vedlozero–Segozero greenstone belt was regionally metamorphosed under greenschist to amphibolite (baric-type andalusite–sillimanite) facies during the main (Rebolian) tectonic stage [3]. As a result, the primary magmatic mineral assemblage was replaced. However, the relics of primary textural (spinifex, cumulate) and structural features are preserved (pillow, massive, differentiated, and variolitic lavas and tuffs can be recognized).

We studied 12 samples of basalts and komatiites collected from various stratigraphic levels of the Koikary and Palasel'ga komatiitic–tholeiitic series. Highly metasomatized samples were excluded. Geochemical analysis was carried out in the Laboratory of Geological Survey of Finland, Espoo. Contents of major elements, as well as Cr, Ni, Sc, V, Cu, Pb, Zn, Bi, Mo, S, As, Rb, Ba, Sr, Ga, Nb, Zr, Y, Th, U were determined with the XRF method using a sequential Phillips PW1480 X-ray spectrometer. Errors are estimated as follows: < 2% for elements in concentrations greater than 0.5 wt%; 5% for concentrations less than 30 ppm; 3% for concentrations greater than 30 ppm. REE concentrations were measured using the ICP–MS method with an accuracy better than 3%. Samples for the Sm–Nd isotope analysis were carried out using the following technique described in [7]. The measurements were made with a VG sector 54 mass-spectrometer. The accuracy of $^{147}Sm/^{144}Nd$ was no worse than 0.4%. The $^{143}Nd/^{144}Nd$ isotope ratio was normalized to $^{146}Nd/^{144}Nd$ = 0.7219. The measured value of the La Jolla standard was $^{143}Nd/^{144}Nd$ = 0.511851 ± 6 (n = 15). The isochron calculations were done using the ISOPLOT program.

The high-Mg volcanics of the Vedlozero–Segozero greenstone belt may be chemically divided into high-Mg basalts (high-Mg tholeiites in the cation system Al_2O_3–MgO–FeO_{tot} + TiO_2), basaltic, pyroxenite, and peridotite komatiites. The MgO content ranges from 3–8% in basaltic lavas to 30–32% in cumulative peridotite komatiites. The TiO_2 content varies between 0.1 and 0.9% in komatiites and 0.8 and 1.5% in basalts. Based on characteristic ratios Al_2O_3/TiO_2 (13–25), CaO/Al_2O_3 (<1), these volcanics may be ascribed to Munro type [5] Al-undepleted rocks. This assumption is consistent with the chondritic HREE pattern at 0.9–2 mantle values (Fig. 1).

The Sm–Nd data are listed in the table. The ε_{Nd} value was calculated to an age of 2940 Ma. For the Palasel'ga structure, the LREE-depleted and highly LREE-enriched basalts were analyzed. All but one (sample 275-16) of the komatiitic samples have positive ε_{Nd} values. Decrease of ε_{Nd} values may be explained by REE migration during Proterozoic tectonometamorphic activation, as was mentioned for the komatiites of Eastern Finland [6, 9].

Similarly, an analyzed sampling of Koikary volcanics with calculated ε_{Nd} = + 1.7 (2940 Ma) contains one sample (90-1) with a highly increased ε_{Nd} = + 4.7 and CaO content of only 0.56%. It is also noteworthy that the Koikary high-Mg basalts (chondritic LREE pattern) and Palasel'ga basalts (LREE-enriched pattern) show similar ε_{Nd} values (from + 1.2 to + 1.8) (table).

The calculated age of Palasel'ga komatiitic association (5 samples excluding sample 275-16) equals 2893 ± 110 Ma (ε_{Nd} = +1.2, MSWD = 7). The calculated age of Koikary volcanics (5 samples excluding 90-1) is 2944 ± 170 Ma (ε_{Nd} = + 1.7, MSWD = 2) (Fig. 2). It should be noted that stratigraphic data confirm calculations suggesting that basaltic and komatiitic magmas are comagmatic and coeval. However, the LREE pattern in the basalts and komatiites of the Palasel'ga structure (Fig. 1) may be interpreted as a result of possible crustal contamination of basaltic magma, which is evidenced by higher contents of Y (26–32), Zr (222–245), Sr (169–226), Ba (383–509), and Rb (56–156), as well as SiO_2. In spite of a high error in Sm–Nd age determination, the results may be considered reliable if we also have age limitation obtained by other methods.

The age of komatiitic–tholeiitic associations of the Vedlozero–Segozero greenstone belt may be estimated using calculations on 10 volcanics from both structures (excluding samples with anomalous ε_{Nd}). In this case, we obtain an age of 2921 ± 55 Ma (ε_{Nd} = + 1.5, MSWD = 5), which is well correlated with age determinations for dacite dikes with ages of 2860 ± 15 Ma [4] and 2935 ± 20 Ma [1].

The parental komatiitic magmas (peridotite komatiites) of the Vedlozero–Segozero greenstone belt may be generated owing to the high-degree of partial melting (>45%) of mantle lherzolite at P ~ 40 kbar (without liquidus garnet) from a single enriched (OIB-type) mantle source.

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