

## Archean Age of Miaskite Lamproites from the Panozero Complex, Karelia

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Ultrapotassic bodies classed with miaskite lamproite [3] were found within the Archean Panozero magmatic complex [1, 2] on the southwestern coast of Lake Segozero, Central Karelia (Fig. 1). The tectonic contacts of these bodies with host rocks make it impossible to determine their geological age and relations with the rocks of the Panozero Complex.

The ages of previously studied ultrapotassic rocks are no older than Proterozoic. Compositionally close rocks were described only in the Udoks layered intrusion [4]. Up to now, only nepheline syenites and carbonatites were known among Archean alkaline rocks [5, 6]. In this context, the isotope dating of the ultrapotassic rocks of the Panozero Complex is of special interest, because the data obtained may expand the age interval of potassic alkaline magmatism in the Early Precambrian.

Based on the chemical composition ( $K_2O > 3\%$ ;  $MgO > 3\%$ ;  $K_2/Na_2O > 2$ ;  $CaO, Al_2O_3, FeO < 10\%$ ), the studied rocks can be ascribed to the ultrapotassic rocks of Group I (lamproites) according to the Foley classification [7]. The Panozero lamproites are chemically close to the Phanerozoic lamproites of Aldan [3]. Unlike lamproites of Australia and some other regions, both these lamproites have an alumina/alkali ratio higher than the boundary values for agpaitic lamproites and can be ascribed to the miaskite type [3].

The Panozero miaskite lamproites form small (2–4 m across) equant and lenslike bodies arranged as chains in the zone of deformed mafic rocks (Fig. 1). They have tectonic contacts with mafic rocks and are intruded by monzonites with an age of  $2741 \pm 21$  Ma [2]. The lamproites have a specific ocellar structure, and the ground-

mass includes zoned ocelli a few centimeters in size with a carbonate core. The Panozero lamproites differ from other mafic phases of the Panozero Complex in the presence of tremolite and barite; the absence of plagioclase; high mg# ( $MgO/(MgO + FeO)$ , mol. % = 0.70–0.78; high Cr contents (>1500 ppm); relatively low Sr contents;  $K_2O/Na_2O > 3$ ; and high contents of Ba, LREE, and  $P_2O_5$ . Sample 8/52 used for zircon dating shows  $K_2O/Na_2O = 3.5$ ,  $K_2O/Al_2O_3 = 0.51$ , and  $(K_2O + Na_2O)/Al_2O_3 = 0.65$  (mol. %).

Zircons were extracted in NATI Research JSC using the ppm-mineralogy technology [8] from the tectonic lens of miaskite lamproite (Fig. 1, sample 8/52). U–Pb analyses were made on a SHRIMP-II ion microprobe at the Center of Isotope Research of the All-Russia Geological Institute following the conventional technique [9, 10] with secondary electron multiplier by scanning for mass peaks. The beam of primary  $O_2^-$  ions was  $27 \times 20$   $\mu m$  in size (intensity  $\sim 8nA$ ). The ion source and collector slits were 80  $\mu m$  and S 100  $\mu m$ , respectively, with a mass resolution of  $M/\Delta M > 5200$  (per 254 AMU), isobaric superposition excluded.

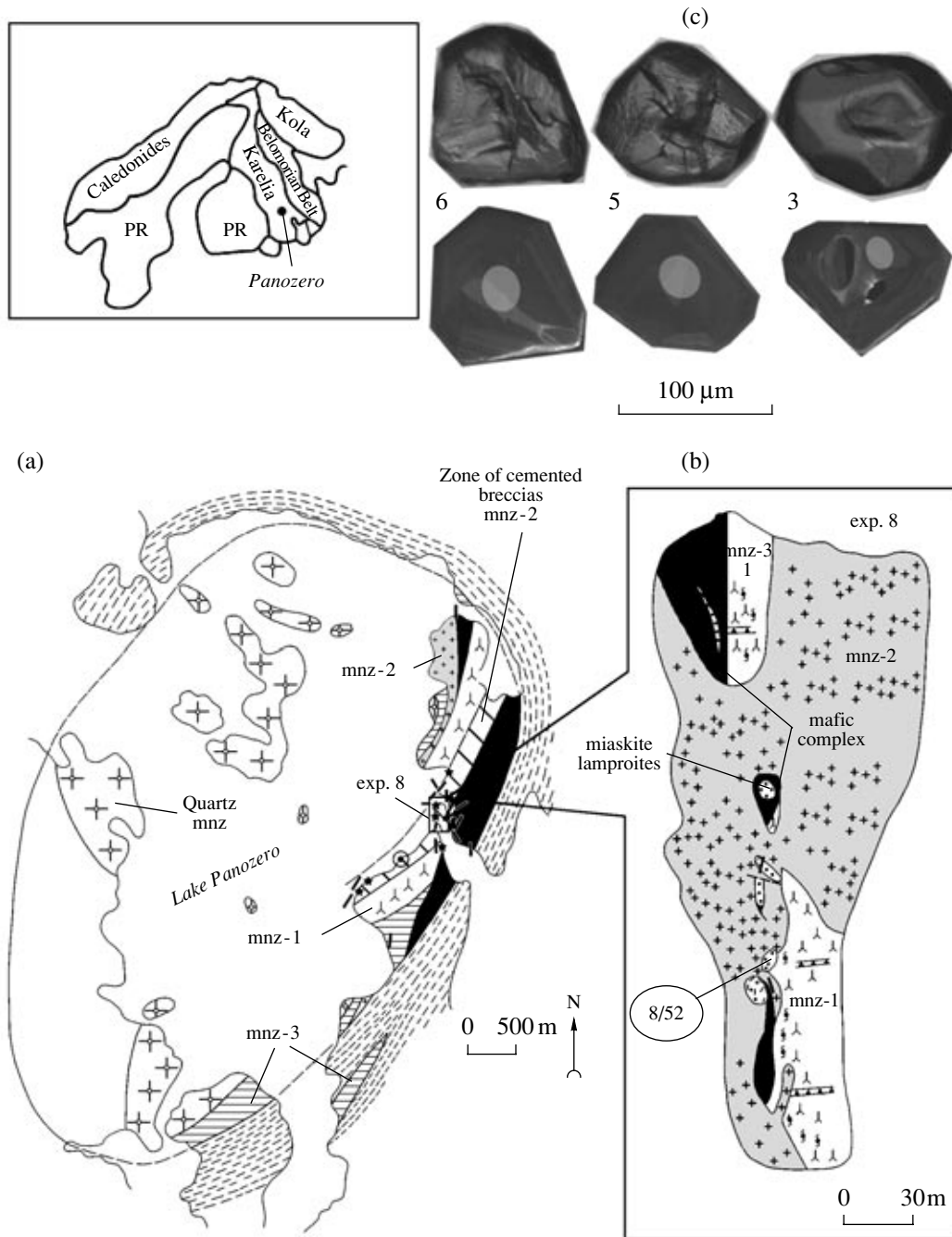
Zircons, including 91 500 [11] and Temora [12] standards were placed in an epoxy resin, polished down to half section, and examined with optical microscopy and cathodoluminescence (CL).

The analysis involved measurement of 4–5 spectra by the following masses:  $^{196}(Zr_2O)$ ,  $^{204}Pb$  10, background ( $\sim 204.2$  AMU),  $^{206}Pb$ ,  $^{207}Pb$ ,  $^{208}Pb$ ,  $^{238}U$ ,  $^{248}ThO$ , and  $^{254}Uo$ . Each fourth measurement was made on the Temora standard. The obtained results were processed with the SQUID v. 1.12 and ISOPLOT/Ex 3.22 programs [13]. Nonradiogenic lead was corrected with measured  $^{204}Pb$  using model [14].

*Zircon characteristics.* Zircon crystals are dominated by large (100–200  $\mu m$ ) transparent and semi-transparent sub- and euhedral crystals and their fragments (Fig. 1c). The grains have an intense violet-brown color. Prismatic faces are mainly suppressed (elongation coefficient 1–1.5). Long-prismatic zircons

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**Fig. 1.** Geological map of the Panozero Massif (a) and position of miaskite lamprophyre bodies in the mafic zone; (b) geological map of the island (exposure 8). In the Panozero map (a, b): black is layered mafic–ultramafic complex, (mnz-1, mnz-2, and mnz-3) monzonites of phases 1, 2, and 3, respectively; (c) zircons from the studied rocks: upper set demonstrates zircons in transmitted light, the lower set is cathodoluminescent images. Numbers correspond to analysis number in table.

(elongation coefficient 3–4) are rare. Pyramidal (tetragonal and ditetragonal) forms are predominant. The faces are smoothed, with no traces of abrasion or resorption. Grains are fissured with no inclusions. Cathodoluminescent images revealed the predominance of wide-band concentric and sectorial growth zoning. Thin zoning is less common (Fig. 1c). Some grains demonstrate discontinuity between zoning of the core and periphery, with bright CL rims, attesting to

the presence of either inherited cores or partial resorption during crystallization.

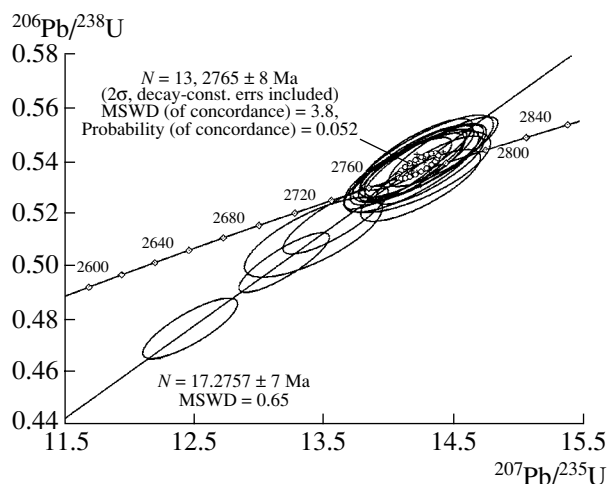
The morphology revealed suggests the magmatic origin of the zircon. The suppression of prismatic faces presumably results from elevated alkalinity of the crystallization environment [15]. The CL pattern is similar to that of zircons from intermediate and basic rocks (for example, TEMORA zircons).

## Results of U–Pb single grain dating of zircon from lamproites of the Panozero Complex (sample 8/52-05)

Analyt. point	$^{206}\text{Pb}_c$ , %	U, ppm	Th, ppm	$\frac{^{232}\text{Th}}{^{238}\text{U}}$	$^{206}\text{Pb}^*$ , ppm	Age $\frac{^{206}\text{Pb}}{^{238}\text{U}}$ , Ma	Age $\frac{^{207}\text{Pb}}{^{206}\text{Pb}}$ , Ma	D, %	$\frac{^{207}\text{Pb}^*}{^{235}\text{U}}$	±, %	$\frac{^{206}\text{Pb}^*}{^{238}\text{U}}$	±, %	Rho
3.1	0.17	146	149	1.05	60.1	2512 ± 20	2741 ± 11	9	12.47	1.2	0.4766	1.0	0.816
5.1	0.06	94	88	0.96	43.9	2793 ± 23	2744 ± 12	-2	14.23	1.2	0.5424	1.0	0.815
2.1	0.11	120	122	1.04	53.6	2689 ± 22	2747 ± 11	2	13.60	1.2	0.5176	1.0	0.833
4.1A	0.33	71	63	0.91	31.5	2661 ± 26	2747 ± 18	3	13.43	1.6	0.5110	1.2	0.744
9.1	0.02	124	180	1.50	57.0	2764 ± 23	2749 ± 11	-1	14.08	1.2	0.5353	1.0	0.850
1.1	0.21	175	120	0.71	75.5	2620 ± 20	2750 ± 9	5	13.20	1.1	0.5015	0.9	0.849
11.1	0.10	96	131	1.41	44.8	2783 ± 23	2752 ± 12	-1	14.23	1.3	0.5398	1.0	0.809
6.1	0.07	125	172	1.42	58.0	2776 ± 23	2753 ± 11	-1	14.20	1.2	0.5383	1.0	0.845
8.1	0.05	91	115	1.29	42.2	2770 ± 23	2753 ± 12	-1	14.16	1.3	0.5368	1.0	0.809
12.2	0.06	82	106	1.35	37.9	2787 ± 28	2755 ± 15	-1	14.28	1.6	0.5408	1.2	0.799
12.1	0.08	89	86	1.00	40.9	2767 ± 27	2759 ± 15	0	14.19	1.5	0.5362	1.2	0.797
13.1	0.15	115	101	0.91	53.5	2784 ± 24	2759 ± 14	-1	14.29	1.3	0.5401	1.1	0.780
10.1	0.11	101	150	1.54	46.9	2781 ± 24	2760 ± 12	-1	14.29	1.3	0.5393	1.1	0.822
7.1	0.03	112	159	1.47	52.2	2798 ± 22	2765 ± 11	-1	14.43	1.2	0.5434	1.0	0.829
14.1	0.26	75	75	1.03	34.6	2765 ± 26	2765 ± 19	0	14.23	1.6	0.5357	1.2	0.720
4.1	0.06	113	140	1.28	52.1	2769 ± 22	2774 ± 11	0	14.33	1.2	0.5365	1.0	0.828
14.2	0.12	130	187	1.48	59.4	2744 ± 23	2784 ± 13	1	14.26	1.3	0.5307	1.0	0.787

Note: Errors are given at 1 $\sigma$  level; ( $\text{Pb}_c$ ,  $\text{Pb}^*$ ) nonradiogenic and radiogenic lead, respectively; 1 $\sigma$  error of standard calibration is 0.32%; isotope ratios were corrected for measured  $^{204}\text{Pb}$ . D, % discordance:  $D = 100 * \{ [\text{Age}(^{207}/_{206}) / \text{Age}(^{206}/_{238})] - 1 \}$ .

**Results of U–Pb local analysis.** Fourteen zircons were analyzed in 17 points. The least altered central parts of the grains were analyzed. The results are shown in the table and Fig. 2. All analyzed zircons show moderate contents of U (70–175 ppm) and elevated Th/U values (1.0–1.5). Similar Th/U values were obtained for zircons from different rocks of the Panozero Massif [1, 2].



**Fig. 2.** Position of analyzed zircons in the concordia diagram.

Data points of 13 analyses form a concordant cluster, while the four remaining points are insignificantly discordant (3–9%). Concordant age on 13 analyses is  $2765 \pm 8$  Ma (MSWD = 3.8) and coincides within the error limit with the upper intercept age of  $2757 \pm 7$  Ma (MSWD = 0.65) obtained on all 17 analyses. Zones of discordant zoning found by CL in the central parts (points 12.2, 14.1, and 14.2) are similar in age, indicating the absence of an inherited component. The results obtained unambiguously suggest the Late Archean age of magmatic crystallization of the studied zircons.

The obtained Archean age of miaskite lamproites of Karelia is of great significance. First, the discovery of ultrapotassic rocks in the Archean significantly promotes understanding of the magmatic evolution and, primarily, mantle alkaline magmatism. Second, study of Archean lamproites, derivatives of the enriched mantle, is the key for understanding metasomatism of the Archean mantle, since the dating obtained rules out the influence of later mantle processes on this rock.

The study of similar rocks is of practical interest, because Phanerozoic lamproites of Australia are diamondiferous rocks. Lamprophyre dikes with diamond contents exceeding those in kimberlites were recently found in Canada. Compositionally similar dikes of Proterozoic diamond-bearing lamprophyres were also found in Greenland.

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