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GEOLOGY

U–Pb Zircon Dating of Rocks of the Platiniferous Fedorova–Pana Layered Massif, Kola Peninsula

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The Proterozoic Fedorova–Pana Massif is one of Russia's most promising targets for low-sulfide PGE ores [1, 2].

The Fedorova–Pana Massif (~400 km^2 in area) located in the central Kola Peninsula belongs to the Northern belt of pyroxenite–gabbronorite PGE-bearing intrusions. The massif is confined to the junction of the Archean Keivy and Kola–Norwegian blocks in the north and Early Proterozoic Imandra–Varzuga structure in the south [3]. The Fedorova–Pana Massif (Fig. 1) incorporates the Fedorova, Lastjavr, Western Pana, and Eastern Pana blocks. The three latter blocks include "stratigraphic" (taxitic gabbronorite, norite, gabbronorite–gabbro) zones [4] with the ore-bearing Upper (ULH) and Lower (LLH) layered horizons. Unlike other blocks, the Fedorova block lacks the ore-bearing horizons.

Previous U–Pb zircon and baddeleyite datings yielded the following results: 2491 ± 1.5 and 2501 ± 1.7 Ma for gabbronorite from LLH, 2470 ± 9 Ma for pegmatite gabbronorite from LLH, as well as 2498 ± 5 Ma for magnetite gabbros and 2447 ± 12 Ma for anorthosites from ULH [5, 6]. These data were used to distinguish the following magmatic phases: the major gabbronorite phase (2501–2491 Ma), the final phase (2470 Ma), and the young (anorthosite) phase (2447 ± 12 Ma) [5].

Further research was aimed at refining the ages of the norites and gabbronorites of the Western Pana block and obtaining new data for the rocks of the Fedorova block (orthopyroxenites, gabbro, and norites enclosing Cu–Ni and Pt–Pd ores).

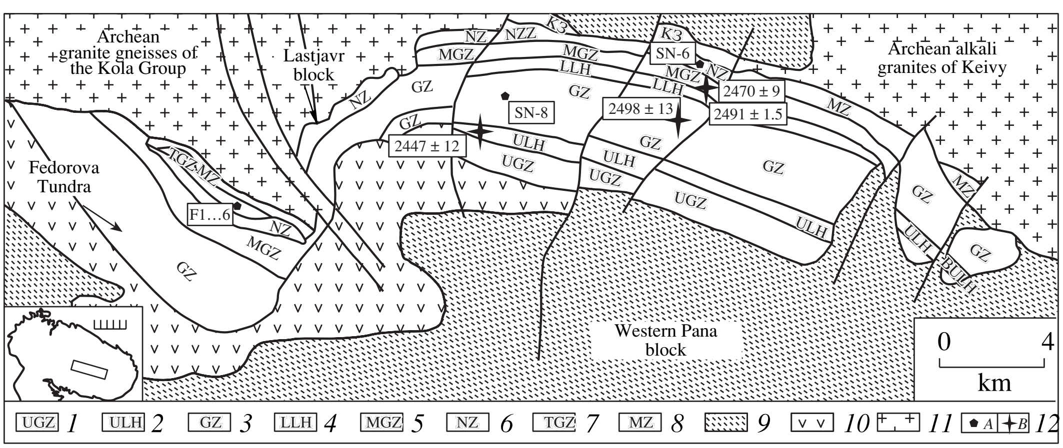

Fig. 1. Geological scheme of the platiniferous Fedorova–Pana layered massif [4]. (*1*) Upper gabbronorite zone; (*2*) upper layered horizon, (*3*) gabbro zone, (*4*) lower layered horizon; (*5*) major gabbronorite zone; (*6*) norite zone; (*7*) taxitic gabbronorite zone; (*8*) marginal zone; (*9*) glacial moraine, (*10*) volcanic rocks of the Imandra–Varzuga structure; (*11*) Archean granite gneisses; (*12*) sampling sites: (*A*) new samples, (*B*) previously dated samples [5, 6].

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Isotope U–Pb zircon data on the rocks of the Fedorova–Pana Massif

No.	Weight, mg	Content, ppm		Pb isotope composition*			Isotope ratios and age, Ma**			*Rho****
		Pb	U	$^{206}Pb/^{204}Pb$	$^{206}Pb/^{207}Pb$	$^{206}Pb/^{208}Pb$	$^{207}Pb/^{235}U$	$^{206}Pb/^{238}U$	$^{207}Pb/^{206}Pb$	
Gabbronorite (SN-8)										
1	0.65	287.1	427.9	746	5.5155	2.2467	10.6619	0.46941	2505	0.71
2	0.55	265.1	394.2	1365	5.7765	2.0557	10.5105	0.46506	2496	0.73
3	0.80	273.2	410.6	2212	5.9155	2.0701	10.4544	0.46413	2490	0.74
Norite (SN-6)										
1	1.15	258.9	394.7	2071	5.8776	2.0621	10.3265	0.45648	2498	0.81
2	1.30	220.3	315.1	1454	5.7840	1.6671	10.2531	0.45272	2500	0.73
3	1.50	252.9	366.4	2259	5.9108	1.7031	10.2158	0.45283	2493	0.81
4	0.90	198.6	303.4	1045	5.6771	1.8809	9.9219	0.43843	2499	0.73
Norite (F-2)										
1	0.30	498.0	833.4	2081	5.9502	2.2111	9.49201	0.42493	2477	0.71
2	0.65	513.8	932.2	5274	6.1519	2.6371	9.1373	0.41378	2458	0.73
3	0.55	583.2	999.3	3194	6.1132	2.0528	8.9869	0.40832	2452	0.72
4	0.80	622.5	1134.5	4114	6.1161	2.1914	8.6638	0.39165	2460	0.71
Gabbro (F-4)										
1	1.80	725.3	1322.8	14649	6.1121	3.8177	10.0132	0.44622	2484	0.75
2	2.00	731.3	1382.8	8781	6.1522	3.5517	9.4306	0.42454	2467	0.74
3	1.95	680.9	1374.0	7155	6.2645	3.6939	8.7401	0.40155	2433	0.78
Orhopyroxenite (F-3)										
1	0.80	374.0	598.6	4588	6.0459	1.9650	9.6782	0.43153	2484	0.91
2	0.85	410.2	630.2	4521	6.0281	1.6592	9.5667	0.42539	2488	0.92
3	1.00	271.0	373.1	2552	5.9916	1.2393	9.4700	0.42406	2476	0.91
4	0.8	48.0	60.9	325	4.9191	1.3039	10.0461	0.44249	2504	0.82

Note: (*) All ratios were corrected for procedure blanks of 0.1 ng (for Pb) and 0.04 ng (for U), and the mass discrimination of 0.12 ± 0.04%; (**) correction for common lead was based on model [12]; (***) *Rho* is the coefficient of correlation on axes.

Zircon separated for isotope dating was studied with a MBS-9 binocular microscope. Its morphological types were distinguished based on crystal habit, faceting, and color. Small zircon fractions for U–Pb isotope dating were hand-picked from various morphological types under binocular microscope. The chemical composition of zircon was studied with a MS-46 Cameca microscope. Zircon for U–Pb precision dating was chemically decomposed at the Laboratory of Geochronology and Geochemistry of Isotopes using technique described in [7]. Isotope measurements were performed on a Finnigan MAT-262 (RPQ) seven-channel mass spectrometer in single-filament mode with a mixed $^{208}Pb/^{235}U$ tracer and silicagel following the technique proposed in [8]. The coordinates of data points and isochron parameters were calculated based on [9, 10] and generally accepted decay constants [11].

Among the samples chosen on the basis of preliminary geological–petrological data, the older rocks are represented by orthopyroxenite (F-3, 42 kg) and gabbro (F-4, 57 kg). The younger rocks are represented by sulfide- and PGE-bearing norites (F-2, 67 kg), norites (SN-6, 60 kg), and gabbronorites (SN-8, 50 kg). Samples F-2, F-3, and F-4 are taken from the Fedorova block; samples SN-6 and SN-8, from the Western Pana block.

The orthopyroxenite sample (F-3) yielded 12 mg of prismatic, dark brown to pink zircon crystals (150–200 μm in size) with thin zoning in immersion liquids and a ZrO_2/HfO_2 ratio of 60–75. Dating was carried out in four morphological types of the zircon (table): (1) dark brown transparent prismatic crystals (200 μm) obtained in the second portion of two-stage dissolution; (2) dark brown transparent prismatic crystals (200 μm in size); (3) light brown prismatic crystals (150 μm); and (4) light pink zircon (150 μm). They yielded the U–Pb zircon age of 2526 ± 6 Ma (Fig. 2), which is interpreted as the crystallization age of the orthopyroxenite. The

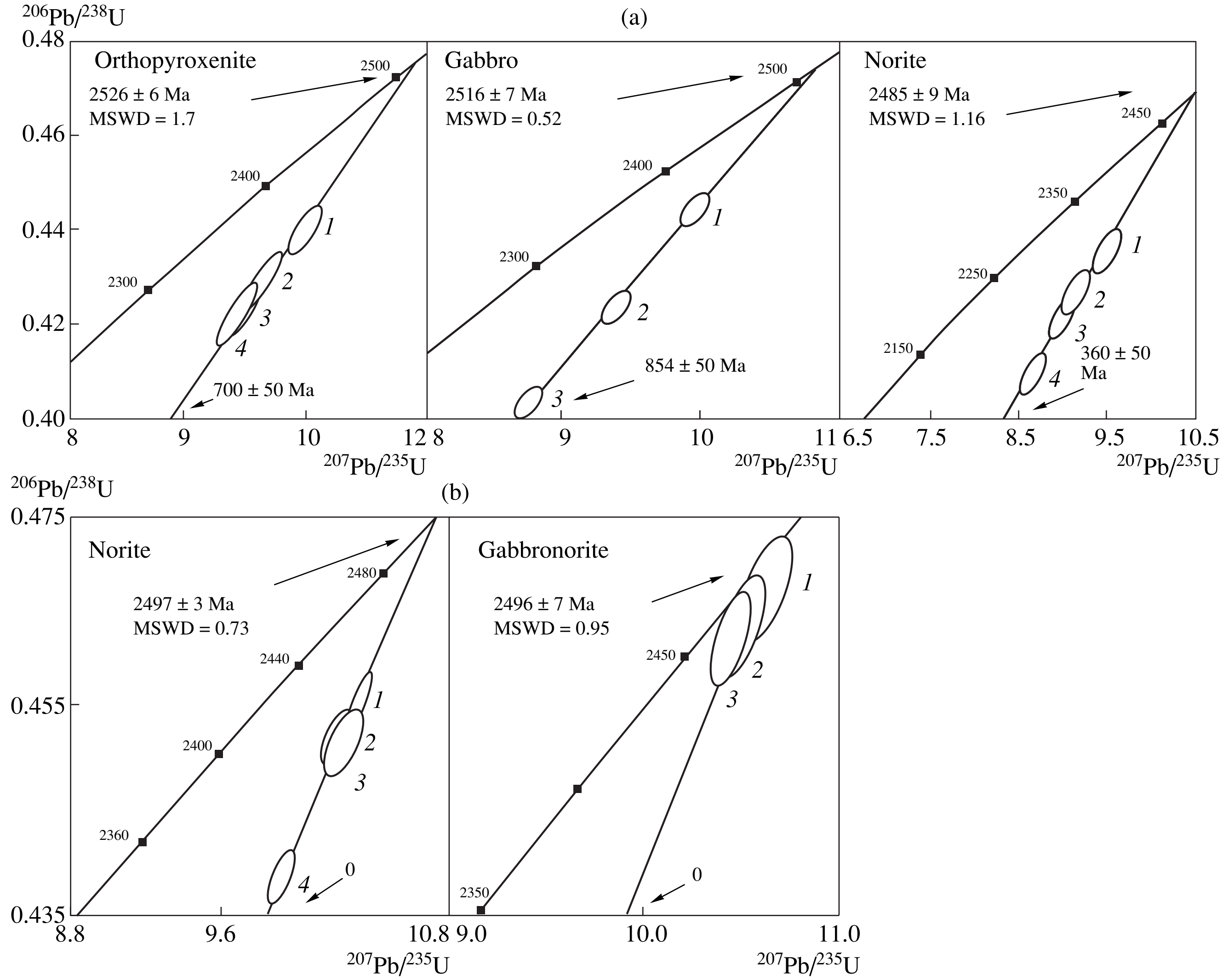

Fig. 2. Concordia U–Pb diagram for the rocks of the (a) Fedorova and (b) Western Pana blocks.

lower interception at 700 ± 50 Ma reflects the Pb loss and disturbance of U–Pb isotope system during Grenville time [13].

The zircon concentrate (110 mg) extracted from the Fedorova Pana gabbro sample (F-4) is represented by dark to light brown prismatic and bipyramidal crystals (200–400 μm) with thin zoning manifested in immersion liquids. The ZrO_2/HfO_2 ratio varies from 43 to 62. U–Pb dating was carried out in three morphological types with adamantine luster (table): (1) dark brown prismatic transparent crystals (350 μm); (2) light brown transparent crystals (200 μm) and their fragments; and (3) light brown opaque fractured crystals (200 μm). Obtained isochron corresponds to an age of 2516 ± 7 Ma (Fig. 2) and presumably reflects the gabbro crystallization time. The lower intercept at 854 ± 50 Ma corresponds to the Grenville orogeny.

The ore norite sample (F-2) yielded 14 mg of bipyramidal prismatic zircon crystals (250–450 μm) with the ZrO_2/HfO_2 ratio varying from 57 to 84. The crystals exhibit a thin zoning in immersion liquid. Isotope dating was carried out in four zircon morphological types (table): (1) light transparent crystals (250 μm); (2) large dark brown prismatic crystals (350 μm); (3) pink fractured crystals (300 μm); and (4) light brown fractured crystals (300 μm). The three-point discordia defines an upper intercept at 2485 ± 9 Ma (Fig. 2), which characterizes the norite crystallization time. The lower intercept at 360 ± 50 Ma corresponds to the Paleozoic tectonomagmatic activation in the northeastern Baltic Shield [13].

The Western Pana norite sample (SN-6, 60 kg) yielded 18 mg of zircon concentrate of brown crystals (150–200 μm) and their fragments with the well-developed faces {110}, {100} and {111}, {221}, and {311}. The ZrO_2/HfO_2 ratio is 48. In immersion liquids, the crystals show thin zoning. Isotope dating was performed in four morphological types. The first and fourth types are represented by light brown crystals

(150 μm) with adamantine luster and their fragments, while the second and third types are represented by dark brown crystals (200 μm) and their fragments. The isochron obtained with an upper intercept at 2497 ± 3 Ma (table, Fig. 2b) is regarded as the norite crystallization time. The lower intercept at zero corresponds to the modern Pb loss.

The Western Pana gabbronorite sample (SN-8, 50 kg) yielded 8 mg of brown zircon crystals (100–150 μm) and their fragments with the faces {110}, {100} and {111}, {221}, and {311}. The crystals have distinct faceting with well-developed faces and thin zoning observed in immersion. The ZrO_2/HfO_2 ratio varies from 55 to 76. We analyzed three types of zircon with adamantine luster (table). The first and second types are large dark brown prismatic crystals (150 μm), while the third type is represented by dark brown prismatic crystals. They yielded a nearly concordant U–Pb zircon age of 2496 ± 7 Ma (Fig. 2b), which is regarded as the gabbronorite crystallization age. The lower intercept at zero indicates the present Pb loss.

Our investigations showed that zircons extracted from the PGE-bearing Fedorova–Pana layered massif for U–Pb isotope dating have a prismatic habit, distinct faceting, thin zonal internal structure in immersion, and a high ZrO_2/HfO_2 ratio, which is typical of the basic magmatic rocks [14]. We have established that orthopyroxenites and gabbros from the main part of the Fedorova block are the oldest rocks (2526–2516 Ma) in the Fedorova–Pana Massif. The second phase (norites and gabbronorites) has an age of 2496–2485 Ma. The third phase produced gabbro pegmatites (2470 ± 9 Ma) and anorthosites (2447 ± 12 Ma). The second and third phases are considered to be associated with long-term multistage scattered and reefal Cu–Ni and Au-bearing PGE (Pt, Pd, Rh) mineralization. Economic-grade reserves of the Fedorova–Pana Massif have been explored at present.

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REFERENCES

1. F. Mitrofanov, V. Smolkin, T. Bayanova, Yu. Neradovsky, et al., *Proceedings of the 9th Platinum Symposium, Billings, United States, 2002* (Billings, 2002), pp. 309–311.
2. F. P. Mitrofanov, *Utilization of Natural Resources in the Euroarctic Region: Experience of 20th Century and Prospects* (Apatity, 2002), pp. 103–108 [in Russian].
3. V. G. Zagorodnyi and A. T. Radchenko, *The Imandra–Varzuga Karelide Zone* (Nauka, Leningrad, 1982), pp. 8–31 [in Russian].
4. D. Schissel, A. A. Tsvetkov, F. P. Mitrofanov, and A. I. Korchagin, Econ. Geol. **97**, 1657 (2002).
5. T. B. Bayanova, *Age of Reference Geological Complexes of the Kola Region and Duration of Magmatism* (Nauka, St. Petersburg, 2004) [in Russian].
6. Yu. Amelin, L. M. Heaman, and V. S. Semenov, Precambrian Res. **75**, 31 (1995).
7. T. E. Krogh, Geochim. Cosmochim. Acta **37**, 485 (1973).
8. U. Scharer, T. E. Krogh, and C. F. Gower, Contrib. Mineral. Petrol. **94**, 438 (1986).
9. K. R. Ludwig, US Geol. Surv. Open-File Rep., No. 88-542 (1991).
10. K. R. Ludwig, Berkley Geochronology Center, Spec. Publ. 1a (1999).
11. R. H. Steiger and E. Jager, Earth Planet. Sci. Lett. **36**, 359 (1977).
12. J. S. Stacey and J. D. Kramers, Earth Planet. Sci. Lett. **26**, 207 (1975).
13. F. P. Mitrofanov, T. B. Bayanova, N. L. Balabonin, et al., Vest. St. Peterb. Gos. Univ. Ser. 7, Issue 3, No. 21, 5 (1997).
14. A. I. Tugarinov, E. E. Vainshtein, and I. D. Shevaleevskii, Geokhimiya, No. 4, 28 (1956).