

Comparison of New U–Pb and Sm–Nd Isotope Data on Rocks of the Early Barren Phase and Basal Ore-Bearing Rocks in the PGE-Bearing Fedorovo–Pana Layered Massif, Kola Peninsula

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Received March 21, 2007

DOI: 10.1134/S1028334X0707032X

The ore-bearing rocks of the Fedorovo–Pana layered massif is a part of the new Kola PGE-bearing province, which is regarded as a promising source of noble metals in Russia [1, 2]. Economic-grade contents of Pd, Pt, Rh, and Au have been established in this massif recently [2, 3]. At present, comprehensive study of these deposits and occurrences is a pressing issue in the geology of the Kola region. In combination with other methods, the isotopic-geochronological and geochemical investigations of rocks and minerals in layered massifs provide insights into processes of rock and ore formation, as well as the metallogeny of separate geological bodies and entire regions with such massifs [4]. The aim of this communication is to compare the results obtained with U–Pb and Sm–Nd methods.

The Fedorovo–Pana massif (about 400 km² in area) is located in the northeastern Baltic Shield within the North (Kola) belt of the layered pyroxenite–gabbro–norite–anorthosite intrusions. These intrusions are characterized by long-term formation 2525 Ma ago and derived from a common mantle reservoir enriched in lithophile elements (based on the REE analysis, $I_{Sr} = 0.702–0.704$ and $\epsilon_{Nd}(T)$ varies from -0.37 to -2.61). The model Sm–Nd characteristics of rock protoliths (T_{DM}), which suggest the age of the mantle reservoir substance, is estimated at ~ 3 Ga [5–7].

The Fedorovo–Pana massif consists of the Fedorovo, Lastjåvr, West Pana, and East Pana blocks, which are now regarded as separate magma chambers [2, 8]. The studied Fedorovo and West Pana blocks, which host synonymous deposits, comprise several “stratigraphic” zones composed of taxitic gabbro–norite,

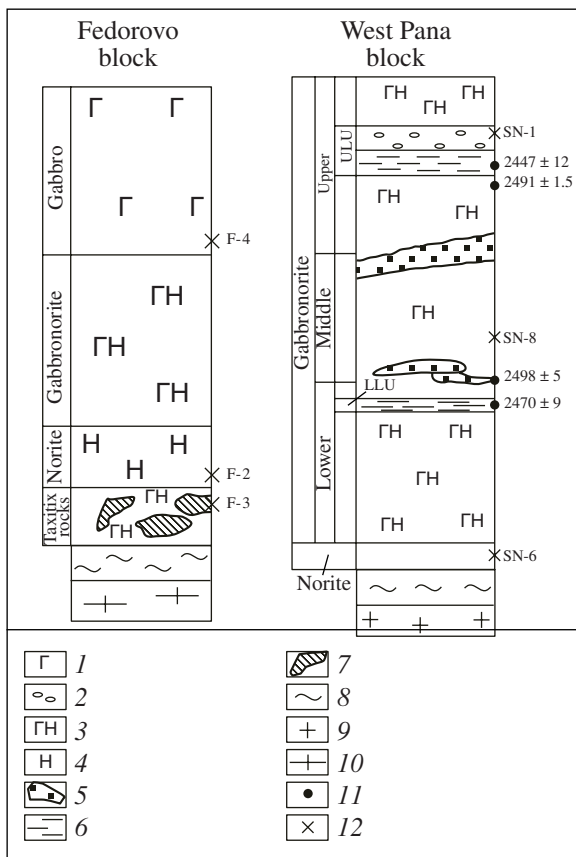
norite, gabbro–norite, and gabbro. Gabbro–norites of the West Pana block host the ore-bearing marginal (norite) zone and the upper (ULU) and lower thin-layered (LLU) units. The Fedorovo block includes the ore-bearing taxitic gabbro–norite and norite zones that contain xenoliths of barren orthopyroxenite.

The following samples have been taken for U–Pb and Sm–Nd dating (figure): the oldest (based on geological and petrological data) barren orthopyroxenite (F-3) xenoliths, gabbro (F-4) from the upper zone, and norite (F-2) with sulfides and PGE mineralization were taken from the Fedorovo block; ore-bearing norite (SN-6) from the marginal zone, gabbro–norite (SN-8) from the central zone, and gabbro–norite (SN-1) from the olivine unit were taken from the West Pana block. The obtained ages are given in the table, and analytical data have been published in [6, 7]. The dating was performed simultaneously by two independent isotopic methods, which sharply differ in the nature of analyzed isotopes, chemical and mass-spectrometric techniques, calculation parameters, and significance of results.

The U–Pb analysis used isochron data on accessory magmatic zircons. The magmatic origin of this mineral in basic rocks is evidenced from the relationship of zircon with baddeleyite (ZrO₂), which is the first zirconium phase crystallized from the melt [9], and cumulative rock-forming minerals. Such magmatic zircons were compared with xenogenic zircons in xenoliths of the Archean country gneisses. The xenogenic zircons are distinguished by the morphology [5, 6] and imperfectness of crystals, lower ZrO₂/HfO₂ values, and Archean U–Pb age (older than 2.8–2.7 Ga in comparison with 2526–2485 Ma obtained for magmatic zircons from basic rocks).

The Sm–Nd dating was carried out only for magmatic minerals of basic rocks (olivine, ortho- and clinopyroxenes, plagioclase). Their isotope data, together with isotope data on whole-rock samples, were consid-

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Schematic geological columns of the Fedorovo and West Pana blocks. (1) Gabbro, (2) olivine unit, (3) gabbronorite, (4) norite, (5) magnetite gabbronorite, (6) rocks of the upper and lower layered units, (7) xenoliths of the early intrusive phase, (8) contact rocks, (9) Archean alkali granite (country rock), (10) Archean gneiss (country rock), (11) samples taken and analyzed before 2003 [5], (12) new data. (ULU) Upper layered unit; (LLU) lower layered unit.

ered for the compilation of isochrons [7]. The Sm–Nd dating of minerals mentioned above is particularly valuable, because this method makes it possible to estimate rapidly the crystallization age of the major mag-

matic minerals rather than zircon, the magmatic origin of which always has to be proved. Of course, the uncertainty of Sm–Nd age estimates (table) is commonly an order of magnitude greater than that of the U–Pb isochron age. However, the Sm–Nd method makes it possible to determine important petrological characteristics, such as $\epsilon_{Nd}(T)$ and T_{DM} . Moreover, the Sm–Nd method also allows us to date the basic rocks, in which the zircon content is very low or insufficient (less than milligrams) for the classic U–Pb method.

Both methods have been used for the study of the oldest (barren) orthopyroxenites (sample F-3) from xenoliths and gabbro (sample F-4) from the upper zone of the Fedorovo block. The results obtained are perfectly concordant: 2526 ± 6 and 2516 ± 7 Ma (U–Pb) and 2521 ± 42 and 2516 ± 35 Ma (Sm–Nd). These data make it possible to assign the initiation of pyroxenite–gabbronorite–anorthosite intrusions in the Kola region to the beginning of the Paleoproterozoic, because the Archean–Proterozoic boundary in this region is accepted at 2550 Ma.

The results obtained with both methods for ore-bearing (Pt, Pd, Ni, Cu) norites from basal units of two blocks (samples F-2 and SN-6) (figure, table) also display a rather good concordance: 2485 ± 9 and 2497 ± 3 (U–Pb) and 2482 ± 36 and 2485 ± 54 Ma (Sm–Nd).

The new data presented above specify phases of the complex and long-term evolution of the Fedorovo–Pana massif: (1) crystallization of barren pyroxenites and gabbros in the Fedorovo magma chamber (2526–2516 Ma ago); (2) crystallization of gabbronorites and gabbros of the main magma chamber in the West Pana block, as well as the early (disseminated) low-grade PGE mineralization and relatively high-grade Cu–Ni sulfide mineralization in the basal sectors of the massif, particularly at the Fedorovo deposit (2501–2497–2485 Ma ago); (3) formation of pegmatoid gabbro anorthosites and PGE-rich ores of the lower layered unit at the Malaya Pana deposit (about 2470 Ma ago) [5] apparently related to fluids derived from pegmatoids; and (4) late anorthosite injections and probably

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Rock	U–Pb zircon age, Ma	Sm–Nd data		
		$\epsilon_{Nd}(t)$	Sm–Nd isochron age, Ma	t_{DM} , Ma;
West Pana block				
Gabbronorite of olivine unit (SN-1)	–	–2.61	2494 ± 36	2976
Gabbronorite of central part (Sn-8)	2496 ± 7	–	–	–
Ore-bearing norite of the marginal zone (SN-6)	2497 ± 3	–0.37	2485 ± 54	2994
Fedorovo block				
Ore-bearing norite (F-2)	2485 ± 9	–2.50	2482 ± 36	3184
Gabbro (F-4)	2516 ± 7	–1.53	2516 ± 35	2935
Orthopyroxenite (F-3)	2526 ± 6	–1.73	2521 ± 42	3045

lenticular segregations of high-grade Pt–Pd ore occurrences in the upper layered unit (about 2450 Ma ago) [5].

ACKNOWLEDGMENTS

This work was supported by the Foundation of the President of the Russian Federation for the Support of Leading Scientific Schools (project no. NSh-1413.2006.5), the Federal Agency on Science and Innovation of the Russian Federation (state contract no. 02.445.11.7403), and the Russian Foundation for Basic Research (project no. 05-05-08-208 and 07-05-00956).

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