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GEOCHEMISTRY

Age of Granitoids in the Man'khambo and Il'yaiz Plutons, the Northern Urals: U–Pb Data

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The Man'khambo and Il'yaiz plutons are situated in the northern Urals at the main divide of the Urals (basins of Shchugor, Ilych, and Severnaya Sos'va rivers). These plutons cut the Upper Riphean–Vendian country rocks [1, 2] and, along with the latter ones, belong to Preuralides of the Central Ural Uplift. The Man'khambo and Il'yaiz plutons cover about 700 and 200 km^2, respectively, and are the largest granitoid bodies of this tectonic unit. The plutons are localized in the core of the Man'khambo Anticlinorium, a part of the Lyapin–Kutim Meganticlinorium of the Central Ural Uplift. The Man'khambo Pluton is a petrotype of the Sal'ner–Man'khambo plutonic complex recognized in the regional scheme of correlation of igneous complexes and in legends of the state geological maps.

The closely located plutons are similar in mineral and chemical compositions (Table 1) and consist of two intrusive phases. The first phase is composed of the major granite and leucogranite (main facies) and the subordinate quartz diorite and granodiorite (hybrid facies). Granitic rocks of the first phase occupy up to 90% of the exposed areas of the plutons. The second phase consists of leucogranite and alaskite. The dike suite is represented by aplite-like granites and aplites; pegmatites and rhyolites are less abundant. According to the petrochemical classification, the rocks of both phases belong to granite, leucogranite, subalkali granite and leucogranite, since the (Na_2O + K_2O) content ranges from 7.24 to 10.6 wt % and the SiO_2 content varies from 68.28 to 79.16 wt % [3, 4].

By concentrations of alkaline earth elements, the biotite granites are comparable with I-type granites in the classification by B. Chappell and A. White, whereas leucogranites are close to A-type, and the medium compositions corresponds to the restite-free subtype of I-granites [3–5]. At the same time, the gradual transitions between all the above rocks do not allow us to consider them as pertaining to different series. It cannot be ruled out that leucogranites are highly evolved derivatives of calc-alkaline granitic magma.

The geodynamic setting of granitic rocks cannot be deduced unequivocally from geochemical data. However, it is evident that they were formed in the thick continental crust. In Nb–Y, Rb–(Y + Nb), and Ta–Yb discriminant diagrams, data points of the granitic rocks fall into the field of intraplate granitoids. In the Rb/30–Hf–3Ta diagram, these compositions are located in the fields of late collisional and syncollisional granitic rocks.

As has been mentioned above, the plutons were emplaced into the Upper Riphean–Lower Vendian country rocks and are overlapped by sedimentary rocks of the Upper Cambrian–Lower Ordovician Obeiz Formation. At the northwestern extremity of the Il'yaiz Pluton, the granitic rocks crosscut the Upper Riphean–Lower Vendian rhyolite and rhyolitic tuff of the Sablegor Formation [2]. Similar relationships are observed at the northern end of the Man'khambo Pluton, where the rocks of the Sablegor Formation are granitized and transformed into hornfels. The Obeiz Conglomerate overlaps the granitic rocks in the southwestern part of the pluton [6].

Thus, the available geological data convincingly indicate that the aforementioned plutons, at least their first phases, were emplaced after the Late Riphean–Vendian but before the Late Cambrian–Ordovician.

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Table 1. Major oxides, wt % and trace elements, μg/g in granitoids

Component	Il'yaiz Pluton	Man'khambo Pluton		Component	Il'yaiz Pluton	Man'khambo Pluton	
	Sample 400704	Sample Γ-1	Sample 189-1		Sample 400704	Sample Γ-1	Sample 189-1
SiO_2	76.20	68.28	78.03	Yb	1.71	7.5	3.42
TiO_2	0.11	0.47	0.20	Lu	0.28	1.23	0.67
Al_2O_3	13.24	14.16	11.16	Cs	2.16	2.65	0.97
Fe_2O_3	0.84	2.15	0.29	Ba	315	1430	115
FeO	0.44	1.01	0.53	Cr	0.81	2.31	1.18
MnO	0.02	0.19	<0.01	Co	0.7	3.5	1.04
MgO	0.65	1.12	<0.01	As	1.46	21.7	1.35
CaO	0.57	1.80	0.06	Sb	0.09	1.38	0.07
Na_2O	2.81	4.99	3.85	Sc	2.98	11.1	1.97
K_2O	4.17	4.44	5.05	Hf	2.34	19.9	6.8
P_2O_5	0.08	0.24	<0.01	Th	4.81	29.9	34.9
L.O.I.	0.87	0.21	0.82	U	1.41	5.52	10.5
Total	100.00	99.06	100.00	Br	0.02	0.41	0.38
H_2O	0.27	0.11	0.08	Ta	1.04	2.72	6.86
CO_2	–	0.10	0.26	Ni	50	50	–
Neutron activation analysis				Se	4.4	2.45	3.13
La	15.1	96.7	8.25	Zn	20	71	16
Ce	30.0	178	13.9	Au (mg/g)	–	3	6
Pr*	3.4	19.7	1.39	Rb	79.4	91.0	170.0
Nd	13.3	73.8	4.2	Sr	31	51	–
Sm	2.72	18.5	0.91	Quantitative spectral analysis			
Eu	0.8	3.63	0.13	Be	4.3	4.6	3.8
Gd*	3.7	19.2	1.72	Pb	7.8	11	5
Tb	0.57	2.82	0.34	Cu	3.7	9	4
Dy*	3.3	16.3	2.62	Ga	9.3	22	10
Ho*	0.72	3.7	0.71	V	9.4	45	13
Er*	2.02	9.7	2.54	F	580	600	70
Tm	0.31	1.43	0.48	Y	20	90	12

Note: Chemical analysis of major oxides and emission spectrometry (Be, Pb, Cu, Ga, V, F, and Y) were carried out at the Institute of Geology, Komi Scientific Center; INAA (other trace elements) was performed at the Institute of Geochemistry and Analytical Chemistry (GEOKhI), Russian Academy of Sciences; interpolated values are indicated by asterisk.

Nevertheless, it was suggested that the granitic rocks of the Man'khambo Pluton are pre-Late Riphean or even Paleoproterozoic. This suggestion contradicts the intrusive character of contacts between granites and Upper Riphean–Vendian sequences. However, it is supported by the age of the overlapping conglomerate (1100 ± 50 Ma, U–Pb age of ferrithorite [7]) containing granite pebbles and occuring as lenses and interlayers within the terrigenous sequence along the eastern contact of the pluton (Fig. 1). The age of this sequence remains debatable. It is regarded either as belonging to the Upper Riphean Hobeyu Formation [7, 8] or to the Obeiz Formation [6].

The available isotopic datings of the above plutons [9, 10] obtained with the K–Ar method for minerals, Rb–Sr method for whole-rock samples, U–Pb method

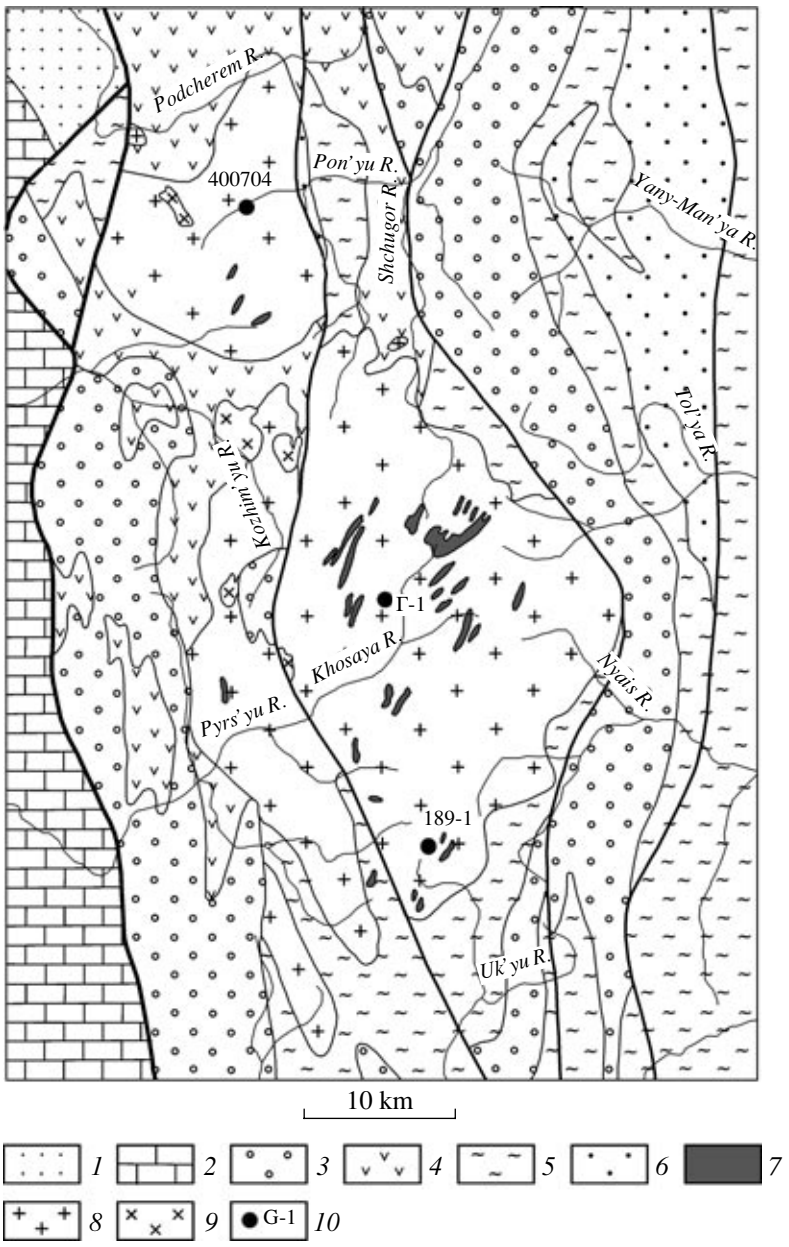

Fig. 1. Schematic geological map of the Man'khambo and Il'yaiz plutons and the adjacent territory. Based on our data and materials reported by M.V. Fishman et al., V.N. Malashevskii, A.A. Saranin, and S.S. Shcherbin. (*1–3*) Terrigenous–carbonate rocks of the West Ural lithotectonic zone of the Uralides: (*1*) Devonian–Lower Carboniferous terrigenous–carbonate rocks, (*2*) Upper Ordovician–Silurian carbonate rocks, (*3*) Upper Cambrian–Middle Ordovician terrigenous rocks with conglomerate at the base (Obeiz Formation); (*4–6*) volcanosedimentary rocks of the Lyapin lithotectonic zone of the Uralides: (*4*) mainly basic and silicic volcanics of the Upper Riphean–Vendian Sablegor Formation, (*5*) mainly slates of the Upper Riphean Moroya Formation, (*6*) terrigenous rocks of the Upper Riphean Hobeyu Formation; (*7*) leucogranite and alaskite of the second phase; (*8*) granite of the first phase; (*9*) granodiorite of the first phase; (*10*) sample location.

for zircon and thorite, and α-Pb method for zircon, thorite, and biotite, are widely scattered from 1100 to 200 Ma with frequency peaks at 400 and 200 Ma. Dates that would fit the geological position of granitoids are unknown.

To specify the age of the Man'khambo and Il'yaiz plutons, we have analyzed three samples of zircon from the first phases of both massifs (Table 2). The U–Pb analysis was performed with a SHRIMP II ion microprobe at the Center of Isotopic Research, All-Russia Research Institute of Geology. Each analysis consisted of five spectra by the following masses: $^{196}(Zr_2O)$, ^{204}Pb, background (average 204.2 AMU), ^{206}Pb, ^{207}Pb, ^{208}Pb, ^{238}U, ^{248}ThO, and ^{254}UO. These data were

Table 2. Results of U–Pb istotopic study of zircons from granitoids

Sample no.	Crystal no.	$^{206}Pb_c$, %	Concentration, μg/g			$\frac{^{232}Th}{^{238}U}$	Isotope ratio		Correlation coefficient	Age, Ma	
			U	$^{206}Pb^*$	Th		$^{206}Pb^*/^{238}U \pm \%$	$^{207}Pb^*/^{235}U \pm \%$		$^{206}Pb/^{238}U$	$^{207}Pb/^{206}Pb$
Man'khambo Pluton											
G-1	1.1	2.20	78	1.41	107	1.41	0.0832 ± 1.3	0.648 ± 9.5	0.133	515.0 ± 6.3	472 ± 210
	2.1	1.49	68	1.90	124	1.90	0.0849 ± 1.4	0.696 ± 11	0.127	525.2 ± 7.1	583 ± 240
	3.1	2.48	68	1.58	105	1.58	0.0842 ± 1.4	0.583 ± 13	0.105	521.2 ± 6.8	206 ± 300
	4.1	1.54	103	2.48	248	2.48	0.08446 ± 1.2	0.602 ± 8.8	0.313	522.7 ± 5.8	270 ± 200
	5.1	2.70	77	1.52	114	1.52	0.0820 ± 1.4	0.541 ± 15	0.093	507.8 ± 7.0	95 ± 360
	6.1	2.47	73	2.02	142	2.02	0.0817 ± 1.3	0.571 ± 13	0.100	506.1 ± 6.5	226 ± 310
	7.1	0.79	113	1.26	138	1.26	0.0827 ± 1.4	0.705 ± 3.2	0.442	512.4 ± 7.0	668 ± 62
	8.1	3.03	43	1.94	81	1.94	0.0819 ± 2.0	0.72 ± 18	0.109	507.3 ± 9.7	731 ± 380
	9.1	1.24	201	1.42	276	1.42	0.08167 ± 1.1	0.610 ± 5.4	0.208	506.1 ± 5.5	378 ± 120
189-1	1.1	0.31	2218	161	2089	0.97	0.0841 ± 1.6	0.676 ± 1.8	0.878	520.8 ± 7.8	541 ± 18
	2.1	0.52	826	58.7	817	1.02	0.0823 ± 1.6	0.657 ± 2.9	0.540	509.6 ± 7.7	527 ± 54
	3.1	5.06	324	22.7	266	0.85	0.0772 ± 1.9	0.66 ± 18	0.108	479.3 ± 9.0	662 ± 380
	4.1	0.12	1777	130	313	0.18	0.0852 ± 1.6	0.672 ± 1.8	0.887	527.2 ± 7.9	500 ± 18
	5.1	0.15	980	70.6	361	0.38	0.0837 ± 1.6	0.672 ± 1.9	0.807	518.4 ± 7.8	538 ± 25
	6.1	0.00	1602	118	84	0.05	0.0856 ± 1.6	0.683 ± 1.7	0.911	529.8 ± 7.9	524 ± 16
	7.1	0.42	2218	164	783	0.37	0.0857 ± 1.6	0.681 ± 1.9	0.836	530.3 ± 7.9	514 ± 22
Il'yaiz Pluton											
400704	1.1	1.15	130	9.42	165	1.32	0.08365 ± 0.98	0.582 ± 6.4	0.152	517.9 ± 4.9	218 ± 150
	1.1	0.68	260	18.3	326	1.29	0.08142 ± 0.71	0.657 ± 3.6	0.195	507.6 ± 3.4	550 ± 78
	1.1	0.74	290	20.9	185	0.66	0.08322 ± 0.64	0.649 ± 2.1	0.305	515.3 ± 3.2	473 ± 44
	1.1	0.14	202	14.2	238	1.22	0.08165 ± 0.72	0.682 ± 3.0	0.243	505.9 ± 3.5	625 ± 62
	1.1	0.74	150	10.7	222	1.53	0.08280 ± 0.90	0.663 ± 5.7	0.157	512.8 ± 4.4	534 ± 120
	1.1	0.91	97	7.02	101	1.07	0.08357 ± 1.1	0.671 ± 6.2	0.174	517.4 ± 5.4	538 ± 130

Note: ($^{206}Pb_c$ and $^{206}Pb^*$) Common and radiogenic Pb, respectively. Common Pb is corrected for the measured ^{204}Pb. Uncertainties are given at 1σ level. Errors in calibration of standard are 0.63% (Sample 189-1) and 0.28% (samples G-1 and 400704).

reduced in line with the procedure for SHRIMP described in [11] using SQUID 1.03 and ISOPLOT/Ex programs [12]. The obtained U/Pb ratios were normalized to $^{206}Pb/^{238}U = 0.0668$ at an age of 416.75 Ma, a value for the Temora standard zircon [13]. Uncertainties of ratios and ages for each analysis are given at 1σ level. Uncertainties for the calculated concordant ages are given within a confidence interval of 95%.

Zircons from Sample 400704 (Il'yaiz Pluton) are transparent and colorless crystals varying from dipyramidal long-prismatic to short-prismatic (short-columnar isometric dipyramidal) in shape. The brown turbid fractured individuals were noted among short-prismatic crystals. Their age was not determined because of probable discordance. Zircons contain fluid and mineral inclusions. The grain size is 80–200 μm. The length/width ratio varies from 1 to 5. The cathode luminescence images demonstrate oscillatory magmatic zoning. Zircons contain 97–290 μg/g U and 101–326 μg/g Th (Th/U = 0.66–1.53). The obtained concordant age at 510.1 ± 5.8 Ma (Fig. 2) is consistent with the geological position of the granitic rocks.

Zircons from Sample G-1 (central Man'khambo Pluton) are transparent and colorless crystals varying from dipyramidal long-prismatic to short-prismatic (short-columnar isometric dipyramidal) in shape. The yellow turbid fractured individuals were noted among short-prismatic crystals. Their age was not determined because of probable discordance. Zircons contain fluid and mineral inclusions. The grain size is 150–600 μm.

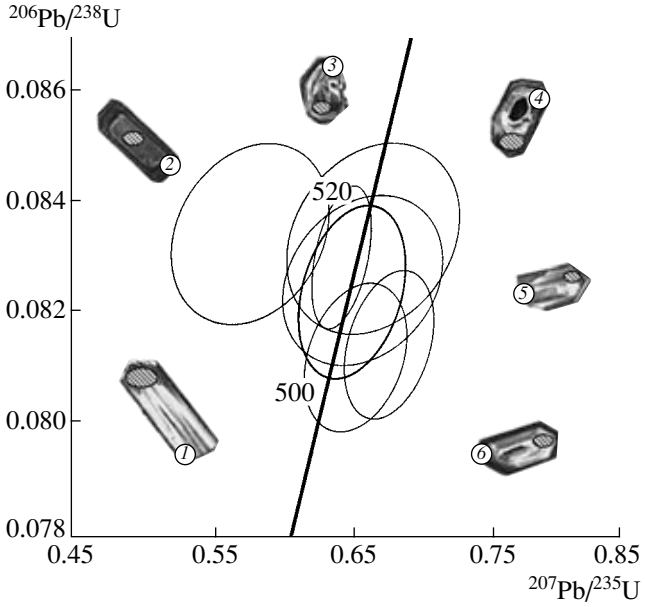

Fig. 2. U–Pb diagram with concordia for zircons from granite of the Il'yaiz Pluton. Sample 400704; $t = 510.1 \pm 5.8$ Ma (2σ); MSWD of concordance is ~0; probability of concordance is 0.998. Coordinates of points are centers of ellipsoids of uncertainties. Point numbers correspond to Table 2.

The length/width ratio varies from 2 to 7.5. The cathode luminescence images demonstrate oscillatory magmatic zoning. Zircons contain 68–201 μg/g U and 81–276 μg/g Th (Th/U = 1.26–2.48). The obtained concordant age at 513.8 ± 5.6 Ma (Fig. 3a) is also consistent with the geological position of the granitic rocks.

In Sample 189-1 from the southern Man'khambo Pluton, zircon crystals are mainly yellow turbid subhedral crystals. Transparent and colorless crystals are present in a small amount (~10%). Inclusions of two types—turbid and dark, almost black, with high U content—are observable. The dark cores and occasional dark rims are seen in transparent, light and zonal crystals. The grain size is 150–200 μm. The length/width ratio varies from 1 to 4. The cathode luminescence images demonstrate oscillatory magmatic zoning. Zircons contain 324–2218 μg/g U and 84–2089 μg/g Th (Th/U = 0.05–1.02). The obtained concordant age at 522 ± 6 Ma (Fig. 3b) is also consistent with the geological position of granitic rocks.

The new data obtained convincingly indicate the Early Cambrian age of granitic rocks in the Man'khambo and Il'yaiz plutons and their belonging to the pre-Uralide complex. The granitic rocks are potassic–sodic and pertain to granodiorite–granite associations varying from I-granite to A-leucogranite. We suggest that they were formed as a result of a collision or syncollisional collapse of the orogen that existed in the Vendian and Cambrian at the northeastern periphery of the East European paleocontinent [14].

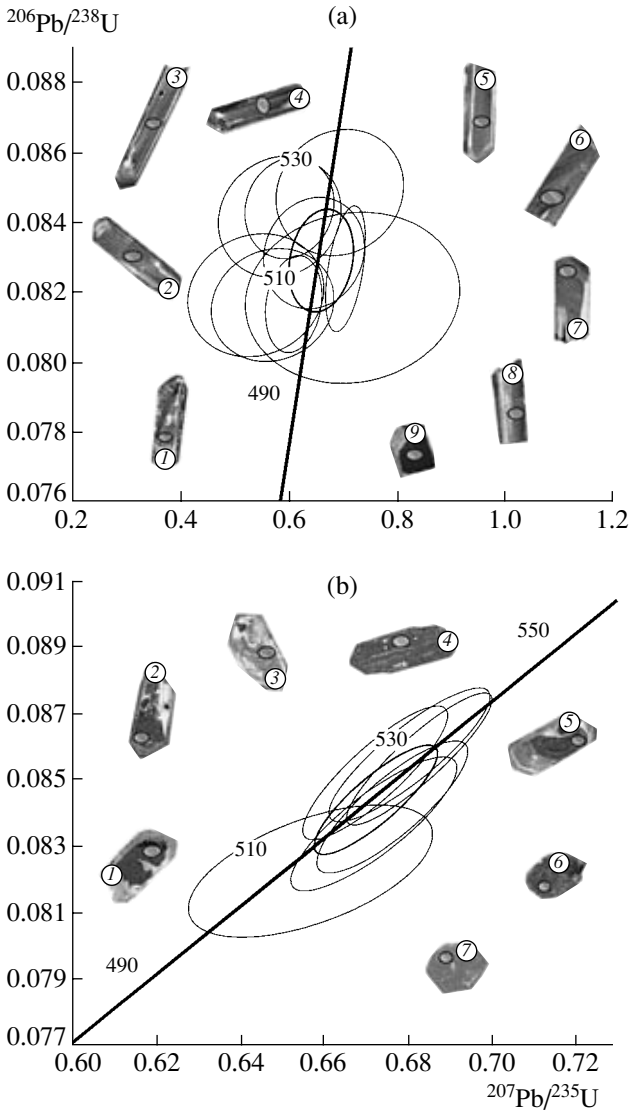

Fig. 3. U–Pb diagram with concordia for zircons from granite of the Man'khambo Pluton. (a) Sample G-1; $t = 513.8 \pm 5.6$ Ma (2σ); MSWD of concordance is 0.05; probability of concordance is 0.82. (b) Sample 189-1; $t = 522 \pm 6$ Ma (2σ); MSWD of concordance is 0.0008; probability of concordance is 0.98. Coordinates of points are centers of ellipsoids of uncertainties. Point numbers correspond to Table 2.

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REFERENCES

1. *State Geological Map of the Russian Federation, Scale 1 : 1 000 000, New Series, Map Sheet P-40 and P-41, Severouralsk. Explanatory Notes* (VSEGEI, St. Petersburg, 1995) [in Russian].

2. *State Geological Map of the Russian Federation, Scale 1 : 200 000, North Urals Series, Map Sheet P-40-VI, Mt. Telposiz, Explanatory Notes* (Moscow, 1999).
3. O. V. Udoratina, Tr. Inst. Geol., Komi Nauchn. Tsentr **103**, 63 (1999).
4. O. V. Udoratina, A. A. Soboleva, N. S. Dorokhov, and N. A. Kuzenkov, Tr. Inst. Geol., Komi Nauchn. Tsentr **113**, 54 (2003).
5. L. V. Makhlaev, *Granitoids in the Northern Central Ural Uplift, the Polar and Subpolar Urals* (Yekaterinburg, 1996) [in Russian].
6. V. N. Puchkov, Tr. Inst. Geol. Komi Filial, Akad Nauk SSSR **8**, 50 (1968).
7. S. S. Shcherbin, in *Proceedings of the 3rd Uralian Petrographic Conference* (Sverdlovsk, 1974), Vol.1, p. 62 [in Russian].
8. V. A. Dushin, *Magmatism and Geodynamics of Paleocontinental Sector of the Northern Urals* (Nedra, Moscow, 1997) [in Russian].
9. V. L. Andreichev, Nauchn. Dokl., Komi Nauchn. Tsentr, No. 413, 3 (1999).
10. O. V. Udoratina and V. L. Andreichev, in *Petrology of Igneous and Metamorphic Complexes* (Tomsk, 2004), Vol. 1 (5), 78 [in Russian].
11. I. S. Williams, M. A. McKibben, W. C. Shanks, III, and W.I. Ridley, Rev. Econ. Geol. **7**, 1 (1998).
12. K. R. Ludwig, US Geol. Surv. Open-File Rep., No. 88-557, 1 (1990).
13. L. P. Black, Chem. Geol. **200**, 155 (2003).
14. N. B. Kuznetsov, A. A. Soboleva, O. V. Udoratina, et al., *Pre-Ordovician Granitoids of the Timan–Ural Region and Evolution of Protouralides and Timanides* (Geoprint, Syktyvkar, 2005) [in Russian].