ISSN 1028-334X, Doklady Earth Sciences, 2007, Vol. 413A, No. 3, pp. 424–427. © Pleiades Publishing, Ltd., 2007.
Original Russian Text © G.Yu. Shardakova, E.S. Shagalov, M.S. Sereda, 2007, published in Doklady Akademii Nauk, 2007, Vol. 413, No. 4, pp. 545–548.

GEOCHEMISTRY

Geochemical Distinctions of Granitoids in the Taganai–Iremel Anticlinorium (Central Ural Megazone)

G. Yu. Shardakova, E. S. Shagalov, and M. S. Sereda

Presented by Academician V.A. Koroteev April 6, 2006

Received April 26, 2006

DOI: 10.1134/S1028334X07030233

As is well known, the geological structure of the Urals is very complicated owing to the overlapping of signatures of all episodes of the evolution of the Earth's crust. Therefore, unambiguous interpretation of the Uralian structure is difficult [1, 7–10]. In terms of composition, age, and genesis of constituents, the Ural Orogen is characterized by sharp asymmetry due to the collision of the ancient East European and the young Kazakhstan continents. According to this scenario, the Ural Orogen is distinctly separated by the Main Ural Fault into two sectors. The western sector corresponds to a tectonic zone where ancient island arcs and the riftogenic margin of the East European Platform collided with several allochthons of oceanic and island-arc complexes, which have roots in the Main Ural Fault zone. The eastern sector represents a stacking of oceanic, island-arc, and microcontinental blocks [7]. This concept suggests that the Earth's crust is very heterogeneous in the Ural Orogen.

The heterogeneity of composition and structure is particularly prominent in the Ural Orogen–East European Platform junction zone. This is reflected in the composition of magmatic rocks, in particular, granitoid series. Specific features of felsic igneous rocks (hereafter, magmatites) in this zone at the modern erosion level are scrutinized for the Polar and Southern Urals [1, 4, 6, 12, and others]. Recent data suggest that boundary structures, such as the Bashkir Anticlinorium and Ufalei Block, incorporate various granitoids with contrasting chemical compositions and isotope–geochemical characteristics. These rocks are products of different stages of granite formation on the western slope of the Urals. Granitoids of the Bashkir Anticlinorium formed in the Middle Riphean and Vendian, whereas their counterparts in the Ufalei Block probably formed in the Riphean and Paleozoic [10, 11]. In 2004 and 2005, we obtained new data on granitoids from two small granitoid massifs located in the Taganai–Iremel Anticlinorium (Central Ural Megazone). These data provide new insights into granitoid magmatism of the Ural Orogen–East European Platform junction zone characterized by an intricate and long-term geological evolution.

The granitoid massifs are located among Middle–Upper Riphean rocks of the Taganai Formation (mainly quartzites, staurolite–garnet–mica–quartz schists, and chloritoid phyllites). Figure 1 shows the location of the granitoid massifs relative to the Shumga–Kuvash Zone and Ufalei Block. In geological maps of the Urals compiled in 1971 (scale 1 : 1 000 000), 1962 (scale 1 : 20 000), and earlier years, the massifs were designated as structures of the Cambrian Period, which is unique for the Urals. The northernmost massif is confined to the southeastern spurs of Mt. Yurma. Our observations revealed that rock exposures in this area do not make up a single intrusive massif, and the geological situation is similar to that in the western Ufalei Block [3, 11]: a large granite gneiss body is associated with amphibolite sheets confined to upper parts of the section. We believe that the association of basic and felsic rocks recorded in this area can be recognized as the *Yurma Complex* by analogy with the Taratash, Ufalei, and Aleksandrov complexes among others. Based on petrographic similarities of rocks, Zhdanova [2] suggested that the Yurma granite gneiss could be cognate with meta- and orthomagmatites of the Kuvash Formation (Middle Riphean) and Shumga Complex. Isotope datings are thus far absent for rocks of the Yurma Complex.

The Yurma Complex is primarily composed of granite gneisses that represent fine-grained granolepidoblastic rocks subjected to cataclasis. If garnet is present, the rocks have porphyroblastic texture. Recrystallization is observed both along grain boundaries and in the

Zavaritskii Institute of Geology and Geochemistry, Ural Division, Russian Academy of Sciences, Pochtovyi per. 7, Yekaterinburg, 620151 Russia; e-mail: shardakova@igg.uran.ru

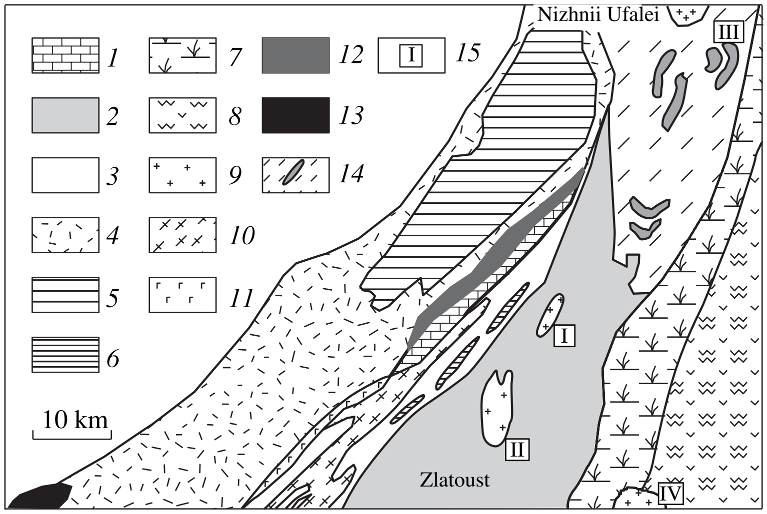

Fig. 1. Geological map of the Shumga–Kuvash zone and its eastern framing (modified after [2]). (*1*) Upper Silurian–Devonian(?) limestones; (*2*) Lower–Upper Riphean Taganai Formation (quartzites, staurolite–garnet–mica–quartz schists, and chloritoid phyllites); (*3*) Upper Riphean Kuvash Formation (amphibolites, greenschists, porphyroids, and others); (*4*) Lower Riphean Bakal and Satka formations; (*5*) Archean–Proterozoic metamorphic rocks of the Taratash Complex; (*6*) Riphean(?) amphibolites and gneisses of the Shumga Complex; (*7*) volcanosedimentary rocks and ultramafics of the Main Ural Fault zone; (*8*) volcanic rocks of the Tagil–Magnitogorsk Megazone (igneous and orthoigneous rocks); (*9*) Lower–Middle Riphean granites of the Ryabinov Massif; (*10*) Lower–Middle Riphean granite gneisses of the Guben Massif; (*11*) Lower–Middle Riphean gabbroids of the Kusa–Kopan Complex; (*12*) Proterozoic gneisses of the Aleksandrov Complex; (*13*) Lower Riphean granites of the Berdyaush Massif; (*14*) Precambrian(?) gneisses and amphibolites of the Ufalei Complex; (*15*) granitoids of the Taganai–Iremel Anticlinorium: (I) Yurma Complex, (II) Kialim Massif, (III) Middle Carboniferous Nizhnii Ufalei Massif, (IV) Middle Carboniferous Turgoyak Massif (Syrostan–Turgoyak group [8]).

rock volume. The mineral composition is as follows (vol %): quartz 15–25, plagioclase (no. 18–30) 45–60, microcline 10–15, biotite 5–10, muscovite 2–10, and epidote 3–5. Accessory minerals are represented by magnetite, apatite, orthite, sphene, and zircon. Garnet is rare. In terms of composition, the Yurma granite gneiss matches granodiorite or granite. Based on the normative rock composition [9], the granite gneiss formed at a pressure of approximately 5 kbar.

The Yurma granite gneiss is associated with massive or slightly gneissic granoblastic amphibolites. Zones of relict ophitic textures are observed in some sectors of thin sections. The compositional features and the relict ophitic textures indicate that amphibolites of the study area represent meta- and orthomagmatites formed after diabases or basalts. Their mineral composition is as follows (vol %): amphibole 50–70, plagioclase 20–40, and quartz 2–5. Ore minerals, epidote, apatite, and sphene make up approximately 5 vol %. The garnet-bearing variety is rare. Based on various geothermobarometers [13–15 and others], amphibolites of the study area formed at 4.5–5 kbar and 570–620°C. Such *PT* values fit the facies of garnet–epidote amphibolites [5].

The table presents chemical compositions of granite gneisses and amphibolites. Figure 2 shows the REE distribution in these rocks. For the sake of comparison, the figure also demonstrates fields of Riphean basic rocks (gabbroids and basaltoids) and felsic rocks (granite gneisses) from the Kuvash riftogenic structure (hereafter, Kuvash Rift) and Ufalei Block [10, 11] that bound the Taganai–Iremel Anticlinorium in the west and northeast, respectively. Ancient orthomagmatites of these structures have similar ages. They are also similar in terms of mineral and chemical compositions. The orthomagmatites are products of the riftogenic stage of granite formation [10, 11]. The Ufalei Block also includes young granites of the Nizhnii Ufalei Massif. The granites differ from ancient (Middle Riphean) orthomagmatites in composition and age. The petrogeochemical signature of the Nizhnii Ufalei granite is similar to that of suprasubduction series. Based on comparison with the granites described above, we can specify the affiliation of rocks of the Yurma Complex in the typification of granitoids.

Trends of the REE distribution in the Yurma granite gneiss are very similar to those for their counterparts in ancient granitoids of the Kuvash Rift and Ufalei Block. Rocks of all three complexes mentioned above are marked by high contents of Y-group elements and total REE (200–450 ppm), an insignificant slope of the trend, a negative Eu anomaly (Fig. 2a), negative Sr and Ti anomalies, and positive Ba and Zr anomalies (Fig. 2b). This trend (typical of within-plate igneous rocks) drastically differs from that for rock series related to suprasubduction and collision processes [8, 10]. The Yurma granite gneiss could be formed at one of the stages of continental rifting on the western slope of the Urals in the Middle–Late Riphean [1, 7].

Contents of the major (wt %) and rare elements (ppm) in granitoids of the Taganai–Iremel Anticlinorium

Component	1	2	3	4	5	6	7	8
	Kia-1	Kia-2	Kia-6	Kia-4	Yur-14	Yur-10	Yur-6	Yur-7
SiO_2	68.68	68.27	69.47	71.26	69.77	72.10	72.36	50.10
TiO_2	0.26	0.28	0.25	0.17	0.71	0.40	0.41	1.65
Al_2O_3	16.44	17.02	16.07	14.46	12.27	13.87	12.28	10.70
Fe_2O_3	1.22	1.38	1.55	1.02	3.12	1.40	1.98	6.43
FeO	0.90	0.90	0.50	0.90	3.10	0.90	2.10	10.80
MnO	0.05	0.05	0.05	0.07	0.11	0.03	0.07	0.22
MgO	0.58	0.66	0.53	0.53	0.80	0.27	0.65	5.57
CaO	2.55	2.59	2.52	1.12	1.92	2.61	1.67	10.20
Na_2O	5.80	5.80	5.80	5.00	3.00	4.40	2.60	2.60
K_2O	2.20	2.30	2.28	4.25	4.32	2.21	4.69	0.60
P_2O_5	0.07	0.08	0.08	0.05	0.13	0.06	0.06	0.20
L.O.I.	0.60	0.60	0.40	0.40	0.90	0.30	0.60	2.60
Total	99.35	99.92	99.50	99.25	100.15	98.54	99.48	101.67
Rb	25	31	23	152	114	48	113	2
Sr	949	905	874	85	105	112	93	157
Total REE	64	25	59	0.70	215	–	144	83
Eu/Eu*	1.3	1.7	1.3	3	0.6	–	0.7	0.9
La/Yb	35	10	31	0.18	7.8	–	3.1	3.5

Note: Kialim Massif: (1–3) granodiorites and granites of the major phase; (4) vein granite porphyry (Yurma Complex); (5–7) granite gneisses; (8) plagioclase amphibolite.

The Kialim Massif located 10 km south of the Yurma Complex cuts metamorphic rocks of the Taganai Formation. Based on the K–Ar mica dating from an unpublished report in 1964, the Kialim Massif is 305 Ma old. In terms of mineral and chemical compositions (table), the main phase of the Kialim Massif consists of porphyric granites and granodiorites with feldspars as phenocrysts. The porphyroblastic texture is less common. The medium-grained hypidiomorphic rocks (with gneissic patterns in some places) are subject to weak cataclasis. Their mineral composition is as follows (vol %): plagioclase 35–45, K-feldspar (15–25), quartz (15–20), biotite (8–10), and muscovite (5–7). Accessory minerals are represented by hornblende, epidote, orthite, sphene, zircon, and magnetite. The absence of intense metamorphism of the rocks is indicated by the presence of well-preserved magmatic structures, the absence of explicit reaction interrelations between minerals, and the magmatic zonality of plagioclases. The granites formed at approximately 5 kbar [13] (based on the amphibole–plagioclase geobarometer) and approximately 600°C [15] (based on the Otten geothermometer).

Trends and patterns of trace element distribution in granitoids of the Kialim Massif significantly differ from those in the granite gneiss of Yurma, the Ufalei Block, and Kuvash Rift (Fig. 2). The Kialim Massif is characterized by a specific appearance, composition, and geochemistry: low concentrations of REE (particularly, HREE), an insignificant Eu anomaly, a negative Ti anomaly, and a positive Sr anomaly. Hence, the Kialim granite is similar to rocks of the suprasubduction and collision series with a typical age of 330–280 Ma [8]. The closest analogues of this type are represented by the Nizhnii Ufalei Massif of the Ufalei Block (Fig. 1) with an Rb–Sr age of 317 Ma [11] and massifs of the Syrostan–Turgoyak group with an Rb–Sr age of 330 Ma [8]. The contrasting features described above indicate that the Kialim granite and Yurma granite gneiss were derived from different substrates.

Thus, the Taganai–Iremel Anticlinorium incorporates granitoids of different geochemical and genetic types related to different stages of granite formation and geodynamic settings. In terms of composition and geochemistry, the Yurma granite gneiss is very close to Middle Riphean riftogenic series on the western slope of the Urals. The Kialim granite is similar to early orogenic (Paleozoic) suprasubduction rocks. Granitoids of various geochemical types (possibly different ages and geodynamic settings) coexist within a rather small area of the Uraltau Zone. These facts testify to the intricate

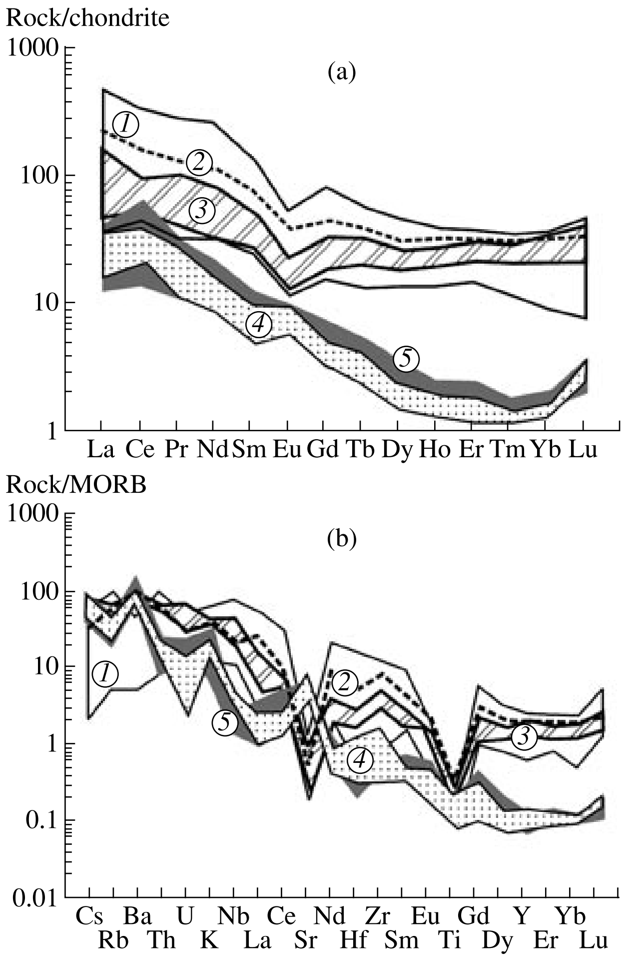

Fig. 2. Distribution of trace elements in granitoids at the junction of the Ural Orogen and East European Platform. Ancient granitoids: (*1*) granite gneisses in the central Ufalei block, (*2*) mean granite trend in the Guben Massif, (*3*) granite gneisses of the Yurma Complex; young granitoids: (*4*) granites of the Kialim Massif, (*5*) granites of the Nizhnii Ufalei Massif.

and long-term evolution of the Taganai–Iremel Anticlinorium and the entire Ural Orogen–East European Platform junction zone. Hence, the Uraltau Zone incorporates blocks with different (in composition, age, and genesis) crusts.

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-4210.2006.5) and the Russian Foundation for Basic Research (project no. 05-05-64079).

REFERENCES

1. A. A. Alekseev, *The Riphean–Vendian Magmatism on the Western Slope of the Southern Urals* (Nauka, Moscow, 1984) [in Russian].
2. S. N. Zhdanova, Candidate's Dissertation in Geology and Mineralogy (Inst. Miner., Ural. Div. Russ. Acad. Sci., 1987).
3. G. A. Keil'man, *Migmatite Complexes of Mobile Belts* (Nedra, Moscow, 1974) [in Russian].
4. N. B. Kuznetsov, A. A. Soboleva, O. V. Udoratina, and M. V. Gertseva *Preordovician Granitoids of the Timan–Ural Region and Evolution of Protouralides–Timanides* (Geoprint, Syktyvkar, 2005) [in Russian].
5. A. A. Marakushev, *Petrology* (MGU, Moscow, 1988) [in Russian].
6. *Sedimentation, Magmatism, and Ore Potential of the Northern Uraltau Zone* (Ufa, 2002) [in Russian].
7. V. N. Puchkov, *Paleogeodynamics of the Southern and Central Urals* (Dauriya, Ufa, 2000) [in Russian].
8. G. B. Fershtater, F. Bea, N. S. Borodina, et al., Geol. Geofiz. **43** (1), 42 (2002).
9. G. B. Fershtater, *Petrology of the Major Intrusive Associations* (Nauka, Moscow, 1987) [in Russian].
10. V. V. Kholodov, G. Yu. Shardakova, G. B. Fershtater, et al., in *Geodynamics and Minerageny* (Geoprint, Syktyvkar, 2005), pp. 364–366 [in Russian].
11. G. Yu. Shardakova, E. S. Shagalov, Yu. L. Ronkin, et al., [Dokl. Earth Sci. **405**, 1404 (2005) [Dokl. Akad. Nauk **405**, 799 (2005)].
12. R. G. Yazeva and V. V. Bochkarev, *Petrology and Geodynamics of the Southern Urals (Experience of Geodynamic Mapping* (Ural. Otd. Ross. Akad. Nauk, Yekaterinburg, 1998) [in Russian].
13. T. Holland and J. Blundy, J. Contr. Mineral. Petrol. **116**, 433 (1994).
14. L. S. Hollister, G. S. Grissom, E. K. Peters, et al., Am. Mineral. **72**, 231 (1987).
15. M. T. Otten, Contr. Mineral. Petrol. **86**, 189 (1984).