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GEOCHEMISTRY

K–Ar Age and Sr–Nd Characteristics of Subalkali Basalts in the Central Georgian Neovolcanic Region (Greater Caucasus)

V. A. Lebedev[a], Corresponding Member of the RAS I. V. Chernyshev[a], A. V. Chugaev[a], O. Z. Dudauri[b], and G. T. Vashakidze[b]

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Late Cenozoic magmatism in the Greater Caucasus during the last 8.5 Ma was manifested in the Elbrus, Kazbek, and Central Georgian neovolcanic regions. In our work, we present K–Ar dates obtained for young rocks of Central Georgia, which, in turn, allowed us to determine the age of volcanism in this region and specify its role in the Neogene–Quaternary magmatic history of the Greater Caucasus. In addition, based on new Sr–Nd isotopic–geochemical and petrochemical data, we consider the petrogenesis of volcanics in this region and the problem of material source for young igneous rocks in the Greater Caucasus as a whole. The present work continues our recent geochronological investigations in this region [1–5].

The Central Georgian neovolcanic region is located on the southern slope of the Greater Caucasus as a narrow near-latitudinal band extending from the Tskhinvali outskirts via the Chiatura and Sachkhere regions to the middle course of the Rioni River (Fig. 1). Young magmatism in this region is represented by flows of subalkali and alkali basaltic lavas confined to five volcanic regions (from the east to west): Tskhinvali, Kvasatali, Goradziri, Perevisa (Chiatura), and Namanevi. According to [6], the study region also includes basic volcanism developed in the Kutaisi region (small teschenite and quartz diorite intrusions, as well as sills, dikes, and subordinate basaltic lava flows) mostly among Middle Jurassic sedimentary rocks (Fig. 1). Until recently, all magmatic rocks of the Kutaisi region were considered Neogene formations [6–8].

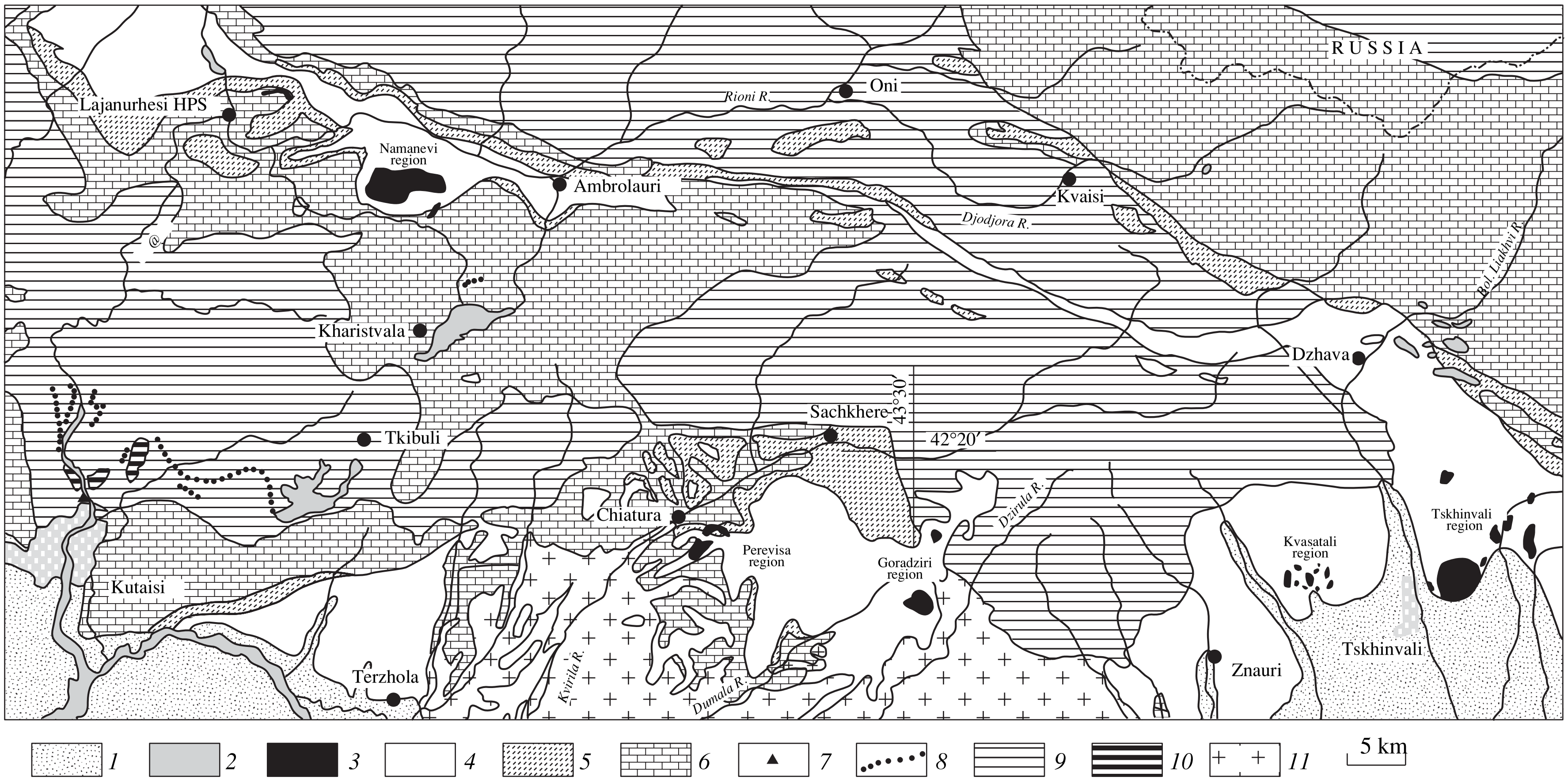
In the Central Georgian volcanic regions listed above, young basic rocks make up small lava flows up to several square kilometers in size. The Tskhinvali region, with numerous manifestations of basaltic volcanism (up to 20 outcrops), also hosts basic rock necks and stocks that represent former magma conduits. Near the settlements of Eredvi and Prisi, east of Tskhinvali, one can see a large tuff field of pyroclastic sediments alternating with lava flows and Miocene–Pliocene sedimentary conglomerates. Small teschenite and alkali basalt dikes are developed in Cretaceous limestones and Paleogene sediments near the Settlement of Chkvishi on the right bank of the Rioni River in the westernmost part of the region.

In the Tskhinvali and Kvasatali regions, lava flows of subalkali basalts occur among conglomerates of the Dusheti Formation [7, 8] corresponding to the Meotian–Pontian regional stages, i.e., 9.3–5.2 Ma [9]. Thus, the late Miocene age of the Tskhinvali and Kvasatali lavas is supported by reliable geological evidence. In other volcanic regions (Goradziri, Perevisa, and Nemanev), basic lavas occur among or overlie Sarmatian sediments. Some researchers have assumed that the basic rocks of these three regions are of the Late Pliocene age, because of the lack of stratigraphic data on their upper age limit [8]. Geochronological dates are virtually absent for young volcanics of the Central Georgian region. The K–Ar biotite date (7 ± 1 Ma) has been reported only for a teschenite dike near the Settlement of Chkvishi in the Namanevi region [10].

We have carried out a petrological and isotopic–geochemical study of lava samples from the Goradziri, Perevisa, and Namanevi volcanic regions of Central Georgia. In their chemical composition, most of the rocks correspond to subalkali basalts with the following composition (%): SiO_2 45.3–49.3, ($K_2O + Na_2O$) 4.8–7.4, and K_2O 1.6–2.4. The rocks are characterized by the porphyric and less common aphyric textures. Phenocrysts of olivine and clinopyroxene (augite) are persistent. They are sometimes accompanied by basic plagioclase (bytownite). The hyalopilitic, pilotaxitic, or doleritic groundmass is composed of volcanic glass and

[a] *Institute of Geology of Ore Deposits, Petrology, Mineralogy, and Geochemistry, Russian Academy of Sciences, Staromonetnyi per. 35, Moscow, 119017 Russia; e-mail: leb@igem.ru*

[b] *Geological Institute, Academy of Sciences of Georgia, ul. M. Aleksidze 1/9, Tbilisi, 380093 Georgia*



Geological map of the central Georgian neovolcanic region. (*1*) Quaternary sediments; (*2*) Quaternary lavas of the Kazbek region; (*3*) late Miocene basic lavas; (*4*) Miocene sediments; (*5*) Oligocene–Miocene sediments; (*6*) Cretaceous sediments and basic volcanics (Mtavari Formation); (*7*) Late Cretaceous quartz diorite intrusions; (*8*) Late Cretaceous teschenite intrusions; (*9*) Jurassic volcanosedimentary formations; (*10*) Jurassic basalts of the Kutaisi region; (*11*) Paleozoic granitoids and metamorphic rocks (Dzirula crystalline massif).

microlites of plagioclase, augite, and, sometimes, analcime. Accessory minerals are represented by magnetite, ilmenite, and apatite.

In terms of their chemistry, the rocks are largely attributed to the K–Na subalkali (less commonly, alkali) series. They are characterized by a relatively high Mg index (0.56–0.67) and elevated contents of Sr, Ba, and Nb (770–1350, 325–650, and 20–30 ppm, respectively), which is usually observed in continental intraplate basalts. At the same time, these rocks from all three regions show some petrological–geochemical peculiarities. They differ, although insignificantly, from each other in their contents of both major and minor components (Cr, Ni, Sr, and Zr), while they are chemically similar within the individual region.

In the known petrogenetic diagrams (Zr/4–Nb×2–Y, Zr–Ti/100–Y×3, and Zr/Y–Zr), data points of young basic lavas from Central Georgia fall into the fields of intraplate alkali basalts. According to the discrimination diagram proposed in [11] for intraplate basic rocks, the examined rocks are close to basalts of continental rifts.

The K–Ar dating version used for the volcanics of Central Georgia was developed at the Institute of Geology of Ore Deposits, Petrography, Mineralogy, and Geochemistry for the study of young igneous rocks [1]. Its detailed characteristics are given in [12]. Isotopic analysis of Sr and Nd was conducted using a Micromass Sector 54 multicollector thermal ionization mass spectrometer. The K–Ar dating of lavas and measurements of isotopic ratios $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ have been performed for the groundmass separated from phenocrysts.

Table 1 presents the K–Ar dates obtained for subalkali basalts of the Central Georgian region. Except for sample ZG-8, which shows signs of secondary alterations (chloritization of the groundmass), all the remaining dates obtained fall into a narrow age interval of 6.4–6.1 Ma (late Miocene). This result is consistent with the above-mentioned geological data, according to which subalkali basalts are coeval with conglomerates of the Dusheti formation dating back to the terminal Miocene–initial Pliocene. The closeness of dates obtained for seven samples from different volcanic regions of Central Georgia and their consistency with geological data makes it possible to consider the age of 6.4–6.1 Ma as the period of basic lava eruption in the region.

It should be noted that lavas of such age have not been recorded in other neovolcanic regions of the Greater and Lesser Caucasus despite the thorough isotopic–geochronological investigations of young magmatism in these regions [1–5]. Thus, subalkali basaltic volcanism of Central Georgia represents an autonomous phase of the Late Miocene stage in Neogene–Quaternary magmatism. The autonomous phase was manifested only in this region of the Caucasus, probably, during a relatively short period (up to a few hundreds of thousand years). Judging from observed lava volumes, this phase was characterized by low productivity. The chemical composition of lavas in different regions was similar despite a large distance between them. The lack of evidence for any other manifestations of young magmatism in Central Georgia suggests that the unique volcanism in this region of the Caucasus was a one-phase event.

The subalkali basalts of Central Georgia demonstrate similar Sr–Nd isotopic signatures: $^{87}Sr/^{86}Sr$ = 0.7040–0.7045, $^{143}Nd/^{144}Nd$ = 0.51279–0.51287, and ε_{Nd} = +2.9 to +4.4 (Table 1). The young age of the rocks under consideration and their low Rb/Sr ratios suggest that the measured isotopic $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ values correspond to initial ones. In the Sr–Nd diagram, data points are close to the field of the "Common" depleted mantle ($^{87}Sr/^{86}Sr \approx 0.7035$ and $\varepsilon_{Nd} \approx +5$ [13]) that is considered a potential source for most subalkali basalts of mantle plumes. Along with petrochemical data, the above-mentioned fact indicates a decisive role of mantle matter in petrogenesis of young rocks from the Central Georgian region.

Although Sr–Nd characteristics of examined subalkali basalts are generally similar, rocks from separate volcanic regions are characterized by some subtle differences that can be explained by either heterogeneities of the mantle source or differences in evolution of melts in volcanic region of the Central Georgian region, initially produced by a homogenous mantle reservoir. In contrast to the lavas of the Goradziri and Namanevi regions, lavas of the Perevisa region are characterized by minimal radiogenic Sr (0.7040–7041) and maximal radiogenic Nd (ε_{Nd} = +3.7 to +4.1) compositions (Table 1). This fact is consistent with petrochemical characteristics of subalkali basalts of the Perevisa region, i.e., high Mg index (0.67–0.63); elevated MgO, Fe_2O_3, TiO_2, P_2O_5, and Ni contents; and lower SiO_2 concentrations. Thus, isotopic–petrochemical data indicate that, relative to subalkali basalts from other volcanic regions, the Perevisa lavas are the least differentiated and compositionally the closest to parental magmas if a common homogenous mantle source is accepted as the main model. In this case, differences in Sr–Nd isotope characteristics indicate that rocks of other volcanic regions represent likely differentiations of mantle melts, which were contaminated to a variable extent by geochemically unbalanced (probably, crustal) matter. In our opinion, simultaneous contamination and differentiation of melts is the most probable scenario.

As is evident from the petrochemical data, crystallizational differentiation in intermediate magma chambers, probably located within compositionally different rocks, was most likely related to fractionation of olivine and magnetite from the melt with a regular decrease of MgO, Fe_2O_3, TiO_2, Ni, and Cr contents and an increase of SiO_2, Na_2O, and Sr concentrations in the liquid phase. The elevated $^{87}Sr/^{86}Sr$ and lowered $^{143}Nd/^{144}Nd$ values

Geochronological and isotopic–geochemical characteristics of lavas in the Central Georgian volcanic region

Sample	K, % ± σ	$^{40}Ar_{rad}$, ng/g ± σ	K–Ar age, Ma ± 2σ	Rb, ppm	Sr, ppm	$^{87}Rb/^{86}Sr$ ± σ
Goradziri region						
ZG-1	1.43 ± 0.02	0.604 ± 0.005	6.10 ± 0.20	28	1500	0.0542 ± 3
ZG-2	1.63 ± 0.02	0.718 ± 0.004	6.35 ± 0.20	42	1450	0.0849 ± 4
Perevisa region						
ZG-4	1.50 ± 0.02	0.635 ± 0.010	6.10 ± 0.20	36	1100	0.0997 ± 4
ZG-5	1.48 ± 0.02	0.657 ± 0.005	6.40 ± 0.20	25	790	0.0917 ± 4
ZG-6	1.49 ± 0.02	0.635 ± 0.004	6.15 ± 0.20	35	1050	0.0963 ± 4
Namanevi region						
ZG-7	1.32 ± 0.02	0.581 ± 0.04	6.35 ± 0.20	31	1030	0.0873 ± 4
ZG-8	1.34 ± 0.02	0.511 ± 0.005	5.50 ± 0.20	32	1220	0.0764 ± 3
ZG-9	1.88 ± 0.02	0.792 ± 0.005	6.10 ± 0.20	43	1740	0.0710 ± 4
Sample	**$^{87}Sr/^{86}Sr$ ± σ**	**Sm, ppm**	**Nd, ppm**	**$^{147}Sm/^{144}Nd$ ± σ**	**$^{143}Nd/^{144}Nd$ ± σ**	**ε_{Nd}**
Goradziri region						
ZG-1	0.70431 ± 2	5.4	29	0.1121 ± 3	0.512828 ± 10	3.7
ZG-2	0.70421 ± 2	6.4	37	0.1036 ± 3	0.512788 ± 10	2.9
Perevisa region						
ZG-4	0.70411 ± 2	6.3	33	0.1144 ± 3	0.512832 ± 10	3.8
ZG-5	0.70406 ± 2	6.5	35	0.1116 ± 2	0.512827 ± 10	3.7
ZG-6	0.70403 ± 2	6.5	34	0.1136 ± 2	0.512848 ± 10	4.1
Namanevi region						
ZG-7	0.70436 ± 2	6.9	40	0.1054 ± 2	0.512828 ± 15	3.7
ZG-8	0.70427 ± 2	4.2	23	0.1083 ± 2	0.512866 ± 15	4.4
ZG-9	0.70451 ± 2	8.3	48	0.1137 ± 2	0.512817 ± 10	3.5

Note: The data characterize the rock groundmass. All the rocks, except for sample ZG-9 (alkali basalt), are subalkali basalts. Sampling sites: (ZG-1) Malyi Goradziri Volcano, (ZG-2) Bol'shoi Goradziri Volcano, (ZG-4) Perevisa Settlement (center), (ZG-5) Perevisa Settlement, (western part, lava flow with columnar jointing), (ZG-6) Chiatura deposit, Perevisa gallery, (ZG-7) Zeda Shavra Settlement (rocks above the settlement, lavas with columnar jointing), (ZG-8) Zeda Shavra Settlement, northern margin, (ZG-9) Chkvishi Settlement (alkali basalt dike among Cretaceous limestones).

in subalkali basalts of the Goradziri and Namanevi regions suggest crustal contamination (Table 1). Taking into consideration the generally similar mineral and chemical compositions of rocks from different volcanic regions of Central Georgia and negligible differences in their Sr–Nd isotopic characteristics, the contamination is insignificant. It was likely maximal in the most differentiated rocks of the Goradziri region, which is located at the northern margin of the Dzirula crystalline massif composed of Paleozoic granitoids and metamorphic schists. The Goradziri subalkali basalts are characterized by the minimal SiO_2 and Mg contents corresponding to andesitic trachybasalts. The exception is the rock from a thin ~1-m-thick dike of alkali basalts near the Settlement of Chkvishi in the Namnev region (sample ZG-9). The maximal Sr concentration and $^{87}Sr/^{86}Sr$ value (0.7045) observed in these rocks can be explained by their occurrence within Cretaceous limestones.

The isotopic–geochronological study of basic rocks from the Kutaisi magmatic region reveals that diorite and teschenite intrusions of this region are Late Cretaceous formations (87–86 Ma), while basic volcanics are Jurassic ones (148–140 Ma). The Jurassic rocks are usually intensely altered (particularly their dark-colored minerals) and characterized by a paleotype appearance. The probably slightly rejuvenated K–Ar dates of basic rocks suggest their genetic relation to one of the impulses of Middle Jurassic basic magmatism that was widespread in Georgia. As was shown in [10], teschenite intrusions in the Rioni River valley north and east of Kutaisi represent a plutonic analogue of the Upper Cretaceous volcanogenic Mtavari Formation. Small quartz diorite massifs, one of which is observed in the Choma Ridge north of Kutaisi, were also produced by this magmatic impulse. Thus, basic magmatism of the Kutaisi region was manifested in the Jurassic–Cretaceous; i.e., this magmatism is not related to the Late Cenozoic volcanism in Central Georgia.

The obtained data on activation of magmatism in the Greater Caucasus in the terminal Miocene (6.4–6.1 Ma ago), with the dominant role of the mantle source in its petrogenesis, suggest the following conclusion: the mantle "hot spot (field)" in the Caucasian segment of the Alpine belt was reactivated synchronously or slightly later than the "rigid" collision between the Eurasian and Arabian lithospheric plates. As is known, the Caucasian continental crust is characterized by a block structure: former microcontinents and fragments of island arcs are sandwiched between the Eurasian and Arabian plates. Therefore, under conditions of significant meridional compression and continuing pressure of the Arabian indenter, the appearance of local extension zones in the Caucasus during the Neogene–Quaternary is quite natural. In such zones, activity of the "hot spot" was manifested as substantially mantle-derived subalkali basaltic volcanism. The terminal Neogene was likely marked by the formation of a system of similar extension zones, probably the earliest structures of such kind in the Caucasus, within the linear Central Georgian neovolcanic region. In the Pliocene, subalkali basaltic volcanism became widespread in the Lesser Caucasus, while centers of basic magmatism were rare in the Greater Caucasus [5, 6].

As was mentioned, the Sr–Nd signature of the mantle source, which has functioned in the Greater Caucasus since the late Miocene, is closest to the "Common" hypothetical reservoir [13] that is considered the most probable source for continental basalts. It can be assumed that precisely the latter mantle reservoir, which served as a source for subalkali basalts of Central Georgia in the terminal Miocene, subsequently participated in the petrogenesis of almost all young rocks of the Greater Caucasus. As was shown in [14], these rocks are products of the mixing and/or contamination of mantle melts of the "hot field" and crustal material.

The chronological study of young magmatism in the Greater Caucasus in the Pliocene–Quaternary reveals that mantle volcanism reactivated in certain periods (3.85–3.65, ~0.9 Ma, and others) [5]. This was probably related to geotectonic factors (for example, high pressure of the Arabian indenter and relevant breakdown of microcontinents in the Caucasian region). The reactivation periods of dominant mantle volcanism alternated with either volcanism-free epochs or periods characterized by decreased contribution of the mantle to products of volcanic eruptions. Intense interaction of mantle melts with crustal material changed the composition of magmatic products up to the point of formation of crustal rocks.

Thus, results of the isotopic–geochronological study made it possible to determine the place of Neogene–Quaternary volcanism in Central Georgia in the geochronological scale of Neogene–Quaternary magmatism in the Greater Caucasus. They also revealed Sr–Nd isotopic characteristic of the mantle reservoir that served, probably, as one of the sources for the majority of young rocks in the study region.

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REFERENCES

1. I. V. Chernyshev, V. A. Lebedev, S. N. Bubnov, et al., Geokhimiya, No. 11, 1 (2002) [Geochem. Int., No.11, 1042 (2002)].
2. V. A. Lebedev, I. V. Chernyshev, A. V. Chugaev, et al., Dokl. Akad. Nauk, **396**, 244 (2004) [Dokl. Earth Sci. **396**, 529 (2004)].
3. V. A. Lebedev, I. V. Chernyshev, E. V. Arutyunyan, et al., Dokl. Akad. Nauk, **399**, 378 (2004) [Dokl. Earth Sci. **399A**, 1227 (2004)].
4. V. A. Lebedev, I. V. Chernyshev, S. N. Bubnov, et al., Dokl. Akad. Nauk, **405**, 389 (2005) [Dokl. Earth Sci. **405A**, 1321 (2005)].
5. V. A. Lebedev, S. N. Bubnov, I. V. Chernyshev, et al., Dokl. Akad. Nauk, **406**, 78 (2006) [Dokl. Earth Sci. **406**, 37 (2006)].
6. E. E. Milanovskii and N. V. Koronovskii, *Orogenic Volcanism and Tectonics of the Alpine Belt in Eurasia* (Nedra, Moscow, 1973) [in Russian].
7. N. N. Skhirtladze, *Post-Paleogene Effusive Volcanism in Georgia* (AN GruzSSR, Tbilisi, 1958) [in Russian].
8. B. G. Tutberidze, *Geology and Petrology of Alpine Late Orogenic Magmatism in the Central Caucasian Segment* (Tbilis. Univ., Tbilisi, 2004).
9. L. A. Nevesskaya, I. A. Goncharova, L. B. Il'ina, et al., Stratigr. Geol. Korrelyatsiya **11** (2), 3 (2003) [Stratigr. Geol. Correlation **11**, 105 (2003)].
10. O. Z. Dudauri, M. G. Togonidze, and E. N. Bartnitskii, Soobshch. AN GruzSSR **134** (1), 137 (1989).
11. S. D. Velikoslavinskii and V. A. Glebovitskii, Dokl. Akad. Nauk, **401**, 213 (2005) [Dokl. Earth Sci. **401**, 308 (2005)].
12. I. V. Chernyshev, V. A. Lebedev, and M.M. Arakelyants, Petrologiya **14** (1), 69 (2006).
13. A. W. Hofmann, Nature **385** (16), 219 (1997) (author's responsibility).
14. S. N. Bubnov, Candidate's Dissertation in Geology and Mineralogy, (IGEM RAN, Moscow, 2003).