ISSN 1028-334X, Doklady Earth Sciences, 2007, Vol. 416, No. 7, pp. 1018–1021. © Pleiades Publishing, Ltd., 2007.
Original Russian Text © M.L. Somin, O.A. Levchenkov, A.B. Kotov, A.F. Makeev, A.N. Komarov, N.I. Ro, V. A. Lavrishchev, V.A. Lebedev, 2007, published in Doklady Akademii Nauk, 2007, Vol. 416, No. 3, pp. 360–363.

GEOLOGY

The Paleozoic Age of High-Pressure Metamorphic Rocks in the Dakhov Salient, Northwestern Caucasus: Results of U–Pb Geochronological Investigations

M. L. Somin[a], O. A. Levchenkov[b], A. B. Kotov[b], A. F. Makeev[b], A. N. Komarov[b], N. I. Ro[b], V. A. Lavrishchev[c], and V. A. Lebedev[c]

Presented by Academician Yu.M. Pushcharovsky September 11, 2006

Received September 14, 2006

DOI: 10.1134/S1028334X07070082

The Dakhov Salient is a small exposure of the pre-Alpine crystalline basement within Jurassic rocks at the northwestern termination of the Front Range of the Greater Caucasus (Fig. 1). Together with the southeastern Beskes and Sakhrai salients, the Dakhov Salient makes up a partly exposed northern framing of the Middle Paleozoic island-arc complex of the Front Range. Like crystalline rocks of the Blyb Salient at the southern framing of the island-arc complex, rocks of the Dakhov Salient are traditionally considered the pre-Paleozoic basement of the Front Range. The Dakhov Salient is mainly composed of pre-Alpine granitoids (primarily, granodiorites), which intrude metamorphic rocks exposed as a narrow band in the northern area. The Dakhov Salient is easily accessible, and ravines of the Belaya River and Syuk Creek are excellently exposed. Nevertheless, several essential aspects of the geology of the Dakhov Salient remain controversial. The age of host rocks is the most important issue. In the 1970s, the K–Ar dating of granitoids and metamorphic rocks of this salient yielded a Neoproterozoic value of 985–612 Ma [4, 5]. Since then, the Dakhov Salient has become a rare reference (in terms of geochronology) object in the Greater Caucasus. This salient is always mentioned for the substantiation of the pre-Paleozoic age of its metamorphic basement [1, 2]. However, there are grounds to doubt the reliability of the datings mentioned above [6].

We performed U–Pb geochronological investigation of one of the oldest components of the Dakhov Salient—metaaplite veins assigned to the symplectitic garnet amphibolites of the Belaya River canyon. We also carried out K–Ar dating of granodiorites intruding the metamorphic rocks.

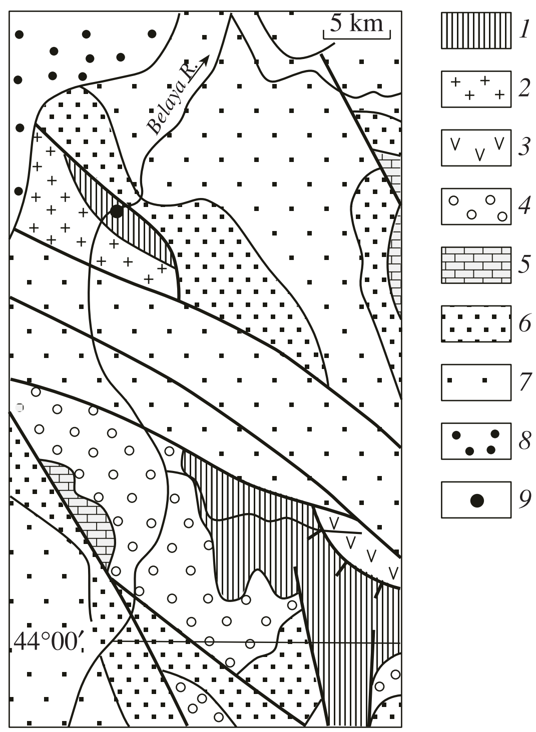

Fig. 1. Geological scheme of upper reaches of the Belaya River. (*1*) Metamorphic rocks; (*2*) granitoids; (*3*) Devonian volcanics; (*4*) Upper Carboniferous and Permian molasses; (*5*) Triassic; (*6*) lower and middle Liassic; (*7*) Aalenian and Middle Jurassic; (*8*) Upper Jurassic; (*9*) the Dakhov Salient site sampled for the U–Pb geochronological investigations (sample 2041-3a).

[a] *Institute of Physics of the Earth, Russian Academy of Sciences, Bol'shaya Gruzinskaya ul. 10, Moscow, 123810 Russia*
e-mail: somin@ifz.ru
[b] *Institute of Precambrian Geology and Geochronology, Russian Academy of Sciences, nab. Makarova 2, St. Petersburg, 199034 Russia*
[c] *FGUGP Kavkazgeols'emka, ul. Kislovodskaya 203, Essentuki, Stavropol krai, 357600 Russia*

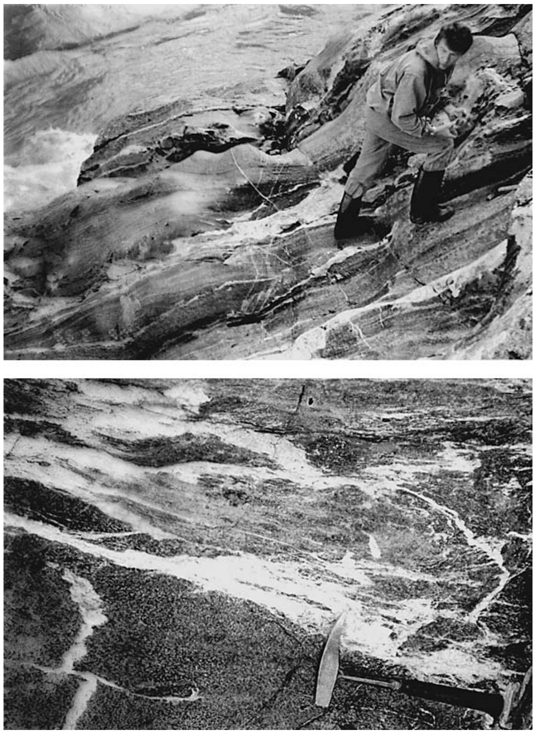

Fig. 2. Relationship between garnet amphibolites and metaaplites exposed 1 km away from the Settlement of Nikel at the right flank of the Belaya River.

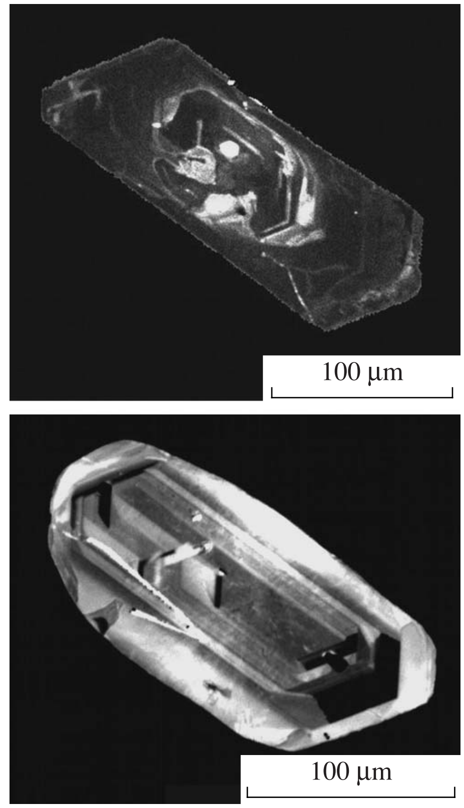

Fig. 3. Cathodoluminescence photomicrographs of zircon crystals from metaaplites of the Dakhov Salient (sample 2041-3a). CamScan scanning electron microscope.

The symplectitic amphibolites make up conformable stratiform bodies (10*n* cm to 10 m thick) among a compositionally variable rock sequence of epidote- and clinopyroxene-bearing amphibolites, hornblende schists, micaceous microgneisses (with relicts of porphyry textures), two-feldspar biotite–hornblende gneisses, and muscovite–quartz schists. Taking the composition of garnet amphibolites and the host rocks into consideration, the maximal temperature of rock metamorphism is 620°C at pressures ranging from 8 to 9.5 kbar. This setting corresponds to the high-pressure amphibolite facies of regional metamorphism [3]. Metaaplite veins (up to 30 cm thick) have both sharp and diffuse contacts with the amphibolites. They make up an intricate system of conformal and discordant veins. The conformal veins extend along the schistosity and banding of amphibolites, whereas the discordant veins steeply crosscut the banding. In the latter case, one can see that the schistosity is common for amphibolites and metaaplites (Fig. 2), suggesting the premetamorphic or synmetamorphic emplacement of aplite veins.

Metaaplites represent fine-grained rocks composed of albite, microcline, quartz, and white mica with a small admixture of chlorite and skeletal garnet crystals of the almandine series. Zoisite is developed in the metaaplites along the contact with amphibolites. The rocks have a lepidogranoblastic texture and schistose structure related to the parallel arrangement of mica flakes and flattened quartz grains.

We extracted accessory zircon grains from the metaaplites using heavy liquids according to the standard procedure. The chemical decomposition of zircon grains and the extraction of U and Pb were carried out according to the modified Krogh's method [8]. The zircon grains were treated with concentrated HF at 220°C for 2 h in order to separate zircon phases with undisturbed isotope age characteristics. The isotopic analysis was carried out with a Finnigan MAT-261 multichannel mass-spectrometer in the static regime. We also used the electron multiplier (the discrimination coefficient of the multiplier was $0.32 \pm 0.11\%$ per a.m.u. for Pb). The fractionation coefficients were 0.10% per a.m.u. for Pb and 0.08% per a.m.u. for U. The procedure blank did not exceed 0.1 ng for Pb and 0.01 ng for U. Based on results of replicate analyses of the standard zircon sample THA-16 with an age of 476 Ma, the coefficients of variation in the $^{206}Pb/^{238}U$ and $^{207}Pb/^{235}U$ ratios were equal to 0.90% (2σ). Experimental data were processed with the PbDAT [9] and ISOPLOT [10] software packages. Calculation of age was based on routine values of the uranium decay constant [12]. Correction for common lead was made in accordance with model values [11]. All errors are quoted at the 2σ level.

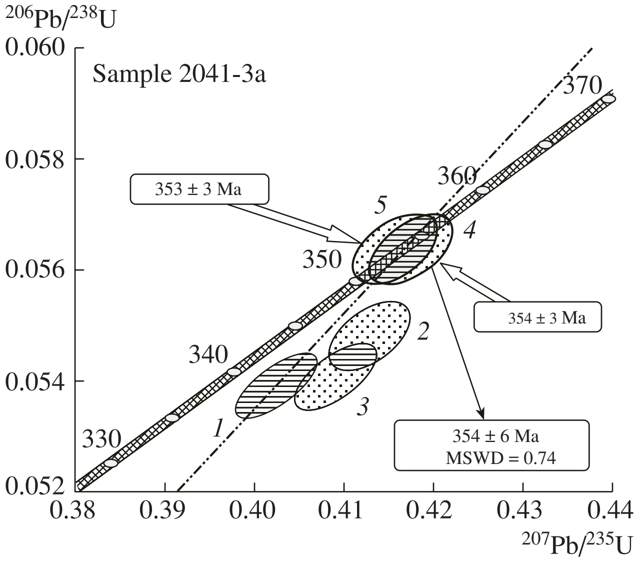

Fig. 4. Concordia diagram for zircons from metaaplites of the Dakhov Salient (sample 2041-3a). Data point numbers are as in the table.

Accessory zircon grains extracted from the metaaplites are represented by transparent idiomorphic colorless prismatic crystals with obtuse pyramids. They contain a small amount of microinclusions. The crystals display a clear zonality in cathodoluminescence rays. The resorbed central part developed in some crystals can be relicts of protonuclei (Fig. 3). The typomorphic features of the zircon grains suggest their magmatic origin.

We analyzed five zircon fractions. Among them, three fractions are characterized by different grain sizes (table, nos. 1–3). The other two fractions are represented by insoluble zircon phases left after acid treatment (nos. 4, 5). All zircon fractions are depleted in U (61–150 μg/g) and characterized by low Th/U values ranging from <0.001 to 0.003 (table).

The size fractions of zircon are characterized by direct age discordance: $t(^{206}Pb/^{238}Pb) < t(^{207}Pb/^{235}U) < t(^{207}Pb/^{206}Pb)$. The zircon residue left after acid treatment has concordant age values (table, nos. 4, 5). Figure 4 shows that the zircon from fraction no. 4 has a concordant age of 354 ± 3 Ma (MSWD of concordance 0.43, concordance probability 0.51). Zircon from fraction no. 5 has a concordant age of 353 ± 3 Ma (MSWD of concordance = 0.13, concordance probability = 0.71).

In the concordia diagram (Fig. 4), the regression line drawn across data points of fraction nos. 1, 4, and 5 virtually passes across the origin and crosses concordia at a point corresponding to 354 ± 6 Ma (MSWD = 0.74). Data points of fraction nos. 2 and 3 are located on the right-hand side of discordia, indicating the presence of an inherited component of ancient Pb in zircons of these fractions. Within the error limits, the age estimate based on the upper intercept matches the concordant age values obtained for two zircon fractions, but the former estimate shows a large error. The zircon age calculated as the weighted-mean value of two concordant estimates is 353 ± 3 Ma. This estimate is considered the crystallization age of the parental melts for the metaaplites.

U–Pb isotope data on zircons (sample 2041-3a)

Ord. no.	Fraction size, μm	Weighed portion, mg	Content, μg/g		Isotope ratios		
			Pb	U	^{206}Pb/^{204}Pb^{a}	^{207}Pb/^{206}Pb^{b}	^{208}Pb/^{206}Pb^{b}
1	>130	0.52	3.4	61.4	581.9	0.05414	0.00091
2	100–130	1.09	5.47	92.9	373.0	0.05463	<0.00001
3	85–100	1.28	5.27	93.0	475.8	0.05487	0.00042
4	85–100 if	1.98	6.55	120	985.2	0.05374	0.00013
5	100–130 if	2.09	6.98	130	1355	0.05348	<0.00001

Ord. no.	Fraction size, μm	Isotope ratios		*Rho*	Th/U	Age, Ma		
		^{207}Pb/^{235}U	^{206}Pb/^{238}U			^{206}Pb/^{238}U	^{207}Pb/^{235}U	^{207}Pb/^{206}Pb
1	>130	0.4024	0.05391	0.74	0.003	338.5 ± 2.9	343.4 ± 2.6	376.8 ± 3.6
2	100–130	0.4128	0.05480	0.53	<0.001	343.9 ± 3.1	350.9 ± 3.0	397.1 ± 5.5
3	85–100	0.4091	0.05407	0.67	0.001	339.5 ± 2.9	348.2 ± 2.6	407.0 ± 3.6
4	85–100 if	0.4176	0.05635	0.53	<0.001	353.4 ± 3.1	354.3 ± 3.0	360.4 ± 5.2
5	100–130 if	0.4156	0.05636	0.49	<0.001	353.4 ± 4.1	352.9 ± 4.0	349.4 ± 7.0

Note: (a) Isotope ratio corrected for the procedure blank and fractionation: (b) isotope ratio corrected for procedure blank, fractionation, and common lead; (if) insoluble zirconium fraction left after acid treatment.

Thus, the data obtained suggest that the veins discussed in this paper formed approximately 353 Ma ago in the Tournaisian (Early Carboniferous). This value defines the lower age limit for the metamorphism of rocks in the Dakhov Salient. According to K–Ar dating carried out at the Institute of Geology of Ore Deposits, Petrography, Mineralogy, and Geochemistry (Moscow), hornblende from unmetamorphosed biotite–hornblende granodiorites formed 301 ± 10 Ma ago (K 0.68 ± 0.015%, $^{40}Ar_{rad}$ (ng/g) 15.4 ± 0.1). This value defines the upper age limit for the Dakhov Salient.

Metaaplites of the Dakhov Salient predated or accompanied the high-pressure metamorphism of rocks. Therefore, the determination of their age has several essential implications. The data obtained show that metamorphic rocks of the Dakhov Salient cannot serve as the basement for the unmetamorphosed Middle Paleozoic island-arc sequences of the Front Range exposed in the adjacent area, because the Middle Paleozoic sequences include Upper Silurian–Lower Devonian rocks. Hence, the age of metamorphism of rocks of the real basement should be at least pre-Silurian. The age of the protolith for amphibolites and other metamorphic rocks of the Dakhov Salient remains unclear. However, metamorphic rocks of this salient are probably derived from Middle Paleozoic protoliths. This conclusion is suggested by data on metamorphic rocks of the Blyb Salient located in a similar lithostructural setting. Metamorphic rocks of the latter salient were metamorphosed during the early Variscan stage, and their age is estimated at 400–323 Ma. Coupled with the recently analyzed geological data [7], the data reported in the present paper indicate that the southern and northern metamorphic belts of the Front Range probably represent parts of a single Variscan subduction complex, whereas the unmetamorphosed island-arc sequences make up an allochthon overlying the Variscan complex. In other words, the Middle Paleozoic unmetamorphosed and metamorphic complexes are tectonically juxtaposed in the structure of the Front Range.

REFERENCES

1. I. P. Gamkrelidze and D. M. Shengelia, *The Precambrian–Paleozoic Regional Metamorphism, Granitoid Magmatism, and Geodynamics of the Caucasus* (Nauchnyi Mir, Moscow, 2005) [in Russian].
2. I. I. Grekov and V. A. Lavrishchev, in *Problems of Geology, Mineral Resources, and Ecology in Southern Russia and Caucasus* (YuRGTU, Novocherkassk, 2002), pp. 49–58 [in Russian].
3. S. P. Korikovsky, M. L. Somin, and S. G. Korsakov, Dokl. Earth Sci. **397**, 778 (2004) [Dokl. Akad. Nauk **397**, 650 (2004)].
4. G. I. Lebed'ko and V. I. Usik, *Geochronology of the Northern Caucasus* (RGU, Rostov-on-Don, 1997) [in Russian].
5. G. I. Lebed'ko, V. I. Usik, and V. Ya. Sharafan, *Petrochemistry of "Krystallanikum" of the Northern Caucasus* (RGU, Rostov-on-Don, 1985) [in Russian].
6. *Petrology of Metamorphic Complexes in the Greater Caucasus*, Ed. by S.P. Korikovsky (Nauka, Moscow, 1991) [in Russian].
7. M. L. Somin and V. A. Lavrishchev, Dokl. Earth Sci. **401A**, 353 (2004) [Dokl. Akad. Nauk **401**, 370 (2005)].
8. T. E. Krogh, Geochim. Cosmochi. Acta **37**, 485 (1973).
9. K. R. Ludwig, *PbDat for MS-DOS. Vers. 1.21* (US Geol. Surv. Open-File Rep. No. 8-542, 1991).
10. K. R. Ludwig, *ISOPLOT/Ex. Vers. 2.06. A Geochronological Toolkit for Microsoft Excel.* (Berkley Geochronol. Center Spec. Publ., No. 1a, 1999).
11. J. S. Stacey and I. D. Kramers, Earth Planet. Sci. Lett. **26**, 207 (1975).
12. R. H. Steiger and E. Jager, Earth Planet. Sci. Lett. **36**, 359 (1976).