ISSN 1028-334X, Doklady Earth Sciences, 2007, Vol. 415, No. 5, pp. 690–694. © Pleiades Publishing, Ltd., 2007.
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Age of the High-Temperature Gneiss Core of the Central Caucasus

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Presented by Academician Yu.M. Pushcharovsky June 12, 2006

Received July 13, 2006

DOI: 10.1134/S1028334X07050066

Different pre-Mesozoic formations dominated by metamorphic complexes are widespread in the mountainous Central Caucasus. Knowledge of their ages is essential for interpretation of the pre-Mesozoic structure, evolution, and geodynamics of the Crimean–Caucasian segment at the southern active margin of Eurasia. These issues are still highly debatable. It is widely accepted that metamorphic rocks are of Proterozoic age in all zones of the Central Caucasus [2, 3, 4]. The most widespread gneiss–migmatite complex (GMC) of the Main Range composed of para- and orthogneisses, amphibolites, and migmatites, which outcrop in its northern part, is also attributed to the Proterozoic based on the following facts: (1) its location in the deepest (core) part of the range; (2) the highest grade of metamorphism in the Greater Caucasus corresponding to high-temperature stages of the amphibolite facies [2, 5]; and (3) several U–Pb zircon ages [2–4] corresponding to the Precambrian, although they have remained debatable for a long time [5]. As was assumed or shown [1, 6], most of the ages were obtained for detrital zircons. Most often, researchers indicate ages of 500 ± 40 and ~2000 Ma obtained by the Pb/Pb evaporation method for zircons extracted from orthogneisses of the Adyl-su River basin [7]. At the same time, dating of zircons from rocks of the same massif using the traditional U–Pb method provided an age of 400 ± 10 Ma [1]. Recently, a U–Pb age of 386 ± 5 Ma was obtained for compositionally similar orthogneisses from the Kyrtyk River basin, while the U–Pb dating of zircons from migmatite leucosomes of the Ulluchiran Glacier area yielded 305 Ma [6]. These data indicate that the gneiss–migmatite complex includes highly metamorphosed Middle Paleozoic granitiods and that regional metamorphism continued, at least partly, in the Late Paleozoic. However, the age of paragneisses, which enclose orthogneisses and migmatites and are most widespread in the GMC, remains,unknown thus far. The accuracy of the above-mentioned Precambrian datings obtained for single zircon grains is also debatable.

To solve these problems, the SHRIMP U–Pb dating of detrital and metamorphic zircons from para-gneisses was carried out for the first time. In order to obtain the most representative results, we carried out the dating of three paragneiss samples taken with a spacing of 150 km. The samples differed in the migmatization degree. For estimating the age of GMC metabasic rocks and, simultaneously, for controlling the data on orthogneisses from the Kyrtyk River basin, we performed the SHRIMP dating of amphibolites intruded by the orthogneisses. The results demonstrated that neither protoliths of the above-mentioned rocks nor their metamorphism can be referred to the Precambrian.

Paragneiss sample 0-17(517) was taken near the mouth of the Adyr-su River located in the large area of the sillimanite–biotite–muscovite subfacies of the amphibolite facies [2, 5]. The paragneiss represents banded migmatized rocks that are typical of the GMC and deformed into overturned folds. Their composition corresponds to Qtz–Grt–Bt–Sil (–Pl–Kfs). Sillimanite and biotite are the dominant minerals. Garnet demonstrates only slight retrograde zoning indicating one-stage metamorphism with $T = 616°\text{C}$ and $P \leq 4$ kbar. Zircon occurs in these rocks as transparent elongated prismatic crystals with rare inclusions and marginal zoning (Fig. 1). They are similar to zircons in the migmatite leucosome. Zircon grains contain rounded inherited cores. In total, 11 grains were analyzed. Cores of three grains yielded a U–Pb age of 2347 ± 40, 1809 ± 33, and 1268 ± 23 Ma. Two other grains yielded 637 ±13 and 665 ± 7 Ma. The age determined for zircon crystals at 12 points located beyond the crystal core (Fig. 2, table) varies from 322 to 288 Ma (average 323 ± 3 Ma;

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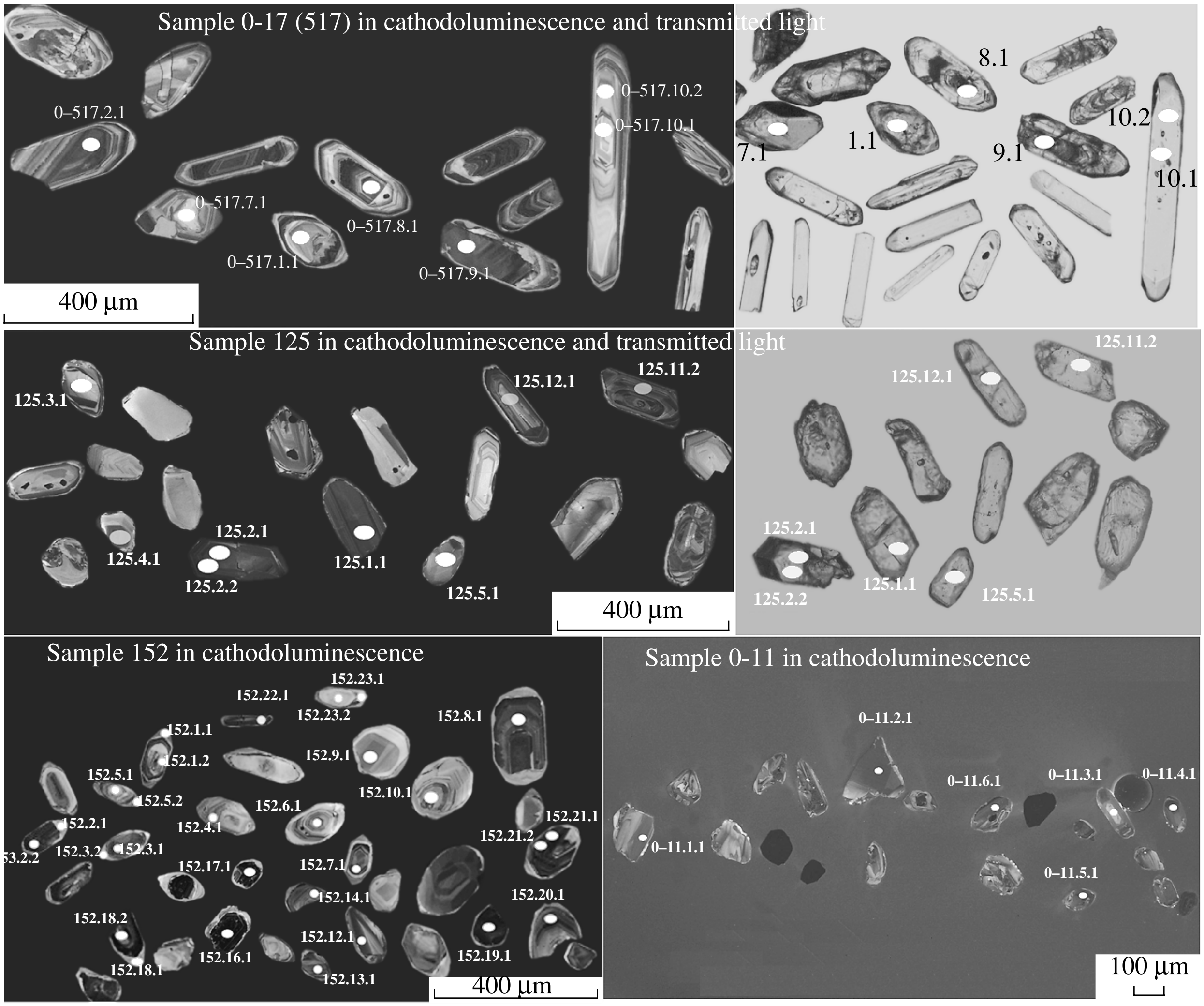

Fig. 1. The structure of dated zircons. Images obtained in cathodoluminescence and transmitted light. SHRIMP dating points are shown.

MSWD 0.014). One-third of all grains are characterized by low Th/U values (table, group A), which are typical of metamorphogenic zircons. The rock contains xenotime and monazite equilibrated with biotite and garnet. The garnet age determined by the CHIME [8] microprobe method is 280 ± 50 Ma.

Paragneiss sample 125 was taken on the left wall of the Damkhurts River (tributary of the Bol'shaya Laba River) 9 km upstream from the river mouth. The sample represents coarsely foliated nonmigmatized rocks composed of the Bt–Ms–Pl–Sil–Qtz association. Sillimanite occurs as complicatedly deformed fibrolite bunches. Zircons consist of rounded detrital cores and very thin rims that slightly mask the grain morphology (Fig. 1). Only cores were dated, because the thickness of rims is insufficient for measurements. Among 11 grains studied, three grains yielded approximately 1337, 1038, and 898 Ma. The dates of six other grains make up an almost continuous series of concordant values ranging from 676 to 561 Ma (Fig. 2; table, group B) corresponding to the Vendian. At the same time, the ages of two grains (four points) fall into the interval of 504 to 474 Ma (Late Cambrian–Early Ordovician). In all cases (table, group B), the Th/U value exceeds 0.15 (usually >0.30). This fact confirms the primary magmatic genesis of detrital grains.

Paragneisses of sample 152 taken in the upper left flank of the Sofiya River are represented by banded foliated and slightly migmatized rocks of the Grt–Bt–Ms–Pl–Qtz association. They enclose paragneiss interbeds with sillimanite and amphibolite lenses. Zircons in this sample are also detrital, but they are coated with thin rims (Fig. 1). In total, 23 grains were analyzed. In some of them, both central and marginal parts were analyzed. The ages of four grains vary from 2002 to 724 Ma (Fig. 2; table, group C), 18 grains yielded a Vendian–Early Cambrian age (634 to 522 Ma), and one grain (two points) yielded 474–432 Ma (Ordovician–

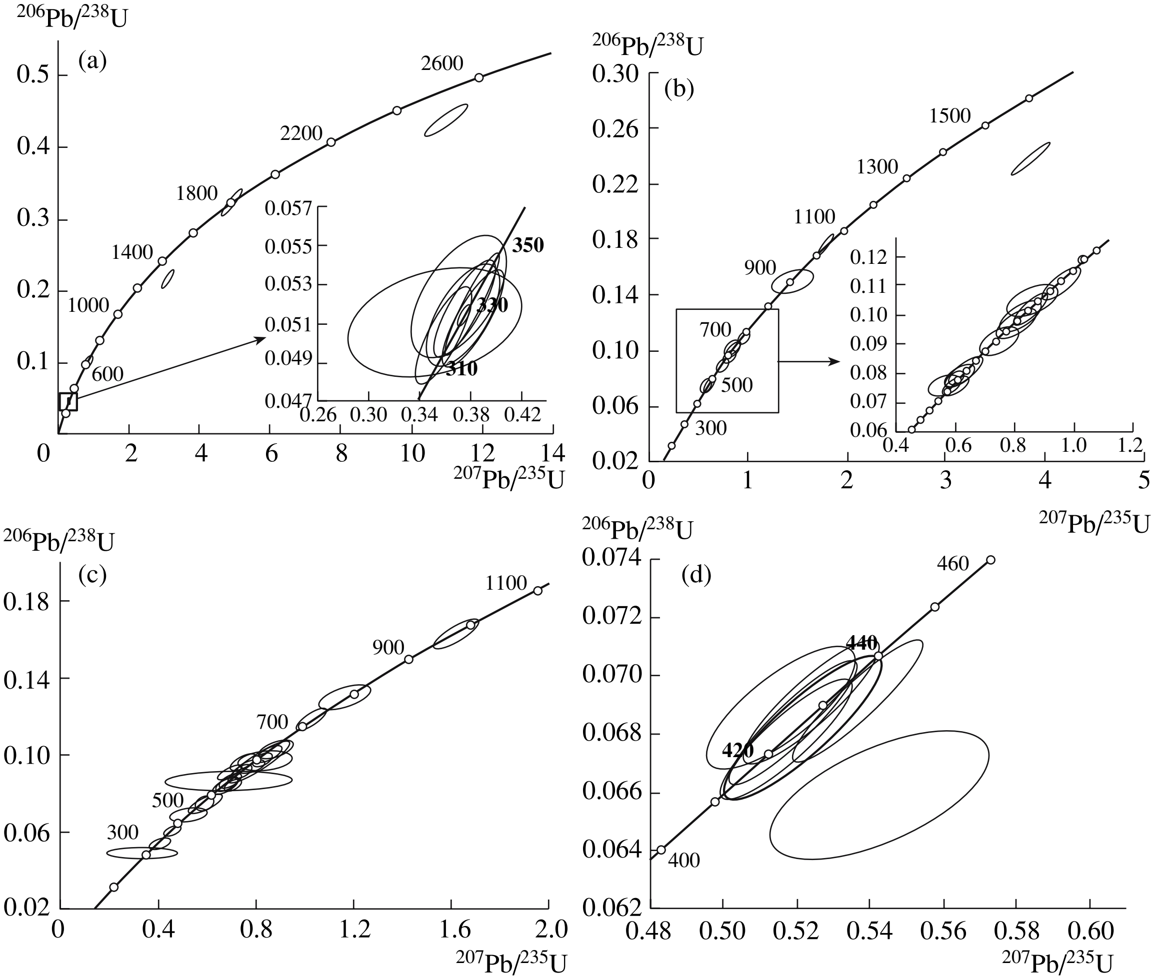

Fig. 2. Diagrams with concordia for dated samples. (a) Sample 0-517; (b) sample 125; (c) sample 152; (d) sample 0-11 (concordia age 425 ± 8.9 Ma, MSWD (of concordance) 0.39, probability (of concordance) 0.53).

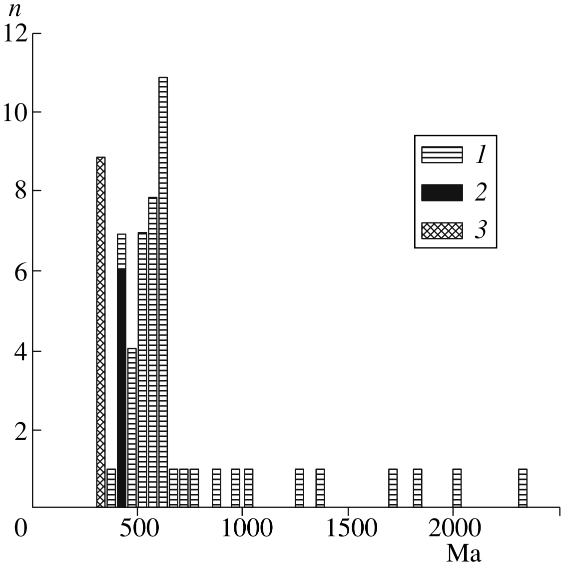

Fig. 3. Bar chart illustrating the distribution of zircon ages. Age (Ma) and number of grains are shown along the horizontal and vertical axes, respectively. Zircons: (*1*) detrital, (*2*) magmatic, (*3*) metamorphic.

Llandoverian). The metamorphic rim yielded 310 Ma. In this case and in grains with an age of 459, 432, and 381 Ma, the Th/U value is very low (0.03–0.07), probably due to alteration of zircons. In other cases, this ratio exceeds 0.12 (table, group C).

Similar to paragneisses of sample 0-17, amphibolites sampled on the left wall of the Kyrtyk River (sample 0-11) belong to the gneiss–migmatite complex. They are uniform massive rocks with a TiO_2 content up to 2 wt %. The rocks are intruded by two-feldspar orthogneisses dated at 386 Ma [6]. Zircons from amphibolites are almost isometric or angular. They are characterized by an absence of zonality or the development of an irregular wide zonality with indistinct boundaries between zones. Fusiform zoning is observed in some places (Fig. 1). Of six dated grains, five provided a concordant age averaging 425 ±9 Ma with MSWD = 0.39 (Fig. 2d; table, group C). The homogeneous composition of amphibolites and the shape of zircon grains suggest that these rocks originated from gabbrodiabases and that the zircons are of magmatic genesis.

Composition and ages of zircons in sample 0-17 (517)

Point	$^{206}Pb_c$, %	U	Th	$\frac{^{232}Th}{^{238}U}$	$^{206}Pb/^{238}U$	$^{207}Pb/^{206}Pb$	*D*, %
		ppm			Ma		
A. Sample 0-17 (517)							
0-517.10.1	0.49	244	111	0.47	321 ± 7	195 ± 180	–39
0-517.2.1	0.18	2195	171	0.08	317 ± 6	275 ± 34	–13
0-517.9.1	0.57	1647	101	0.06	330 ± 8	255 ± 79	–23
0-517.10.2	0.12	462	67	0.15	323 ± 7	321 ± 56	–1
0-517.3.1	0.09	1480	260	0.18	325 ± 6	312 ± 34	–4
0-517.4.1	0.00	715	199	0.29	323 ± 6	370 ± 35	15
0-517.8.1	0.01	2136	151	0.07	328 ± 6	342 ± 20	4
0-517.7.1	0.54	215	51	0.24	637 ± 13	613 ± 120	–4
0-517.5.1	0.00	641	155	0.25	1268 ± 23	1680 ± 11	33
0-517.6.1	0.00	175	31	0.18	1809 ± 33	1785 ± 17	–1
0-517.1.1	0.02	724	59	0.08	2347 ± 40	2664 ± 17	13
B. Sample 125							
125.7.1	0.44	267	96	0.37	474 ± 10	410 ± 92	–14
125.2.2	0.12	1128	455	0.42	479 ± 9	446 ± 32	–7
125.2.1	0.19	616	180	0.30	492 ± 10	465 ± 51	–5
125.11.2	0.04	829	122	0.15	504 ± 10	535 ± 29	6
125.9.1	0.15	233	95	0.42	561 ± 12	591 ± 67	5
125.5.1	0.15	212	265	1.29	597 ± 12	622 ± 57	4
125.7.2	0.00	188	54	0.30	611 ± 13	600 ± 55	–2
125.12.1	0.10	445	456	1.06	624 ± 13	637 ± 34	2
125.4.1	0.33	442	360	0.84	642 ± 13	580 ± 76	–10
125.1.1	0.00	739	166	0.23	676 ± 13	704 ± 37	4
125.3.1	0.00	71	52	0.75	898 ± 21	927 ± 110	3
125.6.1	0.02	1327	153	0.12	1038 ± 19	1023 ± 14	–1
125.8.1	0.00	821	640	0.80	1377 ± 25	1913 ± 10	39
C. Sample 0-11							
0-11.1.1	–	874	420	0.50	423 ± 8.3	424 ± 25	0
0-11.2.1	–	1577	1481	0.97	429.5 ± 8.4	382 ± 37	–11
0-11.3.1	0.07	248	163	0.68	411.3 ± 8.8	593 ± 64	44
0-11.4.1	0.00	1772	2238	1.31	430.7 ± 8.4	466 ± 19	8
0-11.5.1	0.04	1514	1968	1.34	430.7 ± 8.6	413 ± 25	–4
0-11.6.1	0.06	1677	1671	1.03	426.5 ± 8.5	413 ± 22	–3

Thus, the dates obtained for detrital zircons from all paragneiss samples fall into the Paleoproterozoic–Ordovician interval. Most of them correspond to the Late Riphean–Vendian and Early Cambrian (Fig. 3). The occurrence of grains dated back to 470–480 Ma (Th/U > 0.2) among detrital zircons suggests that the age of host rocks is younger than Early Ordovician. Taking into consideration the age of 425 Ma obtained for zircons from amphibolites of sample 0-11, the rocks are presumably not younger than the Wenlockian.

The occurrence of orthorocks with the Middle Paleozoic protolith (Silurian gabbroids and Devonian granitoids) in the gneiss–migmatite complex indicates the Variscan age of the latter complex. However, the dates obtained for metamorphic zircons represented by both thin rims of detrital grains and separate euhedral grains in migmatized paragneiss varieties indicate unambiguously that high-temperature regional metamorphism was in progress in the initial Late Paleozoic approximately 320 Ma ago. The slightly younger (305 Ma) date obtained by the traditional U–Pb method for zircons from leucosome of migmatites taken from the Ulluchiran Glacier area [6] is also consistent with the Variscan age assumed for the gneiss–migmatite complex of the Main Range in the Caucasus probably implying some asynchronism in its formation. Thus, isotopic–geochronological data are inconsistent with concepts of the pre-Paleozoic age of rocks in the high-temperature gneiss core of the Central Caucasus. There are sufficient grounds to believe that old (Precambrian) Pb–Pb ages cited in the literature were obtained for the inherited (largely detrital) zircons preserved in paragneisses or captured by intruding granitoids.

ACKNOWLEDGMENTS

This work was supported by the Federal Agency for Utilization of the Earth's Interior (Rosnedra contract no. AL-02-06/35) and the Kavkazgeols"emka Federal Geological Association.

REFERENCES

1. E. V. Bibikova, M. L. Somin, I. S. Krasivskaya, et al., Izv. AN SSSR. Ser. Geol., No. 9, 23 (1991).
2. I. P. Gamkrelidze and D. M. Shengelia, *Precambrian–Paleozoic Regional Metamorphism, Granitoid Magmatism, and Geodynamics of the Caucasus* (Nauchnyi Mir, Moscow, 2005) [in Russian].
3. I. I. Grekov and V. A. Lavrishchev, in *Problems of Geology, Mineral Resources, and Ecology in Southern Russia and the North Caucasus* (YURTGU, Novocherkassk, 2002), vol. 2, pp. 49–58 [in Russian].
4. G. I. Lebed'ko and V. I. Usik, *Geochronology of the North Caucasus* (Rostov. Univ., Rostov-on-Don, 1985) [in Russian].
5. *Petrology of Metamorphic Complexes of the Greater Caucasus*, Ed. by S.P. Korikovskii (Nauka, Moscow, 1991) [in Russian].
6. M. L. Somin, A. B. Kotov, E. B. Sal'nikova, et al., Stratigr. Geol. Correlation **14**, 475 (2006) [Stratigr. Geol. Korrelyatsiya **14** (5), 16 (2006)].
7. M. Hanel, H. I. Lippold, B. Kober, et al., Petrologiya **1**, 487 (1993).
8. K. Suzuki, M. Adachi, and T. Tanaka, Sediment. Geol. **75**, 141 (1991).