ISSN 1028-334X, Doklady Earth Sciences, 2006, Vol. 408, No. 4, pp. 612–616. © Pleiades Publishing, Inc., 2006.
Original Russian Text © A.A. Krasnobaev, F. Bea, G.B. Fershtater, P. Montero, 2006, published in Doklady Akademii Nauk, 2006, Vol. 408, No. 3, pp. 370–374.

GEOCHEMISTRY

Zircons and the Problem of Precambrian in the Main Granite Belt of the Urals: Evidence from the Kozhubaevo Metamorphic Complex

A. A. Krasnobaev[a], F. Bea[b], G. B. Fershtater[a], and P. Montero[b]

Presented by Academician V.A. Koroteev July 18, 2005

Received August 5, 2005

DOI: 10.1134/S1028334X06040234

Metamorphic rocks of the Kozhubaevo Complex (KC) surround the Dzhabyk–Karagai granite massif in the north and northwest (Fig. 1). Together with granites, the metamorphic rocks belong to the Ural–Tobol'sk anticlinorium of the East Uralian Anticlinorium [1–4]. The issue of the KC age is a characteristic problem of all similar gneissic complexes in the Urals, since geological data suggest both Paleozoic and Precambrian ages for the gneisses, while geochronological data are limited by only a few K–Ar datings within 250–350 Ma. According to [2, 3], regional metamorphism of the KC gneisses corresponds to the amphibolite facies. Repeated events of granitization and migmatization, block movements, and cataclasis produced numerous small bodies of granites, pegmatites, and quartz veins.

Naturally, isotope systems of rocks and minerals (zircon and others) could not remain closed under such conditions. Their alterations were mainly oriented toward rejuvenation. At present, this empirical trend has become a rule encountered by all geologists engaged in the study of metamorphic rocks in foldbelts.

Zircon geochronology is the most reliable method for obtaining information on the early stages of the KC, since zircon is most resistant to secondary alterations among mineral geochronometers. However, zircon dating of KC is a difficult task. First, the study area is insufficiently exposed. One can see only a few outcrops of the metamorphic rocks in the river valley and in excavations near bridges, dams, and so on. The zircons are distinctly polygenetic crystals, and their sorting requires independent mineralogical research.

Rocks. Gneiss specimens taken for zircon extraction strongly differ in composition (Fig. 1, Table 1). Granitized rocks (samples 1771, 1773) are characterized not only by high contents of SiO_2 and zircon but also by the abundance of morphological types of zircon. In terms of the major element composition, the gneisses are similar to plagiogranites and low-alkaline granites of the K–Na series. The REE distribution pattern shows insignificant enrichment of LREEs (La–Nd). Concentrations of other REEs are only 10–15 times higher relative to chondrites.

Zircons. All gneiss samples contain diverse types of zircons (Fig. 2, 1–23), confirming the polygenetic origin of both rocks and zircons. We can distinguish four major zircon populations with inherited development modes and mutual transitions in various combinations even within individual crystals.

The first zircon population (type I) includes transparent (!), almost colorless homogenous crystals, occasionally with zoning or primary inclusions. The grains are equant, locally faceted and euhedral (Fig. 2, *1–9*). Judging from the morphology, zircon I comprises magmatic and metamorphic grains, including granulite varieties, which were affected by brittle deformations (fragmentation) and abrasive (terrigenous) treatment. These data indicate that the gneisses developed after a volcanosedimentary protolith; i.e., they are parametamorphic rocks.

Zircon II (Fig. 2, *18–20*) is related to the transformation (fragmentation and metasomatism) of zircon I and is characterized by the presence of secondary inclusions. In some places, zircon II occurs as gray-brown turbid irregular, often spotty grains presumably formed independently, i.e., without contribution of zircon I.

The transition from zircon I to zircon II can be observed in the intermediate crystals (Fig. 2, *10–17*), which reflect all stages of transformation from trans-

[a] *Zavaritskii Institute of Geology and Geochemistry, Ural Division, Russian Academy of Sciences, Pochtovyi per. 7, Yekaterinburg, 620219 Russia; e-mail: krasnobaev@igg.uran.ru*

[b] *Department of Mineralogy and Petrology, Fuentenueva Campus, Granada University, 18002 Granada, Spain*

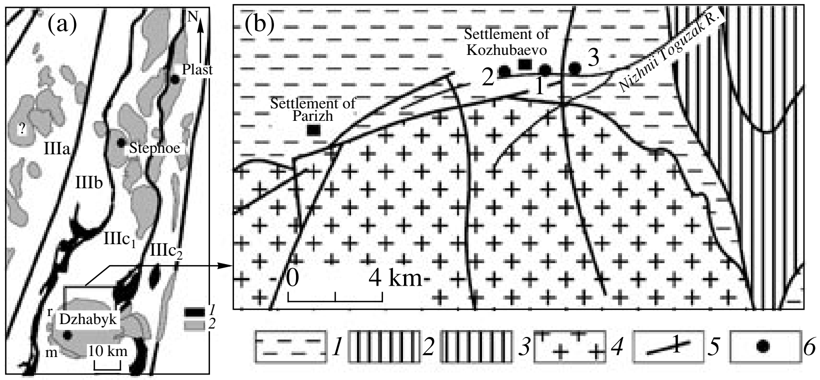

Fig. 1. Geological schemes. (a) Location of serpentinite (*1*) and granitoid (*2*) massifs of the Southern Urals. Zones: (IIIa) Magnitogorsk volcanogenic, (IIIb) southeastern continental-margin; paleocontinental southeastern zones: ($IIIc_1$) Kochkar anticlinorium, ($IIIc_2$) East Uralian trough. (b) Eastern part of the Dzhabyk granite massif and its gneissic framing (based on materials of geological survey by E.V. Shalaginov and E.P. Shchul'kin in 1988–1990). (*1*) Gneisses and migmatites, Kozhubaevo Complex (probably, Paleoproterozoic), (*2*) quartzites and schists, Chulaksai Formation (probably, Late Riphean), (*3*) serpentinites; (*4*) granites; (*5*) faults; (*6*) sampling sites: (1) samples 1771, 1771n, (2) 1773, 1773a, 1773b, (3) 153.

parent homogenous crystals to polygenetic turbid grains. This process is typically accompanied by an increase in U content or a loss of radiogenic Pb, resulting in an underestimation of ages. In addition, involvement of alien admixtures (secondary inclusions) in zircon II increases the content of common Pb, which complicates dating.

Zircon III (Fig. 2, *21–23*), formed during granitization of the gneisses, makes up euhedral, zoned elongated crystals. Their color varies in the course of growth in the evolving environment. Crystals of type III are similar to zircons from abyssal granitoids. Zircon III may contain diverse primary inclusions and cores, which are represented by zircon I in some places. Like other types, zircon III also experienced fragmentation and metasomatic alteration (Fig. 2, *23*).

Zircon IV includes newly formed overgrowths (knobs, crusts, and swells) on the surface of zircons I–III (Fig. 2, *3, 9, 11–17, 19, 23*). Although the share of zircon IV is insignificant, this type has an important genetic significance as an indicator of final stages of mineral formation reflected in all varieties of the metamorphic rocks.

The first datings [5] (Table 2, Fig. 3a) of the KC rocks were conducted on small zircon samples (3–5 mg) by the conventional U–Pb method using standard procedures [6–8]. Therefore, we only used samples 153 and 1771, which could be divided into fractions *a* and *b* mainly including zircons I and II. Zircons from sample 1773 represented a mixture of fractions *a* and *b*. The most altered grains were removed from the sample. Such an approach should extend the data points along the discordia and provide for the two-stage model of zircon evolution; i.e., this method allows us to use zircons with disturbed isotopic ratios. The obtained discordia has intercepts at 1806 ± 74 Ma and 408 ± 13 Ma (MSWD = 0.75), which yield $^{207}Pb/^{206}Pb$ ages within 400–1300 Ma. All these data confirmed the presence of Proterozoic protolith in the KC, but they were considered as preliminary results that required confirmation by other methods. In addition, the weight of the samples was too small to provide reliable data.

The laser ablation method allows the dating of single zircon crystals [9] and significantly facilitates the preparation of samples for analysis. We chose the most homogenous zircon crystals from samples 1771n and 1773a to obtain information about the earliest stages of the KC existence.

Table 2 and Fig. 3b demonstrate the results. The data points are mainly grouped around 400 Ma, which corresponds to the lower intercept. The upper intercept at 1993 ± 21 Ma is similar to the result obtained by the

Table 1. Compositions of gneisses of the Kozhubaevo Complex, wt %

Sample no.	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	K_2O	Na_2O	P_2O_5	L.O.I.	Total
1771	70.41	0.67	14.65	5.22		0.08	1.49	3.00	1.53	2.36	0.12	1.05	100.48
1771n	64.78	0.74	15.78	6.70		0.10	2.91	3.17	2.12	2.15	0.13	0.98	99.56
1773	67.09	0.91	14.67	7.31		0.12	2.14	3.21	1.91	1.79	0.13	1.15	100.43
1773a	63.95	1.14	15.29	7.72		0.11	2.72	2.64	2.42	2.15	0.19	1.21	99.54
1773b	61.46	1.12	15.41	8.42		0.16	3.37	3.14	3.02	2.10	0.19	1.30	99.69

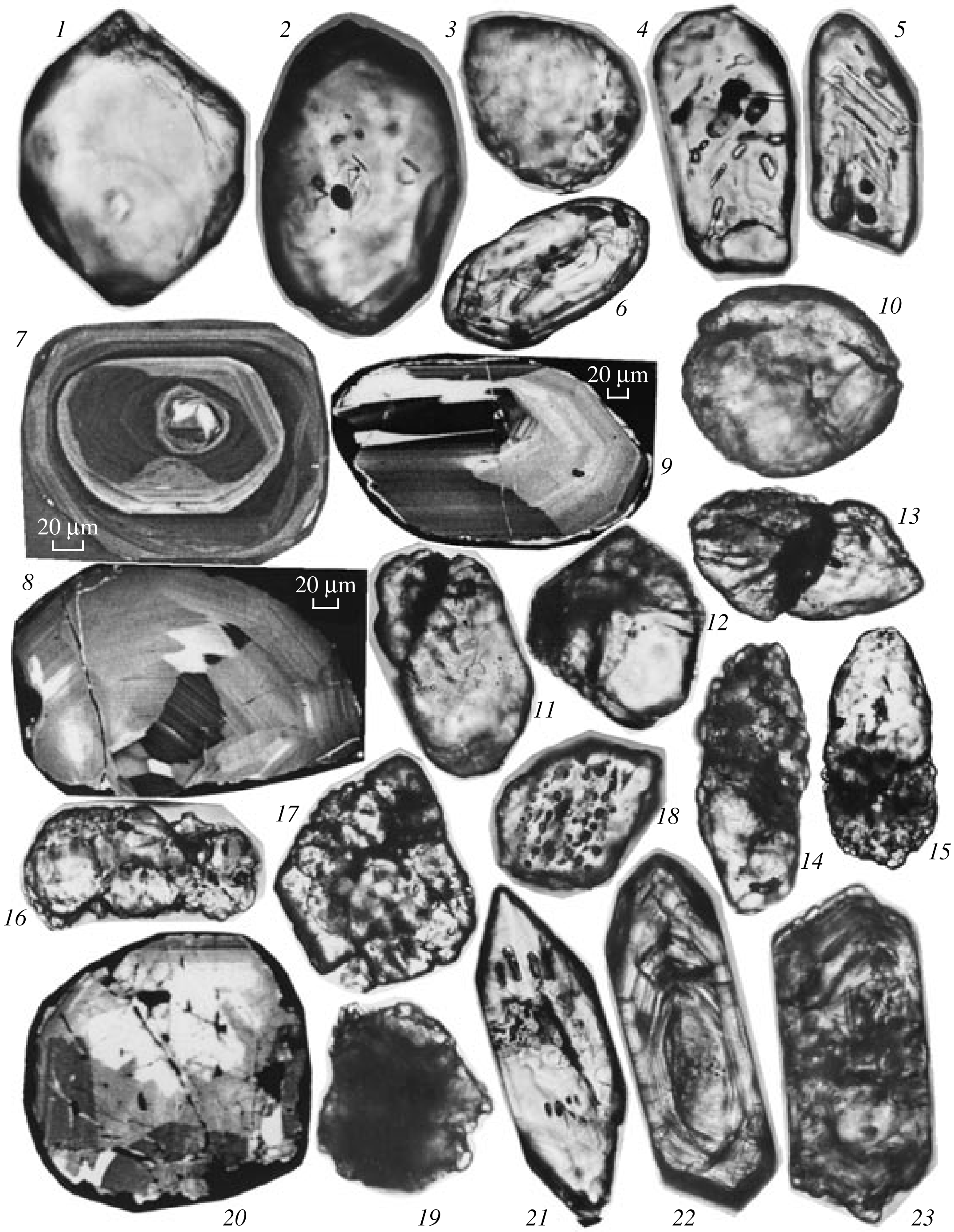

Fig. 2. Morphological features of zircons from the gneisses of the Kozhubaevo Complex. Photomicrographs. Magn. 150–200; cathodoluminescence images, scale is shown.

conventional technique. The use of data on crystal 8-2 may increase the age to 2350 Ma.

Thus, the first zircon datings by different methods yielded the Proterozoic age (no less than 1800–2000 Ma) for the Kozhubaevo Complex. Based on the morphology of zircon I, this age is the age of granulite metamorphism, which initially formed metamorphic rocks of the complex.

The Proterozoic date has a real contribution to the solution of general issues of the Uralian geology as evidence of the presence of the Precambrian lithosphere on the eastern slope of the Urals. This fact may solve the controversial problem of the protolith of Paleozoic granitoids in the Urals.

Now we can also correlate rocks of the KC with other gneissic complexes on the eastern slope of the

Table 2. U–Pb age of the gneisses of the Kozhubaevo Complex

Sample no.	Content, μg/g		Isotopic composition*			Isotope ratios*		Age, Ma	
	U	Pb	$^{206}Pb/^{204}Pb$	$^{207}Pb/^{206}Pb$	$^{208}Pb/^{206}Pb$	$^{207}Pb/^{235}U$	$^{206}Pb/^{238}U$	$^{207}Pb/^{206}Pb$	$^{206}Pb/^{238}U$
	U–Pb method								
1771a	437.3	71.39	59.634	0.29967	0.72391	0.47198	0.06247	404	391
1771b	1030.6	72.75	1742.3	0.06467	0.15557	0.50990	0.06568	464	420
153a	210.2	33.28	418.9	0.11855	0.35888	1.34470	0.11474	1315	700
153b	339.6	33.70	418.3	0.09695	0.31701	0.64803	0.07535	687	468
1773	265.4	27.71	183.1	0.13938	0.33429	0.59133	0.07129	609	444
	Laser ablation method***								
7-3	394	35	403	0.05929	0.19312	0.67746	0.08287	578	512
7-8	492	139	2128	0.11905	0.01145	4.72022	0.28756	1942	1588
7-9	812	188	1205	0.11054	0.20292	3.09643	0.20316	1818	1145
8-1	2104	154	588	0.05701	0.20318	0.52540	0.06684	492	416
8-2	47	26	278	0.15095	0.49881	8.08965	0.38868	2357	2055
8-7	2260	146	1428	0.05726	0.06643	0.52194	0.06611	501	411

Note: (*) Measured ratios; (**) corrected for procedure blank, mass-fractionation, and common lead [8] at age of 400 Ma; (***) crystals 7-3, 7-8, and 7-9 are taken from sample 1771n; other crystals, from sample 1773a.

southern Urals, for which similar dates have been reported in [10–12] (2083 ± 54 Ma for the Il'ich Complex, 2081 ± 15 Ma for the Selyanka Complex, and 1928 ± 146 Ma for the Chelyabinsk Complex). It is highly possible that all these rock complexes and the southeastern Mariinovsk Complex were initially members of an eastern (Kazakhstan (?) continent. After the destruction of this continent, its fragments were incorporated among Uralian complexes of the Uralian Belt. The youngest zircon datings of the rocks of the KC (Fig. 3, 404–408 Ma) presumably correspond to the age of transformations (amphibolite-facies metamorphism and migmatization) reflecting the onset of granite magmatism in the Main Granite Belt of the Urals.

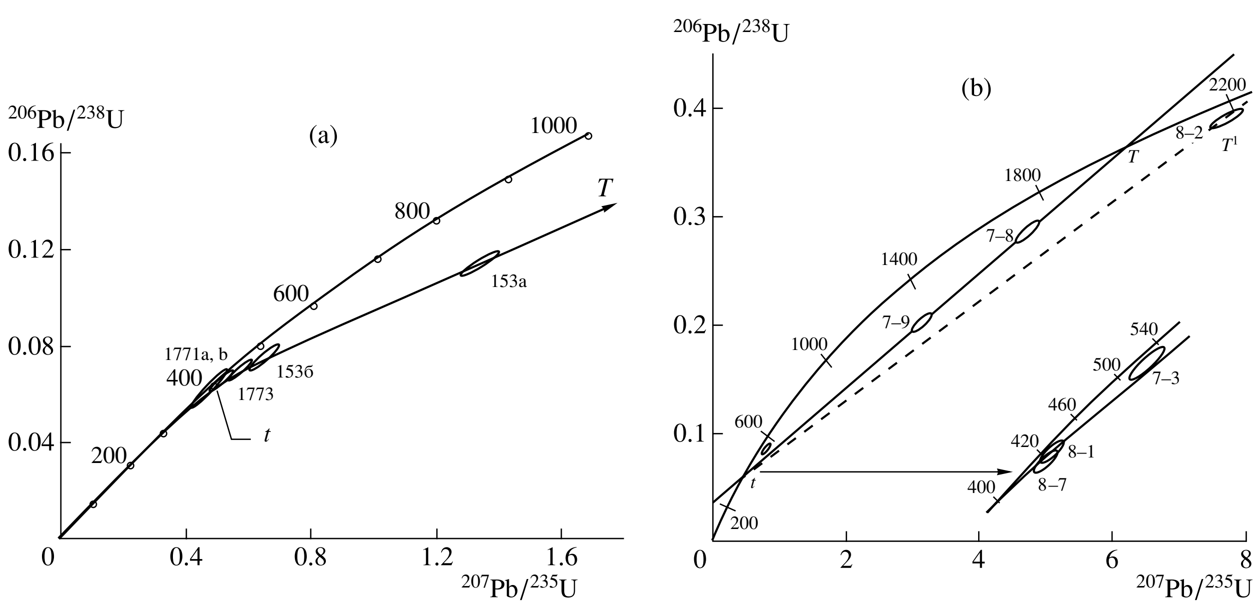

Fig. 3. Concordia diagram for zircons from the gneisses of the Kozhubaevo Complex. (a) U–Pb method, T = 1806 ± 74 Ma, t = 408 ± 13 Ma, MSWD = 0.72; (b) laser ablation method, T = 1993 ± 21 Ma, t = 404 ± 8 Ma, MSWD = 0.50; T^1 = 2350 Ma.

ACKNOWLEDGMENTS

This work was supported by the Russian Foundation for Basic Research (project no. 05-05-64079), the Federal Program for the Support of the Leading Scientific Schools (project no. 85.2003.5) and the Division of Earth Sciences of the Russian Academy of Sciences (Program no. 7).

REFERENCES

1. N. F. Mamaev, *Ancient Sequences of the East Uralian Anticlinorium* (Nauka, Moscow, 1967) [in Russian].
2. V. N. Ogorodnikov, in *Geology of Metamorphic Complexes* (Sverdl. Gos. Univ., Sverdlovsk, 1988), pp. 82–85 [in Russian].
3. V. V. Ogorodnikov, in *Geology of Metamorphic Complexes* (Sverdl. Gos. Univ., Sverdlovsk, 1988), pp. 79–82 [in Russian].
4. G. B. Fershtater, F. F. Tarakanov, and T. A. Osipova, in *Yearbook-1983* (Inst. Geol. Geokhim. Akad. Nauk SSSR, Sverdlovsk, 1984), pp. 65–66 [in Russian].
5. A. A. Krasnobaev, V. A. Davydov, E. P. Shchul'kin, and N. V. Cherednichenko, in *Yearbook-2001* (Inst. Geol. Geokhim. Ural. Otd. Ross. Akad. Nauk, 2002), pp. 185–189 [in Russian].
6. T. E. Krogh, Geochim. Cosmochim Acta **37**, 485 (1973).
7. K. R. Ludwig, U.S. Geol. Surv. Open-File Rep., No. 88-542 (1991).
8. J. S. Stacey and J. D. Kramers, Earth Planet. Sci. Lett. **26,** 207 (1975).
9. A. A. Krasnobaev, F. Bea, G. B. Fershtater, and P. Montero, in *Proceedings of the International Scientific Conference on Geology and Metallogeny of Ultramafic–Mafic and Granitoid Associations of Fold Systems, Yekaterinburg, Russia, 2004* (Inst. Geol. Geokhim Ural. Otd. Ross. Akad. Nauk, Yekaterinburg, 2004), pp. 211–216.
10. A. A. Krasnobaev, G. P. Kuznetsov, and V. A. Davydov, Dokl. Akad. Nauk **360**, 397 (1998) [Dokl. Earth Sci. **360**, 586 (1998)]
11. A. A. Krasnobaev, V. A. Davydov, E. P. Shchul'kin, and N. V. Cherednichenko, Dokl. Akad. Nauk **379**, 807 (2001) [Dokl. Earth Sci. **379**, 749 (2001)]
12. A. A. Krasnobaev, N. V. Cherednichenko, B. A. Puzhakov, and V. A. Chashchukhina, Dokl. Akad. Nauk **380**, 525 (2001) [Dokl. Earth Sci. **380**, 870 (2001)]