ISSN 1028-334X, Doklady Earth Sciences, 2007, Vol. 413A, No. 3, pp. 457–461. © Pleiades Publishing, Ltd., 2007.
Original Russian Text © A.A. Krasnobaev, F. Bea, G.B. Fershtater, P. Montero, 2007, published in Doklady Akademii Nauk, 2007, Vol. 413, No. 6, pp. 785–790.

GEOCHEMISTRY

The Polychronous Nature of Zircons in Gabbroids of the Ural Platinum Belt and the Issue of the Precambrian in the Tagil Synclinorium

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

Presented by Academician V.A. Koroteev April 27, 2006

Received May 10, 2006

DOI: 10.1134/S1028334X07030312

Application of high-precision analytical methods for the investigation of isotope parameters of single zircon crystals has significantly enhanced the potential of zircon geochronology. The issue of the Precambrian in the Tagil Synclinorium zone is related to problematic Proterozoic datings obtained by the laser ablation method at Granada University (Spain) for some zircon grains extracted from the Chernyi Istochnik gabbro massif of the Ural Platinum Belt [1]. The age of the predominant zircon variety was estimated at 422 ± 11 Ma. However, some datings obtained for the classic Late Ordovician–Silurian magmatism created a paradoxical situation that requires not only more reliable substantiation of ancient datings, but also the assessment of their geological significance with consideration of the large body of information pertaining to the TSZ origin.

In addition to the LA method described in [1], we also used the ion microprobe method that makes it possible to analyze single crystals [2]. The ion microprobe analysis was carried out with a NORDSIM microanalyzer (hereafter, NS) at the Swedish Analytical Center (Stockholm). We analyzed new zircon samples from the Volkov and Tagil–Barancha gabbroid massifs of the Ural Platinum Belt. Samples K528 (medium-grained gabbro, central part of the open pit) and K532 (hornblende gabbro, the Anatol'ev Settlement area) were taken from the Volkov Massif (Cu, V, and Pd). Samples K411 (olivine gabbro, estuary of the Lodochnik River) and K521 (gabbronorite, the Karpushikha Settlement area) were taken from the Tagil–Barancha Massif. We also obtained additional (NS-based) information on

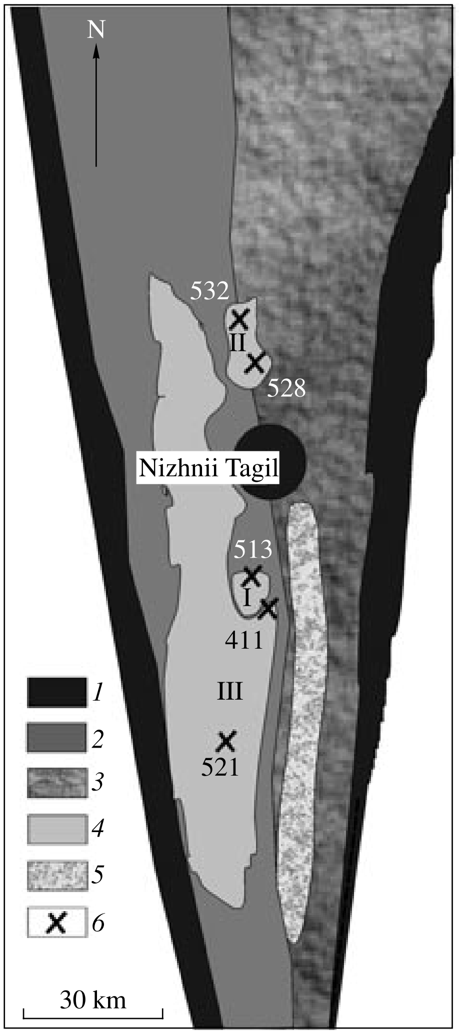

Fig. 1. Geological scheme of the southern Tagil Synclinorium (TS). (*1*) Sutures bounding the TS; (*2*) Platinum Belt zone; (*3*) volcanic zone; (*4*) gabbroid massifs: (I) Chernyi Istochnik, (II) Volkov, (III) Tagil–Barancha; (*5*) Tagil granitoid massif; (*6*) sampling sites.

---

[a] *Institute of Geology and Geochemistry, Ural Division, Russian Academy of Sciences, Pochtovyi per. 7, Yekaterinburg, 620151 Russia; e-mail: krasnobaev@igg.uran.ru*

[b] *Universidad de Granada, Fuenfanueva s/n, 18002, Granada, Spain; e-mail:mailfbea@goliat.ugr.es*

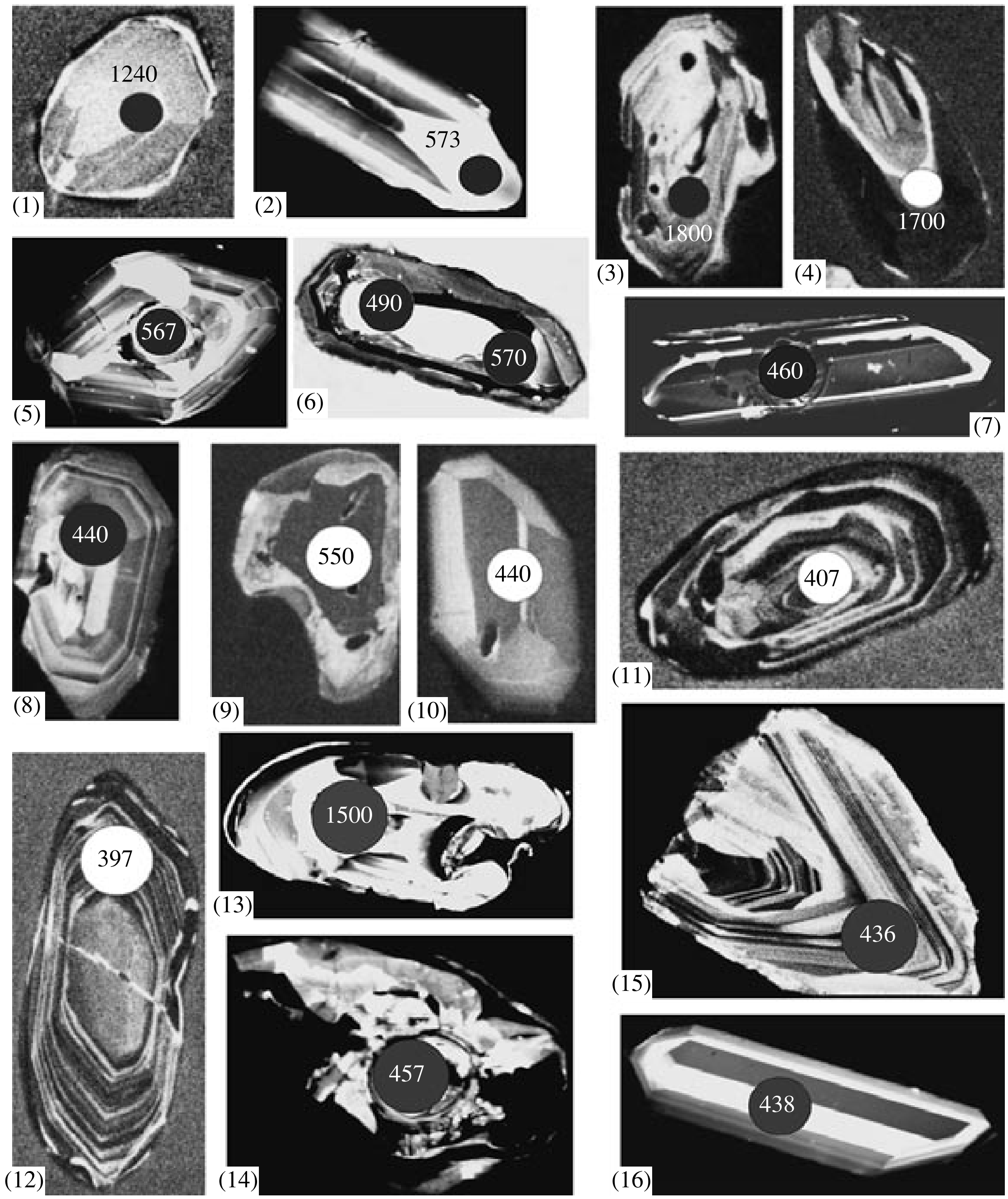

Fig. 2. Cathodoluminescence of zircons from gabbroids of the Ural Platinum Belt. Crystals 1–4, 8–12, 15, and 16 were analyzed by the NORDSIM ion microprobe method (crater 35–40 μm); crystals 5–7, 13, and 14, by the LA ICP-MS method (crater 45–50 μm). The numbers designate T_{cor} ages (see table).

gabbro of the Chernyi Istochnik Massif (sample K513, northern shore of the Chernyi Istochnik pond). Figure 1 shows the location of samples.

The NS analysis of zircons in gabbro sample K513 from the Chernyi Istochnik Massif (Figs. 2a, 2b, 3; table) yielded a slightly older age for the main zircon variety (445 ± 14 Ma) relative to the LA-based dating and confirmed the presence of Precambrian varieties (1239 ± 14 Ma). The date of 563 ± 8 Ma is of principle significance, because this value has been obtained for crystals with distinct primary mineralogical features, such as sandglass-type textures (Fig. 2b). Therefore, the value cited above can be considered a zircon-forming age boundary. Results of the analysis of sample K513 suggest that endogenic activity continued in the Tagil Synclinorium zone until the Early Carboniferous (345 ± 4 Ma).

The polygenous and polychronous nature of zircons in the Volkov gabbro (sample K528) is manifested in both mineralogical (Figs. 2.2–2.8) and age (Figs. 3b, 3c)

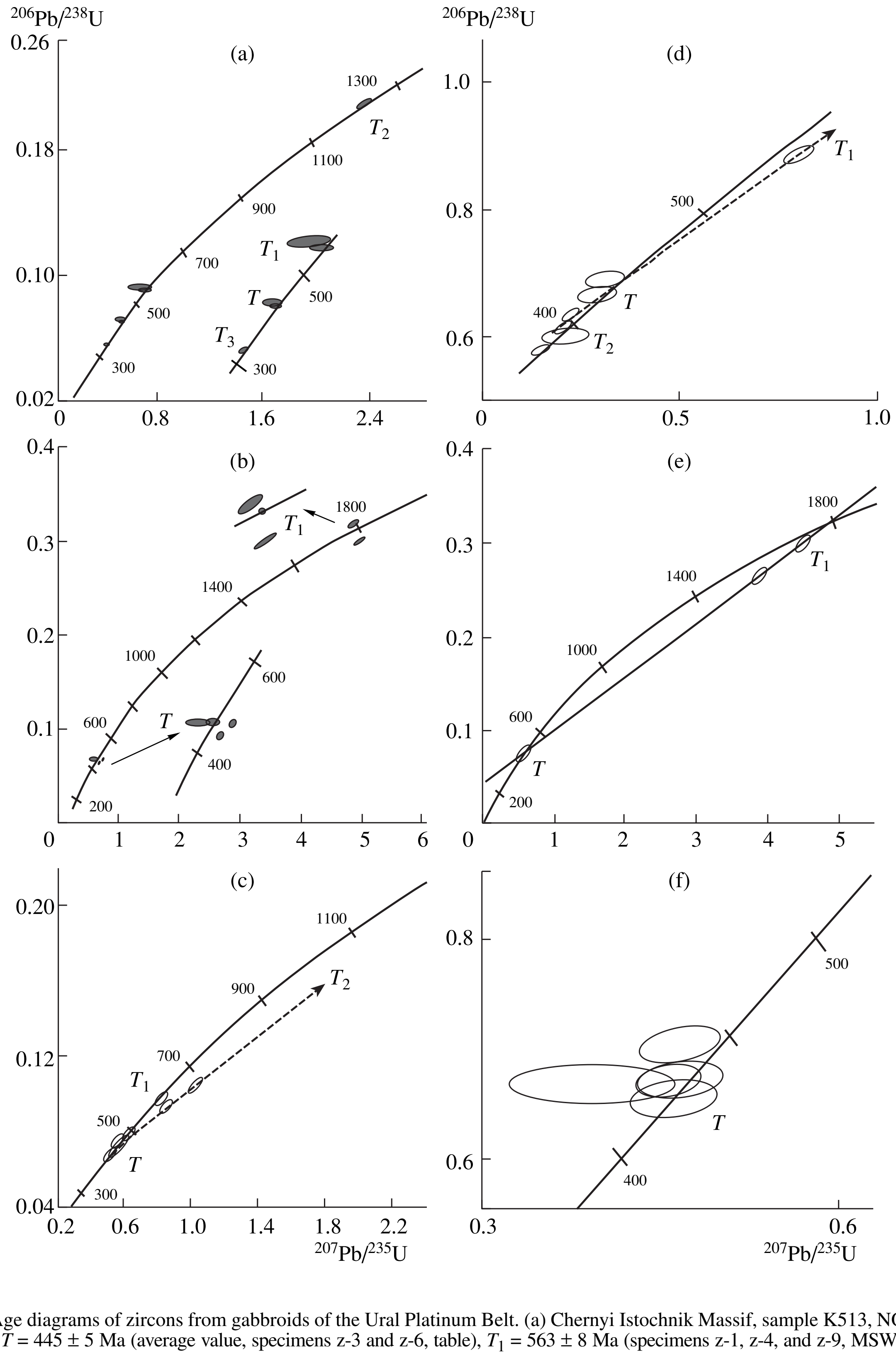

Fig. 3. Age diagrams of zircons from gabbroids of the Ural Platinum Belt. (a) Chernyi Istochnik Massif, sample K513, NORDSIM method, $T = 445 \pm 5$ Ma (average value, specimens z-3 and z-6, table), $T_1 = 563 \pm 8$ Ma (specimens z-1, z-4, and z-9, MSWD = 0.1), $T_2 = 1239 \pm 14$ Ma, $T_3 = 345 \pm 4$ Ma; (b–d) Volkov Massif: (b, c) sample K528, (b) NORDSIM method, $T = 443 \pm 14$ Ma (MSWD = 2.6), T_1 up to 1824 Ma; (c) LA ICP-MS method, $T = 445 \pm 15$ Ma (specimens 3-3 and 3-8), $T_1 = 578$–603 Ma (specimens 3-1C and 3-9), T_2 up to 2250 Ma; (d) sample K532, NORDSIM method, $T = 435 \pm 10$ Ma (specimens z-21 and z-24), T_1 up to 1200 Ma, $T_2 = 395 \pm 8$ Ma (specimens z-13 and z-18, MSWD = 1.8); (e, f) Tagil–Barancha Massif: (e) sample K411, LA ICP-MS method, $T = 462 \pm 15$ Ma, $T_1 = 1763 \pm 22$ Ma (MSWD = 0.63), (f) sample K521, NORDSIM method, $T = 438 \pm 9$ Ma (MSWD = 0.49).

U–Pb zircon age of gabbroids from the Tagil Synclinorium

Ord. no.	Crystal speci-men no.	Content		Isotope ratios			Ratio-based age, Ma			T_{cor}, Ma
		Pb	U	$\frac{^{207}Pb}{^{206}Pb}$	$\frac{^{207}Pb}{^{235}U}$	$\frac{^{206}Pb}{^{238}U}$	$\frac{^{207}Pb}{^{206}Pb}$	$\frac{^{207}Pb}{^{235}U}$	$\frac{^{206}Pb}{^{238}U}$	
Chernyi Istochnik Massif (sample K513)										
1	z-1	2	14	0.05077	0.6443	0.09205	230.4	505	567.6	573 ± 7
2	z-3	7	76	0.05247	0.5125	0.07083	306.1	420.1	441.2	443 ± 5
3	z-4	12	95	0.05488	0.6829	0.09025	407.3	528.5	557	560 ± 6
4	z-6	3	30	0.05007	0.4928	0.07138	198.3	406.8	444.5	448 ± 5
5	z-7	19	286	0.05265	0.3989	0.05494	313.9	340.8	344.8	345 ± 4
6	z-9	10	91	0.05602	0.6956	0.09009	453.3	536.3	556	558 ± 6
7	z-10	29	107	0.08002	2.3319	0.21136	1197.4	1222	1236.1	1239 ± 14
Volkov Massif (sample K528)										
8	z-1	15	182	0.05338	0.5037	0.06844	344.9	414.2	426.8	428 ± 5
9	z-2	14	161	0.05556	0.5560	0.07258	434.8	448.9	451.7	452 ± 5
10	z-3	138	385	0.11583	4.8923	0.30632	1892.9	1800.9	1722.6	1698 ± 21
11	z-4	4	47	0.05123	0.5012	0.07095	251.4	412.5	441.9	444 ± 5
12	z-10	48	105	0.10642	4.7660	0.32482	1738.9	1778.9	1813.2	1824 ± 22
13	z-11	2	29	0.04530	0.4431	0.07094	–39.5	372.4	441.8	448 ± 5
14	3-1Ц	63	610	0.08676	1.1633	0.09725	1355.1	783.5	598.3	578
15	3-1K	5	52	0.05769	0.6294	0.07912	518.1	495.7	490.9	490.4
16	3-3	22	236	0.05604	0.5348	0.06921	539.9	435	431.4	431
17	3-4	29	326	0.05574	0.5286	0.06879	442.1	430.9	428.9	428.7
18	3-5	3	39	0.05761	0.5892	0.07417	514.9	470.3	461.2	460.4
19	3-6	10	113	0.0550	0.5606	0.07393	412.3	451.9	459.8	453.8
20	3-7	14	163	0.05633	0.5672	0.07303	465.5	456.2	454.4	454.2
21	3-8	24	243	0.05758	0.5907	0.07440	513.9	471.3	462.6	461.9
22	3-9	27	227	0.06140	0.8271	0.09820	653.3	614.4	603.9	602.8
Volkov Massif (sample K532)										
23	z-13	34	477	0.05314	0.4781	0.06525	334.9	396.8	407.5	408 ± 5
24	z-15	52	735	0.05368	0.4705	0.06357	357.8	391.5	397.3	398 ± 5
25	z-17	57	817	0.0550	0.4720	0.06224	412	392.5	389.2	389 ± 5
26	z-18	22	336	0.05347	0.4434	0.06015	348.7	372.7	376.6	377 ± 4
27	z-21	4	48	0.05301	0.5172	0.07076	329.2	423.3	440.7	442 ± 5
28	z-22	18	469	0.06090	0.7489	0.08920	635.5	567.6	550.8	549 ± 7
29	z-24	5	59	0.05352	0.5048	0.06842	350.7	415	426.6	428 ± 5
Tagil–Barancha Massif (sample K411)										
30	7-1	109	1834	0.05488	0.4061	0.05371	407.3	346.3	337.3	336.5
31	7-2	30	84	0.010691	4.4502	0.30172	1747.5	1721.3	1699.8	1693.5
32	7-5	8	102	0.05536	0.5617	0.07339	426.9	451.7	456.5	457
33	7-6	30	86	0.10547	3.870	0.26594	1722.5	1606.9	1520.2	1498.3
Tagil–Barancha Massif (sample K521)										
34	z-12	65	705	0.05385	0.5201	0.07004	364.7	425.2	436.4	437 ± 5
35	z-13	3	34	0.04804	0.4610	0.06961	101	385	433.8	438 ± 5
36	z-16	8	77	0.05271	0.5282	0.07268	316.1	430.6	452.3	454 ± 5
37	z-18	5	59	0.05485	0.5285	0.06988	406.3	430.8	435.4	436 ± 5

Note: Analyses 1–13, 23–29, and 34–37 were performed by the NORDSIM ion microprobe method; analyses 14–22 and 30–33, by the LA ICP-MS method. Isotope ratios are corrected for procedure blank, mass fractionation, procedure blank, and common Pb based on ^{204}Pb. (T_{cor}) Age correction based on ^{207}Pb.

parameters. Proterozoic dates (up to 1824 Ma) are distinctly recorded by the NS method, whereas the LA method indicates the presence of additional older zircons (up to 2250 Ma). The Vendian level (578–603 Ma) is recorded not only for crystals with primary structural features (Fig. 2.5), but also for the partly recrystallized variety (Fig. 2.6). Based on both methods, the sample is dominated by crystals with a Late Ordovician age (443 ± 14 and 445 ± 15 Ma based on NS and LA data, respectively) that matches the timing of gabbro melt crystallization.

Sample K532 from the Volkov Massif yielded 435 ± 10 Ma (Figs. 2.9–2.12, 3d; table). This result admits both the retention of relict crystals (up to 1200 Ma) and the appearance of Late Devonian (395 ± 8 Ma) varieties (Figs. 2.11, 2.12). Transformation of zircons in the Vendian is suggested by the date of 549 ± 7 Ma obtained for the core of the altered crystal (Fig. 2.9; table, specimen z-22), which previously could belong to the Precambrian population.

The Tagil–Barancha gabbro (sample K411) includes a heterogeneous population of zircons. Their age signatures are closely associated with the large-scale manifestation of secondary alterations (Figs. 2.13, 2.14). In general, such crystals define discordia (Fig. 3e), the parameters of which indicate the presence of relict Paleoproterozoic varieties (1763 ± 22 Ma) and their intense alteration in the Ordovician (462 ± 15 Ma). The final stage of zircon evolution in gabbro of this sample was marked by the appearance of U-rich zircons (table, sample 7-1). Based on the Pb/U ratio, the latter zircon variety is dated at 337–346 Ma.

In contrast, gabbronorites in sample K521 contain zircon grains of virtually one type, indicating their high degree of retention (Figs. 2.15, 2.16) and one-stage formation (438 ± 9 Ma; Fig. 3f). Secondary alterations of zircons are insignificant, and their influence on the final result is negligible.

Thus, the data presented above testify to the polychronous nature of zircons in gabbroids of the Tagil Synclinorium. Therefore, we can assume that the evolution of this structure occupied a wide age range.

Precambrian dates of zircons suggest that the Tagil Synclinorium is underlain by an ancient basement composed of fragments of the subcontinental lithosphere varying in age from the Mesoproterozoic (1100–1250 Ma) to the Paleoproterozoic (2100–2200 Ma). This conclusion is supported by the fact that the Tagil Synclinorium zone includes exposures of the Murza and Salda blocks of metamorphosed rocks (1600–1800 and 2195 ± 68 Ma, respectively [3, 4]). According to the geological–geochemical data [5], the Salda metamorphic complex can serve as a basement of the Tagil Synclinorium zone. Findings of the eclogite-type xenogenic garnets in gabbroids suggest that the basement underwent eclogite-facies metamorphism [6].

The nature of Neoproterozoic (Vendian) dates of zircon grains (550–600 Ma) is most problematic, although this age level has been recorded for zircons from Silurian basalts of the Immenov Formation in the Tagil Synclinorium [7, 8]. The Neoproterozoic age has been confirmed for the Salda Complex by direct determinations of the age of granulite-hosted zircons [3]. The latter determinations can indicate the existence of an autonomous stage of zircon formation related to magmatic processes of the respective age. These processes could transform older zircon generations initially associated with Precambrian rocks. In any case, the zircon grains could have been generated during one of the stages of endogenic activity of the evolving lithosphere prior to the appearance of the Lower Paleozoic rift valley (Tagil Synclinorium).

The data obtained suggest that the age of the major zircon varieties and, correspondingly, host gabbroids ranges from 462 ± 12 Ma (Tagil Synclinorium) to 445 ± 5 Ma (Chernyi Istochnik Massif) and 444 ± 15 Ma (Volkov Massif). These values define the Middle–Late Ordovician age of magmatic processes in the southern part of the Ural Platinum Belt. The timing of postmagmatic processes and the consequent appearance of new (U-rich, in some cases) zircon varieties varies from 340 ± 10 Ma (Early Carboniferous) in the Tagil–Barancha Massif to 395 ± 8 Ma (Early Devonian) in the Volkov Massif.

ACKNOWLEDGMENTS

This work was supported by the Russian Foundation for Basic Research (project no. 05-05-64079) and the Division of Earth Sciences of the Russian Academy of Sciences (program no. 8).

REFERENCES

1. A. A. Krasnobaev, F. Bea, G. B. Fershtater, and P. Montero, in *Geology and Metallogeny of Ultramafic–Mafic and Granitoid Intrusive Associations in Foldbelts* (Inst. Geol. Geokhim. Ural. Otd. Ross. Akad. Nauk, Yekaterinburg, 2004), pp. 211–216 [in Russian].
2. F. Bea, G. B. Fershtater, and P. Montero, Terra Nova, 407 (2001).
3. A. A. Krasnobaev and V. A. Davydov, [Dokl. Earth Sci. **393A**, 1247 (2003) [Dokl. Akad. Nauk **393**, 388 (2003)].
4. A. A. Krasnobaev, F. Bea, G. B. Fershtater, and P. Montero, [Dokl. Earth Sci. **404**, 1101 (2005) [Dokl. Akad. Nauk **404**, 407 (2005)].
5. Yu. S. Karetin, in *Geology and Volcanic Associations in the Ural Superdeep Borehole SG-4* (Inst. Geol. Geokhim. Ural. Otd. Ross. Akad. Nauk, Yekaterinburg, 2000), pp. 155–172 [in Russian].
6. V. N. Smirnov, V. A. Chashchukhina, E. V. Pushkarev, and V. V. Vedernikov, [Dokl. Earth Sci. **298**, (1998) [Dokl. Akad. Nauk **298**, 218 (1998)].
7. O. M. Rozen and D. Z. Zhuravlev, in *Evolution of Tectonic Processes in the Earth's History* (Sib. Otd. Ross. Akad. Nauk, Novosibirsk, 2004), Vol. 2, pp. 111–114 [in Russian].
8. O. M. Rozen, E. V. Bibikova, I. V. Vikent'ev, et al., in *Results of Drilling and Investigation of the Ural Superdeep Borehole SG-4* (Nedra, Yaroslavl, 1999), Issue 5, pp. 113–132 [in Russian].