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THE PALEOARCHEAN (3.3 Ga) AND MESOARCHEAN (3.0 Ga) TONALITE-TRONDHJEMITE-GRANODIORITE ROCKS OF THE WEST AZOV AREA (THE UKRAINIAN SHIELD)

A large anticline structure that includes the West Azov and Remivka blocks occurs in the western part of the Azov Domain of the Ukrainian Shield. These blocks are composed of rocks of the Mesoarchean (3.2-3.0 Ga) granite-greenstone association and relics of an older basement. The anticline is divided into two parts by the Bilotserkivka structure of sub-latitudinal strike; the northern part includes the Huliaipole and Remivka blocks, and the southern part is comprised of the Saltycha anticline. The Archean plagiogranitoids of the West Azov underwent intense dislocation metamorphism during the Paleoproterozoic. In many areas they were transformed into plagioclase gneisses that were attributed to the Paleoarchean "Kainkulak thickness" of the Azov Series. Detailed geological-structural and geochronological studies are required to define the age of these gneisses. We have chosen two areas for our studies: the Lantsevo anticline within the Bilotserkivka structure, and the Ivanivka area in the eastern part of the Saltycha anticline. The Bilotserkivka structure is composed of rocks of the Central Azov Series and highly deformed Archean formations. We have dated plagiogneisses of the Lantsevo anticline. These rocks contain large relics of metamorphic rocks of unknown age, including two-pyroxene and pyroxene crystalline schists, and pyroxene-magnetite quartzites (BIF). In terms of chemical composition, two-pyroxene crystalline schists correspond to tholeiitic basalts and basaltic komatiites. Ferruginous-siliceous rocks belong to the Algoma type typical for the Archean greenstone belts. Biotite gneisses are similar to the medium-pressure tonalite-trondhjemite-granodiorite rocks (TTGs). The U-Pb age of zircon crystallization from biotite gneisses is 3299 ± 11 Ma. At 30 km in the western part of the Bilotserkivka structure, we have previously identified quartz diorites having an age of 3297 ± 22 Ma. In terms of geochemical characteristics, they correspond to low-pressure TTGs. These data show that the Bilotserkivka structure is a block representing an ancient basement. In the Ivanivka area in the eastern part of the Saltycha anticline, the strike of the Archean rocks was reorientated from northwestern to latitudinal. The studied dislocated trondhjemites of the Ivanivka area correspond to TTGs in terms of the geochemical characteristics. They contain numerous relics of highly altered amphibolites. The U-Pb age of zircon crystallization from trondhjemite is 3013 ± 15 Ma. These rocks are of the same age as TTGs of the Shevchenko Complex cutting through the sedimentary-volcanogenic rocks of the greenstone structures of the Azov Domain. They share age and geochemical characteristics with biotite and amphibole-biotite gneisses of the "Kainkulak thickness" in Zrazkove village located at the Mokra Konka river (3.1-3.0 Ga) and with biotite gneisses in the lower reaches of the Kainkulak river (2.92 Ga). Thus, gneisses of the "Kainkulak thickness" in fact represent the Mesoarchean TTGs of the Shevchenko Complex,

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which were transformed in the Paleoproterozoic time due to the dislocation metamorphism. Late Paleoarchean (3.3 Ga) tonalites are known in the West Azov and the KMA domains; they probably also occur in the basement of the Middle Dnieper domains, where detrital zircons of this age have been reported. These data allow us to conclude the existence of a large Late Paleoarchean (3.3 Ga) protocraton, in which the Mesoarchean (3.2-3.0 Ga) greenstone belts and TTGs of the eastern part of the Ukrainian Shield and the KMA Domain were formed.

Keywords: *West Azov Area; Bilotserkivka structure; Paleoarchean protocraton; Mesoarchean craton; TTG; the Ukrainian Shield; zircon; the U-Pb age.*

Introduction

A large anticline structure that includes the West Azov and Remivka blocks occurs in the western part of the Azov Domain of the Ukrainian Shield. These blocks are composed of rocks of the Mesoarchean (3.2-3.0 Ga) granite-greenstone association and relics of an older basement. The anticline is divided into two parts by the Bilotserkivka structure of sub-latitudinal strike; the northern part includes the Huliaipole and Remivka blocks, and the southern part is comprised of the Saltycha anticline (Fig. 1). The Archean plagiogranitoids of the West Azov underwent intense dislocation metamorphism during the Paleoproterozoic. In many areas they were transformed into plagioclase gneisses that were attributed to the Paleoarchean "Kainkulak thickness" of the West Azov Series (Correlative..., 2004). Alternating thin "layers" of biotite-, amphibole-, and biotite-amphibole gneisses sometimes crop out in the upper reaches of the Konka and Kainkulak rivers. These rocks were previously interpreted as sedimentary structures (Dralov, 1979). A high degree of dislocation metamorphism is observed in plagiogranitoids of the peripheral parts of the Saltycha anticline. Archean rocks are strongly deformed in the Bilotserkivka structure, where plagiogneisses with a thin-striped structure can be observed. For this reason, detailed geological-structural and geochronological studies are required for the chronostratigraphic subdivision of these gneisses. We have chosen two areas for our studies: the Lantsevo anticline within the Bilotserkivka structure, and the Ivanivka area in the eastern part of the Saltycha anticline (Fig. 1).

Geological structure of the studied areas

The Bilotserkivka structure (size up to 20 × 45 km) of a sub-latitudinal strike is located between the Gaichur block and Saltycha anticline (Fig. 1). In the east, it borders the Central Azov syncline, and its western boundary is drawn along the Chernihivka fault (Konkov, Polunovsky, 1967; Razdorozhny et al., 2000; Rusakov, 1977). The inclination of the rocks of the Bilotserkivka structure along the contacts in the west, north, and south is very steep, ranging from 70-80° to 90°. Several anticline and syncline folds are found within its borders. The synclines are composed of rocks of the Dragunove thickness (formerly known as the Temryuk Suite of the Central Azov Series), whereas anticlines (Oleksiivo, Lantsevo, etc.) are composed of plagiogneisses of the «Kainkulak thickness» with relics of two-pyroxene crystalline schists, amphibolites and ferruginous-siliceous rocks (Geological..., 1998; Kravchenko, Dovgan, 1962). Metamorphic rocks compose lenses and slices from a few centimeters to hundreds of meters thick. They are represented by amphibole-pyroxene and biotite-plagioclase gneisses, amphibolites and gabbro-amphibolites, graphite and alumina gneisses; pyroxene-magnetite and feldspar quartzites, pyroxene-garnet-quartz rocks (granulites), and crystalline limestones (Konkov, Polunovskiy, 1967; Geological..., 1998).

The Saltycha anticline is a dome-shaped structure having an area of about 2000 km^2 (Yesypchuk, Tsukanov, 1972). Its prevalent area is composed of plagiogranitoids (TTGs) of the Shevchenko Complex and gneisses of the West Azov Series. Among them, relics of amphibolites and meta-ultrabasic rocks having a thickness of up to 400 m, are found. More than half of the area of the Saltycha anticline is occupied by small (up to 85 km^2) intrusions of gabbro, diorites, and granodiorites of the Obitochne complex having an age of 2.91-2.92 Ga. Their geochemical characteristics correspond to intraplate magmatic rocks (Bibikova et al., 2008). Paleoproterozoic potassium-sodium granitoids of the Saltycha and Anadol complexes are spread in a part of the Saltycha anticline. They compose small stocks having an area of up to 2.5 km^2, as well as smaller bodies confined mainly to tectonic zones.

Analytical methods

Zircon has been extracted from the rock using a shaking table, heavy liquids, and a magnetic separator to produce a heavy non-magnetic fraction. Zircons were hand-picked under a binocular microscope. Zircon morphology has been studied under an optical microscope, whereas the internal structure was documented using cathodoluminescence. U-Pb isotopic data were collected using laser ablation inductively coupled plasma mass spectrometry (LA-ICP-MS) in the GeoHistory Facility, John de Laeter Centre, Curtin University. Zircon was ablated using a Resonetics RESOlution M-50A-LR system, incorporating a COMPex 102-193 nm excimer UV laser that was coupled to an Agilent 8900 QQQ mass spectrometer. Zircon standard OG1((3465 ± 0.6) Ma; Stern et al., 2009; all uncertainties at 2σ) was utilized as the primary reference material and analyzed in blocks with secondary standards GJ-1 ((601.2 ± 0.4) Ma; Jackson et al., 2004), and Plešovice ((337.13 ± ± 0.37) Ma; Sláma et al., 2008). The secondary standards yielded weighted mean $^{207}Pb/^{206}Pb$ ages and $^{238}U/^{206}Pb$ ages within an uncertainty of the recommended values. The time-resolved mass spectra were reduced using Iolite 3.7™ (Paton et al., 2011) and references therein) with final ages calculated using Isoplot. Silicate rock analyses were carried out at the IGMOF of NAS of Ukraine, Kyiv.

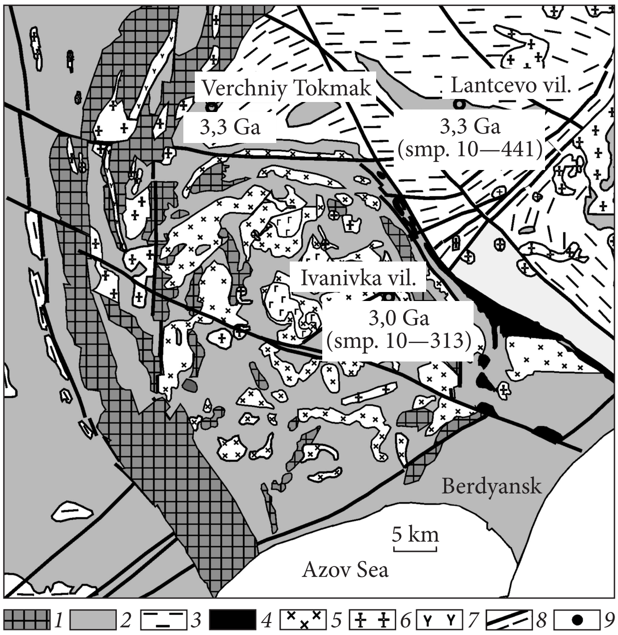

Fig. 1. A schematic geological map of the southern part of the West Azov area (Geological map..., 1998), with changes and additions: *1* — West Azov Series; *2* — Kainkulak; *3* — Dragunka thickness; *4* — greenstone rocks of Greenstone Structure; *5* — gabbro and granitoids of Obitochne complex. Paleoproterozoic intrusions: *6* — granitoids, *7* — carbonatites. *8* — faults, *9* — sampling points and sample numbers

Fig. 2. Strongly deformed tonalite in the Bilotserkivka structure (smp. 10/432)

Results

The Bilotserkivka structure (area of the Lantsevo village)

We have dated plagiogneisses of the Lantsevo anticline that were considered to belong to the Kainkulak thickness (Geologichna..., 1998). They often host large xenoliths of metamorphic rocks, i.e., two-pyroxene and pyroxene schists and pyroxene-magnetite quartzites (Fig. 3). A sample from biotite gneis-

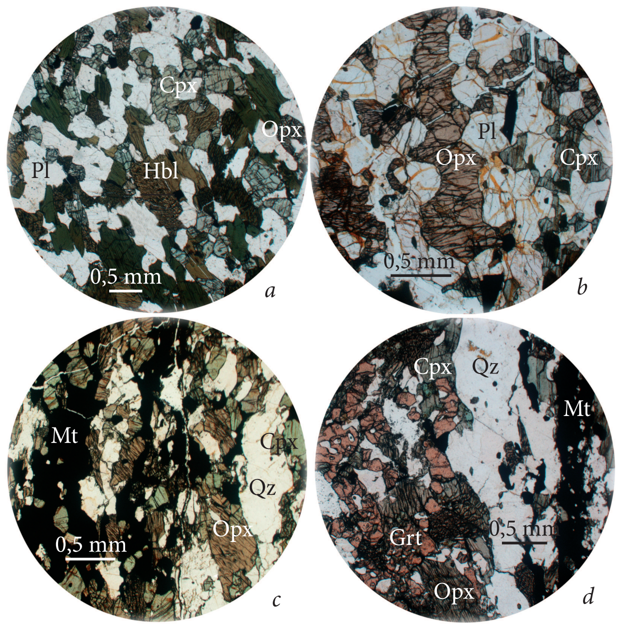

Fig. 3. Photomicrographs of thin sections: *a*) amphibolized two-pyroxene schist (sample 10-440); *b*) two-pyroxene schist (sample 10/373); *c*) silicate-magnetite (pyroxene-magnetite) quartzite (sample 10-397); *d*) garnet-pyroxene-quartz rock (sample 10-380). Cpx — clinopyroxene; Opx — orthopyroxene; Mt — magnetite; Qz — quartz; Grt — garnet. Images are taken using a polarizing microscope ECLIPSE LV100 POL

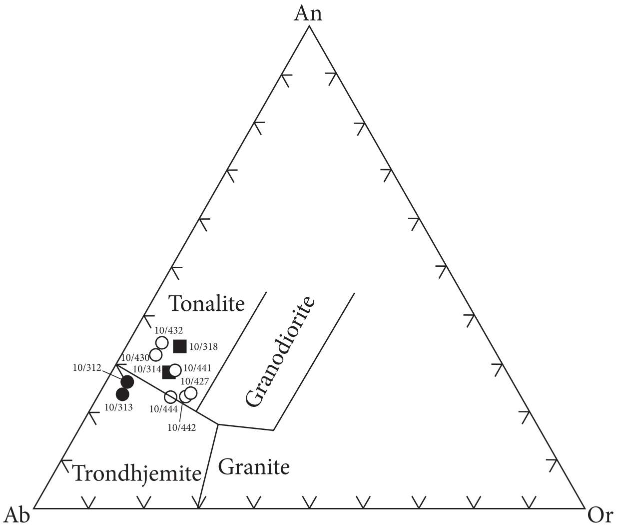

Fig. 4. Ab-An-Or diagram for tonalites of the Bilotserkivka structure and trondhjemites of the Saltycha anticline

ses was taken in the upper reaches of the Berda river right tributary (ravine), at the north-eastern outskirts of the Lantsevo village. Bedding elements of gneisses: strike NW 275°, dip NE 5°, inclination 65°.

Biotite gneiss (sample 10/441) has a lepidogranoblastic texture and the following mineral composition (vol.%): feldspar (albite) — 75; quartz — 15; biotite — 5-7; clinopyroxene — 1-2; apatite, zircon — single grains. In terms of the chemical composition (Igneous rocks…, 1987), biotite gneiss belongs to the family of granodiorite-tonalites of the potassium-sodium series (SiO_2 = = 65.05%; Al_2O_3 = 14.79%; Na_2O = 4.40%; K_2O = 1.16%) (Table 1). These rocks have low Mg# = 33.9. In the O'Connor-Barker classification diagram (Trondjemites ..., 1983) Ab-An-Or (Fig. 4) they plot in the tonalite field. They are poor in Rb (25.7 ppm) and rich in Sr (313 ppm) (Table 2). Average concentrations of high-field-strength *elements* (HFSE) are as follows: Y (7.4 ppm), Nb (6.5 ppm), Yb (0.75 ppm); an average concentration of Ni (the only transition element found) is 19.7 ppm. The multielement diagram shows positive Ti, Eu, and Sr anomalies, and negative Nb anomaly (Fig. 5). The rare-earth elements (REE) pattern is differentiated: $(La/Yb)_N$ =

Table 1. **Silicate chemical composition of rocks of the Bilotserkivka structure and the Saltycha anticline. wt.%**

Sample #	10/441	10/427	10/430	10/432	10/314	10/318	10/312	10/313	10-440	10/378	10/397	10/276	13	14	15
SiO_2	65.05	69.49	69.55	64.69	63.51	62.93	71.67	70.90	51.93	50.54	46.07	49.57	71.12	68.29	68.81
TiO_2	1.04	0.74	0.74	0.94	0.47	0.57	0.09	0.23	1.71	1.71	0.03	0.74	0.25	0.40	0.42
Al_2O_3	14.79	14.88	12.99	15.92	15.76	16.01	15.61	14.69	15.89	10.05	0.61	14.08	15.55	15.65	15.21
Fe_2O_3	2.48	1.02	2.59	1.05	1.16	1.16	<0.01	0.66	2.72	1.45	18.95	0.44	—	—	—
FeO	3.23	2.51	2.37	3.88	4.67	4.81	2.01	2.44	7.33	9.36	25.98	9.69	1.83*	3.02*	3.31*
MnO	0.05	0.04	0.04	0.07	0.08	0.08	<0.02	<0.02	0.07	0.22	0.31	0.21	0.04	0.05	0.06
MgO	1.57	0.94	1.65	1.57	1.97	1.89	0.39	0.55	4.52	10.05	3.23	7.31	0.79	1.33	1.29
CaO	4.83	3.22	4.95	5.17	5.06	5.70	3.42	3.31	8.61	11.26	2.82	10.69	2.63	3.44	3.24
Na_2O	4.40	4.18	3.83	4.40	4.62	4.30	5.24	5.26	4.20	2.00	0.10	3.3	5.24	4.70	4.47
K_2O	1.16	1.66	0.58	0.66	1.24	1.00	0.46	0.46	1.08	1.70	0.05	0.50	1.71	1.64	1.76
$S_{tot.}$	—	—	—	—	—	<0.02	<0.02	<0.02	—	0.03	<0.02	<0.02	—	—	—
P_2O_5	0.27	0.27	0.21	0.27	0.23	0.11	0.05	0.08	0.40	0.12	0.64	0.08	0.09	0.14	0.13
H_2O-	0.19	0.18	0.16	0.22	0.48	0.39	0.38	0.43	0.21	0.26	0.11	0.26	—	—	—
LOI	0.60	0.37	0.31	0.80	0.66	0.69	0.54	0.59	1.15	1.26	0.67	1.83	—	—	—
Total	99.66	99.50	100.02	99.61	99.91	99.66	99.86	99.60	99.82	100.01	99.51	98.72	—	—	—
Mg#	33.9	32.8	38.5	36.7	38.1	36.5	25.7	24.4	45.2	62.7	—	56.4	43.5	44	41

Note: 10/441 — tonalite, outcrop in the upper reaches of the gully flowing into the river Berda in the eastern part of the village Lantsevo; 10-427 — tonalite, outcrop in village Vodyane; 10-430 and 10-432 — tonalite, the same place; 10-314 — tonalite, outcrop in the dam drain on the river Tokmak. in the northern part of the village Verkhniy Tokmak; 10-318 — tonalite, outcrop on the right bank of the river Tokmak, in the middle part of the village Verkhniy Tokmak; 10-312 — trondhjemite, outcrop on the right bank of the river Kiltychcha in the southern part of the Ivanivka village; 10-313 — trondhjemite, in the same place; 10-440 — amphibolized two-pyroxene schist. upper reaches of the gully flowing into Berda river in the eastern part of the village Lantsevo; 10/378 — amphibolized two-pyroxene schist, left side of Ocheretyna stream; 10/397 — pyroxene-magnetite ferruginous quartzite, the same place; 10/276 — amphibolite, outcrop on the right bank of the river Kiltychcha in the village Ivanivka. Composition of various TTG types according to (Martin. 1994): 13 — Low REE TTG; 14 — Medium REE TTG; 15 — high REE TTG. Mg# = 100 × Mg/(Mg + Fe_{total}) in cation mole percent. Silicate chemical analyzes were performed at the IGMOF of NAS of Ukraine.

= 15.5 at Yb_N = 4.4 (Fig. 6). A positive europium anomaly is found Eu/Eu* = 1.2.

A large outcrop of a stratified succession, composed of pyroxene crystalline schists and pyroxene-magnetite quartzites, up to 50 m thick, was studied in the Ocheretyne ravine.

Pyroxene schists of the Ocheretyne ravine (sample 10/378) has a granoblastic to poikilitic-granoblastic texture and the following mineral composition (vol.%): orthopyroxene — 60, plagioclase — 30, biotite — 0-10, quartz — 5, ore mineral — 1, and secondary amphibole replacing orthopyroxene. In terms of chemical composition (SiO_2 = 50.54%; TiO_2 = 1.71%; MgO = 10.05%; Na_2O = 2.0%; K_2O = 1.70%, Mg# = 62.7) (see Table 1), they correspond to basaltic komatiites. They are rich in Cr (748.6 ppm), Ni (239.2 ppm), and V (233.5 ppm) (see Table 2).

Table 2. **Trace elements concentrations in rocks of the Bilotserkivka structure and Saltycha anticline**

Ppm	10/441	10/427	10/432	10/314	10/318	10/313	10/378	10/397	10/276	Low REE	Med REE	High REE
Rb	25,7	38,3	17,5	29,0	25,9	2,8	2,9	3,3	0,5	46,4	55,0	70,6
Sr	313	30	426	315	299	657	290	153	24,9	583	483	327
Ba	583	966	367	417	390	1279	391	162	9,8	542	531	447
V	76	29	82	75	65	29	283	234	13	2l3	36	42
Cr	50	30	50	21,3	14,6	15,5	103	749	22,8	42,5	38,2	27,6
Co	13,6	6,3	13,7	15,9	15,1	5,5	49,10	56,61	3,32	—	—	—
Ni	19,7	13,1	18,9	29,0	31,7	12,8	138	239	13,9	86,2	21,6	15,2
Cu	31,3	12,0	37,8	36,1	45,9	37,4	47,0	29,82	6,95	—	—	—
Zn	45	44	30	83	69	27	117	107	18	—	—	—
Ga	15,7	15,4	15,8	19,5	—	16,1	16,7	16,8	1,9	—	—	—
Y	7,4	5,4	6,2	20,7	30,0	1,3	16,0	14,4	8,4	5,4	8,3	18,2
Nb	6,5	4,3	4,5	9,5	7,1	0,6	2,5	3,1	2,4	2,9	5,3	8,1
Ta	2,0	0,4	1,2	0,56	0,24	0,02	—	—	—	0,52	0,81	0,79
Zr	193	208	195	199	343	168	41	42	2,6	114	143	174
Hf	4,4	4,8	4,2	5,1	7,7	3,3	1,1	1,4	0,1	3,0	4,2	4,5
U	0,60	0,40	0,40	0,24	0,28	0,16	4,50	0,11	0,18	0,83	1,31	1,83
Th	0,40	0,70	1,10	3,10	1,10	1,60	0,66	0,63	0,27	3,86	6,16	7,16
La	16,2	17,2	13,5	43,7	27,8	35,7	4,7	9,0	3,4	16,4	26,9	31,0
Ce	28,3	24,6	22,2	80,8	58,7	53,6	12,4	20,96	8,03	28,72	52,87	57,91
Pr	3,21	2,98	2,33	8,5	6,90	4,70	1,80	2,70	1,03	—	—	—
Nd	13,0	9,9	7,8	30,9	28,0	14,2	7,7	12,1	4,8	11,6	19,3	22,5
Sm	2,05	1,55	1,21	5,70	5,70	3,22	2,20	2,94	1,19	1,82	3,18	3,76
Eu	0,81	0,64	0,77	0,95	1,20	0,95	0,67	0,97	0,60	0,59	0,91	0,95
Gd	2,02	1,56	1,19	5,00	5,90	2,43	2,40	3,37	1,46	1,24	2,43	3,15
Tb	0,27	0,19	0,18	0,76	0,92	0,31	0,41	0,54	0,24	—	—	—
Dy	1,24	1,09	0,93	4,40	5,70	1,31	2,80	3,50	1,68	0,84	1,63	2,68
Ho	0,27	0,19	0,19	0,83	1,20	0,24	0,66	0,68	0,35	—	—	—
Er	0,78	0,56	0,62	2,40	3,30	0,69	2,10	1,99	1,10	0,41	0,81	1,39
Tm	0,12	0,06	0,10	0,32	0,46	0,10	0,31	0,27	0,16	—	—	—
Yb	0,75	0,33	0,66	1,90	3,00	0,52	2,10	1,74	1,07	0,38	0,70	1,18
Lu	0,13	0,06	0,10	0,28	0,44	0,09	0,30	0,25	0,16	0,07	0,13	0,19
Mo	0,5	0,5	0,4	0,5	0,8	<1	0,3	0,5	1,3	—	—	—
Pb	1,1	1,0	1,2	9,4	10,4	7,83	5,70	2,89	0,63	—	—	—
Yb_N	4,4	1,9	3,9	11,2	17,6	3,1	12,4	10,2	6,3	2,2	4,1	6,9
$(La/Yb)_N$	15,5	37,4	14,7	16,5	6,7	49,2	3,7	2,3	1,6	28,7	26,0	17,7
Eu/Eu*	1,2	1,3	2,0	0,5	0,6	1,0	0,9	0,9	1,4	1,2	1,0	0,8
Sr/Y	42,3	55,5	68,7	15,2	10,0	80,3	18,1	10,6	3,0	107,2	58,1	18,0
Nb/Ta	3,3	10,8	3,8	17	29,6	33,6	—	—	—	5,6	6,5	10,3

Note. For the description of samples see Table 1.

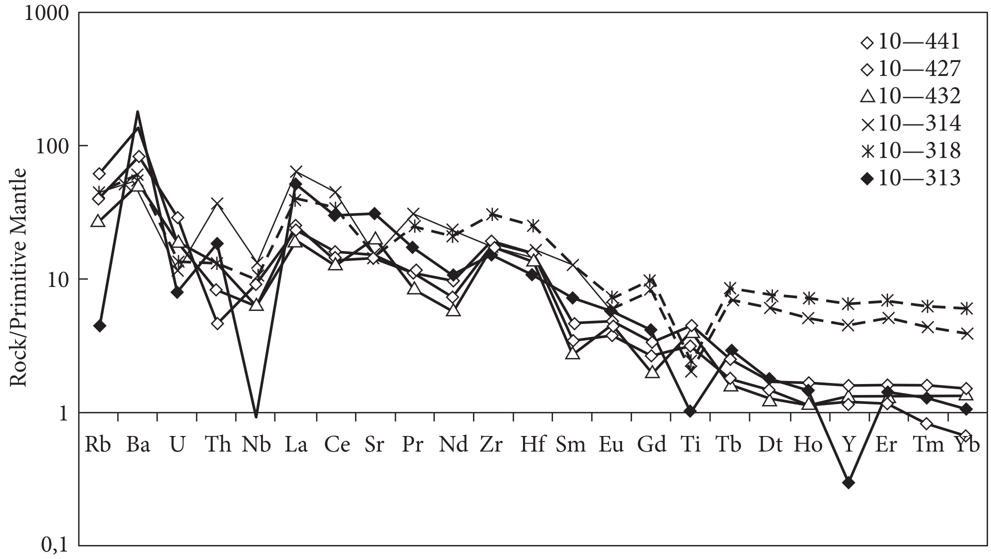

Fig. 5. Multielement diagrames for tonalites of the Bilotserkivka structure and trondhjemites of the Saltycha anticline. Normalized to the primitive mantle (Sun, McDonough, 1989)

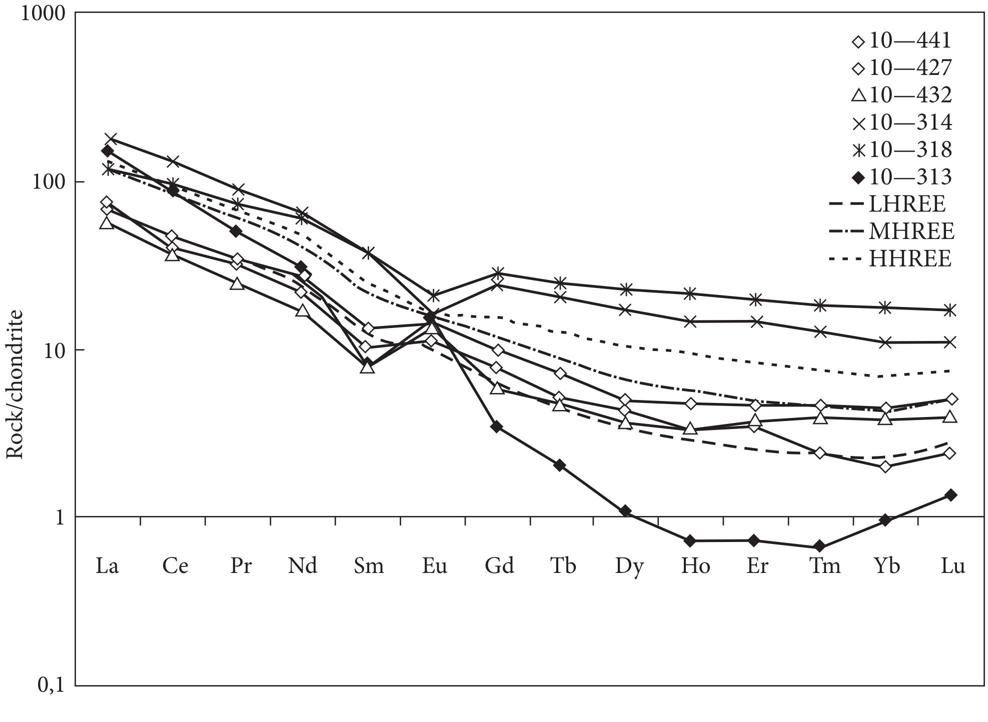

Fig. 6. REE distribution in tonalites of the Bilotserkivka structure and trondhjemites of the Saltycha anticline. Normalized to the composition of chondrite (Sun, McDonough, 1989)

A few meters thick layer of ferruginous pyroxene-magnetite quartzites (sample 10/397) occur among pyroxene schists. The rock has the following mineral composition (vol.%): quartz — 35-40, magnetite — 30, orthopyroxene — 30, clinopyroxene — up to 5. They contain 18.95% Fe_2O_3 and 25.98% FeO, 22.8 ppm Cr, 13.9 ppm Ni, and 13 ppm V (see Table 2).

They have a high $Ni/Fe \times 10^{-4}$ ratio of 0.39, which is characteristic of the Archean ferruginous-siliceous rocks of the Algoma type (Savko et al., 2015).

The Saltycha anticline

Separate outcrops of trondhjemites with numerous metabasite relics are observed in a one-kilometer-long section on the right steep bank of the Kiltichia river in Ivanivka village. Amphibolites are cut by trondhjemite veins. In the southern part of this section, amphibolites strike NW 300°, dip NE 30°, inclination 75°; at the northern edge, their strike is changed to latitudinal.

A sample of trondhjemites (10/313) was taken in the area located ca. 500 m away from the southern outskirts of the Ivanivka village. The rock is

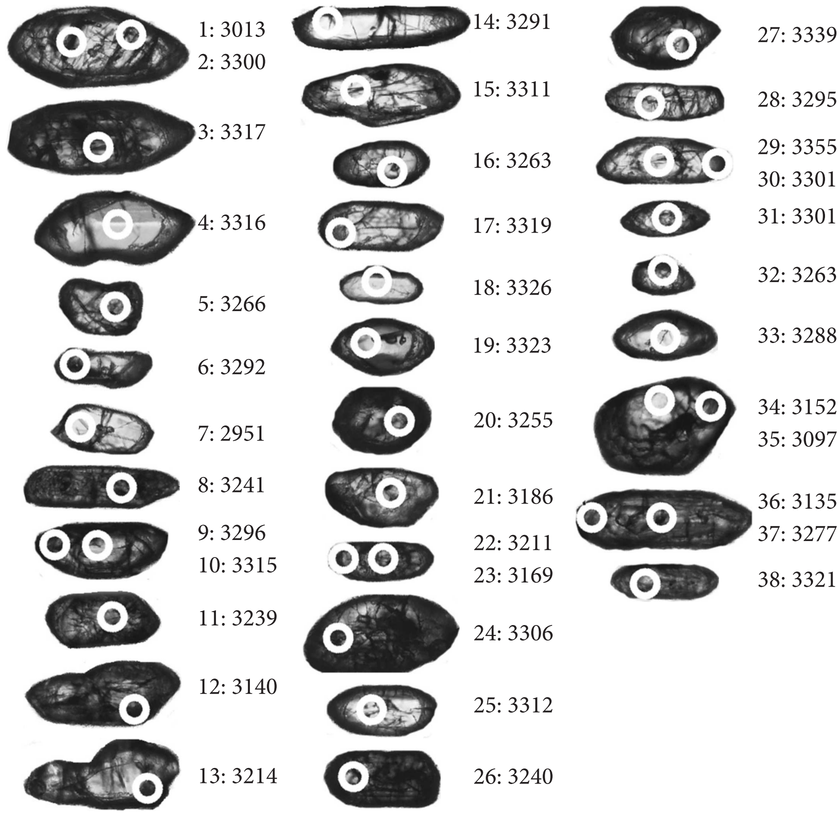

Fig. 7. Optical images of the studied zircon crystals from biotite gneisses of the Lantsevo anticline of the Bilotserkivka structure (sample 10/441). Numbers of the analyzes and their $^{207}Pb/^{206}Pb$ ages as in Table 3

fine-grained, the texture is lepidogranoblastic. Mineral composition (vol.%): plagioclase (albite) — 65; quartz — 25; biotite — 5-7; K-feldspar — 2-3; single grains of apatite, zircon, and opaque minerals. Feldspar is replaced by accumulations of secondary minerals.

In terms of the chemical composition (Igneous rocks…, 1987), trondhjemites correspond to low alkaline granites (SiO_2 = 70.90-71.67; Al_2O_3 = = 14.69-15.61%; Na_2O = 5.24-5.26%; K_2O = 0.46%) of the sodium series (see Table 1). The Mg# of the rock is low (25.7-36.2). In the O'Connor-Barker diagram (Trondhjemites ..., 1983) they plot in the trondhjemite field (see Fig. 4). They are poor in Rb (2.8) and rich in Sr (657 ppm) (see Table 2). They also have a very low content of such of HFSE as Y (1.3 ppm), Nb (0.6 ppm), Yb (0.5 ppm), and of transitional elements, namely Ni (12.8 ppm) and Cr (15.5 ppm).

Negative anomalies of Nb and Ti and positive anomalies of Sr and Eu (see Fig. 5) are seen in the multielement diagram. The REE pattern is highly differentiated: $(La/Yb)_N$ = 49.2, Yb_N = 3.1 (see Fig. 6). In terms of their geochemical characteristics, trondhjemites correspond to TTGs (Martin, 1994).

Numerous amphibolite xenoliths of uniform composition, a few meters in size, are found in trondhjemites in the Ivanivka area. In terms of the chemical composition, these are mafic rocks of the normal sodium series (SiO_2 = 49.57%; TiO_2 = = 0.74%; MgO = 7.31%; Na_2O = 3.3%; K_2O = = 0.50%) (see Table 1). They are low in Ti and have a low Mg# = 42. In terms of geochemical characteristics, they are similar to THI tholeiitic basalts (Condie, 1981).

Results of the U-Pb zircon dating
Sample 10/441

We have analysed 32 zircon grains in sample 10/441. In six grains two analyses were performed, one in the core part of the crystal, and another one in the marginal part (Fig. 7). Altogether, 38 analyses were carried out in this sample. Results of these analyses are reported in Table 3.

In general, obtained results spread along the discordia line that intercepts the concordia at 3374 ± 61 and 2530 ± 240 Ma (Fig. 8, *A*). However, most of the results (22 spots) cluster near the upper intercept; the concordia age calculated for this cluster is 3299 ± 11 Ma (Fig. 8, *B*). We accept that age

Table 3. **Results of U-Pb isotope dating of zircons from tonalite (sample 10/441) and trondhjemite (sample 10/313)**

Analysis #	Isotope ratios						Isotope ages, Ma				Concentrations, ppm	
	$^{238}U/^{206}Pb$	2 σ	$^{207}Pb/^{206}Pb$	2 σ	Err Corr	$^{206}Pb/^{204}Pb$	$^{238}U/^{206}Pb$	2 σ	$^{207}Pb/^{206}Pb$	2 σ	U	Pb
Sample 10/441												
1	1,88218	0,09211	0,2257	0,0057	0,30	3300	2746	30	3013	42	206,8	67,7
2	1,49566	0,07382	0,2691	0,0060	0,43	64000	3303	36	3300	34	187,2	91
3	1,52207	0,07645	0,2727	0,0057	0,35	11700	3252	45	3317	34	132	73,8
4	1,50830	0,07507	0,2735	0,0078	0,25	18000	3273	49	3316	46	97,1	105,3
5	1,54083	0,07597	0,2645	0,0053	0,13	8200	3226	43	3266	32	267	127
6	1,51768	0,07371	0,2687	0,0047	0,35	200	3262	30	3292	28	256,9	146,5
7	1,72414	0,08918	0,2149	0,0080	0,30	2000	2951	55	2951	62	78,2	82,9
8	1,49009	0,07105	0,2598	0,0034	0,53	28000	3309	30	3241	21	832	1860
9	1,53374	0,07528	0,2698	0,0060	0,14	42000	3235	42	3296	34	201	108
10	1,50105	0,07210	0,2719	0,0043	0,34	10000	3290	31	3315	25	327	180,1
11	1,57779	0,07468	0,2592	0,0024	0,17	243000	3164	22	3239	15	1169	368
12	1,60565	0,07477	0,2431	0,0022	0,29		3121	17	3140	14	952	68,8
13	1,58479	0,08539	0,2553	0,0093	0,33	4000	3145	64	3214	58	63,2	36,3
14	1,61031	0,08039	0,2652	0,0065	0,40	10000	3116	43	3291	37	157,4	63,1
15	1,50038	0,07429	0,2709	0,0058	0,25	30000	3290	38	3311	34	230	408
16	1,64745	0,08142	0,2618	0,0066	0,39	8300	3055	38	3263	38	181,6	74,9
17	1,54488	0,07637	0,2728	0,0066	0,03	8100	3215	38	3319	38	193	141
18	1,52905	0,07715	0,2749	0,0071	0,47	6000	3242	46	3326	40	121,1	104,9
19	1,55039	0,07932	0,2707	0,0082	0,21	3100	3219	47	3323	51	90,2	60,3
20	1,49656	0,07391	0,2613	0,0051	0,46	4000	3297	37	3255	31	238,7	207
21	1,62417	0,07914	0,2518	0,0056	0,30	15400	3095	31	3186	36	207	250
22	1,58454	0,07783	0,2549	0,0054	0,23	800	3152	31	3211	33	204	198,1
23	1,70649	0,08445	0,2470	0,0032	0,05	350000	2980	34	3169	21	754	98,4
24	1,53610	0,07315	0,2709	0,0041	0,29	22000	3231	28	3306	24	388	562
25	1,52091	0,07402	0,2709	0,0043	0,39	7600	3256	33	3312	25	418	520
26	1,50060	0,07206	0,2586	0,0041	0,39	40000	3294	29	3240	25	379	367,5
27	1,47275	0,07375	0,2769	0,0066	0,38	67000	3348	42	3339	38	155,2	258,8
28	1,49054	0,07109	0,2691	0,0046	0,40	55000	3312	32	3295	27	360	219,7
29	1,55958	0,07540	0,2795	0,0061	0,38	6500	3192	35	3355	35	239	276
30	1,5528	0,07957	0,2708	0,0075	0,43	3100	3202	52	3301	44	135,2	101,6
31	1,49993	0,07199	0,2698	0,0034	0,26	360000	3292	23	3301	20	800	766
32	1,53610	0,07551	0,2632	0,0047	0,19	84000	3234	33	3263	27	274	290
33	1,51515	0,07346	0,2656	0,0070	0,38	16000	3265	40	3288	40	142,3	116
34	1,66389	0,08859	0,2440	0,0100	0,15	11300	3050	59	3152	68	82,4	73,5
35	1,69751	0,08068	0,2368	0,0034	0,19	17000	2984	29	3097	23	474	252
36	1,73340	0,08413	0,2421	0,0044	0,50	1700	2934	32	3135	29	384	412
37	1,55933	0,07538	0,2654	0,0045	0,22	260000	3193	32	3277	27	373	423
38	1,50921	0,07289	0,2725	0,0048	0,29	1100	3280	35	3321	28	376	391
Sample 10/313												
1	2,77008	0,16881	0,1944	0,0035	0,28	61000	1978	66	2773	29	597	129,5
2	1,79856	0,09381	0,2160	0,0110	0,14	8400	2851	57	2947	84	46,1	47,8
3	1,89753	0,09722	0,2159	0,0062	0,44	68000	2736	51	2945	47	155	259
4	1,75747	0,08957	0,2167	0,0080	0,33	4200	2900	48	2950	60	85,4	155,2
5	1,95695	0,09574	0,2040	0,0049	0,33	23000	2659	33	2857	42	171,3	238
6	2,22222	0,12346	0,1885	0,0090	0,24	5100	2388	61	2712	85	65,4	79

The End of the Table 3.

Analysis #	Isotope ratios						Isotope ages, Ma				Concentrations, ppm	
	$^{238}U/^{206}Pb$	2 σ	$^{207}Pb/^{206}Pb$	2 σ	Err Corr	$^{206}Pb/^{204}Pb$	$^{238}U/^{206}Pb$	2 σ	$^{207}Pb/^{206}Pb$	2 σ	U	Pb
7	1,62602	0,08196	0,2352	0,0061	0,23	7500	3092	45	3080	42	183	182,7
8	1,64745	0,08414	0,2224	0,0075	0,41	9100	3065	48	3004	57	126,1	94,8
9	1,76678	0,09052	0,2284	0,0049	0,16	270000	2893	52	3035	35	326	211,5
10	1,76991	0,10338	0,2292	0,0044	0,01	28000	2878	78	3051	31	333	151,8
11	1,87266	0,10521	0,2266	0,0099	0,50	102000	2760	71	3009	73	77,7	68,5
12	1,72117	0,10072	0,2260	0,0069	0,05	36000	2962	81	3043	48	213	102
13	2,34192	0,12066	0,2125	0,0032	0,07	60000	2297	46	2920	24	794	333
14	1,90114	0,09759	0,2319	0,0054	0,47	2000	2731	43	3059	37	298,6	528
15	1,60772	0,08013	0,2326	0,0062	0,30	19200	3114	43	3060	43	187,5	29,5
16	1,64881	0,08156	0,2433	0,0056	0,21	6600	3054	38	3135	37	259,1	130
17	2,08812	0,10465	0,2228	0,0038	0,27	14000	2521	34	3005	28	598	318
18	2,07426	0,10756	0,2170	0,0041	0,21	30000	2534	42	2951	31	570	123
19	1,60000	0,08192	0,2196	0,0051	0,17	33000	3131	51	2982	36	178	79,6
20	1,73611	0,08741	0,2051	0,0064	0,40	59000	2929	45	2853	52	135,9	64,7
21	1,60514	0,07987	0,2246	0,0064	0,26	1300	3120	42	3015	47	117,4	85,8
22	2,37530	0,19183	0,2201	0,0082	0,04	9600	2240	120	2977	62	231	139
23	2,47525	0,12866	0,2272	0,0040	0,37	10000	2184	46	3030	28	552	170
24	1,73130	0,08692	0,2170	0,0047	0,18	35000	2937	39	2963	35	177,7	60,7
25	1,76991	0,09085	0,2295	0,0089	0,26	800	2881	53	3046	60	66,2	1,37
26	3,62319	0,22317	0,2058	0,0037	0,08	4760	1566	57	2870	30	781	102,6
27	3,82117	0,18982	0,1708	0,0027	0,19	22000	1498	24	2575	27	1245	109,6
28	1,81752	0,08919	0,2257	0,0047	0,32	90000	2824	37	3024	34	250	62,2
29	1,72414	0,08918	0,2261	0,0057	0,12	20000	2944	50	3027	41	157,2	80,6
30	1,89502	0,09337	0,2237	0,0065	0,25	13600	2730	37	2990	47	148	160
31	1,80505	0,08797	0,2207	0,0049	0,32	9200	2854	37	2989	38	179,5	169
32	2,28833	0,16233	0,2206	0,0057	0,16	7100	2320	100	2988	42	368	61,8
33	2,60417	0,18989	0,2093	0,0057	0,12	6600	2080	100	2890	48	348	125
34	6,13121	0,31201	0,1911	0,0041	0,61	2600	974	18	2747	35	1399	261
35	1,66389	0,08859	0,2269	0,0087	0,52	5300	3038	59	3010	63	68,4	53,6
36	1,72414	0,08621	0,2268	0,0057	0,28	21000	2945	47	3021	40	250	114,1
37	3,22061	0,17633	0,2151	0,0038	0,12	11100	1740	47	2938	28	580,9	93
38	1,79212	0,09314	0,2057	0,0060	0,22	8600	2854	50	2878	48	183	103,2
39	2,25734	0,15287	0,2288	0,0062	0,08	13200	2350	94	3035	43	191	143
40	2,88268	0,14958	0,2123	0,0053	0,23	23000	1917	41	2910	41	440	59,8
41	3,53357	0,21226	0,2017	0,0057	0,13	10500	1616	51	2837	45	450	80
42	3,39789	0,17319	0,1935	0,0029	0,30	5320	1665	34	2769	24	1151	100,5
43	1,71438	0,08523	0,2294	0,0044	0,27	7400	2960	37	3044	32	281	204
44	1,84843	0,09908	0,2336	0,0082	0,35	4600	2790	58	3060	56	118	59,4
45	3,87597	0,28544	0,2105	0,0095	0,02	1000	1474	72	2940	72	202	6,6
46	2,40385	0,15024	0,2185	0,0056	0,22	4600	2232	78	2961	42	329	110,9
47	1,74216	0,08802	0,2190	0,0068	0,20	14100	2925	49	2966	50	71,4	9,2
48	1,83824	0,10137	0,2140	0,0100	0,18	500	2795	64	2907	79	47,1	34,9
49	1,75747	0,09575	0,2210	0,0048	0,22	11000	2899	64	2994	34	187	79,6
50	1,84502	0,10893	0,2323	0,0055	0,29	28000	2793	82	3082	38	215	136
51	1,73913	0,09074	0,2110	0,0100	0,43	2900	2926	53	2905	82	50,8	56,5
52	1,69205	0,12025	0,2350	0,0210	0,49	330	2980	130	3000	140	12,98	4,17

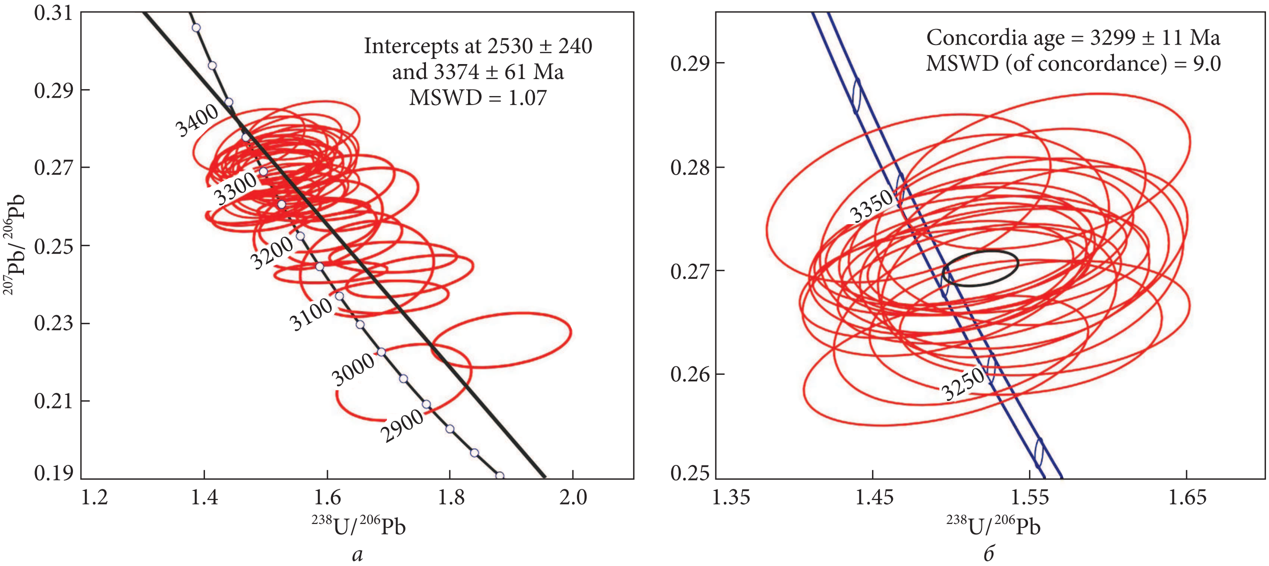

Fig. 8. U-Pb diagram for zircons from biotite gneisses of the Lantsevo anticline of the Bilotserkivka structure (sample 10-441). *а* — diagram showing all results and corresponding concordia intercepts; *б* — the concordia age for the ca. 3000 Ma cluster

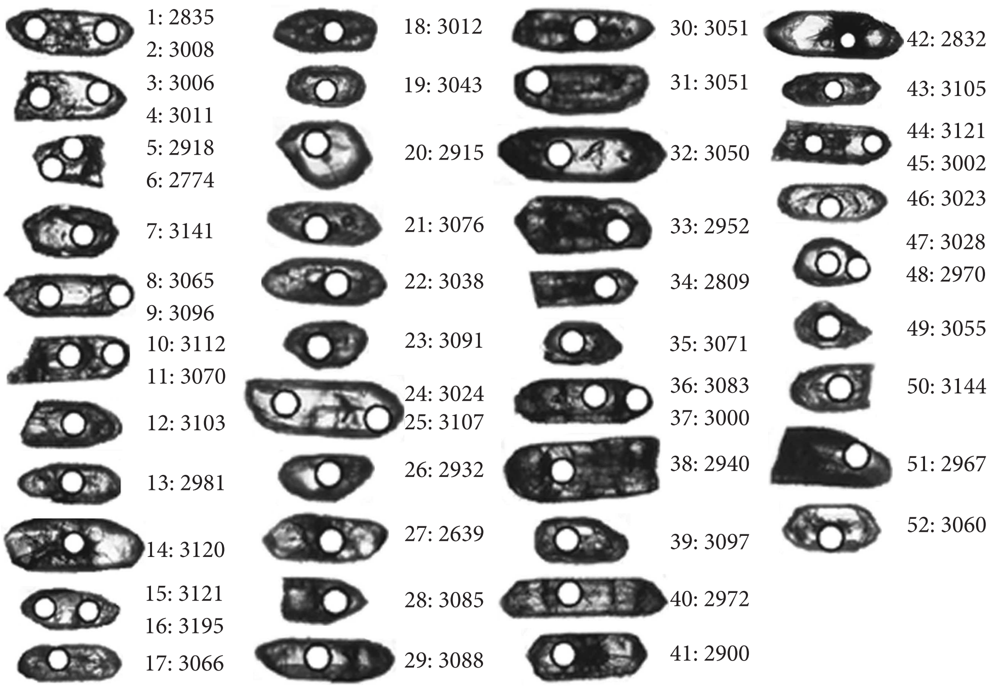

Fig. 9. Optical images of the studied zircon crystals from trondhjemite of the Saltycha anticline (sample 10-313). Numbers of the analyzes and $^{207}Pb/^{206}Pb$ ages as in Table 3

as the time of primary tonalite crystallization. The lower intercept age may indicate a metamorphic event during which primary igneous tonalite was transformed into biotite gneiss. In the cases when zircon grains were analyzed in two spots, the core portions have yielded lower ages than the margins (Fig. 7). This may be explained by variable Pb-loss during the metamorphic event rather than by the presence of younger zircon populations in the sample.

Sample 10/313

In total, 52 analyses have been performed in 42 grains separated from trondhjemite of the Saltycha anticline (Ivanivka village). Ten grains were analyzed both in the core and marginal parts of the crystals (Fig. 9). Results of the analyses are reported in Table 3.

About 65% of the analyses yielded concordant results, while the rest demonstrate a significant spread towards younger ages. The upper intercept age calculated for all results is 3027 ± 30 Ma (the low intercept is at ca. 500 Ma, MSWD = 12) (Fig. 10). The weighted average $^{207}Pb/^{206}Pb$ age calculated for the concordant results is 3013 ± 15 Ma (MSWD = 3.9). We assume that this age corresponds to the time of initial trondhjemite crystallization.

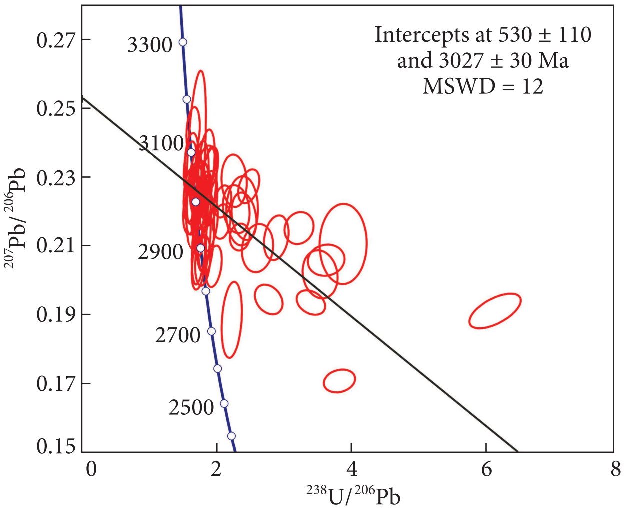

Fig. 10. U-Pb diagram with concordia for zircon from trondhjemite (Saltycha anticline, Ivanivka village, sample 10/313)

Discussion and conclusions

The Paleoarchean (ca. 3.3 Ga) age of tonalites of the Lantsevo anticline in the Bilotserkivka structure has been established. A similar age was earlier obtained for tonalites located at 30 km in the western part of the Bilotserkivka structure (Verkhniy Tokmak area) (Artemenko et al., 2014). Tonalites of the Lantsevo anticline have been formed under medium pressure according to (Moyen, Martin, 2012). They have low concentrations of heavy REE and a positive anomaly Eu/Eu* = 1.2. Rare earth elements are highly differentiated $(La/Yb)_N$ = 14.7-37.4; Nb/Ta ratio varies from 3.3 to 10.8. In contrast, tonalites of the Verhniy Tokmak area belong to the low-pressure TTG according to (Moyen, Martin, 2012). They have high concentrations of heavy REE and negative anomaly Eu/Eu * = 0.54-0.63. Rare earth elements are highly differentiated - $(La/Yb)_N$ = 6.65-16.50; Nb/Ta ratio varies from 17 to 29.6.

Paleoarchean tonalites of the Lantsevo anticline contain remnants of metamorphosed in the granulite facies supracrustal rocks (two-pyroxene schists, pyroxene-magnetite quartzites, and garnet-pyroxene-magnetite rocks) of unknown age. In terms of chemical composition, two-pyroxene schists correspond to tholeiitic basalts and basaltic komatiites, whereas ferruginous-siliceous rocks correspond to the Algoma type which is typical for the Archean greenstone belts.

The Mesoarchean (ca. 3.0 Ga) age of trondhjemites of the Ivanivka area of the Saltycha anticline was determined. In terms of geochemical characteristics, they correspond to the TTGs (Moyen, Martin, 2012). They are strongly depleted in HFSE: Y (1.3 ppm), Nb (0.64 ppm), Yb (0.52 ppm). Rare earth elements are highly differentiated — $(La/Yb)_N$ = 49.2. These trondhjemites are of the same age as TTGs of the Shevchenko complex that cut through the sedimentary-volcanogenic rocks of the greenstone structures in the Azov block. These trondhjemites could have been formed due to the partial melting at depths >40 km of metabasic rocks with a restite bearing garnet and/or hornblende.

A similar age was obtained for biotite and amphibole-biotite gneisses of the "Kainkulak thickness" in the area of Zrazkove village located on Mokra Konka river (3.1-3.0 Ga) (Bibikova et al., 2008) and for biotite gneisses in the lower reaches of the Kainkulak river (2.92 Ga) (Artemenko et al., 2013). Correspondingly, rocks of the «Kainkulak thickness» represent TTGs of the Shevchenko complex transformed into gneisses in the Paleoproterozoic due to the dislocation metamorphism.

The Late Paleoarchean (ca. 3.3 Ga) TTGs occur in the West Azov and the Kursk Magnetic Anomaly block of the Voronezh crystalline massif (Savko et al., 2021). They can also be present in the basement of the Middle Dnieper Domain, where detrital zircons of this age occur in the Vysokopillya greenstone structure (Artemenko et al., 2020). These data indicate that extensive late Paleoarchean (ca. 3.3 Ga) protocraton existed in the eastern part of the Ukrainian Shield and the Kursk magnetic anomaly block of the Voronezh massif. Greenstone belts and TTGs were formed on this protocraton in the Mesoarchean (ca. 3.2-3.0 Ga) time.

REFERENCES

Artemenko, G.V., Bibikova, E.V., Samborskaya, I.A., Demedyuk, V.V., Shvaika, I.A. (2013). Age, geochemical features and stages of metamorphism of rocks of the Western Azov series (Azov block). *Mineralogical Journal* (Ukraine), 35 (4), 73-85 (in Russian).

Artemenko, G.V., Shumlyanskyy, L.V., Shvaika, I.A. (2014). Late Paleoarchean tonalite gneisses of the Western Azov block (Azov Domain of the Ukrainian shield). *Geologìčnij žurnal,* 4 (349), 91-102 (in Russian).

Artemenko, G.V., Shumlyanskyy, L.V., Wilde, S.A. (2020). The Neoarchean age of metaterrigenous rocks of the Vysokopillya greenstone structure, Middle-Dnieper Craton of the Ukrainian Shield. *Geologìčnij žurnal,* 2 (371), 3-17 (in Russian).

Bibikova, E.V., Lobach-Zhuchenko, S.B., Artemenko, G.V., Claesson, S., Kovalenko, A.V., Krylov, I.N. (2008). Late Archean magmatic complexes of the Azov terrane, Ukrainian Shield: Geological setting, isotopic age, and sources of material. *Petrology,* 16, 211-231 (in Russian).

Condie, K. (1981). Archean greenstone belts. Moscow: Nedra (in Russian).

Correlative chronostratigraphic chart of the Early Precambrian of the Ukrainian shield (chart and explanatory note). K. Yu. Isipchuk, O.B. Bobrov, L.M. Stepanyuk et al. (2004). Kyiv: UkrDGRI (in Russian).

Dralov, V.M. (1975-1979). On the results of work on deep geological mapping in scale 1:50 000 on the territory of the map sheets L-37-13-V, G and L-37-25-A,B (Western Azov). Dnepropetrovsk: Novopoltavska PGGK (in Russian).

Geological map and map of the minerals of the crystalline basement — 1 : 200 000, Central-Ukrainian Series. L-37-YII (Berdyansk). B.V. Borodinya (Ed. Glevassky) (1988). Kyiv: State Geological Survey of Ukraine, Ministry of Ecology and Nature resources of Ukraine (in Russian).

Igneous rocks. Acid and intermediate rocks (Eds. O.A. Bogatikova et al.) (1987). Moscow: Nauka, vol. 4 (in Russian).

Jackson, S.E., Pearson, N.J., Griffin, W.L., Belousova, E.A. (2004). The application of laser ablation-inductively coupled plasma-mass spectrometry to in situ U-Pb zircon geochronology. *Chem. Geol.,* 211, 47-69.

Konkov, G.G., Polunovsky, R.M. (1967). Features of mapping and lithostratigraphic subdivision of the study of metamorphic complexes of the Central Azov region. Conference materials: Problems of sedimentary geology of the Precambrian. Moscow: Nedra, issue 2 (in Russian).

Kravchenko, G.L., Dovgan, R.N. (1962). Materials for the state geological map of the USSR, scale 1:200 000, map sheets: L-37-VII and L-37-VIII. UTGF (in Russian).

Martin, H. (1994). The Archean grey gneisses and the genesis of continental crust. H. Martin In: K.C. Condie (Ed.), *Archean Crustal Evolution.* Amsterdam: Elsevier.

Moyen, J.F., Martin, H. (2012). Forty years of TTG research. *Lithos,* 148, 312-336.

Paton, C., Hellstrom, J., Paul, B., Woodhead, J., Hergt, J. (2011). Iolite: freeware for the visualisation and processing of mass spectrometric data. *J. Anal. At. Spectrom*. 26, 2508-2518.

Razdorozhny, V.F., Vasilchenko, V.V., Borodynya, B.V. (2000). Stratigraphy of the Precambrian Berdyansk sheet (the South-Western Azov. *Collection articles of the meeting "Geology and magmatism of the Precambrian of the Ukrainian Shield".* Kyiv, pp. 97-101 (in Russian).

Rusakov, N.F. (1977). Results of deep mapping at the scale 1:50 000 Eliseevka-Andreevka area — map sheets - L-37-25-G (b, d), L-37-26-V, G (a, c), L-37-37-B (b), L-37-38-A (a, b). (in Russian).

Savko, K.A., Bazikov, N.S., Artemenko, G.V. (2015). Geochemical evolution of ferruginous-siliceous formations of the Voronezh crystalline massif in the Early Precambrian: sources of matter and geochronological limitations. *Stratigraphy, geological correlation,* 23 (5), 3-21 (in Russian).

Savko, K.A., Samsonov, A.V., Larionov, A.N., Chervyakovskaya, M.V., Korish, E.K., Larionova, Y.O., Bazikov, N.S., Tsybulyaev, S.V. (2021). A buried Paleoarchean core of the Eastern Sarmatia, Kursk block: U-Pb, Lu-Hf and Sm-Nd isotope mapping and paleotectonic application. *Precambrian Research*, 353 106021, 1-24.

Sláma, J., Koљler, J., Condon, D.J., Crowley, J.L., Gerdes, A., Hanchar, J.M., Horstwood, M.S., Morris, G.A., Nasdala, L., Norberg, N. (2008). Pleљovice zircon – a new natural reference material for U-Pb and Hf isotopic microanalysis. *Chem. Geol.,* 249, 1-35.

Stern, R.A., Bodorkos, S., Kamo, S.L., Hickman, A.H., Corfu, F. (2009). Measurement of SIMS instrumental mass fractionation of Pb isotopes during zircon dating. *Geostand. Geoanal. Res*., 33, 145-168.

Sun, S.S., McDonough, W.F. (1989). Chemical and isotopic systematics of oceanic basalts: implications for mantle composition and processes. Saunders A.D. & Norry M.J. *Magmatism in the Ocean Basins, Geological Society Special Publication,* 42, 313-345.

Trondhjemites, dacites and related rocks: Translation from English. F. Barker, A. Evart, J.G. Art et al. (1983). Moscow: Mir (in Russian).

Yesipchuk, K.Yu., Tsukanov, V.O. (1972). Gneiss-migmatite complex of Western Azov. In: Stratigraphy of the Ukrainian SSR. Vol. I: Precambrian. Kyiv: Naukova Dumka, pp. 155-172 (in Russian).

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ПАЛЕОАРХЕЙСЬКІ (3,3 Ga) ТА МЕЗОАРХЕЙСЬКІ (3,0 Ga)
ТОНАЛІТ-ТРОНД'ЄМІТ-ГРАНОДІОРИТОВІ ПОРОДИ
ЗАХІДНОГО ПРИАЗОВ'Я (УКРАЇНСЬКИЙ ЩИТ)

У західній частині Приазовського блоку знаходиться велика антиклінорна структура, що включає Західноприазовський і Ремівський блоки, складені породами мезоархейської (3,2—3,0 Ga) граніт-зеленокам'яної асоціації і реліктами більш давнього фундаменту. Вона розділена Білоцерківською структурою субширотного простягання на дві частини: північну, що включає Гуляйпільський і Ремівський блоки, і південну — Салтичанський антиклінорій. У палеопротерозої архейські плагіогранітоїди Західного Приазов'я зазнавали інтенсивного дислокаційного метаморфізму. На багатьох ділянках вони перетворені на плагіогнейси, які були віднесені до палеоархейської «кайінкулацької товщі» західноприазовської серії. Для наших робіт обрано дві ділянки: Ланцівська антикліналь у Білоцерківській структурі та Іванівська ділянка у східній частині Салтичанського антиклінорія. Білоцерківська структура складена сильно дислокованими породами центральноприазовської серії і нерозчленованими архейськими утвореннями. Ми датували плагіогнейси Ланцівської антикліналі. У цих плагіогнейсах знаходяться ксеноліти метаморфічних порід невідомого віку — двопіроксенові і піроксенові кристалічні сланці та піроксен-магнетитові кварцити. Залізисто-кременисті породи відповідають типу Альгома, які характерні для архейських зеленокам'яних поясів. За геохімічними характеристиками біотитові гнейси відповідають тоналіт-тронд'ємітовим гранодіоритовим породам (ТТГ), які формуються в умовах середнього тиску. U-Pb вік кристалізації циркону біотитових гнейсів становить (3299 ± 11) Ma. На відстані 30 км у західній частині Білоцерківської структури раніше нами були виявлені кварцові діорити такого ж віку — (3297±22) Ma. За геохімічними характеристиками вони відповідають ТТГ, які формуються в умовах низького тиску. Ці дані показують, що Білоцерківська структура є блоком давнього фундаменту. На Іванівській ділянці в східній частині Салтичанського антиклінорія, де виконані наші дослідження, спостерігається переорієнтування простягання архейських порід з північно-західного на широтне, що виникло в результаті колізійних процесів. Вивчені тронд'єміти Іванівської ділянки за геохімічними характеристиками відповідають ТТГ. В них спостерігаються численні ксеноліти сильно змінених амфіболітів. U-Pb вік кристалізації циркону тронд'ємітів — (3013 ± 15) Ma. Ці тронд'єміти, таким чином, є одновіковими з ТТГ шевченківського комплексу, які проривають осадово-вулканогенні породи зеленокам'яних структур Приазовського мегаблоку. Такий же вік і геохімічні характеристики ТТГ мають біотитові та амфібол-біотитові гнейси «кайінкулацької товщі» району с. Зразкове на р. Мокра Конка (3,1—3,0 млрд років), біотитові гнейси в нижній течії р. Кайінкулак — 2,92 млрд років. Гнейси «кайінкулацької товщі», таким чином, є мезоархейськими ТТГ, які були перетворені в результаті дислокаційного метаморфізму у палеопротерозої. Пізньопалеоархейські (3,3 млрд років) тоналіти, поширені на Західному Приазов'ї, знайдені також на мегаблоці Курської магнітної аномалії Воронезького кристалічного масиву; ймовірно, вони є у складі гнейсового фундаменту Середньопридніпровського блоку, де у Високопільській зеленокам'яній структурі було знайдено кластогенний циркон такого ж віку. Ці дані вказують на вірогідне існування більш давнього протократону віком 3,3 млрд років, на якому формувалися мезоархейські (3,2—3,0 Ga) зеленокам'яні пояси східної частині Українського щита і мегаблоку Курської магнітної аномалії.

***Ключові слова**: Західне Приазов'я; Білоцерківська структура; Салтичанський антиклінорій; палеоархейський прократон; мезоархейський кратон; ТТГ; Український щит; циркон; U-Pb вік.*