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G.V. Artemenko,[1] DrSc (Geology), Prof., Head of Department
E-mail: regulgeo@gmail.com; https://orcid.org/0000-0002-4528-6853
L.V. Shumlyanskyy,[2] DrSc (Geology), Professor
E-mail: lshumlyanskyy@yahoo.com; https://orcid.org/0000-0002-6775-4419
D. Chew,[3] PhD, Professor
E-mail: chewd@tcd.ie; https://orcid.org/0000-0002-6940-1035
F. Drakou,[3] PhD
E-mail: drakouf@tcd.ie; https://orcid.org/0000-0001-6618-4541
I.A. Shvaika,[1] PhD (Geology), Research Fellow
E-mail: ishvaika@gmail.com; https://orcid.org/0000-0001-9585-4380
[1] M.P. Semenenko Institute of Geochemistry, Mineralogy and Ore Formation of the NAS of Ukraine
34, Acad. Palladin Ave., Kyiv, Ukraine, 03142
[2] Institute of Geological Sciences of the PAS
1, Senacka, Kraków, Poland, 31-002
[3] Department of Geology, School of Natural Sciences, Trinity College
College Green, Dublin 2, Ireland

THE AGE AND ORIGIN OF THE ROCKS OF THE WEST AZOV GROUP (LOZUVATKA ANTIFORM, THE UKRAINIAN SHIELD)

Geochronological studies of amphibole-biotite gneisses of the Verkhnii Tokmak Unit and amphibolites and Banded Iron Formation (BIF) of the Kaiinkulak Unit of the West-Azov Group in the Lypovets area of the Lozuvate antiform in the West Azov block of the Ukrainian Shield were carried out. A multi-stage history of the formation of amphibole-biotite gneisses has been established. In terms of chemical composition they correspond to quartz diorites. Rare earth elements are differentiated — (La/Yb_N = 7.54), with a significant negative europium anomaly — Eu/Eu = 0.66. The REE distribution indicates that the initial melt for quartz diorites was produced in a crustal magmatic source. In zircon crystals from amphibole-biotite gneisses, relics (cores) of older zircon and mantles that surround them were distinguished. Relict zircon is coarse-zoned, cracked, and its mantles have a thin-zoned structure. A small amount of transparent non-zonal zircon crystals was also found. Based on the results of zircon dating by the LA-ICP-MS method, it was determined that the age of the relict zircon is 3.16 Ga. The thin-zonal mantles have an age of 2.9-2.8 Ga, which probably corresponds to the time of crystallization of quartz diorites. Non-zonal transparent zircon with an age of 2.1 Ga corresponds to the time of dynamometamorphism (collision). BIF of the Lypovets deposit in the West Azov iron ore province, which belongs to the Kaiinkulak Unit of the West Azov Group, has a high $Ni/Fe\times10^{-4}$ = 0.5-2.1 ratio, typical for the Archean BIFs of the Algoma type. This deposit is confined to an Archean greenstone belt in a synclinal structure composed of metamorphosed basaltic komatiites and sedimentary rocks. Thus, the Verkhnii Tokmak Unit comprises Mesoarchean quartz diorites of crustal genesis, while the Kaiinkulak Unit probably represents heavily metamorphosed rocks of an Archean greenstone belt.*

Keywords: *West Azov block, Saltycha anticlinorium, Lozuvatka antiform, Lypovets iron ore deposit, U-Pb age, zircon, gneiss, West Azov Group.*

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Introduction. The stratigraphy of the Archean rocks of the Azov Domain of the Ukrainian Shield was developed in the 1960s based mainly on geological observations (Shcherbak et al., 1985; Usenko, 1952). Since then, no targeted geochronological and geochemical studies of these rocks have been carried out. The oldest rocks belong to the West Azov Group, which in the West Azov block form the large Lozuvatka antiform structure oriented approximately in a north-south direction (Dralov, Isakov, 1979; Eynor, Esipchuk, Tsukanov, 1971) (Fig. 1). Rocks of this Group also occur in the Bilotserkivka structure (Borodynya et al., 1998; Artemenko, Shumlyanskyy, 2021; Artemenko, Shumlyanskyy, Shvaika, 2014). In addition, they form a 0.5-2.0 km wide band located to the east of the Saltycha dome structure. The West Azov Group is subdivided into two units, the lower Verkhnii Tokmak Unit and the upper Kaiinkulak Unit (Dralov, Isakov, 1979). The Verkhnii Tokmak Unit have a thickness of up to 3.0 km and comprises two-pyroxene plagioclase gneisses, in places garnet-bearing, mafic crystalline schists and rarely amphibolites, which irregularly alternate with each other in the studied section (Borodynya et al., 1998). The Kaiinkulak Unit is up to 4.0 km thick and is comprised of biotite, amphibole-biotite, biotite-two-pyroxene, amphibole-clinopyroxene and amphibole-orthopyroxene plagioclase gneisses, garnet-biotite mafic two-pyroxene crystalline schists and clinopyroxene and orthopyroxene-bearing amphibolites (Borodynya et al., 1998). In addition, horizons of ferruginous quartzite and eulysite, as well as thin calciferous interbreds, are occasionally observed.

Research objectives. The authors intended to determine the isotopic age, geochemical features and origin of metamorphic rocks of the West Azov Group in the Lypovets area of the Lozuvate antiform in the West-Azov block of the Ukrainian Shield.

Research methods. Zircon separation was done using a Wilfley table, heavy liquids and magnetic separator. Zircons were hand-picked under a binocular microscope and their morphology was studied under an optical microscope. ICP-MS whole-rock chemical analyses were carried out at the M.P. Semenenko Institute of Geochemistry, Mineralogy and Ore Formation (IGMOF) of the NAS of Ukraine, Kyiv. The samples were prepared by acid decomposition using an ETNOS microwave oven manufactured by MILISTONE (Italy) according to standard analytical procedures. The measurements were carried out using the Thermo Element 2 High-Resolution ICP-MS system in the laboratory of trace element and isotope analysis at the same Institute. The reliability of analyses was controlled by measuring international standard rock samples JG1-a, JG2, JB3.

The U-Th-Pb analyses of zircon crystals were conducted by laser ablation-inductively coupled mass spectrometry (LA-ICP-MS) on crystals in epoxy mounts at the Department of Geology, Trinity College, Dublin, Ireland. A Photon Machines Analyte Excite 193 nm ArFexcimer laser-ablation system with a HelEx 2-volume ablation cell, coupled to an Agilent 7900 mass spectrometer was employed. Line scans on NIST612 standard glass were used to tune the instrument, by obtaining a Th/U ratio close to unity and low oxide production rates (i.e., ThO^+/Th^+ typically <0.15%). A circular laser spot of 24 μm, a repetition rate of 11 Hz and a fluence of 2.25 $J \times cm^{-2}$ were employed. The helium carrier gas was fed into the laser cell at ~0.4 $l \times min^{-1}$, and was mixed with ~0.6 $l \times min^{-1}$ Ar make-up gas and 11 $ml \times min^{-1}$ N_2. Each analysis comprised 27.3 s of ablation (300 shots) and 12 s of washout time and the latter portions of the washout were used for baseline measurements. The data reduction of raw U-Th-Pb isotopic data was undertaken using the freeware IOLITE package (Paton et al., 2011), with the "Vizual Age" data reduction scheme (Petrus, Kamber, 2012). The primary U-Pb zircon calibration reference material was 91 500 zircon ($^{206}Pb/^{238}U$ age of 1065.4 ± 0.6 Ma (Wiedenbeck et al., 1995; Wiedenbeck et al., 2004) and the secondary reference materials were Plešovice zircon ($^{206}Pb/^{238}U$ age of 337.13 ± 0.37 Ma (Sláma et al., 2008) and WRS 1348 zircon ($^{206}Pb/^{238}U$ age of 526.26 ± 0.70 (Pointon et al., 2012). Final ages were calculated using Isoplot (Ludwig, 2011).

Geological setting. The research area is located to the west of the Saltycha anticlinorium, within the Lozuvatka antiform (West Azov block) (Fig. 1). The core of the Saltycha anticlinorium is composed mainly of Archean plagioclase granites of the Obitochne and Shevchenko

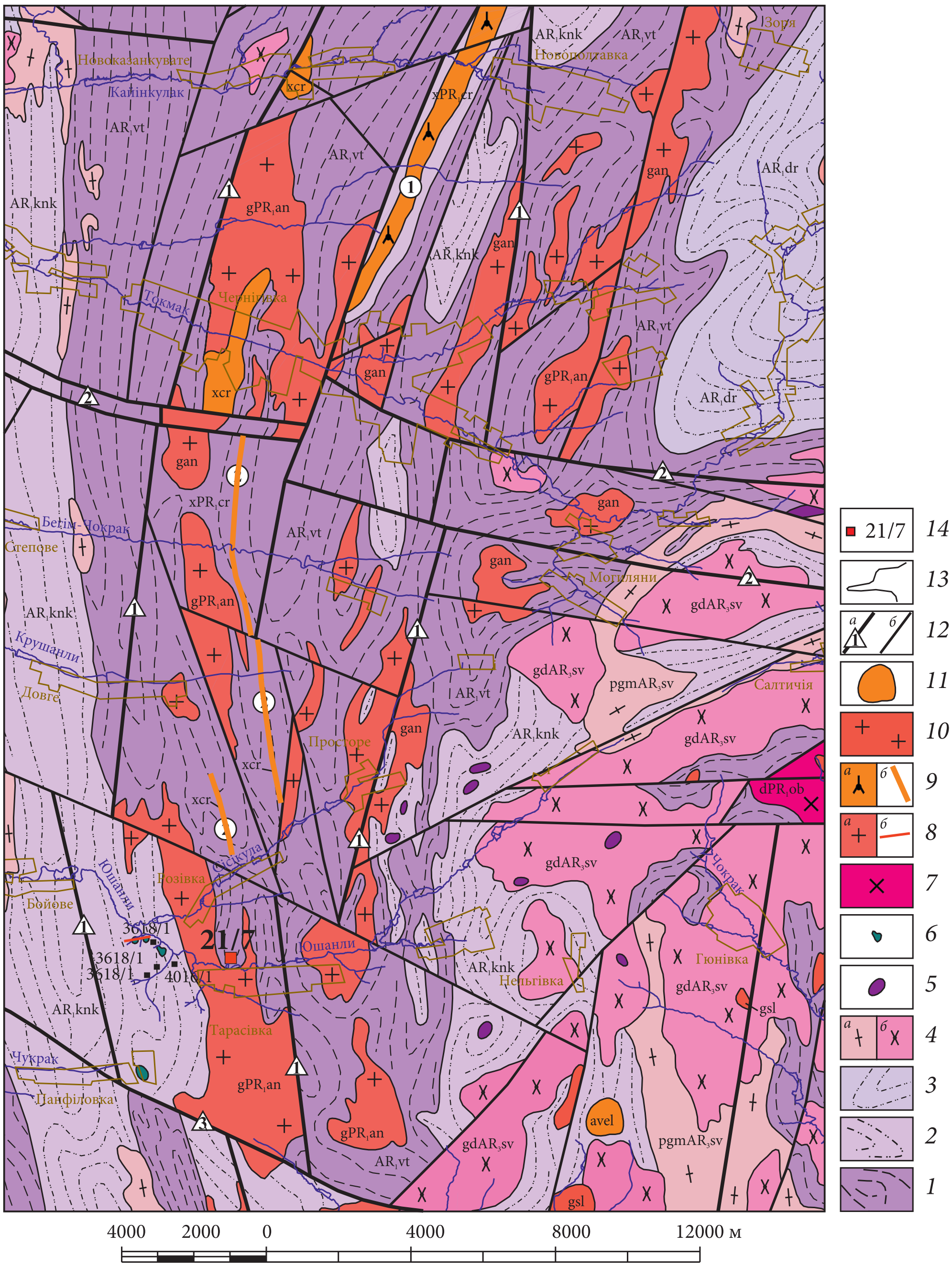


Fig. 1. Schematic geological map of the studied area of the Lozuvatka antiform (Borodynya et al., 1998 with changes and additions): *1* — Verkhnii Tokmak Unit; *2* — Kaiinkulak Unit; *3* — Dragoonka Unit; *4* — Shevchenko Complex: *a* — migmatite, *b* — granodiorite; *5* — small intrusions of the Novoselitska association; *6* — diabases of the dyke complex; *7* — diorite of the Obitochne Complex; *8* — Anadol Complex: *a* — granite intrusions; *b* — veins; *9* — Chernihivka Complex: *a* — alkaline feldspar syenites, *b* — alkaline metasomatites; *10* — granites of the Saltycha Complex; *11* — small intrusions of the Volnovakha-Yelanchik Complex; *12* — faults (*a* — main, *b* — subordinate), number in a triangle — name: 1 — Chernihivka, 2 — Stulnivo, 3 — Elizavetivka; *13* — geological boundaries; *14* — outcrop and their number (sampling location)

complexes (2.92—3.0 Ga). The Lozuvatka antiform is composed of metamorphic rocks of the Verkhnii Tokmak and Kaiinkulak Units, which are folded in steep, often isoclinal folds (Borodynya et al., 1998; Eynor, Esipchuk, Tsukanov, 1971). Rocks are reasonably well exposed on the banks of the Yushanly River and its tributaries in the vicinity of the village of Tarasivka (Fig. 1). The Lypovets iron deposit is located in this area. In the Lypovets area, an association of metamor-

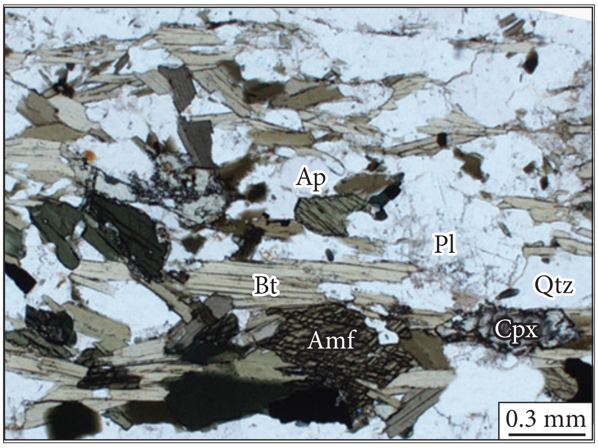


Fig. 2. Photomicrograph of amphibole-biotite gneiss (sample 21/7) taken under plane-polarised light

phosed supracrustal rocks is exposed within a synclinal fold (Rodionov, 1946). From the bottom to top it is composed of amphibolites, pyroxenites, and serpentinites; a complex sequence of sillimanite-granite-biotite gneisses and ferruginous rocks (pyroxene-magnetite itabirites) with total thickness up to 25 m structurally overlies the mafic rocks. The whole sequence of metamorphic rocks is cut by numerous veins of pink granite. The same rock assemblage forms the Kaiinkulak and Krushanly iron deposits that occur in the Lozuvatka antiform to the north, and also in the Bilotserkivka structure. In the eastern part of the village of Tarasivka, amphibole-biotite gneisses hosting relics of pyroxene were found. Gneisses of this composition were attributed to the Verkhnii Tokmak Unit of the West Azov Group (Borodynya et al., 1998). Amphibole-biotite gneiss of the Verkhnii Tokmak Unit (sample 21/7), and ferruginous-siliceous rock (sample 21/13) of the Kaiinkulak Unit have been collected from outcrops near the village of Tarasivka for chemical and geochronological studies.

Chemical characteristics of the studied rocks. Amphibole-biotite gneiss (sample 21/7). The structure of the rock is gneissic and the texture is lepidogranoblastic (Fig. 2). The rock is made of (vol. %) plagioclase — 62, quartz — 20, biotite — 10, hornblende — 8, along with rare relicts of clinopyroxene, opaque mineral, apatite, and zircon.

To determine the nature of amphibole-biotite gneisses, FAK discrimination diagram (Predovsky, 1970) and Al_2O_3 — ($K_2O + Na_2O$) plot (Predovsky, 1980) were used.

In the FAK diagram, amphibole-biotite gneiss plot in the field of diorite, plagioclase granite, and their volcanic analogues (Table 1, Fig. 3). In the Al_2O_3 — (K_2O+Na_2O) diagram, amphibole-

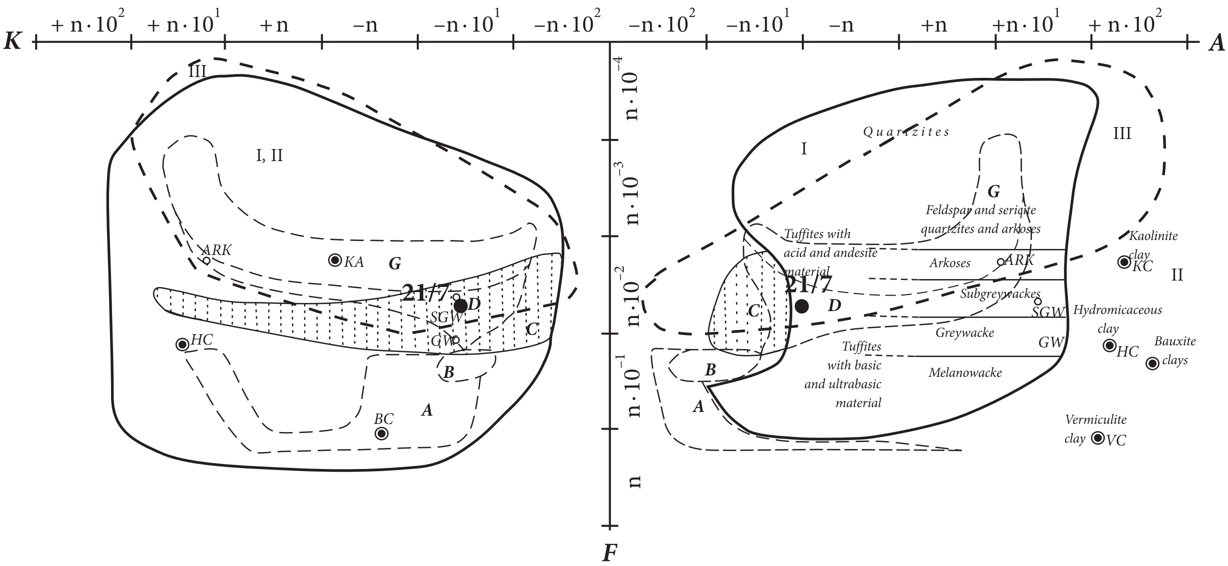


Fig. 3. The FAK diagram (Predovsky, 1970) is used for the reconstruction of the primary composition of amphibole-biotite gneiss. Fields of sedimentary, volcanogenic-sedimentary and mixed rocks: I — sedimentary and mixed rocks; II — pelites; III — chemogenic silicites. A — ultrabasites; B — basites; C — syenites, alkaline syenites, and their volcanic analogues; D — diorites, plagioclase granites, and their volcanic analogues; G — granites, and their volcanic analogues. F = ($FeO + MgO + Fe_2O_3$)/SiO_2; A = Al_2O_3 — ($CaO^* + K_2O + Na_2O$), where CaO^* = = $CaO + CO_2$; K = K_2O — Na_2O (in molecular units)

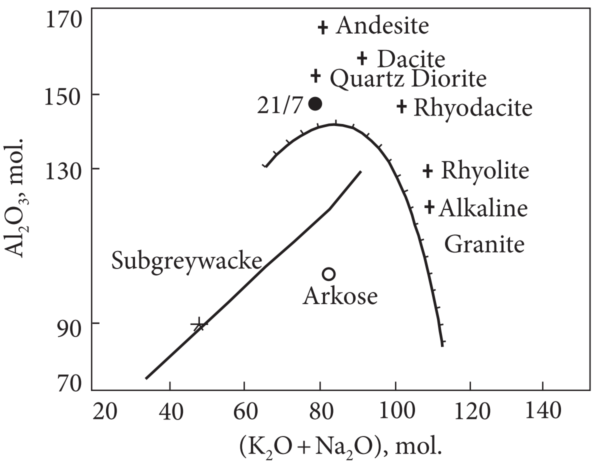


Fig. 4. Diagram Al_2O_3 — ($K_2O + Na_2O$) (molar amounts) (Predovsky, 1980) for the reconstruction of the primary composition of amphibole-biotite gneiss. The trend in the diagram indicates the change of the composition of ordinary subgreywacke and arkose with a decreasing amount of quartz

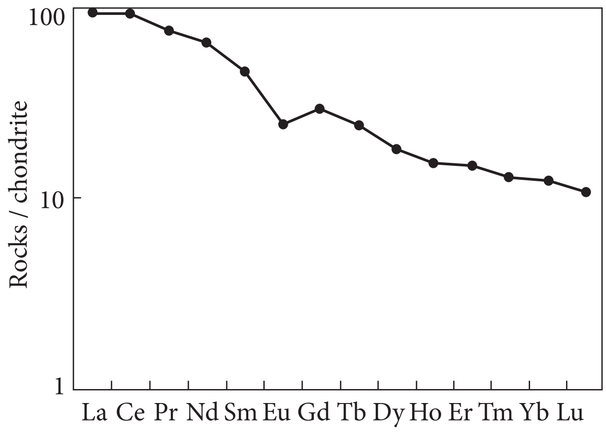


Fig. 5. Chondrite-normalized REE pattern for the amphibole-biotite gneiss (sample 21/7). Chondrite composition after (Sun, McDonough, 1989)

biotite gneiss plot near the point of quartz diorite (Table 1, Fig. 4).

The chemical composition of amphibole-biotite gneiss (sample 21/7) corresponds to quartz diorites of the normal K-Na series (Table 1) (Bogatikov et al., 1983). The total amount of REE is 142.32 ppm (Table 2). The content of highly charged elements, Y (25 ppm), Nb (7.4 ppm), Ta (0.80 ppm), and heavy rare earth elements is significantly higher than in average TTG (Moyen, 2011) (Table 2). The REE pattern is differentiated — (La/Yb_N = 7.54), with a notable negative Eu anomaly (Eu/Eu^* = 0.66) (Fig. 5).

Table 1. **Chemical composition of the rocks in the Lypovets area**

Oxides, %	1/ 21/7	2/ 3618/5	3/ 3618/6	4/ 3618/1	5/ 4016/1	6/ I	7/ II
SiO_2	61.53	47.00	47.9	43.2	46.7	42.30	41.43
TiO_2	0.56	0.23	0.29	0.14	0.63	—	—
Al_2O_3	15.34	10.00	9.0	2.8	3.4	2.19	2.25
Fe_2O_3	2.22	4.02	4.47	48.2	41.3	29.64	22.04
FeO	3.7	7.50	7.5	1.8	1.79	18.19	27.58
MnO	—	0.26	0.31	0.04	0.03	0.39	0.63
MgO	2.7	10.10	10.8	0.3	1.5	2.13	2.20
CaO	5.11	16.00	16.1	0.8	0.71	1.68	1.40
Na_2O	3.74	0.90	0.9	0.21	0.23	0.14	0.14
K_2O	1.86	0.80	0.75	0.28	0.19	—	—
S_{tot}	0.143	0.03	0.04	0.04	0.06	—	—
P_2O_5	0.08	0.04	0.06	0.06	0.09	0.39	0.10
H_2O^-	—	2.00	1.1	1.91	0.23	—	—
LOI	2.3	0.06	1.75	0.6	1.91	2.07	2.02
Total	99.28	98.9	99.9	98.1	98.6	99.83	99.80
#mg	0.46	0.62	0.63	—	—	—	—
Elements determined by quantitative spectral analysis, ppm							
Ni	—	—	300	20	70	—	—
Cr	—	—	500	50	50	—	—
V	—	—	50	15	70	—	—
$Ni/Fe \cdot 10^{-4}$	—	—	—	0.5	2.1	—	—

N o t e. 1 — amphibole-biotite gneiss (Borodynya et al., 1998); 2, 3 — amphibolite (Borodynya et al., 1998); 4, 5 — itabirite (Borodynya et al., 1998); 6, 7 — ferruginous hornfels (Rodionov, 1946).

Amphibolites (samples 3618/5, 3618/6; Borodynya et al., 1998) in terms of chemical composition correspond to basaltic komatiite (Table 1). They have high #mg = 0.62-0.63 and Ni (300 ppm) and Cr (500 ppm) concentrations.

Ferruginous-siliceous rocks (samples 3618/1, 4016/1; Borodynya et al., 1998) are represented by ferruginous quartzites (itabirites) and ferruginous hornfels, which occur interlayered with amphibolites (Rodionov, 1946). The mineral composition of itabirites is dominated by magnetite. They are rich in iron, nickel and chromium (Fe_2O_3 — 41.3%; FeO — 1.79%, Ni — 50 ppm, Cr — 70 ppm; V — 70 ppm (Tables 1, 2). They have a high $Ni/Fe \times 10^{-4}$ = 0.5-2.1 ratio, which is typical for Archean ferruginous-siliceous rocks of the Algoma type (Savko, Bazikov, Artemenko, 2015). Ferruginous hornfels were also described in the Lypovets area (Rodionov, 1946). They have similar concentrations of Fe_2O_3 (22.04-29.64%) and FeO (18.19-27.58%) (Table 1).

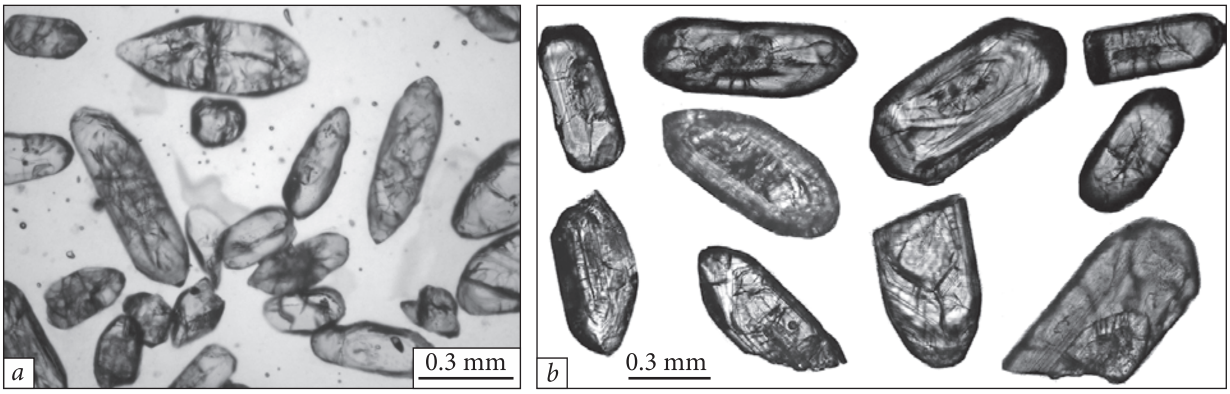
Zircon description. Zircon crystals from amphibole-biotite gneiss (sample 21/7) are light pink, most of the crystals (80%) are transparent, and a small portion (20%) are fractured and opaque (Fig. 6, *a*). The length of the crystals along the L_4 axis reaches 0.2 mm, and the elongation coefficient varies from 3 to 5. Relics (cores) of older zircon and mantles surrounding them were distinguished (Fig. 4, *a*, *b*, *c*). The relict zircon is coarse-zoned, cracked, and the mantles have thin-zoned structure (Fig. 6, *b*, *c*). A small amount of transparent homogeneous zircon crystals was also found.

Table 2. **Trace element composition of amphibole-biotite gneiss sample 21/7 in the Lypovets area**

Element	ppm	Element	ppm	Element	ppm	Element	ppm
Sc	16.14	Cs	1.11	La	22.128	Tb	0.876
Cr	50.31	Ba	392.34	Ce	57.155	Dy	4.593
Ni	37.74	Hf	6.07	Pr	7.161	Ho	0.867
Rb	28.20	Ta	0.80	Nd	30.130	Er	2.401
Sr	419	Pb	10.12	Szm	6.95	Tm	0.237
Zr	232	Th	5.58	Eu	1.405	Yb	2.106
Nb	7.44	U	0.80	Gd	6.073	Lu	0.274

Table 3. **U-Pb zircon dating results for amphibole-biotite gneiss (sample 21/7)**

# analysis	Concentration, ppm				Isotopic ratio						
	U	Pb	Th	U/Th	$^{207}Pb/^{235}U$	2σ	$^{206}Pb/^{238}U$	2σ	Rho	$^{207}Pb/^{206}Pb$	2σ
21/7-1	63,1	72,5	53	1,21	15,04	0,2	0,551	0,0066	0,55474	0,1974	0,0025
21/7-2	199	144	88	2,371	22,05	0,26	0,6489	0,0096	0,69387	0,2459	0,0024
21/7-3	166	257	156	1,084	21,15	0,24	0,6072	0,0086	0,60169	0,2516	0,003
21/7-4	97,1	123,7	85,1	1,144	16,62	0,2	0,5716	0,009	0,17205	0,2113	0,0025
21/7-5	82	65,4	45,8	1,68	15	0,19	0,5441	0,007	0,54278	0,2021	0,0028
21/7-6	47,8	46	30,5	1,486	15,1	0,28	0,5486	0,0065	0,50715	0,1999	0,0033
21/7-7	358	225,1	211	1,579	7,06	0,16	0,4046	0,0094	0,67349	0,129	0,0021
21/7-8	210	110,7	64,3	3,18	20,33	0,28	0,6136	0,0095	0,67705	0,2406	0,003
21/7-9	480	222	151	2,943	14,37	0,2	0,5312	0,0075	0,6897	0,1961	0,0023
21/7-10	1928	94	59,2	29,9	17,54	0,17	0,6001	0,0061	0,66538	0,2128	0,0017
21/7-11	214,1	108,9	65,7	2,998	21,53	0,25	0,6333	0,008	0,69636	0,2469	0,0024
21/7-12	1548	507	305,3	4,65	15,31	0,21	0,5423	0,0097	0,83714	0,204	0,0022
21/7-13	256,4	116,8	99,3	2,379	6,804	0,089	0,3819	0,0066	0,56322	0,13	0,0016
21/7-14	209,5	81,5	54,8	3,461	16,71	0,29	0,556	0,011	0,80006	0,2196	0,0026
21/7-15	579	98,3	66,8	7,94	12,52	0,26	0,469	0,013	0,78699	0,1948	0,0035
21/7-16	97,7	56,9	33,9	2,698	21,56	0,25	0,6346	0,0082	0,66624	0,2462	0,0029
21/7-17	105,2	73	47,2	2,04	19,55	0,54	0,596	0,017	0,77149	0,2395	0,0055
21/7-19	251	153,7	93,7	2,422	19,81	0,36	0,604	0,014	0,81045	0,2398	0,0038



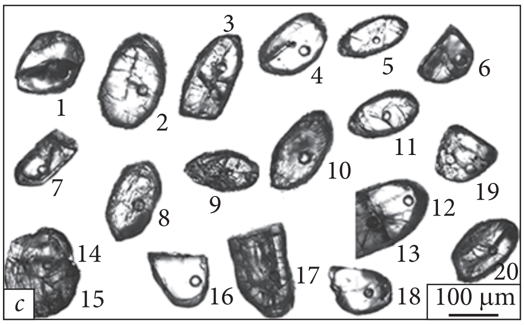


Fig. 6. Microscopic images of zircon crystals from amphibole-biotite gneiss (Lozuvatka antiform, Lypovets area, sample 21/7): *a* — general view; *b* — zircon crystals with cores; *c* — zircon with dating spots

Results of a geochronological study. A total of 18 zircon crystals were analysed and 19 analytical points were obtained (Table 3). One of the analyses was strongly discordant and is not further considered. The zircon grains yielded concordant and close to concordant results at the following ages: 3.16 Ga, 2.9-2.8 Ga, and 2.1 Ga (Fig. 7, *a*, *b*). The U-Pb concordia age of relict zircon, calculated using two analytical points having the oldest ages is 3163 ± 9 Ma (MSDW = 0.032) (Fig. 7, *a*, *b*), whereas the concordia age of the second population, defined by three analytical points, is 2818 ± 9 Ma.

Isotopic age, Ma					
$^{207}Pb/^{235}U$	2σ	$^{206}Pb/^{238}U$	2σ	$^{207}Pb/^{206}Pb$	2σ
2818	12	2828	27	2802	21
3185	11	3227	37	3159	15
3145	11	3058	34	3194	19
2912	12	2913	37	2913	20
2814	12	2800	29	2840	23
2821	17	2822	26	2833	27
2121	20	2189	43	2082	29
3106	13	3089	39	3122	20
2773	13	2756	31	2792	19
2964	10	3030	25	2926	13
3163	11	3161	32	3163	16
2834	13	2792	40	2858	17
2089	12	2084	31	2098	21
2916	17	2847	44	2979	20
2643	20	2478	56	2781	29
3163	12	3166	33	3158	18
3067	26	3011	70	3114	37
3084	16	3043	56	3120	25

Discussion of the results and conclusions. Based on mineralogical and geochronological data, a multi-stage history of the formation of amphibole-biotite gneisses of the Lypovets area of the Lozuvate antiform has been suggested. Chemical features of this rock indicate that its igneous precursor, quartz diorite, was probably derived from a crustal source. The minimum age of the relict zircon was defined at 3163 ± ± 9 Ma, it represents the primary crustal precursor of this rock, probably belonging to the tonalite-trondhjemite-granodiorite association. The thin-zonal mantles surrounding the zircon relics have an age of 2.9-2.8 Ga, which probably corresponds to the time of partial melting of the primary crustal source, and formation of quartz diorites. Alternatively, it may correspond to the high-grade metamorphic event. Homogeneous transparent zircon domains yielding an age of 2.1 Ga corresponds to the time of dynamometamorphism (collision). Interestingly, a similar set of the crust-forming processes was previously

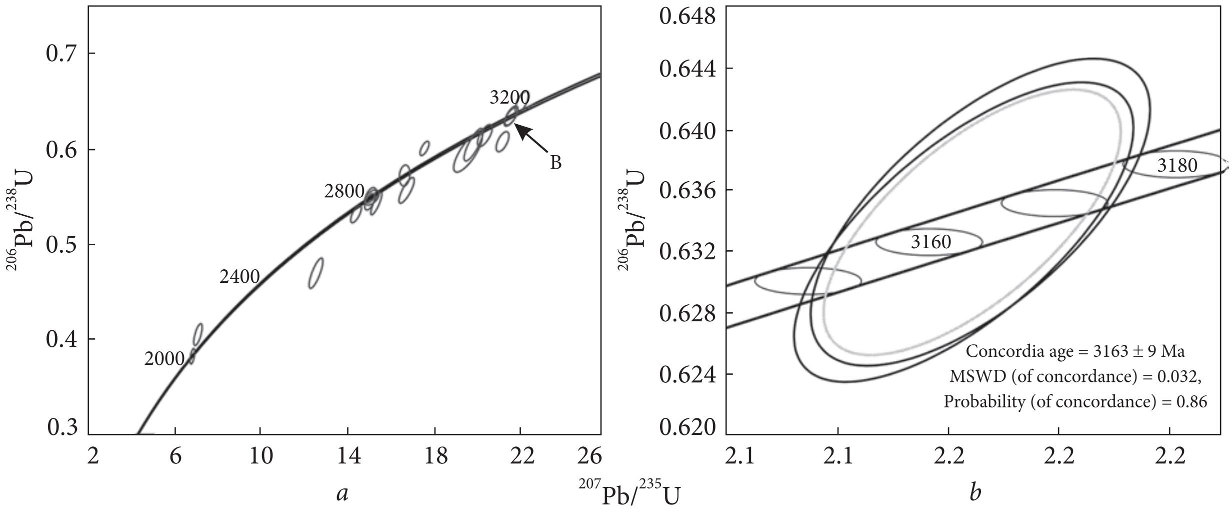


Fig. 7. U-Pb concordia diagram for zircon crystals from the amphibole-biotite gneiss (Lozuvatka antiform, Lypovets area, sample 21/7) (*a*); concordant age of the two oldest concordant grains (*b*)

defined in the Dniester-Bouh Domain of the Ukrainian Shield (e.g., Claesson et al., 2015, 2019; Shumlyanskyy et al., 2021).

The rocks of the sedimentary-volcanogenic sequence composing the eroded syncline (Kaiinkulak Unit) are probably the remnant of the an Archean greenstone belt composed of strongly metamorphosed basaltic komatiites and sedimentary rocks, including ferruginous-siliceous formation with a high $Ni/Fe \times 10^{-4}$ = 0.5-2.1 ratio, which is typical for Archean ferruginous-siliceous rocks of the Algoma type. A similar highly metamorphosed rocks including pyroxenitic komatiites and itabirites, was found earlier in the Bilotserkivka structure. Thus, the Verkhnii Tokmak Unit of the West Azov Group comprises Mesoarchean quartz diorites of crustal genesis, while the Kaiinkulak Unit probably represents heavily metamorphosed rocks of an Archean greenstone belt.

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Г.В. Артеменко, [1] д-р геол. наук, проф., зав. відділу
E-mail: regulgeo@gmail.com; https://orcid.org/0000-0002-4528-6853
Л.В. Шумлянський, [2] д-р геол. наук, проф.
E-mail: lshumlyanskyy@yahoo.com; https://orcid.org/0000-0002-6775-4419
Д. Чью, [3] PhD, проф.
E-mail: chewd@tcd.ie; https://orcid.org/0000-0002-6940-1035
Ф. Дракоу, [3] PhD
E-mail: drakouf@tcd.ie; https://orcid.org/0000-0001-6618-4541
І.А. Швайка, [1] канд геол. наук, наук. співроб.
E mail: ishvaika@gmail.com; https://orcid.org/0000-0001-9585-4380
[1] Інститут геохімії, мінералогії та рудоутворення ім. М.П. Семененка НАН України
03142, м. Київ, Україна, просп. Акад. Палладіна, 34
[2] Інститут геологічних наук Польська академія наук
31-002, м. Краків, Польща, Senacka, 1
[3] Трініті-коледж, Школа природничих наук, кафедра геології
College Green, Дублін 2, Ірландія

ВІК І ГЕНЕЗИС ПОРІД ЗАХІДНОПРИАЗОВСЬКОЇ СЕРІЇ (ЛОЗУВАТСЬКА АНТИФОРМА, УКРАЇНСЬКИЙ ЩИТ)

Виконано геохронологічні дослідження амфібол-біотитових гнейсів верхньотокмацької товщі й амфіболітів і залізистих кварцитів кайінкулацької товщі західноприазовської серії Липовецької ділянки Лозуватської антиформи Західного Приазов'я. Установлено багатоетапну історію формування амфібол-біотитових гнейсів. За хімічним складом вони відповідають кварцовим діоритам. Рідкісноземельні елементи диференційовані — (La/Yb_N = 7,54), зі значною негативною європієвою аномалією — Eu/Eu* = 0,66. Характер розподілу РЗЕ свідчить, що кварцові діорити виплавились у коровому магматичному джерелі. У кристалах циркону з амфібол-біотитових гнейсів вирізняються релікти (ядра) давнішого циркону та оболонки, які їх оточують. Реліктовий циркон грубозональний, тріщинуватий, а оболонки складені тонкозональним цирконом. Також наявна невелика кількість кристалів прозорого незонального циркону. За результатами датування циркону методом *LA-ICP-MS* визначено, що реліктовий циркон має вік 3,16 млрд рр. Тонкозональні оболонки, що оточують релікти циркону, мають вік 2,9—2,8 млрд рр., який збігається з часом утворення кварцових діоритів. Незональний прозорий циркон віком 2,1 млрд рр. відповідає часу динамометаморфізму (колізії). Встановлено, що залізисто-кременисті породи Липовецького родовища Західноприазовської залізорудної провінції, які належать до кайінкулацької товщі західноприазовської серії, мають високе значення відношення $Ni/Fe \times 10^{-4}$ = 0,5—2,1, характерне для архейських залізисто-кременистих порід альгомського типу. Ці залізисті кварцити приурочені, ймовірно, до архейської зеленокам'яної структури, складеної метаморфізованими базальтовими коматіїтами й осадовими породами. Отже, до складу верхньотокмацької товщі західноприазовської серії у Лозуватській антиформі включені мезоархейські кварцові діорити корового генезису, а до кайінкулацької товщі — високометаморфізовані породи, ймовірно, архейської зеленокам'яної структури.

Ключові слова: Західне Приазов'я, Салтичанський антиклінорій, Лозуватська антиформа, Липовецьке залізорудне родовище, U-Pb вік, циркон, ітабірити, гнейси, західноприазовська серія.