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AGE AND SULFUR ISOTOPE COMPOSITION OF THE PRUTIVKA INTRUSION (THE 1.78 Ga PRUTIVKA-NOVOGOL LARGE IGNEOUS PROVINCE IN SARMATIA)

There are a number of dykes and layered intrusions of the Ni-bearing tholeiitic dolerites and gabbro in the Northwestern region of the Ukrainian Shield. These dykes and intrusions were considered either as feeders for the completely eroded continental flood basalts emplaced in an extensional setting or as syn-collisional complexes that crystallized from the mantle melts during the collision of Fennoscandia and Volgo-Sarmatia cratons. Recent U-Pb dating of these rocks indicates that their age is 1780 to 1790 Ma. A U-Pb baddeleyite age is presented for the Prutivka layered dolerite intrusion that hosts the only known Ni-Cu(-PGE) sulfide deposit on the Ukrainian Shield. The new baddeleyite age (1779.2 ± 6.9 Ma) corresponds within the error with the zircon age (1777.0 ± 4.7 Ma) obtained previously for the same sample (Shumlyanskyy et al., 2012) and differs from the zircon age of 1990 ± 5 Ma reported by Skobelev et al. (1991), which is now considered to be incorrect. The new baddeleyite age definitively confirms that this intrusion belongs to the Prutivka-Novogol Large Igneous Province (LIP) and emphasises the potential of gabbroic, layered intrusions belonging to this event to host Ni-Cu(-PGE) sulphide ores. We have also analyzed sulfur isotope composition of sulfide minerals from the Prutivka deposits. Samples were selected from the near-bottom accumulations of sulfide minerals. Sulfur isotope composition ($\delta^{34}S$ values) ranges from +0.8 to +3.6 ‰, which corresponds to the previously established range and indicates mantle sulfur source. Sulfur isotope data and U-Pb ages are consistent with the emplacement of the Prutivka-Novogol LIP in an extensional setting, developed shortly after the assembly of Baltica.

Keywords: baddeleyite, U-Pb age, sulfur isotope composition, Prutivka intrusion, Ukrainian Shield.

Introduction. The Ukrainian Shield and adjacent regions of Sarmatia host two Precambrian Large Igneous Provinces (LIPs) — the Vendian (c. 570 Ma) Volyn continental flood basalt province of which a c. 400 m thick pile of basaltic rocks is still preserved [26, 39], and the Palaeoproterozoic (c. 1790—1780 Ma) Prutivka-Novogol province that includes numerous dolerite dykes and layered intrusions widely distributed throughout the Ukrainian Shield

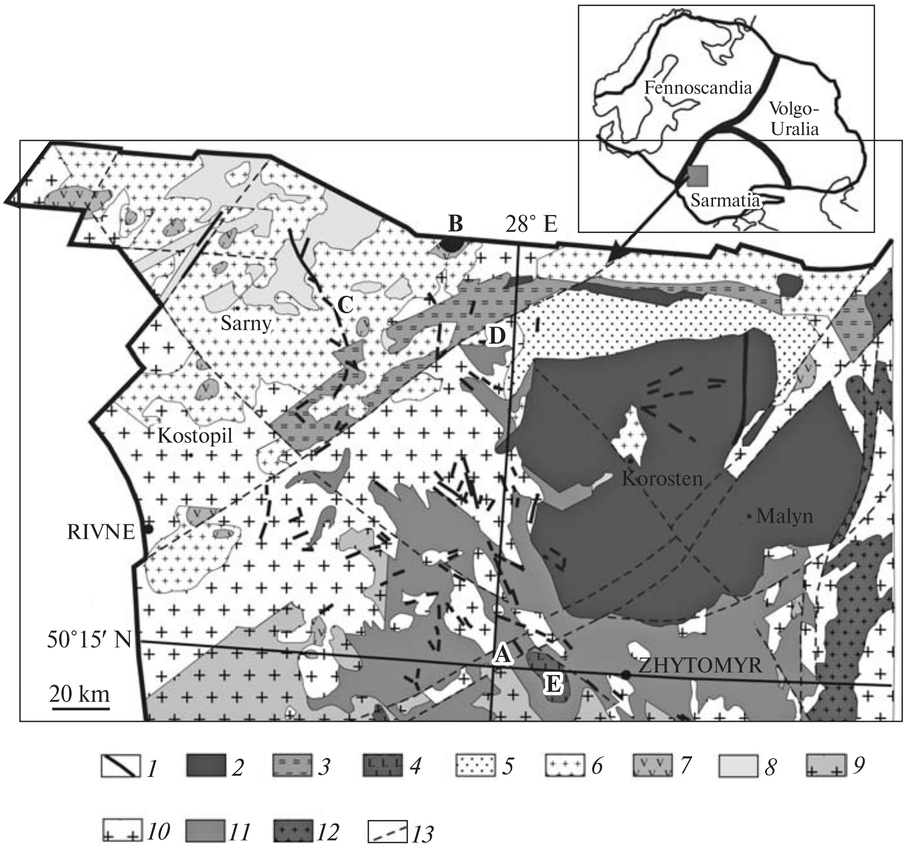

Fig. 1. Geology of the NW Ukrainian Shield. Modified from the map produced by the Zhytomyr geological enterprise. A — Prutivka massif; B — Kamyanka layered massif; C — Tomashgorod dyke swarm; D — Zamyslovychi dyke; E — Buky massif. *1* to *11* — Early Proterozoic: *1* — mafic dykes and layered intrusions; *2* — rocks of the Korosten AMCG complex (1.81—1.74 Ga); *3* — granites probably related to the Korosten magmatic event; *4* — ultramafic-gabbro-norite-monzonite layered intrusions of the Buky complex, 1.99 Ga; *5* — metavolcanites and metasediments of the Ovruch and Bilokorovychi basins, c. 1.9—1.7 Ga; *6*—*8* — Osnitsk-Mikashevychi igneous belt, 2.0—1.95 Ga (*6* — granite of the Osnitsk complex, *7* — mafic intrusions of the Osnitsk complex, *8* — metavolcanics of the Klesiv Series); *9* — granite of the Berdychiv complex; *10*, *11* — rocks of the Zhytomyr-Teteriv belt, 2.1—2.05 Ga (*10* — granite of the Zhytomyr complex; *11* — metamorphic rocks of the Teteriv Series); *12* — Late Archaean metamorphic rocks and migmatites, c. 2.6 Ga; *13* — major fault zones

and Voronezh Crystalline Massif. Palaeoproterozoic dykes of the northwestern Ukrainian Shield have been extensively studied and dated [4, 7, 24, 25, 42], whereas dykes of the central part of the shield (Ingul domain) are less studied [4, 22, 31, 33, 45].

In the northwestern Ukrainian Shield there is a group of Ni-enriched dolerite dykes and layered intrusions of tholeiitic composition that were previously regarded as either feeders for a now completely eroded continental flood basalt sequence formed in an extensional setting [38] or products of crystallization of a mantle-derived tholeiitic melt developed in response to the collision of two large crustal segments that comprise the East European platform — Fennoscandia and Volgo-Sarmatia [4, 24]. In addition to typical tholeiites, there are also coeval subalkaline mafic and ultramafic rocks, and kimberlites on the Ukrainian Shield [4, 26, 35, 43].

Tholeiitic rocks of the northwestern Ukrainian Shield occur as numerous dolerite dykes and layered intrusions confined to major regional fault zones (Fig. 1). Dykes are variable in size: the width varies from few meters up to 500 m and they can be traced for up to 12 km in length, whereas sets of dykes can be traced even for 50 km or more. All dykes of this group, except one, are located outside of the 1815—1740 Ma old Korosten anorthosite-mangerite-charnockite-granite (AMCG) plutonic complex where they cut various country rocks, the youngest of which are c. 1980 Ma old. However, a high-Ni and high-Mg tholeiitic dolerite dyke was recently discovered in the Malyn quarry where it cuts granite of the Korosten plutonic complex. Most of the tholeiitic dykes are Ni-enriched (over 100 ppm Ni) and composed of olivine-bearing pigeonite and pigeonite-augite dolerites and gabbro-dolerites. A low-Ni variety is also known although it is less common (e. g., Zamyslovychi dyke). In their central parts, thick dykes often contain pods of pegmatitic dolerite enriched with felsic interstitial material (quartz, Na-plagioclase and less abundant K-feldspar) [34, 37, 42] that contain abundant baddeleyite and zircon that are suitable for U-Pb dating.

U-Pb ages of the Ni-bearing tholeiites were reported [4, 24, 25, 44] as follows: zircons from the Tomashgorod dyke pegmatite pod yielded an age of 1787.4 ± 6.4 Ma, whereas baddeleyite dating of dolerite from the same dyke gave an age of 1790.7 ± ± 5.1 Ma; pegmatitic dolerite of the Prutivka intrusion yielded a zircon age of 1777.0 ± 4.7 Ma (see discussion below); the Kamyanka massif was dated at ca. 1.79 Ga; finally, baddeleyite from olivine dolerite of the Zamyslovychi dyke yielded an age of 1786 ± 3 Ma. These c. 1800 Ma U-Pb ages of tholeiitic dolerite dykes of the northwestern Ukrainian Shield are also consistent with composite, whole-rock Rb-Sr (1772 ± 39 Ma) and Sm-Nd (1890 ± ± 190 Ma) isochrones [44].

Earlier dating of zircons from the Prutivka intrusion was undertaken [34] and a 1990 ± 5 Ma age was reported. This work was carried out at the same time as dating of the large (ca. 180 km^2) Buky layered, pyroxenite-gabbro-monzonite-granodiorite intrusion that is located near the Prutivka massif. A large number of samples from the Buky intrusion were processed in order to separate zircons; these zircons yielded ages around 1990 Ma. It was concluded that the Prutivka intrusion was emplaced simultaneously with the Buky layered intrusion that led to the erroneous suggestion about the potential of the Buky intrusion with respect to Cu-Ni sulphide mineralization. Subsequent dating of zircons from the Skobelev et al. (1991) original sample confirmed the 1990 Ma age for these zircons [44]. However, these zircons are very different from the zircons separated from mafic pegmatites of the Prutivka intrusion [24]. Moreover, the Hf isotope compositions of zircons from the original sample, calculated at 1990 Ma, (εHf = 1.2 ± 0.4) were very close to the Hf isotope composition of zircons from the 1990 Ma Buky massif (εHf = 0.8 ± 0.7; [40]), and significantly different from the Hf isotope composition of zircons from the Prutivka massif (εHf = 9.0 ± 0.8 at 1990 Ma). It should be noted that dolerites (apart from pegmatitic dolerites) of the Prutivka intrusion are poor in zircon, and the dated dolerite sample [34] was the only dolerite (excluding the pegmatitic dolerite) sample among over 100 investigated ones that yielded enough zircons for the purpose of a conventional dating. Hence, we suggest that the original sample of Skobelev et al. (1991) may have been contaminated during mineral separation by zircons from the Buky massif.

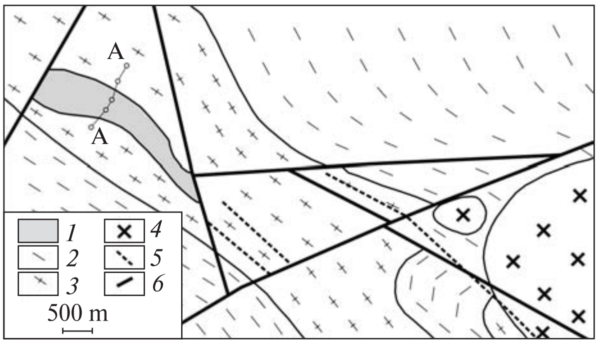

Fig. 2. Geological map of the Prutivka intrusion (according to M.M. Kostenko). *Legend*: *1* — rocks of the Prutivka massif; *2* — gneisses of the Horodska Suite of the Teteriv Series (biotite, graphite-biotite, amphibole-biotite, and garnet-biotite gneisses); *3* — plagioclase migmatites of the Zhytomyr Complex (biotite and amphibole-biotite migmatites); *4* — rocks of the Buky layered massif (diorite, gabbroic diorite, monzonite, and gabbronorite); *5* — dolerite dykes; *6* — faults

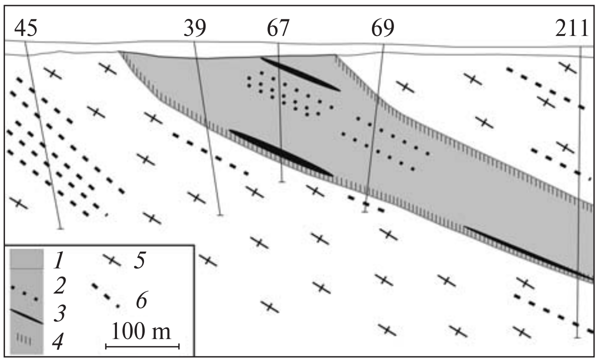

Fig. 3. Vertical cross-section through the Prutivka intrusion along the A—A line on Fig. 2 (after M.M. Kostenko). *Legend*: *1* — rocks of the Prutivka intrusion; *2* — gabbroic pegmatites; *3* — ore bodies (not to scale); *4* — zones of dispersed sulphide mineralization; *5* — plagioclase migmatite of the host Zhytomyr Complex; *6* — granitic pegmatites and aplites of the host rocks

Zircons from the mafic pegmatites of the Prutivka massif are rich in U (typically over 1000 ppm U); similarly high concentrations of U were found in zircons from the Tomashgorod dolerite dyke [24, 44], and in zircons from the Kharaelakh [14] and Noril'sk-1 [13] mafic-ultramafic intrusions that both belong to the Siberian continental flood basalt province. Hence, high concentrations of U may be a common feature of zircons from continental tholeiites. In the absence of other U-bearing mineral

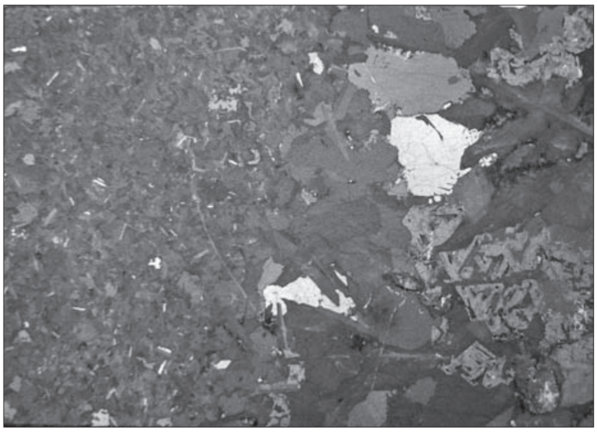

Fig. 4. Gabbroic pegmatites of the Prutivka layered intrusion. The macrophotograph shows the contact between gabbroic pegmatite (on the right) with medium-grained dolerite (on the left). Sample 268/165.6, width of the photo is 7 cm

phases in mafic rocks, zircon can accommodate large amounts of U.

In order to fully resolve the question of the age of the Prutivka layered intrusion we have separated baddeleyite from a sample of pegmatitic dolerite that was taken from the drill core #268 at 162 m depth. Results of U-Pb dating of zircon from the same sample (1777.0 ± 4.7 Ma) were reported previously [24, 44]. We should emphasize that, unlike zircon, baddeleyite is always considered to be a syngenetic mineral in mafic rocks (e. g., [27]). It could not be inherited from either source rocks or country rocks. Hence, U-Pb age of baddeleyite unequivocally corresponds to the age of the mafic rock that hosts baddeleyite.

Prutivka massif. The Prutivka intrusion is a nearly concordant sheet-like dolerite body with a thickness varying from 110 to 210 m and extending along strike for over 3 km. It is hosted by metasedimentary and metavolcanic units of the c. 2.2—2.1 Ga Teteriv Series [23]. The Prutivka intrusion dips gently (23—35°) towards the southeast and was traced in drill holes to a depth of up to 800 m (Figs. 2 and 3) [34]. The syngenetic rock series of the Prutivka intrusion includes plagioclase-bearing wehrlite, melanotroctolite, troctolite, olivine gabbro, gabbro, quartz-bearing gabbro and gabbro-pegmatite. Three zones were recognized in a vertical section of the Prutivka intrusion: (1) a contact zone; (2) a basal zone composed of melanogabbro and ultramafic rocks and (3) a thick main zone composed of fine- to medium-grained dolerite that alternates rhythmically with coarse-grained (pegmatoid) dolerites. The Prutivka intrusion hosts the only known (sub-economic) Ni-Cu(-PGE) sulfide deposit within the Ukrainian Shield [32] and potential for Ni-Cu(-PGE) sulfide deposits was noted for c. 1790 Ma dolerites on the Voronezh massif [36].

Ore beds in the Prutivka massif are located near the upper and lower contacts of the intrusive body [32], and partly within the host rocks near the lower contact. The thickness of the ore beds varies from a few meters to 15.1 m with an average thickness of 4.3 m. Concentration of sulfide minerals varies from 3 to 20 %, reaching 50—70 % in places. Thin (up to a few cm thick) massive ore veins can be found locally. Nickel concentration in the mineralized rock varies from 0.3 to 3.84 % (with the average of 0.58 %), copper varies from 0.1 to 2.84 % (with the average of 0.26 %) and cobalt is c. 0.022 %. PGEs were found in low concentrations (ranging from a few hundredths of ppm to a few ppm). The predominant ore mineral assemblage includes chalcopyrite, pentlandite, and pyrrhotite; the pentlandite-cubanite-chalcopyrite-pyrrhotite assemblage is less abundant [32].

Syngenetic gabbroic pegmatite bodies in the Prutivka intrusion are of special interest since these rocks are the best target for zircon and baddeleyite. These rocks were described in detail [34, 37]. According to [34], gabbroic pegmatites were found in all parts of the massif, making up about 36 % of its total volume, but are more abundant in the central parts of the vertical section (Fig. 3). Contacts between fine- to medium-grained dolerites that prevail in the massif and their pegmatitic varieties are rather sharp, but not intrusive (Fig. 4). Similar syngenetic relationships between fine- to medium-grained and pegmatitic varieties have been seen in outcrops of the Tomashgorod dyke [42].

Pegmatite bodies are often layered, being enriched in mafic minerals in their lower parts and in quartz and feldspar in their upper parts. There is no doubt about the syngenetic nature of pegmatite bodies in the Prutivka intrusion; they are the natural result of in-chamber evolution of the tholeiite melt and do not represent later intrusions of melts from an external source. There is also no reason to suppose that crystallization of the 110 to 210 m thick dolerite body lasted ca. 200 myr, as might be proposed to explain the age between 1990 Ma (age of zircons in dolerite [34]) and 1780 Ma (age of zircon and baddeleyite in syngenetic pegmatites [24, 44]).

U-Pb geochronology. The gabbro-pegmatite sample 268 was processed at the M.P. Semenenko Institute of Geochemistry, Mineralogy and Ore Formation, Kyiv, Ukraine, where a heavy fraction was separated using a shaking table, heavy liquids and magnetic separator. The heavy mineral separate was examined under the binocular microscope and rather large (up to 100 μm) grains of dark-brown baddeleyite of optically good quality were selected for U-Pb dating. Each fraction, represented by 1—2 grains, was spiked with a ^{205}Pb—$^{233-236}U$ isotopic tracer solution at the Museum of Natural History in Stockholm, Sweden. The grains were dissolved in a 10 : 1 HF : HNO_3 acid mixture at 190 °C for 3 days, which was then evaporated on a hot plate at 100 °C. The precipitates were re-dissolved in 10 drops of 6 N HCl and 1 drop of 0.25N H_3PO_4 acids and then dried down on a hot plate at 90°C. Lead and U were purified using ion-exchange miniaturised columns. Uranium and Pb isotopic ratios were measured on a Finnigan Triton mass-spectrometer at the Museum of Natural History in Stockholm, Sweden (Table 1; Fig. 5). The U and Pb isotopic composition were analysed using a Secondary Electron Multiplier equipped with RPQ in the peak-switching mode. The procedural total blank was estimated to be 0.5 pg for Pb and 0.05 pg for U. The U-Pb data indicate an age of 1779.2 ± ± 6.9 Ma with the lower intercept anchored to 0 Ma.

Sulfur isotope geochemistry. Four samples were collected from the marginal zone (grading from ultramafic cumulates to dolerites) of the Prutivka massif from 2 drill cores. In addition, for comparison, a drill core sample bearing sulfides from the marginal zone of the similar-age Kamyanka massif and another drill core sample bearing sulfides from the middle part of the c. 2.0 Ga Zaliznyaky massif [34] were also analyzed (Table 2). Sulfur was extracted from the powdered samples and converted to Ag_2S through a Cr(II) reduction procedure following [5] at the Stable Isotope Laboratory of the Department of Earth and Planetary Sciences (McGill University). The extracted Ag_2S was fluorinated at 225 °C in a Ni bomb under ~20x stoichiometric excess of F_2 for >9 h to produce SF_6, which was then purified cryogenically and chromatographically and analyzed on a Thermo Electron

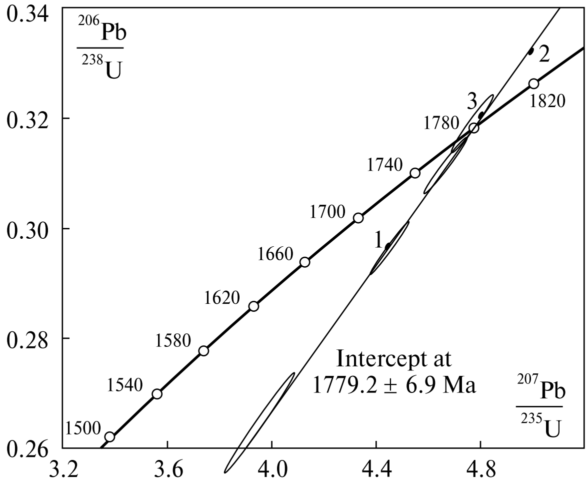

Fig. 5. U-Pb concordia diagram for baddeleyites separated from the gabbroic pegmatite of the Prutivka intrusion. Numbers on the diagram correspond to fraction numbers in Table 1. Zircon U-Pb data (large ellipses) previously reported [24] are also shown for comparison

Table 1. **Results of the U-Pb baddeleyite dating of the Prutivka gabbroic pegmatite**

Fraction	Sample weight, μg	Concentrations, ppm			Isotope ratios							Age, Ma		
		U	Pb_{tot}	Pb_{com}	$^{207}Pb/^{206}Pb$	± σ, %	$^{207}Pb/^{235}U$	± σ, %	$^{206}Pb/^{238}U$	± σ, %	Rho	$^{207}Pb/^{206}Pb$	$^{207}Pb/^{235}U$	$^{206}Pb/^{238}U$
1	3.0	600.3	180.5	8.9	0.10883	0.064	4.44848	0.229	0.29647	0.220	0.96	1779.8	1721.4	1673.8
2	5.3	294.7	104.5	9.4	0.10898	0.080	4.98878	0.219	0.33200	0.203	0.93	1782.5	1817.4	1848.1
3	12.5	207.2	67.8	3.7	0.10864	0.060	4.79907	0.138	0.32039	0.124	0.90	1776.7	1784.7	1791.6

Table 2. **Sulfur isotope composition in sulfides**

Sample	Massif	$\delta^{33}S$	$\delta^{34}S$	$\delta^{36}S$	$\Delta^{33}S$	$\Delta^{36}S$
		‰ V-CDT				
201/512.5	Prutivka	1.47	2.9	5.4	–0.02	–0.13
201/521.7	"	0.40	0.8	1.5	–0.03	–0.12
201/528.5	"	1.30	2.6	4.8	–0.02	–0.09
72/140.2	"	1.82	3.5	6.6	–0.01	–0.16
3501/695.3	Kamyanka	0.45	0.9	1.6	–0.01	–0.11
63/116	Zaliznyaky	1.39	2.7	5.1	–0.02	–0.12

MAT 253 mass spectrometer for multiple sulfur isotope ratios in a dual-inlet mode at McGill University. Sulfur isotope compositions are reported on the V-CDT scale, defined by the $\delta^{34}S$ value of IAEA-S-1 of –0.3 ‰. We take the $\Delta^{33}S$ value of IAEA-S-1 to be 0.094 ‰. Repeat analyses throughout the entire analytical procedure returned 2σ uncertainties on $\delta^{34}S$ and $\Delta^{33}S$ values that are <0.25 and <0.02 ‰, respectively.

Sulfur isotope data for all three studied intrusions show a small range of $\delta^{34}S$ values from +0.8 to +3.6 ‰, similar to the range previously observed [34, 41] and also to that of the mantle [2]. $\Delta^{33}S$ values for the whole set range from –0.007 to –0.026 ‰, indicating the lack of mass-independent fractionation of S that was previously used as a signature for crustal assimilation in cases when volcanic or intrusive units are hosted by Archaean metasediments [1]. These data are however less definitive in cases when magmatism occurred in terranes lacking metasediments deposited before the Great Oxygenation Event [see 10]. Deposition of the Teteriv Series straddles the end of the c. 2.22—2.1 Ga Lomagundi carbon isotope excursion in seawater composition, when seawater sulfate level dramatically increased [21] and sedimentary sulfides and sulfate show a large range of $\delta^{34}S$ values [e. g., 20]. A small range of $\delta^{34}S$ values observed in sulfides of studied intrusions is thus also inconsistent with significant crustal assimilation resulting in formation of sulfide xenomelt.

Discussion

The 1790—1780 Ma Ni-bearing intrusions (Prutivka-Novogol LIP). The 1779.2 ± 6.9 Ma baddeleyite age of the Prutivka intrusion confirms its relation to the 1790—1780 Ma Prutivka-Novogol LIP (equivalent to the Tomashgorod-AMCG LIP in [8]). In the northwestern Ukrainian Shield, the units that belong to the Prutivka-Novogol LIP include: high-Ni and low-Ni tholeiitic intrusions (dykes and layered massifs), and dykes of subalkaline olivine gabbro. In addition, dykes and small intrusions of alkaline ultramafic rocks of the Horodnytsya complex with unknown age might be related. In the central part of the Ukrainian Shield, the Prutivka-Novogol LIP includes three compositionally different series of intrusions: (1) kimberlites; (2) subalkaline mafic and ultramafic rocks; and (3) tholeiitic dolerites [22]. Tholeiitic dolerite dykes are also known from other parts of the Ukrainian Shield, however, their ages remain unknown.

Dykes and layered intrusions of tholeiitic composition of this age are also common on the Voronezh Crystalline Massif [36]. Moreover, dykes of this age and similar composition are known on other cratons that could have been adjacent to Sarmatia within the Palaeoproterozoic supercontinent Nuna (or Columbia). There are a number of paleotectonic and paleomagnetic reconstructions for the Palaeo-Mesoproterozoic supercontinent [11, 12, 18, 29, 30]. Some of these reconstructions locate Sarmatia next to Amazonia in the west, with West Africa being attached in the south. Position of the North China craton is less certain, but some models (e. g., [6]) place it in the vicinity of Baltica. Mafic dykes emplaced between c. 1800 and 1750 Ma are abundant in Amazonia, West Africa and on the North China craton [3, 16, 17, 19, 28], which within the framework of these reconstructions might imply that they are related to a single plume-induced LIP event [9].

Source of sulfur and origin of the Prutivka deposit. Assimilation of large amount of sulfur from the metasedimentary rocks of the Teteriv Series should have resulted in a large range of $\delta^{34}S$ values than observed in this study. We therefore infer, following [2], that assimilation of the metasedimentary rocks of the Teteriv Series contributed only small amount of S with most S of the Prutivka massif being of mantle origin; furthermore assimilation of silicates could have lowered S solubility resulting in precipitation of low-sulfide, PGE-rich mineralization.

As has been shown with an example of sulfide Cu-Ni-PGE deposits of the Noril'sk type [15], a large-scale contamination of the initial melt with sulfur from evaporite deposits widely available in the Noril'sk area was a key factor in their formation. An excess of the evaporitic sulfur, indicated by high $\delta^{34}S$ values varying from +8 ‰ to +12 ‰, has resulted in separation of the initial melt into immiscible silicate and sulfide liquids [15]. In case of the Prutivka massif, absence of the large external source of sulfur did not allow formation of a large sulfide deposit, though some contamination is evidenced from heavier sulfur isotope compositions seen in ores located in the host migmatites.

The 1790—1780 Ma Ni-bearing intrusions (Prutivka-Novogol LIP) and implications for the regional economic potential. Potential for finding economic sulfide ores is greater for other intrusions of the Prutivka-Novogol LIP such as the Kamyanka layered massif, which is much larger than the Prutivka massif (over 1100 m thick) and layered from peridotite at the bottom to anorthosite in the upper part. Small amounts of sulfide ore were indeed revealed by drilling, whereas deep electrical sounding indicated the presence of zones of low electric conductivity in the bottom part of the Kamyanka intrusion [34]. Ni-bearing, layered gabbroic intrusions of the same age are also known in the Voronezh Crystalline Massif, where they belong to the Smorodino-Novogol rock complex.

New geochronological data indicate that the Prutivka massif is some 200 m. y. younger than the located nearby layered intrusions of the Buky complex. It was previously assumed [34] that the Prutivka massif is genetically linked to the Buky intrusion. This led to the suggestion that the Buky layered massif and related intrusions are promising for prospecting for Cu-Ni sulfide ores. The new U-Pb baddeleyite age of 1779.2 ± 6.9 Ma presented herein rules out any genetic link between these two intrusive complexes and contests economic potential of the Buky complex with respect to Cu-Ni sulfide ores.

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ВІК ТА ІЗОТОПНИЙ СКЛАД СІРКИ ПРУТІВСЬКОГО ІНТРУЗИВУ (ПРУТІВСЬКО-НОВОҐОЛЬСЬКА МАГМАТИЧНА ПРОВІНЦІЯ ВІКОМ 1,78 МЛРД РР. У САРМАТІЇ)

У межах Північно-Західного району Українського щита розповсюджена велика кількість дайок і розшарованих інтрузивів нікеленосних толеїтових долеритів та габроїдів. Ці дайки та масиви розглянуто як канали, по яких в умовах розтягнення вкорінювалися і виливалися на поверхню базальтові розплави (ці базальтові потоки тепер повністю еродовані), або як синколізійні породні комплекси, що виникли внаслідок кристалізації мантійних розплавів під час колізії Фенноскандинавського та Волго-Сарматського сегментів Східно-Європейської платформи. Проведене нещодавно датування цих порід вказує на їхній вік в інтервалі 1780—1790 млн рр. Для Прутівського нікеленосного долеритового інтрузиву отримано новий вік за баделеїтом (1779,2 ± 6,9 млн рр.), який, у межах похибки вимірювання, відповідає віку циркону (1777,0 ± 4,7 млн рр.), отриманому раніше для цього ж зразка

(Shumlyanskyy et al., 2012). Це значення віку суттєво відрізняється від отриманого раніше для цирконів із Прутівського інтрузиву 1990 ± 5 млн рр. (Скобелев и др., 1991). Зроблено висновок, що останнє значення є хибним. Нова дата, отримана за баделеїтом, остаточно підтверджує належність Прутівського масиву до Прутівсько-Новогольської магматичної провінції та підкреслює потенціал розшарованих габроїдних масивів цієї провінції щодо Ni-Cu (-PGE) сульфідного зруденіння. Проаналізовано також ізотопний склад сірки в сульфідних мінералах Прутівського родовища, зразки відібрано з придонних рудних покладів. Ізотопний склад сірки (величина $\delta^{34}S$) варіює від +0,8 до +3,6 ‰, що знаходиться в межах діапазону варіацій, який було встановлено раніше, і вказує на мантійне джерело сірки. Ізотопні дані свідчать про формування Прутівсько-Новогольської магматичної провінції в умовах розтягнення, що виникли невдовзі після утворення Східно-Європейської платформи (Балтики).

Ключові слова: баделеїт, U-Pb вік, ізотопний склад сірки, Прутівський масив, Український щит.

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ВОЗРАСТ И ИЗОТОПНЫЙ СОСТАВ СЕРЫ ПРУТОВСКОГО ИНТРУЗИВА (ПРУТОВСКО-НОВОГОЛЬСКАЯ МАГМАТИЧЕСКАЯ ПРОВИНЦИЯ ВОЗРАСТОМ 1,78 МЛРД ЛЕТ В САРМАТИИ)

В пределах Северо-Западного района Украинского щита распространено большое количество даек и расслоенных интрузивов никеленосных толеитовых долеритов и габброидов. Эти дайки и интрузивы рассматривали либо как подводящие каналы для ныне полностью эродированных базальтов (траппов), сформированных в обстановке растяжения, либо как синколлизионные породные комплексы, возникшие в результате кристаллизации мантийных расплавов во время коллизии Фенноскандинавского и Волго-Сарматского сегментов Восточно-Европейской платформы. Проведенное недавно датирование этих пород указывает на их возраст в интервале 1780—1790 млн лет. Для Прутовского расслоенного долеритового интрузива, который содержит единственное известное на Украинском щите Ni-Cu(-PGE) сульфидное месторождение, получен возраст по бадделеиту. Это новое значение возраста (1779,2 ± 6,9 млн лет) в пределах ошибки измерения соответствует возрасту циркона (1777,0 ± ± 4,7 млн лет), полученному ранее для того же образца (Shumlyanskyy et al., 2012), и отличается от возраста циркона 1990 ± 5 млн лет (Скобелев и др., 1991). Сделан вывод, что последнее определение ошибочно. Новое значение возраста по бадделеиту окончательно подтверждает, что данный интрузив относится к Прутовско-Новогольской магматической провинции, и подчеркивает потенциал расслоенных габброидных массивов этой провинции в отношении Ni-Cu(-PGE) сульфидного оруденения. Нами также проанализирован изотопный состав серы в сульфидных минералах Прутовского месторождения. Образцы были отобраны из придонных рудных залежей. Изотопный состав серы (величина $\delta^{34}S$) варьирует от +0,8 до +3,6 ‰, что соответствует ранее установленному диапазону вариаций, и указывает на мантийный источник серы. Изотопный состав серы и U-Pb возраст указывают на формирование Прутовско-Новогольской магматической провинции в условиях растяжения, которые установились вскоре после формирования Восточно-Европейской платформы (Балтики).

Ключевые слова: бадделеит, U-Pb возраст, изотопный состав серы, Прутовский массив, Украинский щит.