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A U-Pb BADDELEYITE AGE OF THE DAVYDKY GABBRO-SYENITE MASSIF OF THE KOROSTEN PLUTONIC COMPLEX

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An age is provided for the Davydky massif, one of the intrusive bodies within the Korosten AMCG complex in the Ukrainian shield. The unexpected 1790 ± 1 Ma U-Pb baddeleyite age obtained for the Davydky massif (concentrically zoned gabbro to syenite) provides additional support for the simultaneous emplacement of the early phase of the Korosten AMCG complex and regional Ni-enriched tholeiitic magmas. The petrologic relationships of these two simultaneously emplaced magma types are discussed.

Key words: Davydky massif, Korosten complex, Ukrainian shield, Palaeoproterozoic, U-Pb age.

Introduction. The Ukrainian shield hosts two large anorthosite-mangerite-charnockite granite (AMCG) plutonic complexes – Korosten (KPC) and Korsun-Novomyrgorod (KNPC). The Korosten plutonic complex is located in the north-western region of the Ukrainian shield while the Korsun-Novomyrgorod complex – is in the central part, in the Kirovograd region. Basement of both regions is Paleoproterozoic in age and formed during a 2.1–2.05 Ga orogenic event that resulted in the formation of thick metavolcanic and metaterrigenous sequences and numerous granitic intrusions. Both regions can be considered as parts of a single active continental margin (or its Paleoproterozoic equivalent) that rimmed the Archaean Dniester (Podolian)-Bug craton. The northwestern margin of Sarmatia was also affected by an important crust-forming process that took place at 2.0–1.95 Ga and resulted in formation of the Osnitsk-Mikashevychi igneous belt.

The KPC is one of the largest and most typical examples of an AMCG complex in the world. It occupies an area of about 12 000 km^2 and appears as a multiphase anorogenic intrusive complex formed in the Paleoproterozoic. About 75 % of the Korosten complex is composed of rapakivi granite while the rest belongs to various basic rock types. The KPC is predominantly bimodal and composed of a variety of granitic rocks generally regarded as rapakivi and rapakivi-like granites, and a family of basic rocks that includes predominant anorthosite and leucogabbro and subordinate gabbroic rocks. Other rock types include syenites, monzonitic syenites, etc. and are minor in abundance.

The basic rocks occur predominantly as sheet-like bodies varying in thickness from a few kilometers to a few hundreds of meters. On the basis of detailed field investigations it was shown that basic rocks of the large gabbro-anorthosite massif were intruded in several pulses (represented by sub-phases). Each of such subphases corresponds to specific rock assemblages ter-

med "rock series" [5]. Five rock series were distinguished: early anorthositic (A_1), main anorthositic (A_2), early gabbroic (G_3), late gabbroic (G_4) and dyke (D_5).

The oldest rocks of the KPC are represented by bronzite anorthosite, norite-anorthosite and leuconorite of the early anorthositic rock series (A_1). These rocks occur as xenoliths in anorthosite, gabbro-anorthosite and gabbroic rocks of the later intrusive phases, as well as in various granitoids and dykes of basic and intermediate composition. The most abundant basic rocks of the KPC belong to the main anorthositic series (A_2). This embraces leucocratic rock varieties from anorthosite to leucogabbronorite that compose the main volume of the gabbro-anorthosite massifs. These rocks contain xenoliths of the A_1 rocks but in turn are cut by later gabbroic intrusions and granites. The early gabbroic rock series (G_3) is rather minor and is represented by gabbro-norite and leucogabbronorite that occur in the southern part of the Volodarsk-Volynsky massif. In the Slipchitsy quarry these rocks contain xenoliths of A_2 anorthosites and are cut by rocks of the late gabbroic series (G_4). The late gabbroic series (G_4) embraces various gabbroic rocks from leucogabbro to ultramafic rocks that form dykes, stocks and sheet-like bodies which cut mainly A_2 series rocks. Geological data indicate a pre-granitic age of the G4 massifs. Intrusions of the G_4 are known from all large gabbro-anorthosite massifs of the KPC. The youngest manifestations of mafic magmatism within the KPC belong to the dolerite dykes (D_5) that cut through granitic rocks [5]. However, recent geochronological data indicate that the dykes formed at multiple times during the entire interval of KPC formation (as discussed below). We have dated gabbro from the Davydky gabbro-syenite massif, using the U-Pb technique on baddeleyite, in order to shed further light on the geochronological evolution.

Previous U-Pb geochronologal data for the KPC. Rocks of the A_1 (early anorthositic) series were dated by [1, 9] using the U-Pb method on zircon and baddeleyite. For the sample 1/90 (coarse-grained anorthosite taken on the right bank of the river Uzh nearby Pugachivka village) the following U-Pb ages were obtained: 1800 ± 1.3 Ma by zircon and 1794 ± 6.7 Ma by baddeleyite. Old anorthosite xenoliths among labradorite-type anorthosite of the main anorthositic series sampled in the Ignatpil quarry yielded a concordant U-Pb zircon age of 1789 ± 2 Ma. Finally, sample 1/89 represents a xenolith of the old anorthosite found among A_2 anorthosite at the Granitne quarry. Sub-concordant zircon results for this sample yielded an age of 1784 ± 2.7 Ma. Huge anorthosite bodies of the main anorthosite series (A_2) are typical for the KPC, and were dated at two spots within the Volodarsk-Volynsky massif. Sample 7/90 belongs to the labradorite-type anorthosite that outcrops in the Golovino quarry. Concordant zircon age for this rock is 1758.1 ± 1.0 Ma while the baddeleyite age for the same sample is 1760.6 ± 0.7 Ma. Zircons separated from the Turchynka anorthosite (sample 15/90) yielded a concordant age of 1758 ± 1.8 Ma. The G4 rock series that embraces numerous gabbroic massifs is represented by a single dated sample (10/90) taken at the Buky quarry. A concordant zircon age for this sample is 1758.8 ± 0.9 Ma [1, 9].

Basic dykes within the KPC were dated by [1, 8, 9]. According to their results a plagioclase-porphyritic dolerite dyke that crops out nearby the Pugachivka village (sample 23/90) yielded a U-Pb concordant age of 1760.7 ± 1.7 Ma. Zircons from dolerites of the Bilokorovychi dyke swarm yielded an upper intercept age of 1799 ± 10 Ma. Finally, SIMS analyses of zircon separated from the Bondary dolerite sill cutting a rapakivi-like granite yielded a concordant age of 1751 ± 12 Ma.

In spite of predominance of granitic rocks at the surface of the KPC only two of them were dated by means of U-Pb method. Zircons separated from the rapakivi granite that crops out at the Kyivshlyakhobud quarry nearby the city of Malyn (sample 23/84) were repeatedly dated by [1, 6, 9]. The age obtained by combining of all of the analytical results quoted in the mentioned papers is 1764.6 ± 5.1 Ma. The second sample belongs to the Lezniki massif that is regarded as one of the latest expressions of magmatic activity in the KPC. The age obtained for the Lezniki biotite granite is 1752 ± 16 Ma.

Davydky massif. The Davydky massif was described by [4]. It is located in the extreme north-eastern corner of the Korosten AMCG complex (Figs. 1, 2) and occurs as a rounded body that occupies an area of ~30 km^2. The massif is concentrically-zoned and composed of doleritic gabbro, gabbro, andesine-type anorthosite and syenite. Syenite occupies the central part of the massif and dominates at the current erosional level. The thin (150–300 m) marginal part of the intrusion is composed of doleritic gabbro and gabbro (Fig. 2). Fine-grained (chilled) gabbro can be found directly against contact with host granite.

The thickness of the syenite in the central part of the massif exceeds 360 m. Andesine-type anorthosite occurs between syenite and marginal gabbro; the thickness varies between 30 and 300 m. In addition thin layers of andesine-type anorthosite can be found occasionally among marginal gabbro. Rather thin layers of ilmenite or apatite-enriched gabbro occur in the marginal gabbro.

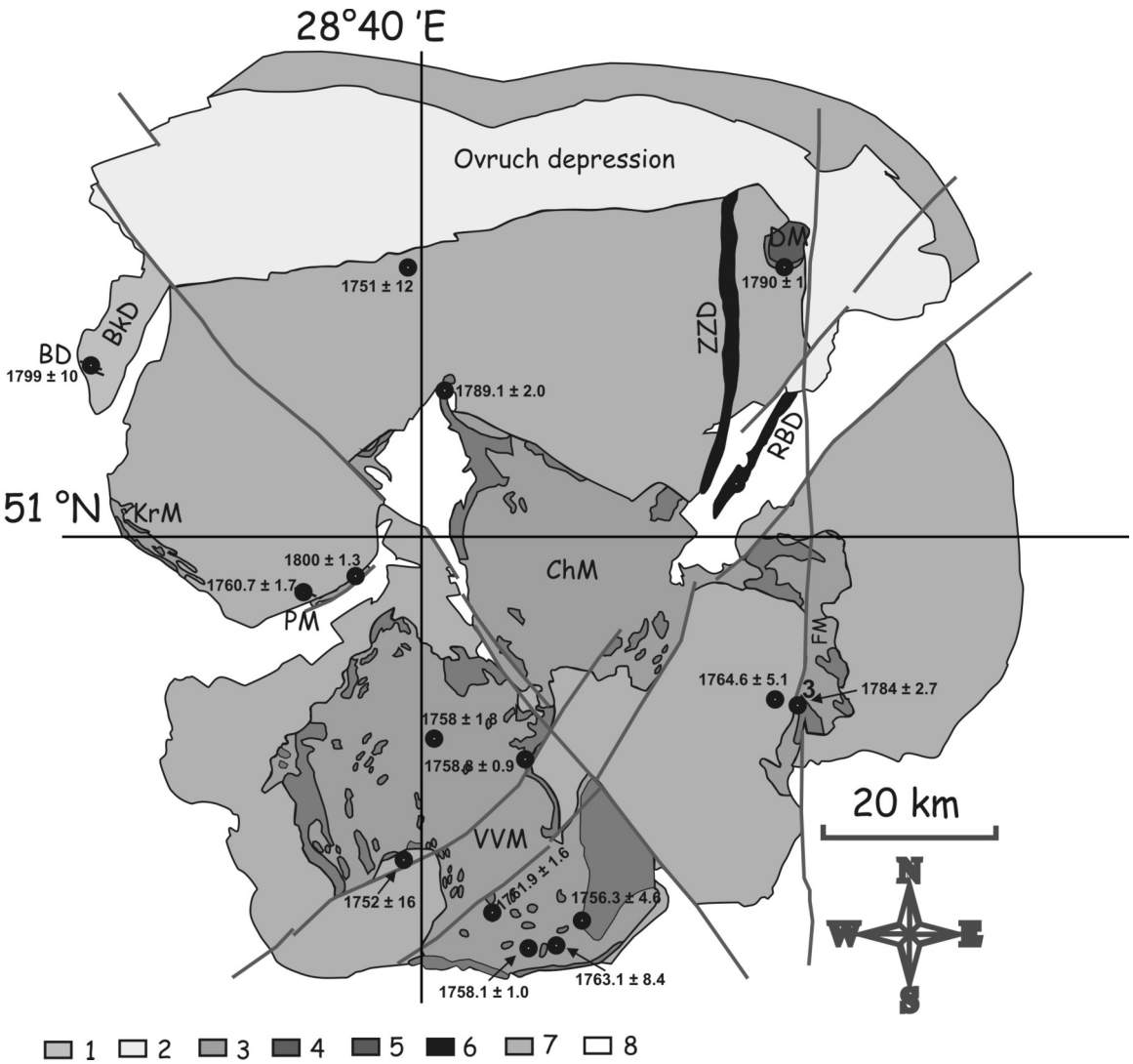

Fig. 1. Geological map of the Korosten plutonic complex with ages of the dated rocks indicated. The Davydky massif is located in the north-eastern corner of KPC and marked with as DM. *Legend:* 1 – Sedimentary rocks of the Bilokorovychi depression; 2 – Metavolcanites and sedimentary rocks of the Ovruch depression; 3 – Anorthosites and related rocks (VVM – Volodarsk-Volynsky, ChM – Chopovychi, FM – Fedorivka, KrM – Kryvotin massif, and PM - Pugachivka massifs); 4 – Gabbro, melagabbro; 5 – Gabbro-syenites and syenites (DM – Davydky massif); 6 – Dolerites, trachydolerites (ZZD - Zvizdal-Zalissya dyke, RBD – Rudnya-Bazarska dyke, BD – Bilokorovychi dyke); 7 – Rapakivi granites and related rocks; 8 – Host rocks

The Davydky massif is rather unique for the Korosten plutonic complex since it displays a clear fractionation trend from gabbro to syenite that is absent from the other gabbroic massifs within the complex. This peculiarity of the Davydky massif has led to the suggestion that it may be much younger and not related to the KPC. On the other hand, gabbroic rocks of the Davydky massif are, from a geochemical and petrological point of view, very similar to those that belong to G4 massifs of the KPC.

U-Pb geochronology. A sample from the Davydky massif was obtained from drill hole (Fig. 2). It was initially processed at the Institute of Geochemistry, Mineralogy and Ore Formation, Kiev, 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 grains of dark brown baddeleyite of optically good quality were selected for U-Pb dating (Fig. 3). Two fractions of 2–3 grains in each and one single-grain fraction were analysed on a Finnigan Triton thermal ionisation multicollector mass spectrometer at the Museum of Natural History in Stockholm (Table 1, Fig. 4). The data indicate an age of 1790 ± 1 Ma (Table, Fig. 4).

Discussion. Connection to the Korosten gabbroic intrusions. It had been considered possible that the Davydky massif belongs to the suite of ca. 1760 Ma

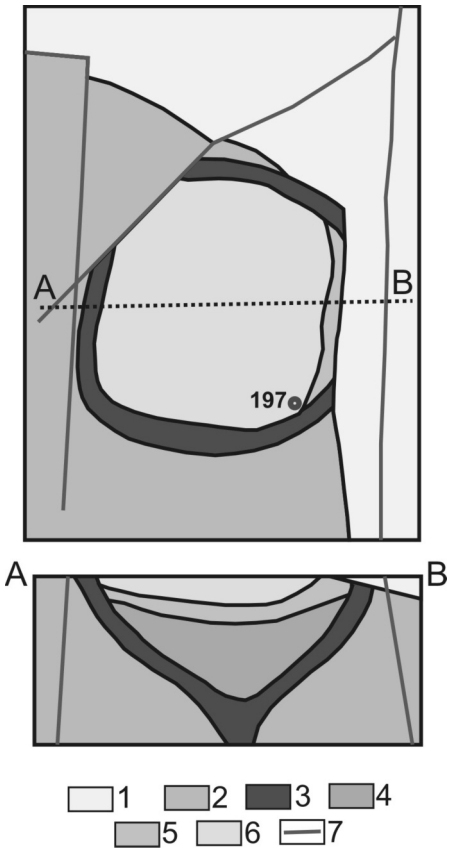

Fig. 2. Map and section across the Davydky massif (after Kryvdik and Tkachuk, 1990): 1 – volcanic and sedimentary rocks of the Ovruch and Vilcha depressions, ca. 1770–1760 Ma; 2 – host granite of the Korosten complex; 3 – marginal dolerite and gabbro-dolerite; 4 – mafic and ultramafic rocks of the layered series; 5 – andesine-type anorthosites of the layered series; 6 – syenite of the layered series; 7 – main faults. Position of the drill hole 197 indicated

Fig. 3. Baddeleyite crystals separated from the sample 289/197. Largest grain is ca. 1 mm long

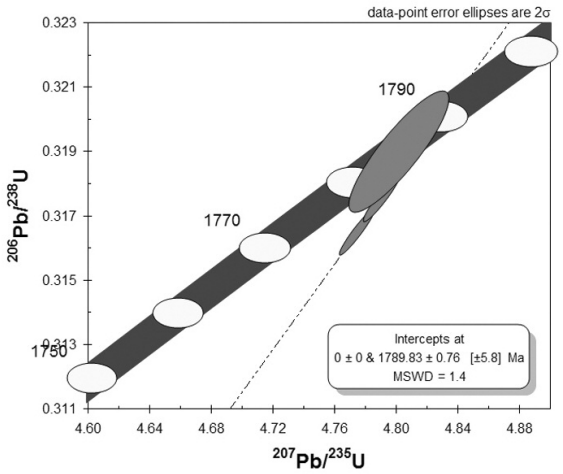

Fig. 4. U-Pb concordia diagram

high-Ti, ilmenite-bearing gabbro that are widely distributed across the KPC. These belong to the G_4 rock series [5] and occur either as weakly differentiated gabbro massifs at marginal parts of huge anorthosite bodies (Volodarsk-Volynsky and Chopovychi), or as rather small, strongly differentiated layered intrusions in the internal parts of the anorthosite bodies. These layered intrusions often contain rich ilmenite-apatite mineralization. One of such intrusions, the Fedorivka massif, has been described in detail by Duchesne et al. [3].

However, in contrast to the Davydky massif, G_4 intrusions cut through anorthosite of the main anorthosite series (A_2). So, from the cross-cutting relationships it is evident that there is a difference in the time of emplacement of the Davydky massif and gabbroic massifs of the G_4 series. This is confirmed by U-Pb dating of G_4 units. Anorthosites of the Volodarsk-Volynsky massif were dated at 1758–1761 Ma [1]. G_4 gabbro of the Buky massif were dated by zircon at 1758.8 ± 0.9 Ma [1], of the Fedorivka massif – at

Results of the U-Pb dating of the Davydky massif gabbro

Fraction	Sample weight (μg)	Concentrations, ppm			Isotope ratios								Age, Ma		
		U	Pb tot	Pb com	$^{207}Pb/^{206}Pb$	± s (%)	$^{207}Pb/^{235}U$	± s (%)	$^{206}Pb/^{238}U$	±s (%)	Rho	Conc.	$^{207}Pb/^{206}Pb$	$^{207}Pb/^{235}U$	$^{206}Pb/^{238}U$
1	42192	476.4	146.8	42125	0.10943	0.06	4.77477	0.19	0.31646	0.18	0.95	0.99	1789.9	1780.5	1772.4
2	42036	1144.3	361.7	42134	0.10943	0.06	4.79038	0.20	0.31750	0.19	0.95	0.99	1789.9	1783.2	1777.5
3	42186	802.2	313.8	7.0	0.10918	0.27	4.80174	0.56	0.31897	0.48	0.87	1.00	1785.8	1785.2	1784.7

1761.9 ± 1.6 Ma, of the Pivnichna Slobidka massif – at 1763.1 ± 8.4 Ma, and of the Torchyn massif – at 1756.3 ± 4.6 Ma (Shumlyanskyy et al., in prep).

Another important difference between the Davydky massif and the G_4 series is absence of syenite differentiates in G_4 massifs. Kryvdik and Tkachuk [4] explained this by the shallower level of erosion in case of the Davydky massif. However, Duchesne et al. [3] argued that upper part of the Fedorivka massif has been preserved at least in part. So, the Davydky massif is the only gabbroic body that contains a syenite differentiate, the only one intruded as early as 1790 Ma, and the only one that intruded granite.

In spite of such differences, 1790 Ma gabbro of the Davydky massif is otherwise indistinguishable of ca. 1760 Ma G_4 gabbro and Korosten dolerite dykes in terms of their geochemistry and Sr-Nd isotope composition.

Relation to the 1790–1780 Ma Ni-bearing rocks. Our new U-Pb baddeleyite data indicate that Davydky massif is coeval with numerous ca. 1790 Ma Ni-enriched dykes and layered intrusions widely distributed within the north-western region of the Ukrainian shield [7]. The coincidence in time of formation naturally leads to the assumption that both rock suites (high-Ni dolerite and high-Ti gabbroic rocks of the Korosten complex) may be related in terms of their origin. Geochemical and isotope data indicate that high-Ni and high-Ti rock suites are quite different. High-Ti gabbro and dolerites are much less magnesian compared to high-Ni rocks, strongly enriched with respect to incompatible trace elements and depleted with compatible ones. The Nd composition of the high-Ti rocks is somewhat more evolved, indicating the presence of an older crustal component in their source.

However, preliminary results of geochemical modelling indicate that both rock suites may be related to each other by a combination of fractional crystallization and crustal contamination. In this model depleted mantle derived mafic melts fractionate by removal of a high-temperature mineral assemblage that includes essentially chromite, olivine and clinopyroxene; early separation of Ni- and PGE-bearing sulphides also may occur. As a result of such process residual melts become depleted in compatible trace elements and less magnesian; in contrast, concentration of incompatible trace elements gradually increases. Variations in Nd isotope composition indicate an increasing role of the crustal material in the late differentiates. The thermal effects of the emplacement of the hot mantle melts and decompression caused by crustal extension led to the partial melting of the lower crustal material. So while ca. 1790 Ma high-Ni rocks originated from moderately depleted mantle, the role of the crustal component gradually increases in course of melt evolution to the point that the latest (1760 Ma) G_4 (AMCG) rocks are probably derived entirely from melting of lower crust.

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Шумлянский Л., Ернст Р., Білстрьом К.

Вік баделеїту з Давидківського габро-сієнітового масиву коростенського комплексу.

Наведено U-Pb вік по баделеїту (1790 ± 1 млн років), отриманий для габро Давидківського масиву, що входить до складу Коростенського анортозит-рапаківігранітного плутону. Давидківський масив розташовується в крайній північно-східній частині Коростенського плутону, де частково перекритий відкладами Вільчанської западини. Масив має округлу форму і займає площу біля 30 км^2. Він складений габро-долеритами, габро, андезиновими анортозитами, та сієнітами. Давидківський масив відрізняється від інших габроїдних масивів коростенського комплексу тим, що проявляє чітку еволюцію складу від габро до сієніту. Подібна диференційованість не спостерігалася в жодному іншому масиві комплексу. Так само, Давидківський масив відрізняється за часом кристалізації від всіх інших датованих габроїдних масивів, які вкорінювалися біля 1760 млн років тому. Водночас, за геохімічними особливостями габроїди масиву тотожні породам інших габроїдих масивів Коростенського плутону.

Вік, отриманий для габро Давидківського масиву, близький до віку численних дайок нікеленосних толеїтових долеритів та розшарованих габроїдних масивів прутівського комплексу, широко розповсюджених у Північно-Західному районі Українського щита. Такий збіг у часі формування масивів дозволяє припустити, що обидві породні серії (високонікелеві толеїтові долерити прутівського комплексу та високотитанові габроїди Коростенського плутону) можуть мати певну генетичну спорідненість. Водночас, геохімічні та ізотопні дані щодо високонікелевих та високотитанових порід помітно різні. Високотитанові породи значно менш магнезіальні, помітно збагачені на некогерентні мікроелементи, та збіднілі на когерентні. Ізотопний склад неодиму високотитанових порід відображає присутність давнішого корового матеріалу в їхньому джерелі. Результати попереднього геохімічного моделювання свідчать, що породи обох серій можуть бути пов'язані комбінацією фракційної кристалізації та корової контамінації. Термальний ефект, спричинений вкоріненням гарячих мантійних толеїтових розплавів, та декомпресією, внаслідок розтягнення кори, призводив до часткового плавлення нижньокорового матеріалу. Таким чином, високонікелеві толеїти походять з помірно деплетованого мантійного джерела, тоді як роль нижньокорової речовини значно зростає в розплавах, з яких кристалізувалися породи Коростенського плутону.

Ключові слова: Давидківський масив, коростенський комплекс, Український щит, палеопротерозой, U-Pb вік.

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Возраст бадделеита из Давидковского габбро-сиенитового массива коростенского комплекса.

Установлен U-Pb возраст по бадделеиту (1790 ± 1 млн лет), полученный для габбро Давидковского массива, входящего в состав Коростенского анортозит-рапакивигранитного плутона. Давидковский массив располагается в крайней северо-восточной части Коростенского плутона, где частично перекрыт отложениями Вильчанской впадины. Массив имеет округлую форму, и занимает площадь около 30 км^2. Он сложен габбро-долеритами, габбро, андезиновыми анортозитами и сиенитами. Давидковский массив отличается от других габброидных массивов коростенского комплекса тем, что проявляет четкую эволюцию состава от габбро до сиенита. Подобная дифференцированность не наблюдалась ни в одном другом массиве комплекса. Кроме того, Давидковский массив отличается по времени кристаллизации от всех остальных датированных габброидных массивов, которые внедрялись около 1760 млн лет тому назад. В то же время, по геохимическим особенностям габброиды массива идентичны породам других габброидных массивов Коростенского плутона.

Возраст, полученный для габбро Давидковского массива, близок к возрасту многочисленных даек никеленосных толеитовых долеритов и расслоенных габброидных массивов прутовского комплекса, широко распространенных в Северо-Западном районе Украинского щита. Такое совпадение во времени формирования массивов позволяет допустить, что обе породные серии (высоконикелевые толеитовые долериты прутовского комплекса и высокотитановые габброиды Коростенского плутону) могут иметь некоторое генетическое родство. В то же время, геохимические и изотопные данные в отношении высоконикелевых и высокотитановых пород заметно различны. Высокотитановые породы значительно менее магнезиальны, заметно обогащены некогерентными микроэлементами и обеднены когерентными. Изотопный состав неодима высокотитановых пород отображает присутствие более древнего корового материала в их источнике. Результаты предварительного геохимического моделирования свидетельствуют о том, что породы обеих серий могут быть связаны комбинацией фракционной кристаллизации и коровой контаминации. Термальный эффект как результат внедрения горячих мантийных толеитовых расплавов и декомпрессией, вызванной растяжением коры, приводил к частичному плавлению нижнекорового материала. Таким образом, высоконикелевые долериты – это производные умеренно деплетированного мантийного источника, тогда как роль нижнекорового вещества значительно возрастает в расплавах, из которых кристаллизовались породы Коростенского плутона.

Ключевые слова: Давидковский массив, коростенский комплекс, Украинский щит, палеопротерозой, U-Pb возраст.

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