GRANITOIDS, RARE-METAL PEGMATITES AND TA-NB MINERALIZATION OF SHPOLIANO-TASHLYK ORE AREA (INGUL MEGABLOCK, UKRAINIAN SHIELD)

Introduction. Shpoliano-Tashlyk ore area became known after intensive exploration and prospecting works carried out by local geological enterprises, SE "Kirovgeology" and "Centergeology" during 1980-90th. As a result of these works two ore-bearing fields, Polohivka and Stankuvatka, with general specialisation on rare metals (Li, Rb, Cs, Be, Ta, Nb, Sn) are discovered and outlined within the western area of Ingul megablock of Ukrainian Shield (Fig. 1) (Ivanov et al., 2000).

Polohivka ore field is found to be confined to the western flank of Korsun-Novomirgorod pluton that is comprised by anorthosite - rapakivi granite associations. Several swarms of pegmatites with associated rare-metal mineralisation are found here, within the marginal area of Polohivka ore field. This field includes Polohivka deposit of lithium that is situated at the immediate proximity of the Korsun-Novomirgorod pluton and Petroosrivske ore site. The Petroosrivske site itself is situated to the northwest of the Novoodeske rare-metal manifestations and lithium deposits (greisens) which are commonly formed at the exocontact areas of granite massifs. Nb-Ta mineralization commonly shows superimposed nature and rarely might be found at the margin areas of early formed lithium-rich pegmatites.

Stankuvatka ore field includes Lipnazhka and Novoodeske rare-metal manifestations and lithium deposits of Stankuvatka, Nadezhda. They are spatially localized within the west and northwest exocontacts of Lipnazhka granite massif (Fig. 1). Stankuvatka lithium deposit does not show high concentration of Nb and Ta, with average values reaching 0,015 % for Ta2O5 and 0,015 % for Nb2O5. The most rich sites of Ta-Nb mineralization are confined to veins of metasomatically altered pegmatitic granites and albite-microcline metasomatites. Ore mineralization is characterised by dessiminated nature when most tantalo-niobite occurrences are found as accessory minerals in metasomatically altered (greisenised) pegmatites spatially confined to the exocontact zones of Lipnazhka granite massif. Majority of ore bodies and manifestations are characterized by distinct internal ore zonality. Petalite and petalite-spodumene associations are found to be confined to the central parts of ore bodies as well as tantalite-niobite occurrences as confined to zones of thinning of pegmatitic veins. In general, high concentration of tantalum-niobate mineralization are found in thinning zones of lithium pegmatites and superimposed...
metasomatites that are spacially (and genetically) associated with them.

**General geological setting.** The Shpoliano-Tashlyk ore area is situated in the northwest of Ingul megablock where it occupies the northern part of so-called Bratsky synclinorium. The synclinorium itself might be traced as uniform regional-scale structure (belt) that strikes in submeridional direction along western margin of intrusive-magmatic system comprised by differently aged structures – Korsun-Novomyrgorod anortosite-rapakivi-granite pluton and Novoukrainka diorite-monzonite massif. From the southwest, synclinorium is bordered by exposed structures of granulitic basement – Golovanivka zone (block). The overall submeridional symmetry of the Bratsky synclinorium is additionally marked by a number of granite massifs of ultrametamorphic origin that are elongated in the same direction and S-N strike of linear folding of relic metamorphic rocks. Structurally, the synclinorium is interpreted as regional-scale epicratonic (as well as epi-Archean) depression that hosts rock association of Proterozoic age. Geological section generally includes two separate stratigraphic units that show distribution of regional scale. The first unit includes rocks of Kamenno-Kostuvatka suite which are widely distributed within the southern area of the Bratsky synclinorium. This suite includes pyroxene gneisses, crystalloclasts, garnet-biotite, garnet-cordierite-biotite, graphite-biotite gneisses, calciphrys and skarns. Rocks of the second unit are mostly abundant in the northern area of the Bratsky synclinorium and are presented by biotite, graphite-biotite, amphibole-biotite, graphite-garnet-amphibole gneisses that are rhythmically intercalated with layers of amphibolites, quartzites and ultramafic rocks. All this rock associations are combined into the single Roschahivka suite. Metamorphic rocks of both suites are intensively changed by ultrametamorphic alterations. They are deeply silicified and thinly-layered with formation of migmatites. Coarse-grained biotite granites of pegmatitic nature are abundant here and mapped mostly everywhere. Rhythmic interlayerring of metamorphic rocks is additionally marked by layers of metaultramafic rocks which are commonly found within ore-bearing zones.

![Fig. 1. Location scheme of ore fields, deposits and manifestations of Shpoliano-Tashlyk ore area](image-url)

Rare-metal pegmatites and metasomatites are commonly found to be confined to the exocontacts of granite massifs which are widely abundant within Shpoliano-Tashlyk ore area – Novopavliva, Mykhyalivka, Berezivka, Lipniazhka, Doropeivka, Yaroshivka massifs.

All these granites are formed at processes of ultrametamorphic alterations of rocks of Kamenno-
Kostuvatka and Roschahivka suites and are related to Kirovograd complex, which is treated as typical for the whole area of Ingul megablock. At the same time, granitoids of the western area of Ingul megablock show some features that distinguish them from possible analogues distributed in the eastern and central areas of the megablock. This fact has caused some early proposals to distinguish granitoids of Bratsky synclinorium into the separate Voznesensky complex (Scherbakov, 2005).

It is necessary to note, that among numerous schemes granite classification, the most suitable as to metallogenic forecast is still remained the scheme proposed by Chappell and White (Chappell et al., 2001). According to this scheme, granites are classified into two different I- and S- types that are formed as a result of ultrametamorphic alterations (anatexis) of mostly igneous (I) or sedimentary (S) protoliths. This scheme broadly corresponds to local scheme proposed earlier by Shcherbakov (Scherbakov, 2005) according to which granites of Ukrainian Shield were classified into apobasic (I) and apopelitic (S) types. Sedimentary type granites that are formed after primary-sedimentary rocks can inherit high contents of fluxing components (B, P, F etc.). These components can essentially lower the temperature of crystallization and make S-type granites especially favorable for formation of pegmatite-generating melts enriched in rare lithophile elements (Li, Cs, Ta, Nb and others).

Apopelitic type granites are widely abundant within Shpoliano-Tashlyk area. Here, they are characterized by common presence of biotite, garnet or cordierite as rock-forming minerals as well as ilmenite and uraninite as typical accessory minerals. Some varieties of these granites are predominantly peraluminous (Al₂O₃ > Na₂O + K₂O + CaO), enriched in potassium over sodium and characterized by high silica content (64–77 % SiO₂). These granites as well as associated pegmatites and metasomaties are potentially ore-bearing.

Nature of Ta-Nb mineralization. Deposits and numerous ore manifestations of rare metals of Shpoliano-Tashlyk ore area are formed in rather similar geologic-and-tectonic settings and consequently show common geologic features. These features are manifested in both mineralogy of country rocks and ore mineral associations that comprise most occurrences of Ta-Nb mineralization. Main concentrators of Ta and Nb are represented by minerals of three isomorphic series – columbite-tantalite (Fe,Mn)(Nb,Ta,Ti)₂O₆, ilmenorutile-struverite (Ti,Nb,Ta)O₂ and pyrochlore-microlite (Ca,Na)₂Ta₂O₆(O,B,O,F) (Nechaev et al., 1992; Grinchenko et al., 2008).

Minerals of columbite-tantalite series are mostly abundant in Shpoliano-Tashlyk ore area. From 60 to 80 % of niobium and tantalum are concentrated in minerals of this series. Ore minerals of columbite-tantalite series only sometimes show less abundance in comparison to minerals of ilmenorutile-struverite series. In many cases it depends on composition of host rocks and degree of their alterations by superimposed metasomatic processes.

The most of Ta-Nb minerals of the series occur as impregnated idiomorphic aggregates or form intergrowths with other minerals (cassiterite, ilmenorutile, microlite, and uraninite). Electronic microscope investigations indicate steady presence of inner zonation and mosaic structure of columbite-tantalites. Typical feature is variable chemical composition which is observed both at macroscale (ore body) and microscale (single grain) levels. Several mineral phases with wide range of Ta₂O₅ (9,80 to 71,0 %) and Nb₂O₅ (10,6 to 70,1 %) can be established within the single ore mineral grain. Microprobe data indicate predominance of ferruginous varieties (FeO/MnO = 2,80–6,56 in average) of columbite-tantalites (Fig. 2).

Fig. 2. Mn/(Mn+Fe) and Ta/(Ta+Nb) ratios in minerals of columbite-tantalite series of Shpoliano-Tashlyk ore area

Minerals of columbite-tantalite series are also characterised by high contents of admixture elements present (%): Ti (TiO₂ up to 5,88), W (WO₃ up to 3,70), Sn (SnO₂ up to 9,20) and even Sc (Sc₂O₃ up to 5,40).

Titanium is a characteristic admixture-element in minerals of this series. Occurrence of titanium in the structure of tantalo-niobates is caused by close affinity of their crystallochemical properties. Contents of titanium varies from 0,5 to 2 % in average, with the highest contents (5,88 %) being established for columbite-tantalites of Stankuvatka deposit.

Tin is also found as present in composition of minerals of this series and rarely its content can reach 9,40 %. At the same time, most columbite-tantalites are characterised by rather low contents of tin (0,3–1 %). Abnormal high contents of tin are found in ixiolite (disordered phase of tantalo-niobates) that is sampled from muscovitized two-feldspar pegmatite of Yaroshivka ore manifestation.

Tungsten is found as present in all mineral varieties of columbite-tantalite series. The contents of tungsten found in tantalites show considerably the average values (up to 3,30 %). At the same time columbite with low tantalum show essentially low contents of tungsten (0,1–1 %).

Scandium is found in minerals of tantalite-columbite series of Shpoliano-Tashlyk ore area for the first time. Ore minerals of Polohivka manifestation are mostly scandium-bearing with scandium content reaching high (up to
economic) ore grade values. Sc is established in practically all varieties of tantalo-niobates with scandium content ranging from 0,1 to 1%.

Other admixtures in minerals of columbite-tantalite group are represented by magnesium, calcium, rare earth elements and uranium, with their contents that do not exceed 1%.

Minerals of ilmenorutile-struvite series are mainly occurred in the zones of metasomatic alterations of pegmatitic granites and rare-metal pegmatites. On the distribution they take the second place after columbite-tantalites, and sometimes occur as the main mineral-concentrators of Nb and Ta mineralisation.

For most ore objects the occurrence and nature of ilmenorutile-struvite mineral series are mostly similar to that of columbite-tantalites. Crystallochemically minerals of this series are interpreted as Fe(Nb,Ta)2O6 solid solutions, formed in TiO2 matrix. Natural intergrowths between these two mineralogical varieties are commonly observed.

For the first time, high concentrations of Ti-Nb-Ta mineralization were established in natural outcrops situated at the flank of Lipnizhka ore manifestation, and have been traced in similar pegmatites at the sections of deep boreholes. Aggregates of subgraphic intergrowths of these minerals are constantly found as desseminated impregnations in dark grey quartz among cataclised formations of muskovite-spodumene-petaltite pegmatites. The ilmenorutile is the main mineral-concentrator of Nb and Ta in biotite-apatite-cordierite apogabroic metasomatites. Here it forms impregnated grains of subidiomorphic habit and occur in association with ilmenite, pyrohitite, pentlandite, niccolite and gersdorftite. This type of Ta-Nb mineralization is characterised by predominance of ilmenorutile over struvite. According to the microprobe analysis minerals of this series show Nb2O5/Ta2O5 values ranging from 0,6 to 1,4. Among admixture elements found are (%): Sn (SnO2 up to 3,1), V (V2O5 up to 5,05), Fe (up to 11,51) and Cr (Cr2O3 up to 1,20).

Minerals of pyrochlore-microlite series are mostly represented by microlite which occur in association with tantalo-niobates and cassiterite. In most cases, microlite is formed as a result of superimposed alteration of tantalo-niobates and talantal-rich cassiterites. Mineralogically segregation are represented by veinlet and net-like patterns. Under ore microscope microlites are found as light-brown spongy-like pseudomorphs (0,1 to 0,3 mm in diameter) formed after tantalite minerals.

Microlite is characterised by complex and heterogenic structure. It commonly includes such element as calcium, tician, tin, aluminium and uranium in its composition. Ta2O5/Nb2O5 ratio varies within the range of 2,5 to 6,9. Microlites collected from spodumene-almellite pegmatites of Stankuvatka deposit show essentially high values of tungsten and tin.

Besides typical Ta-Nb minerals described above, rare metal pegmatites include other ore-mineral phases that contain Ta and Nb. They are represented by such varieties as tapiolite FeTa2O6, ixiolite (Nb,Ta,Sn,Fe,Mn, Ti)O6 and some other non-precisely identified mineralogical phases of tantalo-niobates. Among other minerals found as closely associated with different series of Ta and Nb minerals are cassiterite, nigerite, gahnite, uraninite, chrysoberyl, stannite, sphaerelite and chalcopyrite.

Age of ore mineralization of rare-metal pegmatites of Shpoliano-Tashyk ore are under discussion during the long period of time. Difficulties in determination of the age of rare-metal mineralisation are caused mainly by absence in their composition of so-called minerals-geochronometers (zircon or monazite) and multistage nature of rock formation and ore mineralisation occurrences.

Some researchers followed the idea, that age of formation of rare-metal pegmatites of Polohivka ore field should be coeval to the age of of Korsun-Novomirgorod pluton intrusion (Bezvinn, 2005). The age of rapakivi granites of this pluton is dated to 1750 million years (Esypchuk et al., 2004). At the same time, some metallogenetic interpretations treat hypothetical dating of 2,3 billion years, obtained early by Pb-Pb method (Eremenko et al., 1996), as possible age of rare-metal pegmatites. Age dating at 2,0 billion years obtained for granitoids of Kirovograd complex (Shcherbak et al., 1995) is interpreted as the age of regional scale ultrametamorphic alterations of primary gneisses. It was assumed that pegmatites formed early to 2,3 billion years might be intensively altered by the subsequent ultrametamorphic processes. (Ivanov et al., 2001).

For the first time, based on the results of direct determination of U-Pb ratios in columbite-tantalites collected from Mostove ore manifestation, the age of Ta-Nb mineralization is established to be about 1965 ± 25 million years. At the same time, based on microprobe investigations and calculations according to CHIME method (Suzuki et al., 2008) the age of uraninite associated with tantalo-niobate minerals is estimated to be about 1925 million years.

Conclusions. Granites, genetically associated pegmatites and superimposed metasomatites are widely distributed within Shpoliano-Tashyk ore area in the western part of Ingl megablock, Ukrainian Shield. Their Petrochemical and geochemical features of these rocks can indicate their potential ore-bearingness as to rare-metal mineralization.

Numerous deposits and ore manifestations of Ta-Nb mineralizations of ore area were formed in similar geologic-and-tectonic setting and have many the common features - as in chemical composition of host rocks and associations of ore minerals. Mineralogical composition of Ta-Nb mineralization is defined by isomorphic series of minerals represented by columbite-tantalite and ilmenorutile-struvite series. Moreover ore parageneses sometimes includes other Ta-Nb minerals such as microlite, tapiolite, ixiolite and non-identified phase of tantalo-niobates. According to microprobe analyses minerals of columbite-tantalite group contain Ta and Nb in approximately equal amounts. Typical admixture-elements in minerals of this given group are represented by (%): TiO2 – to 5,88; WO3 – to 3,70; SnO2 – to 9,20; Sc2O3 – 5,40. High contents of scandium in tantalum-niobates are established in Ukrainian Shield for the first time.

Manifestations of Ta-Nb mineralization of Shpoliano-Tashyk ore area are unique high-grade ore objects specialised on tantalum on the Ukrainian Shield. Therefore, their studying has high economic importance as to the prospects of development of raw-material base of tantalum and other rare elements (Rb, Cs, Nb, Sn, Li, W, Sc).

Potential prospections of these objects are also substantiated by their geological and mineralogical-and-geochemical features that are widely similar to those established as typical classical (world-known) deposits of rare-metal pegmatites of LCT (Li-Cs-Ta) type, such as Greenbushes (Australia), Tanco (Canada). (Cerny, 1989; Cerny et al., 2005).

For the majority of rare-metal granitic pegmatites of this type their spatial and genetic relations with granites of "sediment-type" origin (S-type) are established. They are formed as a result of anatectic alteration of primary-sedimentary strata. Inherited high contents of such fluxing elements as B, P, Li and F can cause these rock associations to be favorable on formation of rare-metal pegmatites. One more characteristic feature of LCT pegmatites is the fact, that host rocks around these pegmatites are commonly metasomatised. The dissemination of alkaline elements in
метасоматические аурелий вокруг этих пегматитов могут быть использованы как важный критерий для их возможной проекции на карте.

Литохронологические анализы, проведенные на рудничных образцах, показали возраст не менее 1,9-2,0 млрд лет. Эти данные подтверждают гипотезу о сильной метасоматической активности данной области в течение длительного времени.

Список литературы

1. Ivanov et al., 2001. Some ore sites show so high abundance of metasomatisms that some researchers even treat metasomatic alterations as the key factor of formation of rare-metal mineralization. Bezzinny, 2005. At the same time the results of age determination for Ta-Nb mineralization of Shpoliano-Tashlyk ore area obtained on the basis of zircon and xenotime dating, may indicate that these dating might be broadly correlated with the age of formation of ultrametamorphic granitoids of Kirovgrad complex.

Слова для пошуку: Гранітоїді, Рідкіснометалічні пегматити та Ta-Nb Мінералізація ШПОЛЯНО-ТАШЛИЦЬКОГО РУДНОГО РАЙОНУ (ІНГУЛЬСЬКИЙ МЕГАБЛОК, УКРАЇНСЬКИЙ ЩИТ)
За допомогою мікрозондового аналізу було досліджено хімічний склад тантало-ніобатів з рудноносних пегматитів і метасоматитів. Мінерали групи колумбіт-танталіту показують внутрішню дрібнозернисту і контрастну мозаїчність, яка позбавлена зі значними неоднорідностями хімічного складу. У межах одного мінерального ареалу встановлюються фази із широким діапазоном значень — від 9,80 до 71,0 % для Ta₂O₅ та від 10,6 до 70,1 % для Nb₂O₅. Серед мінералів переважають залізисті різновиди, які за складом відповідають Fe-колумбіт-танталітам (Nb₂O₅/Ta₂O₅ = 1–1,2; FeO/MnO = 2,5–6). Колумбіт-танталіти характеризуються високим вмістом елементів-домініючих (%): TiO₂ до 5,88; WO₃ до 3,70; SnO₂ до 9,20; Sc₂O₃ до 5,40. Сканідноніобієві виявилися переважно мінерали групи колумбіт-танталіту Положівського рудного поля. Високі концентрації Sc₂O₃ у тантало-ніобати фіксуються на Українському щиті вперше.

Мінерали групи ільменорутило-тапиолиту кількісно не поступаються мінералами групи колумбіт-танталіту. Для мінералів даної групи значення відношення Nb₂O₅/Ta₂O₅ змінюються в діапазоні 0,6–1,4. Серед характерних елементів-домініючих переважають (%): SnO₂ до 3,1; V₂O₅ до 5,05; FeO до 11,51; Cr₂O₃ до 1,20. Мінерали групи пірохлор-мікроліту мають підпорядковане значення.

Уперше за результати U-Pb датування колумбіт-танталітів з рудопрояву Мостове (Шполяно-Ташлыцький район) був визначений вік формування Ta-Nb мінералізації, який становить 1965 ± 25 млн років.

Ключові слова: рідкіснOMETаллічнIe пегматити, Ta-Nb мінералізація, Український щит.

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ГРАНІТОІДИ, РЕДКОMETАЛЛІЧНІ ПЕГМАТИТИ І ТА-NB МІНЕРАЛІЗАЦІЯ ШПОЛЯНО-ТАШЛЫЦЬКОГО РУДНОГО РАЙОНА (ИНГУЛЬСЬКИЙ МЕГАБЛОК, УКРАЇНСЬКИЙ ЩИТ)

Рассмотрен вещественный состав гранитов, родственных им пегматитов и метасоматов, распространенных в пределах Шполяно-Ташлыцкого рудного района (Ингульский мегаблок, Украинский щит). Установлено, что гранітоїди района на основе сходства их петро графических и петролого-геохимических особенностей могут быть отнесены к одному комплексу. Особенности проявления рудной минерализации определяются как составом гранитов (S-граниты), по которым формируются редкометаллические пегматиты, так и интенсивностью проявления наложенных метасоматических преобразований.

Главные минерал-концентраторы Ta и Nb в минерализации в гранитных pegматитах и метасоматах представлены минералами трех групп: два рудных — группы колумбіт-танталіту (Fe,Mn)(Nb,Ta,Ti)₂O₆, ільменорутило-тапиолит (Ti,Nb,Ta)O₂, и пірохлор-мікроліту (Ca,Na)(Ti,Ta, Nb)₂O₆,B₂O₅H₂O. В зависимости от геологической обстановки в ассоциации с этими минералами часто отмечаются также рудные ми нералы, как тапиолит, итсюолит, касситерит, ураніт, нишерит, гант.

С помощью микрозондового анализа исследован химический состав тантало-ніобатов из рудноносных пегматитов и метасоматов. Мінерали группы колумбіт-танталіту показывают внутреннюю ритмическую жильность и контрастную мозаичность, которая связана со значительными неоднородностями химического состава. В пределах одного минерального ареала устанавливаются фазы с широким діапазоном значений — от 9,80 до 71,0 % для Ta₂O₅ и от 10,6 до 70,1 % для Nb₂O₅. Середи мінералів преобладають железисті різновиди, які за складом відповідають Fe-колумбіт-танталітам (Nb₂O₅/Ta₂O₅ = 1–1,2; FeO/MnO = 2,5–6). Колумбіт-танталіти характеризуються високим вмістом елементів-домініючих (%): TiO₂ до 5,88; WO₃ до 3,70; SnO₂ до 9,20; Sc₂O₃ до 5,40. Сканідноніобієві охоплюють в основному мінерали групи колумбіт-танталіту Положівського рудного поля. Високі концентрації Sc₂O₃ в тантало-ніобати фіксуються на Українському щиті вперше.

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Ключові слова: редкометаллические пегматиты, Ta-Nb минерализация, Украинский щит.