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Features of the Geological Structure and Assessment of the Prospects of the Delbegetey Tin Ore Node (Western Kalba)

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Abstract. *The main goal of the article is prospecting of the Southern exo-contact of the Delbegetey massif for revealing hidden rare-metal mineralization and gold. The features of the geological structure and ore content of the Delbegetey granitoid massif of the Western Kalba formed during the Hercynian cycle in the post-collisional (orogenic) geodynamic environment of the Permian time are considered. The mineralogical and geochemical characteristics of hydrothermal-metasomatic formations that are genetically related to granites of the delbegetey complex are given. The development of rare minerals such as emerald, aquamarine, and aksinite in mineral complexes is emphasized, while crystals of Topaz, aquamarine, Morion, and tourmaline are search indicators of rare – mineral ore formation in miarol nests of granites. The objects in question were developed by ancient miners, and in modern times, the prospector's artel was developing an Emerald ore phenomenon. The main objective of the study was to identify typomorphic minerals and indicator elements of latent tin mineralization in hydrothermally altered rocks developed in the southern exocontact of the granite massif.*

Keywords: *Western Kalba, Delbegetey massif, granites, greysens, hydrothermalites, rare metals, assessment of prospects, metasomatic formations, ore occurrence, petrochemical.*

Introduction. The Delbegetey ore node is located in the West Kalba metallogenic zone of Eastern Kazakhstan, covers the endo – and exocontact zones of the granite massif of the same name, which is part of the Semipalatinsk-Buran-Burgyn granitoid belt of the north-western direction [1, 2]. It is characterized by the development of greisen and quartz-core tin deposits and ore occurrences (Kyzylzhal, Sherlovoye, Arkat, etc.), as well as the manifestation of tin ores of increased sulfidity (such as mineralized zones) superimposed on the dykes of the Kunush complex (Jubilee October). The objects in question were developed by ancient miners, and in modern times the prospector's artel was developing an Emerald ore phenomenon. A great contribution to the study of these objects was made by V.F. Kashcheev, A.R. Butko, A.G. Alekseev, M.P. Continents and other geologists.

Despite the fairly good knowledge of the area [1,2], there are still issues that have not been fully resolved. The mineral composition of the Jubilee-October ore occurrence has not been sufficiently studied, the main mineral associations have not been established.

The main objective of the study was to identify typomorphic minerals and indicator elements of latent tin mineralization in hydrothermally altered rocks developed in the southern exocontact of the granite massif. The correlations of the group of sulfide elements (Cu, Pb, Zn, As, etc.) and rare metals (Sn, Be, Li, Mo, etc.) were also clarified. The distribution of rare elements in the lakes of the Delbegeteysky district was studied.

Research methodology. Field visits, sampling of ore minerals and host rocks were carried out. Sample preparation and study of the material composition were carried out in the laboratory «VERITAS» named D. Serikbaev EKTU. The chemical composition of ICP-MS and structural and textural characteristics of ore minerals were studied using a FlexSEM II scanning electron microscope with an AzTec One energy dispersion prefix.

The theory of the question. Geological structure of the Delbegetey massif. In tectonic terms, the Delbegetey massif of the central type is confined to the junction of the latitudinal, meridional and northwestern deep faults, the activation of which was accompanied by repeated influx of granite melts and metasomatic transformations of granites and host sedimentary rocks of the superintrusive zone (Figure 1).

In the geological structure, terrigenous deposits of the Aganaktin (C_1S) and Bukon (C_{2-3}) formations are developed, overlain by loose sediments of the Neogene and Quaternary systems. Intrusive formations are represented by dikes of gabbro-diabases of the Argimbai complex (C_{2-3}), small intrusions and dikes of the Kunush complex (C_3) and granitoids of the Delbegetey complex (P_2). Geological evidence of an earlier Upper Carboniferous (pre-granite) age of porphyry dykes of the Kunush complex, which break through the sedimentary thickness of the Bukon formation (C_2), and themselves are cut and metamorphosed by granites of the Delbegetey massif with the imposition of sulfide-cassiterite mineralization on the dykes (Jubilee October), is of fundamental importance. In turn, these dikes and their thin apophyses intersect the gabbro-diabases of the Argimbai complex (C_{2-3}). The Upper carboniferous dating of the Kunush complex is confirmed by radiological studies of previous years and new analysis results [2].

Three intrusive phases with their ore content are distinguished in the structure of the Delbegetey massif: 1) granosienite (mineralization is not manifested); 2) granite (Sn, Be) and 3) leucogranite (Sn). The constructed geological and genetic model reflects the vertical zonality of the manifestation of metasomatic processes and mineralization in the filtering column, the sequential change of ore formations and mineral types of tin ores (Figure 2).

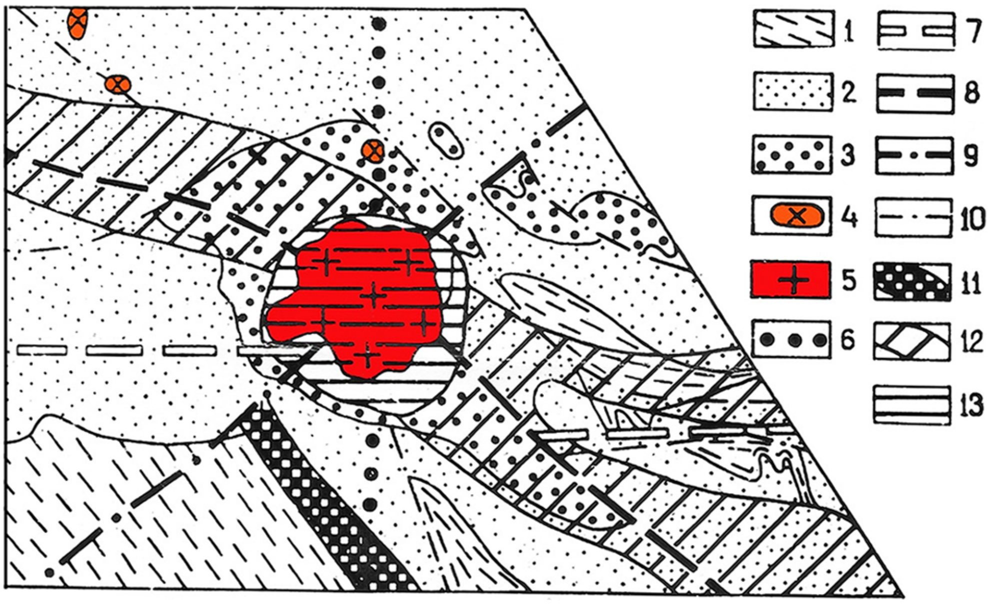
The granosienite phase by the nature of alkalinity belongs to the sub-alkaline group of rocks and is compared in material composition with the Buran complex, geochemically specialized for Ti, Zr [3].

The ore-containing medium-grained coarse-grained biotite miarol granites of phase II, consisting of potassium feldspar (36.1%), acid plagioclase (31.5%), xenomorphic quartz (30%), biotite (2.3%) and accessories (0.1%). The average composition corresponds to normal granites of the plumasite series, with a total ferruginous content of f=79.25 and a content of F (0.4%). These granites are characterized by miarol nests containing idiomorphic crystals of morion, rauchtopase, microcline, sherl, topaz and aquamarine, large plates of muscovite (Figure 3). These minerals are typical for miarolic granite pegmatites and are regarded as an indicator of rare-mineral mineralization [4,5,6].

Geochemically, the clarke concentrations of Pb (7.4 times), Sn (2.7 times), Mo, Li, Nb, Yb (2-3 times) were increased in miarol granites, and high fluorine contents – 2.4-5.2% were found in the micas of their miarol nests and tin-bearing greysens.

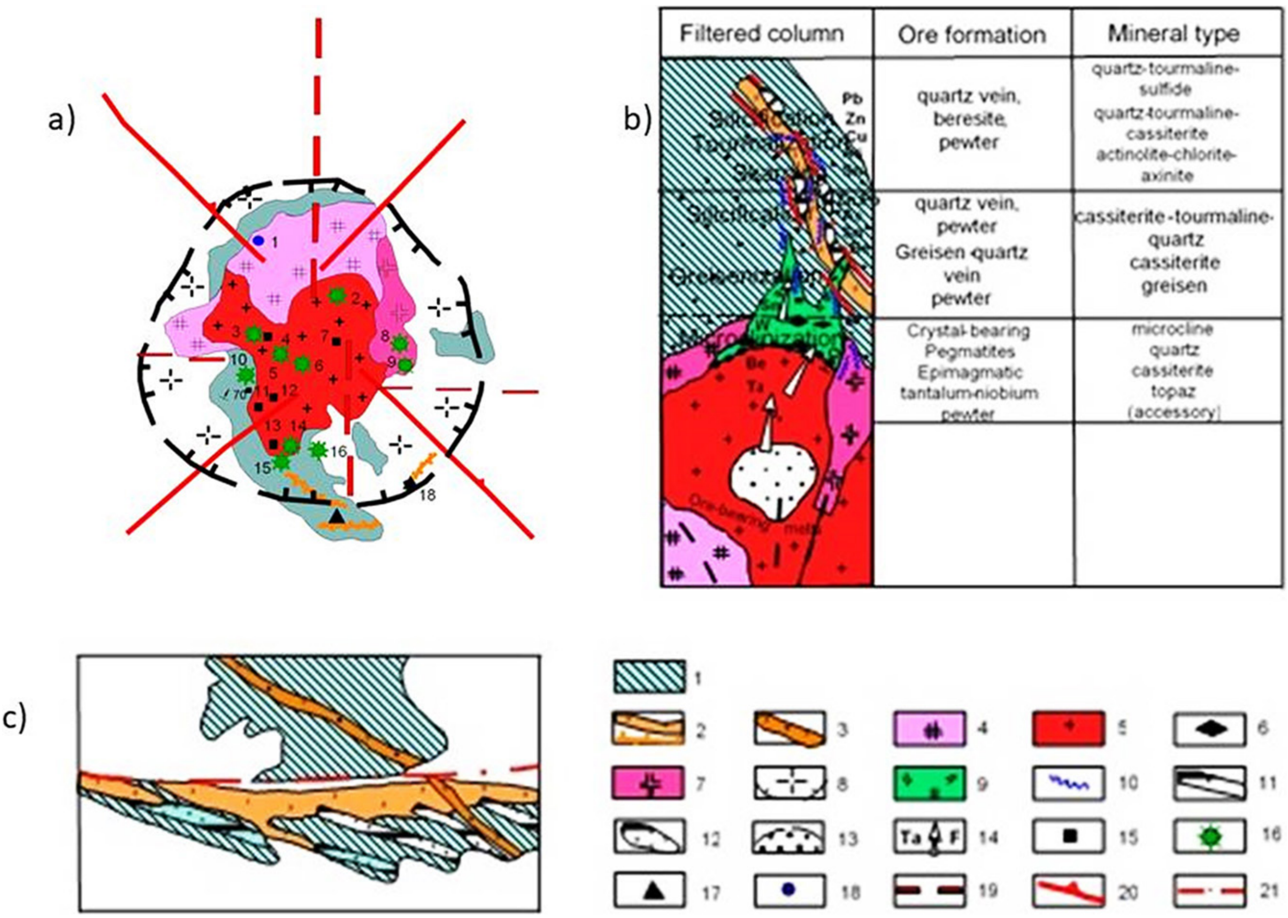
Metasomatic formations: The formation of the granite massif was accompanied by contact-metasomatic transformation of the host rocks, the composition of which had a significant impact on the mineral types of metasomatites and their ore content.

Particular attention is paid to the scarring of calcareous sandstones of the Bukon formation with the



1-5 – geological formations (1 – carbonate-terrigenous, Arkalyk formation, C_1v_{2-3}; 2 – grauvak siltstone-sandstone, Aganakta formation, C_1S; 3 – conglomerate-sandstone molasse, Bukon formation, C_{2-3}; 4 – small intrusions of plagiogranite-granodiorite formation, Kunush complex, C_3; 5 – granite-leucogranite, delbegetey complex, P_2); 6-9 – deep faults (6-7 – orthogonal longitude-latitude, 8-9 – longitudinal-transverse); 10 – small breaks; 11-13 – ore-bearing structures (11 – fragments of the Char chromium-cobalt-nickel-mercury zone, 12 – the West Kalba gold-sulfide zone, 13 – tin ore node).
Geophysical materials of G.P. Nakhtigal were used

Figure 1 – Geological and structural position of the Delbegetey tin ore node



a – geological scheme-plan, b – scheme of the zonal ore column, c – the Jubilee October deposit. 1 – conglomerate-sandstone deposits of the Bukon formation, C_2; 2-3 – Kunush complex, C_3: 2 – granite-porphyry, quartz porphyry, 3 – granodiorite-porphyry; 4-8 – delbegetey complex, P_1, 4 – monzonites, granosienites of phase I, 5 – medium-grained porphyry and 6 – miarol granites of phase II, 7 – leucogranites of phase III, 5 – contour granite massif at depth (according to geophysical data); 9 – greisenization; 10 – tin-bearing quartz veins and veins; 11 – scarring; 12 – zones of sulfide-cassiterite mineralization; 13 – emanation halo of ore-bearing intrusion; 14 – direction of movement of ore-bearing elements; 15-18 – tin manifestations: 15 – greisen quartz-vein, 16 – quartz-vein, 17 – sulfide and 18 – tin-polymetallic; 19 – deep faults according to geological and geophysical data Caledonian and 20 – Hercynian; 21 – small ruptures

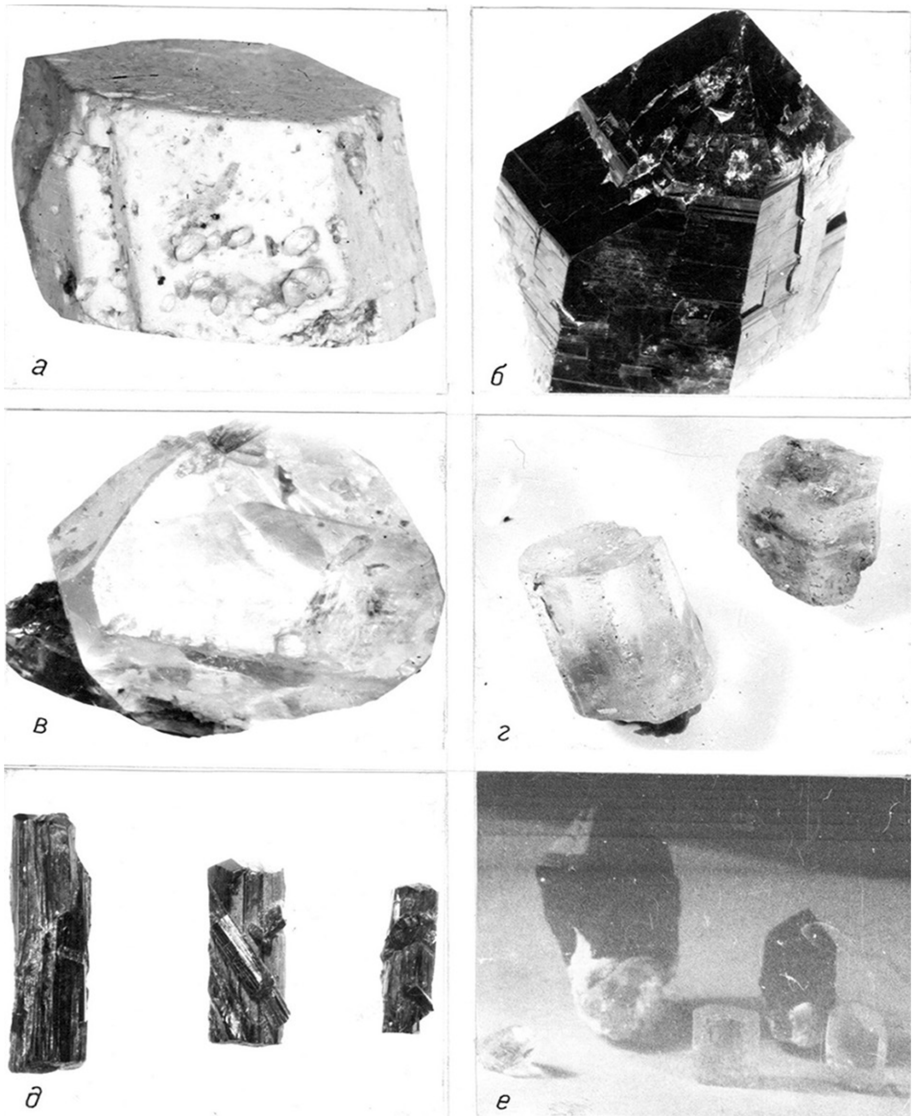
Figure 2 – The model of the formation of the Delbegetean intrusive array

formation of secondary minerals in them – monoclinic pyroxene, chlorite, actinolite, epidote, carbonate and axinite [1, 2]. Axinite is an aluminoborosilicate (formula $Ca_2Fe{+}2Al_2$ $[BSi_4O_{14}](OH)$, refers to rare minerals, usually formed in skarns, hydrothermal and metamorphic formations. At the Delbegetey site, this mineral was found in scanned calcareous sandstones of the Bukon formation in association with actinolite and chlorite. It is represented by well-developed crystals of lilac color.

Strips of amphibolitized sandstones can be traced in length for several kilometers at a power of 1-20 m. They are confined to zones of increased fracturing, brecciation and are associated with contact-hydrothermal effects of hidden granite apophysis. Macroscopically, these are rocks of light gray and greenish-gray color, massive texture and microgranoblastic structure. Petrochemical compared to unchanged sandstones, they have a deficiency of SiO_2 (52-56%), alkalis and the introduction of Ca, Mg, Fe2+. Geochemical specialization is manifested in the introduction of Sn (up to 0.01-0.2%), Zn (up to 0.1%), Li (0.05%), Cu (0.01%). **Discussing the results.** Hydrothermally altered weathered sandstones developed in the area of the Yubileyny – Oktyabr deposit have been studied.

Elevated contents (g/t) have been established: Cu (412), As (313), Sn (2378) with a high positive correlation of Sn $\rightarrow$ As (+0.64), Mo (+0.72). Abnormal concentrations of Sn (4636), As (507) and Cu (805 g/t) are also recorded in quartz-tourmaline, quartz-tourmaline and axinite-chlorite-actinolite metasomatites, manifested respectively in the Southern, Central and Curved zones In these formations, typical of the upper part of the ore-bearing column, a positive correlation of Sn $\rightarrow$ Mo (+0.50), Sn (+0.58) was revealed at supraclark values of Cu, Zn, Ni, Cr. Positive connections Li $\rightarrow$ Zr (+0.79), Mo (+0.73), As (+0.62) are also noted.

For axinite-chlorite-actinolite metasomatites, a



a – short-prismatic microcline crystal with overgrown topaz grains; b – pyramidal-prismatic morion; c – transparent tetrahedral topaz; d – prismatic aquamarine crystals; d – prismatic tourmaline crystals of various nucleations with vertical striping; e – morion and topaz splices. Increased by 1.5 times

Figure 3 – Morphological types of crystals from miarol nests

high correlation of Sn with Zn, As (+0.89), Li (+0.62), Mn (+0.55) was established. Quantitative spectral analysis of ore samples established Sn (from 0.1 and more than 0.3%), Be (from 0.008 and more than 0.3%), Li (0.02-0.1%). Cassiterites contain impurities Cu (0.4%), Zn (0.1%), As (0.15%) and are not tantalum-bearing (Ta_2O_5 < 0.001%), Nb_2O_5 (< 0.003%). They are associated with tourmaline (sherl) containing Sn 0.08-1% (mean 0.179), As (0.06%).

Quartz-tourmaline metasomatites at the Yubileyny Oktyabr deposit are localized mainly in quartz-feldspar porphyry and granite porphyry. Their petrochemical formation was accompanied by the removal of alkalis, to a lesser extent silica. Geochemical are characterized by the introduction of Sn, Bi, As, as well as Cu and Pb. Tin has strong bonds with Li (+0.79) and weak correlation with As (+0.37), Pb (+0.32), Cu (+0.29). Tourmaline contains elevated concentrations of Sn (0.1 – 0.15%), As (0.05 – 0.1%), Zn (0.05%), Cu (0.06%).

The Jubilee October deposit as a whole is emphasized by the halos of Sn, As, Pb, Cu. According to quantitative spectral analyses (18 samples), all ore veins are characterized on average by low contents of Cu (0.05%), Pb (0.03%), Zn (0.015%) and As (0.17%). The average values of Ta_2O_5 and Nb_2O_5 (according to 17 analyses) for metasomatites are also low (0.0017 and 0.0058%).

The considered metasomatic formations were formed in the superintrusive zone of the Delbegetey granite massif by the enclosing sedimentary rocks of the Bukon formation and dykes of the Kunush complex, are characterized by increased tin content and reflect the upper part of the ore-bearing column. The minerals-indicators of tin mineralization in the mineralization zones are quartz, pyrite, arsenopyrite, tourmaline and axinite, which indicates the manifestation of a predominantly sulfide-cassiterite stage of ore formation of the Delbegetey ore node. The genetic relationship of all types of tin mineralization with granites of the Delbegetey complex, based on geological-structural and mineralogical-geochemical criteria, is clearly shown. Examples of some tin ore objects are given.

The Kyzylzhal ore occurrence is located in the southern endocontact of the granite massif, represented by muscovite-quartz greysens with cassiterite, topaz and fluorite. Petrochemically, they differ from the host granites of phase II by the introduction of Si, F and the removal of alkalis. Geochemically, greysens have high concentrations of Sn (0.364%), Li (0.11%) and elevated clark concentrations of Bi, Li, Ge. Tin here has an extremely uneven distribution and does not form a noticeable correlation with the elements of the sulfide group and Li, Nb, Y. A positive relationship is established for Li $\rightarrow$ V (+0.62).Macroscopically, greysens are fine-grained draining, essentially quartz formations with a fine rash of black cassiterite. Later veins of vitreous and druze quartz contain grains of blue fluorite and brown cassiterite (up to 3-4 mm across). Microinclusions of cassithyrite associated with a ferruginous mineral (presumably ferrosilite – $FeSiO_3$) were determined on a scanning electron microscope (Figure 4). The workings of ancient miners have been preserved at the ore manifestation.

Interesting results were obtained by analyzing the distribution of rare elements in beryl varieties of various mineral complexes, differing in color and other characteristics. Beryl from block microcline pegmatites of a greenish-gray flask is characterized by the highest content of Ve and low values of Ta and Ti. Aquamarines of the Delbegetey area are enriched with Ta, Nb, they have more Sn and especially Cr, which explains their color of the color of seawater. Emeralds are even more enriched with Cr (636.4 g/t). For comparison, in the blue beryls of the Koktogai pegmatite field (China), the contents of Ta, Nb, W and lower values of Ve are increased, and white beryls are characterized by concentrations of Cs (15220 g/t) and Li (6782 g/t). As can be seen, the color of beryl crystals can serve as a search indicator in rare metal areas.

The distribution of rare elements in lakes in the area of the studied area was also studied. According to the results of analyses performed in the laboratory of the Vodokanal (Ust-Kamenogorsk), the waters are dominated mainly (mg/dm^3): sulfates (86.1-101.8), bicarbonates (250.1-1256.6) with a low content of nitrates and iron. The waters are characterized by sodium alkalinity and the pre-fertilization of Cl-ions over F-. According to mass spectrometry data (VERITAS laboratory of EKTU), they have an increased content (mkr/l) of As (up to 186.38), Al (up to 692.90), P (up to 174.5-366.0) and B (1204.67) and an enrichment of Li (386.7). These indicators are obviously linked to the mineral composition of the rare-metal objects of the Delbegetey ore node, in which tourmaline, muscovite, actinolite, chlorite, fluorite, axinite and sulfides are common minerals.

Conclusion. The performed studies show that topaz, fluorite, tourmaline and beryl are the indicator minerals for predicting and searching for tin ore graysens in granitoids. Indicators of metasomatic formations with sulfide-cassiterite mineralization developed in the exocontact of the Delbegetey massif include cassiterite, tin-bearing tourmaline, quartz, axinite and actinolite. Elements-indicators of sulfide-tin mineralization – Sn, Bi, As, Ag, Cu. From these positions, a prospective assessment of the Delbegeteysky site recommended for prospecting is determined. The Yubileyny Oktyabr deposit, which combines three types of tin ores, seems to be the most promising: 1) quartz-tourmaline-sulfide (for sandstones and siltstones); 2) actinolite-axinite

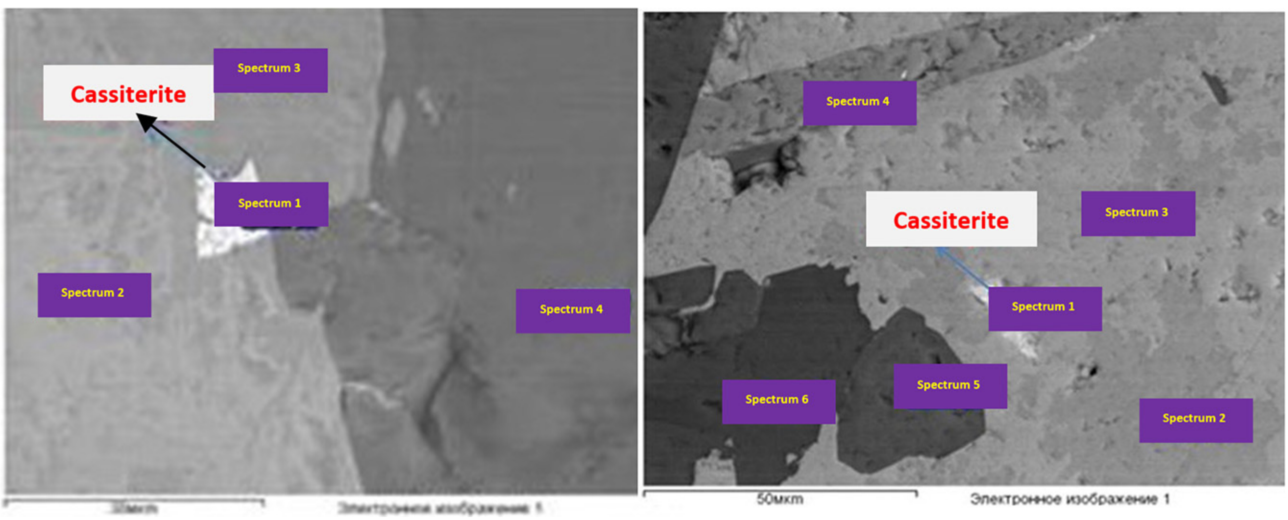


Figure 4 – Cassiterite microinclusions in ferrosilite (?) in association with quartz and ilmenite (Analyst A. Sadibekov)

(for sandstones and conglomerates of increased calcareousness) of the Bukon formation; 3) quartz-tourmaline for porphyry dykes of the Kunush complex (Figure 3).

Tin-bearing mineralized zones are located in the upper part of the ore column. The geophysical data (O.K. Averin et al.) on the shallow contacts of the granite massif (15-450), the presence of granite protrusions in the exocontact zone and the weak study of the object to a depth (up to 40-150 m) are taken into account. In addition, dikes of quartz and quartz-feldspar porphyries are traced on the site, separate outcrops and collapses of granites of the Delbegetey complex with an increased content of Pb, Zn (0.15%) and Sn (0.16%) are recorded. The host sedimentary rocks are subject to hydrothermal-metasomatic changes (brecciation, calcification, tourmalinization, sulfidization and limonitization), geochemical halos of Sn, As, Pb, Cu are noted, the content of Sn is increased in quartz-tourmaline metasomatites (up to 0.1%). According to the type of tool, Jubilee October is compared with the tin ore object «Rusty Sopka» located in the Shchulbinsky ore district [6, 7].

In the area under consideration, zones of circumfined limonitized and quarried sandstones (up to 100 m wide) containing Cu (up to 0.4%), Zn (0.01-0.02%) and Au (0.2-1.8 g/t) in separate quartz ore samples are also distinguished. Mineralization zones are emphasized by secondary halos of Cu (0.006-0.02%), Zn (0.005-0.08%) and Pb (0.002-0.01%). Metallogenically, one of the branches of the gold-quartz-sulfide zones of the Charsky zone is probably traced here. On this basis, the Delbegetey site is of interest for rare metals and gold. The main direction of the search work should be to identify hidden granite apophysis and ridge-like protrusions in the superintrusive zone of the granite massif at a depth of up to 300-500 m, where greisen stockwork and mineralized zones with more significant reserves of tin ores can be found.

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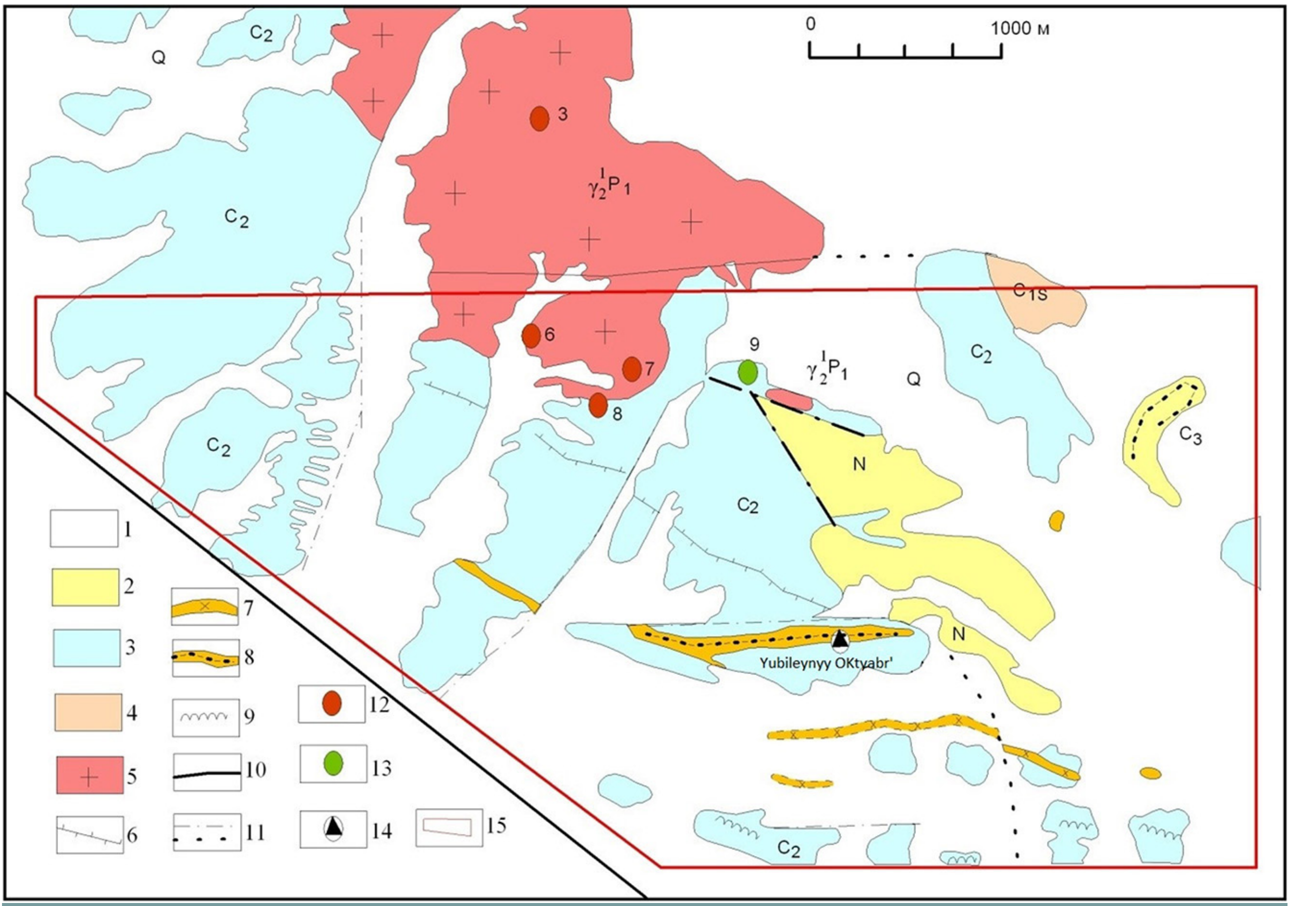

1 – loose quaternary deposits; 2 – red-colored loams, clays; 3 – sandstones, conglomerates, gravelites, calcareous siltstones of the Bukon formation; 4 – sandstones, carbonaceous-clay siltstones of the Aganaktin formation; 5 – medium-grained and weakly porphyritic biotite granites of the II phase of the Delbegate complex; 6 – dikes of granodiorite porphyry; 7 – granite porphyry; 8 – quartz porphyry of the Kunush complex; 9 – gold-bearing quartz veins and veins; 10 – faults of the first order and 11 – secondary on the surface and under the cover of loose sediments; 12-14 – ore occurrences (12 – greisen-quartz-stranded tin; 13 – beryllium and 14 – sulfide-tin-type mineralized zones); 15 – recommended area for prospecting

Figure 5 – Geological structure of the prospective Delbegetey site

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Делбегетей массивінің геологиялық құрылымның ерекшеліктері және сирек металдар мен алтын кендену болашақтылығын бағалау (Батыс Калба)

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Аңдатпа. *Мақаланың мақсаты – Делбегетей массивінің оңтүстік экзоконтактінің жасырын сирек кездесетін кендену мен алтынды анықтау перспективаларын негіздеу. Пермь уақытының коллизиядан кейінгі (орогендік) геодинамикалық жағдайында герцин циклінде қалыптасқан Батыс Калбаның Делбегетиялық гранитоидты массивінің геологиялық құрылымы мен рудасының ерекшеліктері қарастырылады. Делбегетей кешенінің граниттерімен генетикалық байланысты гидротермальды-метасоматикалық түзілімдердің минералды-геохимиялық сипаттамасы келтірілген. Сирек кездесетін минералдардың минералды кешендерінде – изумруд, аквамарин, аксиниттің дамуы, ал граниттердің миарол ұяларында – топаз, аквамарин, морион, турмалин кристалдары, олар сирек кездесетін кен түзудің іздеу индикаторлары болып табылады.*

Кілт сөздер: *Батыс Калба, Делбегетей массиві, граниттер, грейзендер, гидротермалиттер, сирек металдар, перспективаларды бағалау, метасоматикалық түзілімдер, кен көрінісі, петрохимиялық.*

Особенности геологического строения и оценка перспектив Дельбегетейского массива на редкометальное и золотое оруденение (Западная Калба)

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Аннотация. *Цель статьи – дать обоснование перспектив южного экзо-контакта Дельбегетейского массива на выявление скрытного редкометалльного оруденения и золота. Рассматриваются особенности геологического строения и рудоносности Дельбегетейского гранитоидного массива Западной Калбы, сформированного в герцинский цикл в постколлизионной (орогенной) геодинамической обстановке пермского времени. Приводится минералого-геохимическая характеристика гидротермально-метасоматических образований,* *генетически связанных с гранитами дельбегетейского комплекса. Подчеркивается развитие в минеральных комплексах редко встречающихся минералов – изумруда, аквамарина, аксинита, а в миароловых гнездах гранитов – кристаллы топаза, аквамарина, мориона, турмалина, которые являются поисковыми индикаторами редкометалльного рудообразования.*

Ключевые слова: *Западная Калба, Дельбегетейский массив, граниты, грейзены, гидротермалиты, редкие металлы, оценка перспектив, метасоматические образования, рудопроявление, петрохимические.*

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