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REGULARITIES OF GEOTECTONIC DEVELOPMENT AND METALLOGENY OF THE RARE METAL KALBA-NARYM ZONE

СИРЕК МЕТАЛДЫ ҚАЛБА-НАРЫМ АЙМАҒЫНЫҢ ГЕОТЕКТОНИКАЛЫҚ ДАМУ ЗАҢДЫЛЫҚТАРЫ ЖӘНЕ МЕТАЛЛОГЕНИЯСЫ

ЗАКОНОМЕРНОСТИ ГЕОТЕКТОНИЧЕСКОГО РАЗВИТИЯ И МЕТАЛЛОГЕНИЯ РЕДКОМЕТАЛЛЬНОЙ КАЛБА-НАРЫМСКОЙ ЗОНЫ

Abstract. *Identification of new ore objects at deep horizons (up to 300-500 m), assessment of small deposits of pegmatite and ore occurrences for complex tin-tantalum-lithium ores. A promising direction is the practical evaluation of unconventional «extrapegmatite» rare metal ores associated with albitized and grazenized granites.*
Keywords: *Kalba-Narym zone, rare metals, granitoids.*

Аңдатпа. *Терең көкжиектерде (300-500 м дейін) жаңа кен объектілерін анықтау, күрделі қалайы-тантал-литий кендері үшін пегматиттің және кен көріністерінің шағын кен орындарын бағалау. Альбитизацияланған және грейзенделген граниттермен байланысты дәстүрлі емес «экстрапегматитті» сирек металл кендерін практикалық бағалау перспективалы бағыт болып табылады.*
Түйін сөздер: *Қалба-Нарым белдемі, сирек металдар, гранитоидтер.*

Аннотация. *Выявление новых рудных объектов на глубоких горизонтах (до 300-500 м), оценка небольших месторождений пегматита и рудопроявлений для сложных олово-танталово-литиевых руд. Перспективным направлением является практическая оценка нетрадиционных «экстрапегматитовых» редкометаллических руд, связанных с альбитизированными и грейзенизированными гранитами.*
Ключевые слова: *Калба-Нарымская зона, редкие металлы, гранитоиды*

Introduction. The research territory comprises geological structures of Kalba-Narym zone. The history of geological exploration of geology and rare metal metallogeny of Kalba Narym is provided in a range of publications [1-3]. The considered territory began to be studied in 1930-s in connection with opening of some stannum-tungsten deposits in North-West Kalba (Kaiyndy group), that were developed by «Kalbaolovo» enterprises. The first data concerning these objects was provided in the book Bolshoi Altai (1936).

Then in late 1950-s the work on rare metal metallogeny was intensified due to discovering rare metal pegmatite workable deposits (Ta, Nb, Be, Li, Cs, Sn). Main deposits (Bakennoye, Yubileinoye, Belaya Gora) were developed by Belogorsk mining and processing integrated plant till 1994 that are suspended at present.

The period of 1980-s – 1990-s was marked by deliberate geological mapping of Kalba-Narym zone territory. Summarizing of geological surveying materials resulted in development of Kazakh SSR geological map on the scale of 1:500 000 published in 1979 (I.A. Rotarash et.al) [4]. Big amount of accumulated materials on ore-bearance of granitoid magmatism and rare metal metallogeny of Kalba-Narym zone was published in monographs (Dyachkov, 1972, Lopatnikov et.al., 1982, Dyachkov et.al., 1994).

Further, there were exploration works in the region in complex with geophysical and geochemical methods, and scientific researches were carried out by different organizations (Institute of Mineralogy, Geochemistry and Crystal Chemistry of Rare Elements, Kazakh Minerals Research Institute and others). 1998-2003 scientific research work on fundamental problem of Great Altai (geology and metallogeny) was completed under the supervision of academician G.N. Shcherba in Altai department of K.I. Satpaev Institute of geological sciences [5-6]. Main findings became a scientific basis for forecasting-exploration work on the territory of Great Altai and are still relevant at present. The following works were devoted to belt distribution of rare metal objects, mineralization zoning in ore belts and metallogenic zones, metallogenic specialization of different geodynamical settings where these concepts were further developed [7-10].

The scientists of Geology and Minerology Institute of SB RAS (A.G. Vladimirov, S.V. Khromykh, I.Yu. Annikova, M.L. Kuibida, P. D. Kotler, A.V. Travin et.al.) contributed heavily into studying of granitoid magmatism of Kalba-Narym zone. The following new geochronological data is of special importance: the age of Kunush complex plagiogranites, reasoning of I-phase granitoids (Kalba complex and rare metal deposits) formation synchroneity, ore-bearance and age position of ongonite dikes (Mirolyubovsky complex) [11-15].

Nowadays there is an urgent need to strengthen mineral-raw-material base for operating enterprises of rare metal production. As rare metals are of high demand at the world market (especially lithium), minerals developers are interested again in Kalba rare metal objects. However, the fund of easily-discovered deposits at the surface have nearly been depleted, so the most important objective is to identify new ore objects at deep horizons (up to 300-500 m), to assess small pegmatite deposits and ore occurrences for complex stannum-tantalum-lithium ore.

Perspective direction is practical assessment of unconventional «extrapegmatite» rare metal ore (Ta, Nb, Be, Li, Sn etc.) potentials connected with albitized and greisenized granites (Novo-Akhmirovo, Karasu, Malo-Chernovinsky, Apogranitny etc.). They are similar to Alakha deposit (Gorny Altai) in the type of mineralization and is worth studying in detail based on modern scientific-methodological technologies and laboratory researches. It is also relevant to re-assess a particular type of lithium-bearing albite-spodumene pegmatites, associated with minor intrusions and dikes of Kunush complex [16]. There are similar objects in Karagoin-Saryozek ore zone, that are characterized by poor tantalum content and spodumene enrichment (Akhmetkino, Tochka, Aldai, Kenebai etc.). Unconventional type includes also greisen-quartz-veined ore (Sn, W) superimposed on minor intrusions of plagiogranites and dikes of Kunush complex (Cherdoyak deposit, Kara-Ayak, Sersimbai areas and others). All the mentioned objects can be an additional resource of rare metals and should be taken into account in exploration work practice.

Geotectonic position. Main structures of the region in where most of the rare metal objects are concentrated such as granitoid belt (Tigereksko-Chernevsk, GornoAltaisk, Kalba-Narym, Semipalatinsk-Buran-Burgansk, Akbiik-Akzhailaysk and Tleumbet-Degeleskiombe) formed in post-collisional (orogenic) geodynamic setting Perm time different geotectonic position, scale development, internal structure, real-formational composition and ore potential. A regular spatial association of rare metal belts with tectonically weakened WK blocks of increased sialicity is established, and their North-Western linearity and significant length (500-800 km) are emphasized [6,17].

The Kalba-Narym granitoid belt combines many deposits and ore occurrences of pegmatite, albitite-greisen, greisen-quartz-stranded and other types of different formations. Rare metal objects are concentrated in four ore regions (Shulbinsky, North-West Kalbinsky, Central Kalbinsky and Narymsky), two ore zones (Gremyachinsko-Kiinskaya, Karagoin-Saryozekskaya) and 22 ore clusters. The known commercial deposits are Bakennoye, Yubileinoye, Belaya Gora, etc. The main source of rare metals are deposits of rare metal pegmatites (Ta, Nb, Be, Li, Cs, Sn). Greisen and quartz-stranded mineralization is represented by small deposits and ore occurrences of stannum and tungsten, which were the root source of placers of cassiterite, wolframite and scheelite. Based on the analysis of a large amount of factual material from previous years and new research results using modern scientific trends in Geology, high-precision laboratory studies are used to clarify the patterns of formation of rare metal deposits leading types that are important for the practice of prospecting.

Geological and structural criteria. Fault tectonics is considered to be of high importance in position of granitoid massifs, ore fields and deposits. Northwestern deep-seated faults (Kalba-Narym, Terekty and their feathering structures) provided linear position of the Kalba-Narym granitoid pluton and served as the main magma discharges. Main industrial rare-metal pegmatite deposits were formed in the Central Kalba increased tectonic activity block, pushed along the system of North-Eastern faults on the Irtysh zone (with an amplitude of 15 km), characterized by a powerful development of multiphase granitoid magmatism, more intensive metasomatosis processes and the formation of large vein fields.

In the distribution of rare-metal fields and deposits, the regmatic system of latitudinal regional faults and their feathering fractured structures (Kiinsko-Gremyachinsky, Asubulaksky, Belogorsky, Mirolyubovsky, and others) were of controlling significance. Their activation during the intra-Intrusive stage was accompanied by the penetration of ore-bearing fluid flows (H_2O, F, B, Cl, SO4, Ta, Be, Li and others) and the formation of ore bodies [18].

Magmatic control. Main types of rare metal deposits are genetically related to the granites of the Kalbinsk complex (P_1). Leucogranites of the monastic complex (P_2) are accompanied by chamber crystal-bearing pegmatites and tungsten-bearing hydrothermalites, and later dikes of the mirolyubovsky complex do not contain mineralization of practical significance.

According to the formation conditions and material composition, the Kalbinsk complex is divided into two age-related Intrusive phases accompanied by their own vein rocks, metasomatic formations and rare-metal deposits [19, 20]. Main types of rare-metal-pegmatite deposits (Ta, Nb, Be, Li, Cs, Sn) are spatially and genetically related mainly to large-medium-grained porphyry biotite granites of phase I. Petrochemical data shows that these are granitoids of a normal series, sodium-potassium alkalinity, low-plumasite agpaity, and slightly increased basicity. On the TAS diagram of silicic acid-alkalinity, they occupy an intermediate position between granodiorites and granites (figure 1).

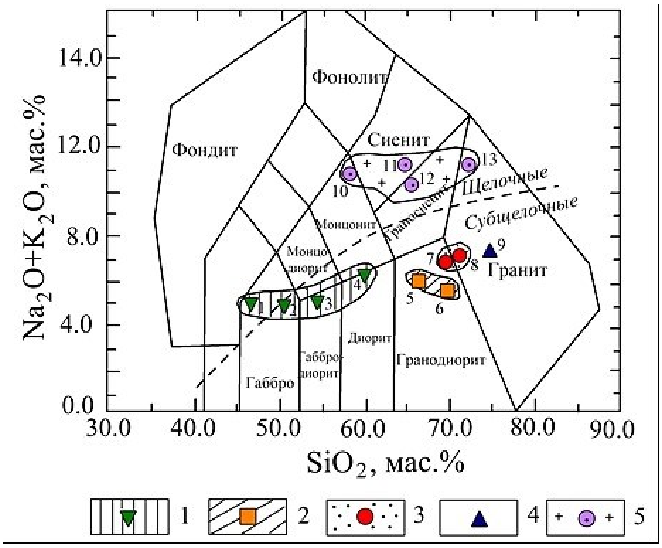

Figure 1. Petrographic diagram of silicic acid-alkalinity of intrusive Flask complexes (Le Bas et al., 1986) with a line dividing rocks into alkaline and subalkaline (Irvine and Baragar, 1971)

Geochemical granitoids of I phase are specialized for Sn (up to 20.55 g/t) and, in comparison with other granitoid complexes, are enriched with sharp alkalis (∑REE=480 g/t) (figure 2).

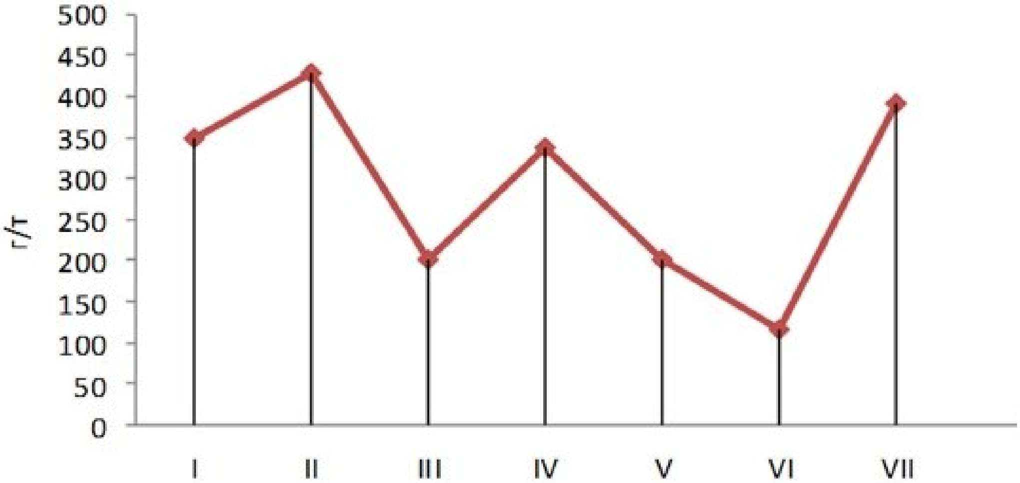

Figure 2. Graph of the distribution of the sum of rare alkalis (Li+Rb+Cs) in the granitoids of the Flask and Zharma-Saur: I-VII – intrusive complexes: I – Kunush granodiorite-plagiogranite, P_1; II-IV – Kalbinsky P_1 (II – porphyritic biotite granites of the first phase, III – biotite and IV – muscovitized granites of the second phase); V – Monastic leucogranite P_2; VI – Keregetas-Espinsky alkaline granite P_2; VII – mirolyubovsky dyke R_2-T_1

Medium-grained biotite and muscovitized granites of II phase of the kalbinsky complex are productive for albite-greisen Sn-Ta-Li mineralization (Novo-Akhmirovskoe, Karasu, etc.) rare-metal pegmatite objects of a simpler quartz-albite-Muscovite type (Quartz, etc.) are also associated with them [20].

During the development of ore-petrological criteria for ore content, great importance was attached to the geodynamic conditions for the formation of Intrusive massifs, the material composition of granitoids, and the scale of ore-bearing gas-liquid melts. From these positions, certain granitic ore-magmatic systems have been identified that they are close in value to ore-forming systems (Beus, Marin 2019, Smirnov 2015). The most favorable conditions for the separation of pegmatite-forming fluid solutions-melts enriched (Ta, Nb, Li, Be, Sn, H2O, F, Cl etc.) were created during the formation of granite massifs under non-equilibrium physical and chemical conditions [21]. According to the results of mass spectrometry has been a tendency to reduce the amount of rare alkalis in the evolutionary series of granitoids (from the granites of I phase kalbi complex to alkaline granites of the month-Uspenskogo complex) and a sharp increase in monitoredby quartz albitophyre mirolyubovka complex [22]. At the same time, there was a noticeable increase in the Rb/Li ratio in the distribution of rare elements in granitoids, the predominance of unchanged Nb/Ta, Ch/Ta, Ch/W ratios and close values of Sn and Ta in the I phase of the kalbinsky complex is emphasized.

Mineral and geochemical criteria. The detailed mineral and geochemical studies using scanning electron microscopy and mass spectrometric analysis of ICP-MS resulted in new data on the material composition of pegmatite ores at the macro and micro levels, the stages of ore process with the formation of many mineral complexes, among which the most productive are spodumene-containing and caesium-bearing pegmatites (Ta, Li, Cs, Sn) [18]. Typomorphic minerals (clevelandite, lepidolite, colored tourmalines, fluoroapatite, spodumene, microlithite, etc.) and geochemical elements-indicators of rare metal pegmatite formation (Ta, Nb, Be, Li, Cs, F, B, P) were determined. Increased lithium-bearance of micas (muscovite, transparent and green gilbertite, lepidolite) was found. For the first time, the types of tantalum-bearing minerals (columbite, tapiolite, tantalite-columbite, mangano-tantalite, ixiolite and microlite), a lithium, manganese and phosphate minerals (sclerit, beuzit, necrophilic, etc.) were identified at the micro level.

Materials and methods of research. Samples of rare-metal pegmatites and country rocks were collected for analyses. The analyses were performed at the VERITAS Laboratory of the D. Serikbaev East Kazakhstan Technical University (Ust'-Kamenogorsk, Kazakhstan). The compositions of rocks and minerals were determined, respectively, by mass spectrometry with inductively coupled plasma (ICP-MS) on an Agilent 7500cx (Agilent Technologies, Santa Clara, CA, USA) spectrometer and by electron probe microanalysis (EPMA), under standard operation conditions, on a Cameca MS-46 analyzer (Cameca, Gennevilliers, France) that allowed detection and precise measurements of seventy three elements (Au, Ag, Pt, Cd, In, Ir, Y, Cd, REE, U, etc.). Scanning electron microscopy and energy dispersive spectrometry (SEM-EDS), with a Jeol-100C microscope with a Kevex-Ray detector and a Jeol ISM-6390 LV microscope (JEOL, Tokyo, Japan) with an Oxford INCA Energy system were applied to study fluid inclusions, as well as micrometer inclusions of metallic and gangue minerals, and to analyze impurity elements (Au, Ag, Sb, As, Pt, In, U, etc.).

Results and discussion.

1. Albitite-greisen (apogranite) type. Novo-Akhmirovo site.

The deposit is represented by the stock of albitized and greisenized granites (P_1) that transect carbonate-terrigenous sediments by Kystav-Kurchum suite (D_2gv) overlapped by Mesozoic and Cenozoic loose sediments cover on the most part. Surovsky massif gabbro-diabase is detected in the north-east, its age is 312 million years according to Ar/Ar isotope mapping [23]. Chechek cupola gneiss-granites are found in south-east among metamorphites of the Irtysh shear zone.

Novo-Akhmirovo stock on the surface is represented by tabular oval-shaped granite bodies that are north-west extended. 220 m long, up tp110 m wide (figure 3). Dikes of aplite granites and aplite-pegmatites containing brownish-black spots of lithium phosphates, iron, manganese are developed in contacts with shale formations. Aplite-pegmatites are characterized by coarse structure and have distinct and permeative boundaries and contain disseminated ore of arrow-shaped feldspar.

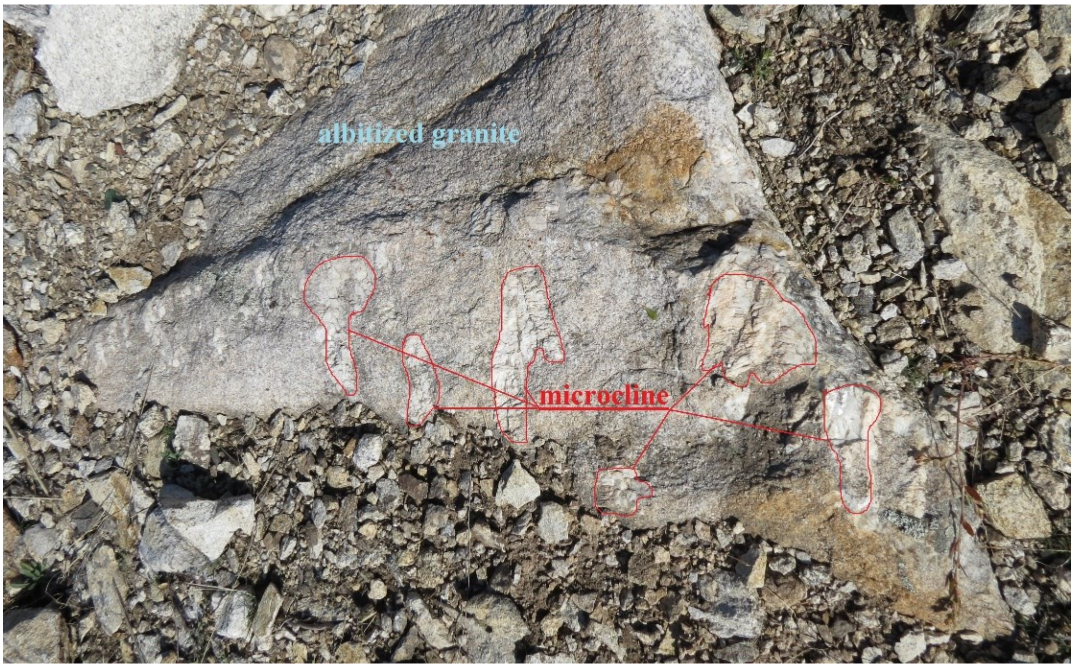

Figure 3. Fragments of the outputs of albitized granites with pegmatoid veins in the Novo-Akhmirovo site

Novo-Akhmirovo stock is an apophyse or an outshot of the big granite massif that is more than 1.5 km deep. According to petrochemical data, topaz-zinnwaldite granites are compared with subalkaline leucogranites (table 1).

According to petrographic data, rock-forming granite minerals are quartz (30-40 %), albite (25-40 %), microcline (15-35 %), zinnwaldite - lepidolite (10 %). Accessory minerals: topaz (до 5 %), lithium muscovite, fluor apatite, cassiterite and ambligonite. Rare disseminated ore is represented by potassic feldspar and quartz.

There are grains of quartz, kalifeldspath, topaz, and muscovite flakes on microphotographs of polished sections (figure 4).

According to microprobe analysis (V.N. Dovgal), lithium mica has high content of Li_2O (2,6-4,44 %), F (3,04-4,39 %), increased values of Ta_2O_5 (up to 0,006 %), Nb_2O_5 (up to 0,025 %) and Sn (0,028-0,043 %). They are distributed in the rock unevenly, and their composition changes from lepidolite to zinnwaldite and polylithionite. Primary topaz is crystal-shaped, 1-2 mm in size, and the secondary one is found in the shape of irregular grains in association with albite and lepidolite.

Mica composition is characterized by high content of K_2O, Li_2O, F and increased values of FeO (up to 6,07 mass. %), that enables to refer them to lepidolites and zinnwaldites (table 2).

Table 1. The content of rock-forming oxides and related elements in granites of the Novo-Akhmirovsky stock and cornea [12]

№ sample	BK-16-60	BK-16-61	BK-16-62	BK-16-63	BK-16-64	BK-16-65	BK-16-72	BK-16-66	BK-16-67/1	BK-16/70	BK-16/71
rock	1	2	3	4	5	6	7	8	9	10	11
SiO_2	71.39	72.02	70.49	70.97	71.54	74.38	72.25	73.79	74.59	69.11	64.94
TiO_2	0.03	0.02	0.03	0.02	0.03	0.04	0.03	0.03	0.04	0.33	0.67
Al_2O_3	15.88	15.43	15.68	15.60	15.52	14.00	15.50	14.95	14.57	15.80	16.60
S	0.81	0.72	0.82	0.55	0.86	1.02	0.91	0.73	1.22	3.56	4.75
MnO	0.16	0.15	0.18	0.16	0.18	0.07	0.09	0.05	0.06	0.15	0.08
MgO	0.03	0.05	0.05	0.05	0.04	0.05	0.04	0.05	0.07	0.73	1.44
CaO	0.26	0.23	0.57	0.50	0.31	0.56	0.34	0.45	0.36	0.57	1.56
Na_2O	5.33	4.96	4.95	4.93	5.20	4.43	4.50	5.03	3.64	2.44	2.69
K_2O	3.64	3.73	3.60	3.39	3.33	3.84	3.89	2.86	2.93	3.93	3.63
P_2O_5	0.13	0.11	0.12	0.11	0.11	0.04	0.12	0.14	0.08	0.08	0.15
F	1.43	1.43	1.17	1.45	1.45	1.05	1.28	0.85	0.56	1.28	0.95
Li	0.22	0.22	0.28	0.26	0.25	0.10	0.13	0.051	0.036	0.092	0.039
Rb	1250	1270	1380	1340	1260	828	973	509	416	633	397
Cs	44	46	52	52	55	42	49	48	20	127	157

1-7 – topaz-zinnvaldite granites; 8 – grazenized granite; 9 – grazen granite; 10-11 – cornea.
The content of oxides, fluorine, lithium (wt. %), Rb, Cs (g/t).

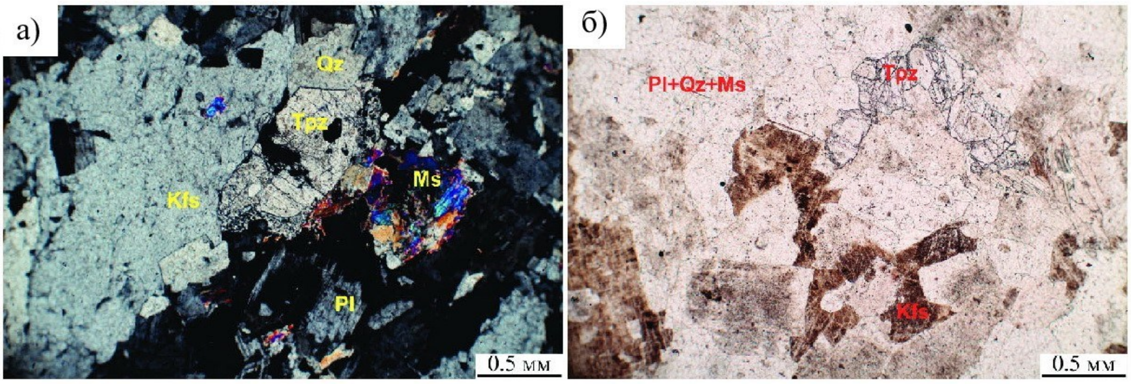

Figure 4. Microphotographs of lithium-fluorine granites polished sections of Novo-Akhmirovo stock (according to I.Yu. Annikova et.al., 2019): a – granites of basic intrusive phase in crossed and б – parallel nicols under the microscope

In comparison, muscovites of rare metal pegmatite Kalba deposits differ from mica of rare metal granites by lower content of (mass. %): F (in average 1.5), Li_2O (0.13-0.20), FeO (0.21-0.44) and increased values of Al_2O_3 (33,93-36,54), Na_2O (0,32-0,70) [18].

Cassiterite forms individual small grains or clots (1-2 mm in size) of zonal colour from brown to black. It confined to albitized areas. Microprobe analysis carried out with microprobe CAMEBAX enable to define Ta_2O_5 content – 0.978 mass.%, but according to quantitative spectrum analysis this content is up to 2.76 , and that makes it similar to cassiterites of pegmatite deposits.

Table 2. The composition of lepidolites and zinnvaldite from lithium-fluoride granites of the Novo-Akhmirovsky stock, wt. % [12]

Component	1	2	3	4	5	6	7	8	9	10
SiO_2	49.88	51.2	49.34	53.80	43.95	52.46	48.66	48.58	49.66	47.36
Al_2O_3	20.01	18.11	18.18	24.24	25.40	17.63	20.04	22.58	19.46	20.46
FeO	5.17	3.96	4.04	1.12	6.07	4.04	6.10	5.23	5.06	5.35
MnO	1.83	1.44	1.44	0.48	2.32	1.29	2.01	1.74	1.88	1.96
MgO	0.03	0.03	0.06	0.01	0.06	0.05	0.05	0.06	0.042	0.04
CaO	0.016	0.004	0.026	-	0.002	-	0.013	0.016	0.02	0.08
Na_2O	0.19	0.14	0.11	0.2	0.3	0.11	0.13	0.22	0.24	0.24
K_2O	8.67	8.67	8.64	8.23	8.26	8.76	9.64	7.43	9.31	8.94
Rb_2O	0.96	1.09	0.85	1.02	0.37	0.91	1.04	0.79	1.15	0.90
Cs_2O	0.028	0.032	0.036	0.018	0.002	0.04	0.06	0.02	0.031	0.029
Li_2O	6.00	6.56	6.59	8.24	4.37	6.65	6.73	4.06	6.14	6.51
F	8.55	9.03	9.05	10.37	7.05	9.10	9.17	6.74	8.67	8.98
Cl	0.016	-	-	-	0.001	-	-	-	-	-
total	98.03	96.77	94.86	100.72	95.43	97.52	100.09	94.87	98.32	97.33
The Li_2O content was calculated based on fluorine concentrations using the formula Li_2O*=0.177xF1.642 [Tieschendorf et.al.]										

Albitized granites of Novo-Akhmirovo site is compared in peculiarities of their material composition with plumasite typical rare metal granites enriched with stannum and tantalum (Tauson, 1970). According to geochemical sampling from the surface, granites are enriched with Li, Rb, Sn, Ta mostly in the central part of intrusive body. There is a tendency of rare elements content increase in holes depending on the depth up to 300 m (mass. %): Li_2O (0.148-0.16 %), Sn (0.044-0.1 %), Ta_2O_5 (0.005-0.094 %). Ore concentration is particularly evident in north-west apophyse and in the central part of truncated prism – shaped granite stock 300 m deep.

Rare earths are distributed differentially and lanthanide elements (La/Yb=13,8-41,8) predominate in hornfels of Kystav-Kurchum suite. Anomalous contents have been identified (g/t): Cu (70.02), Zn (89.01), Ba (392), Zr (310,2), Ti (51100), Sr (173.9), P (1060). The values of rare earth and rare alkalis are increased (figure 5).

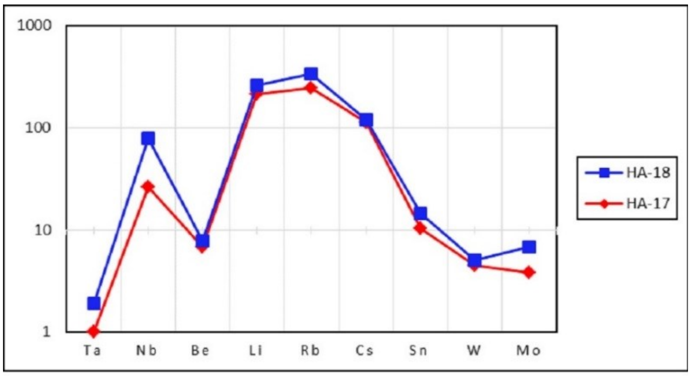

Figure 5. Graph of the distribution of rare metals in the cornea (g/t)

There is anomaly of Rb (656.1) и Li (311.4) in coarse- grained pegmatites, Nb content is 20.77 and Sn content is 24.2. Similar values of these elements are also defined in microclinized granite varieties. Veined granites are also enriched (g/t): Li (753), Rb (773), they have high content of Ta (6.57), Nb (37.16), Sn (14.62). Rare earth content is low, the anomalies (Cu (65.85) and Zn (90.38), and Ga, Zr, Sr maxima are defined. Lanthanide rare earth elements (La/Yb=2.8) predominate in albitized granites. Maxima are defined for Cu (78.38), Zn (129.9), Ba (149.1). Content of alkali elements is nearly the same (g/t): Na-38721, K-37023.

Li-Rb geochemical specialization of altered granites is underlined: (Li up to 2152 g/t) and Rb (1413 g/t) with maximum values of Ta (up to 16,16 g/t), Nb (195.2), Be (13.31), Sn (32). There are Ga (33.65), Zr (136.9) и Sr (105.50) maxima among disseminated elements. In general, the conducted laboratory studies of samples by electron microscopy methods prove rare metal specialization of Novo Akhmirovo albitized granites on Li-Rb and foreign-metal impurities – Ta, Nb, Sn.

Rare earths in chondrite standardized albitized granites are characterized by differentiated pattern of distribution, forming contrast maxima of lanthanide (La, Pr) and heavy elements (Ho,Tm etc.) (figure 6). Most elements on multielement spectrum diagram occupy ten parts of primitive mantle composition, and maxima are defined for Cs, Ba, K, U, Y (figure 7).

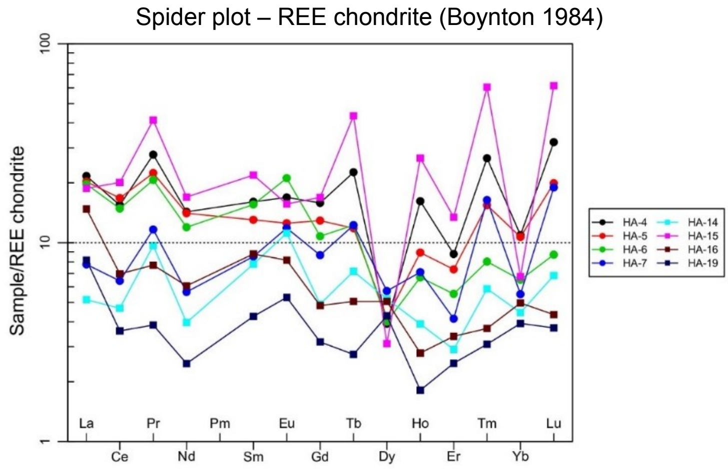

Figure 6. Geochemical diagram of the spectra of rare earth elements normalized by CI chondrite [Boynton, 1984] in albitized granites of the Novo-Akhmirovskoye deposit

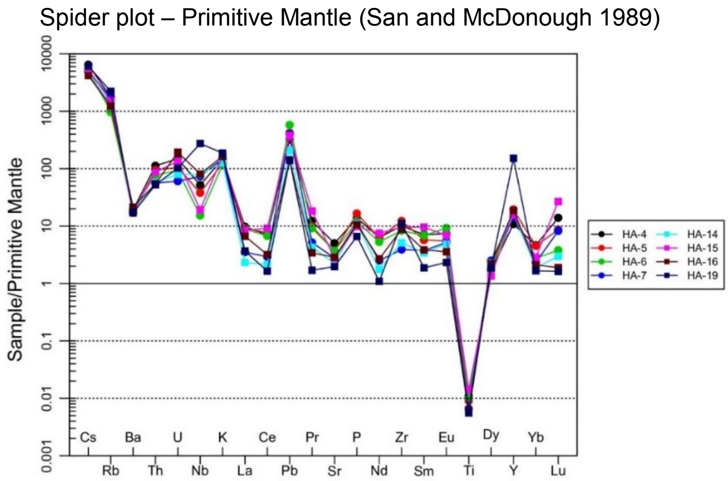

Figure 7. Geochemical diagram of multielement spectra normalized by the composition of the primitive mantle [Sun, McDonough, 1989] in albitized granites of the Novo-Akhmirovskoye deposit

Conclusions. Potentials assessment. According to the data provided by V.I. Maslova etr.al. forecast resources of Novo-Akhmirovo site in P1 category is (thou.t): Li2O – 110, Rb2O – 40, Sn – 13-20, Ta2O5 – 1 thou.t. The considered area is potential for identifying «extrapegmatite» lithium-stannum-tantalum, its type is similar to Alakha deposit in Gorny Altai, but compared favourably with its location in economically developed region of East Kazakhstan with enabling infrastructure.

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