ISSN 2518-170X (Online)
ISSN 2224-5278 (Print)

«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ
АКАДЕМИЯСЫ» РҚБ

«ҚАЗАҚСТАН РЕСПУБЛИКАСЫ
ҰЛТТЫҚ ҒЫЛЫМ АКАДЕМИЯСЫ» РҚБ
«ХАЛЫҚ» ЖҚ

ХАБАРЛАРЫ

ИЗВЕСТИЯ

РОО «НАЦИОНАЛЬНОЙ
АКАДЕМИИ НАУК РЕСПУБЛИКИ
КАЗАХСТАН»
ЧФ «Халық»

NEWS

OF THE ACADEMY OF SCIENCES
OF THE REPUBLIC OF
KAZAKHSTAN
«Halyk» Private Foundation

SERIES

OF GEOLOGY AND TECHNICAL SCIENCES

5 (466)

SEPTEMBER – OCTOBER 2024

THE JOURNAL WAS FOUNDED IN 1940

PUBLISHED 6 TIMES A YEAR

ALMATY, NAS RK

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ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Меншіктеуші: «Қазақстан Республикасының Ұлттық ғылым академиясы» РҚБ (Алматы қ.).

Қазақстан Республикасының Ақпарат және қоғамдық даму министрлігінің Ақпарат комитетінде 29.07.2020 ж. берілген **№ KZ39VPY00025420** мерзімдік басылым тіркеуіне қойылу туралы куәлік.

Тақырыптық бағыты: *геология, мұнай және газды өңдеудің химиялық технологиялары, мұнай химиясы, металдарды алу және олардың қосындыларының технологиясы.*

Мерзімділігі: жылына 6 рет.

Тиражы: 300 дана.

Редакцияның мекен-жайы: 050010, Алматы қ., Шевченко көш., 28, 219 бөл., тел.: 272-13-19

http://www.geolog-technical.kz/index.php/en/

«Известия РОО «НАН РК». Серия геологии и технических наук».
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)

Собственник: Республиканское общественное объединение «Национальная академия наук Республики Казахстан» (г. Алматы).

Свидетельство о постановке на учет периодического печатного издания в Комитете информации Министерства информации и общественного развития Республики Казахстан **№ KZ39VPY00025420,** выданное 29.07.2020 г.

Тематическая направленность: *геология, химические технологии переработки нефти и газа, нефтехимия, технологии извлечения металлов и их соеденений.*

Периодичность: 6 раз в год.

Тираж: 300 экземпляров.

Адрес редакции: 050010, г. Алматы, ул. Шевченко, 28, оф. 219, тел.: 272-13-19

http://www.geolog-technical.kz/index.php/en/

News of the National Academy of Sciences of the Republic of Kazakhstan. Series of geology and technology sciences.
ISSN 2518-170X (Online),
ISSN 2224-5278 (Print)
Owner: RPA «National Academy of Sciences of the Republic of Kazakhstan» (Almaty).
The certificate of registration of a periodical printed publication in the Committee of information of the Ministry of Information and Social Development of the Republic of Kazakhstan **No. KZ39VPY00025420,** issued 29.07.2020.
Thematic scope: *geology, chemical technologies for oil and gas processing, petrochemistry, technologies for extracting metals and their connections.*
Periodicity: 6 times a year.
Circulation: 300 copies.
Editorial address: 28, Shevchenko str., of. 219, Almaty, 050010, tel. 272-13-19
http://www.geolog-technical.kz/index.php/en/

NEWS of the National Academy of Sciences of the Republic of Kazakhstan
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224–5278
Volume 5. Number 466 (2024), 6–22
https://doi.org/10.32014/2024.2518-170X.441

UDC. 552.12:552.13

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PETROGRAPHIC AND MINERALOGICAL FEATURES OF THE KARAGAILY-AKTAS RARE METAL DEPOSIT (SOUTH KAZAKHSTAN REGION)

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Abstract. This article examines tin-tungsten-lithium mineralization associated with the magmatic, postmagmatic and volcanogenic-sedimentary stages, provides a general description of mineral composition of grazenized, albitized granites of the Karagaily-Aktas deposit (South Kazakhstan region). Petrographic characteristics and mineral composition of intrusive rocks were studied using a polarization microscope, X-ray diffraction diffractometer DRONE-3, scanning electron microscopy (Zeiss EVO 15LS SEM), and microprobe analysis (CAMECA-100). The main rare metal minerals are represented by wolframite, molybdenum, cassiterite, zinnwaldite, lepidolite and scheelite, monazite and xenotime. The rock-forming minerals include quartz, feldspar (sodium and potassium), muscovite, hornblende and biotite, sphenes, rutile, zircon, apatite and fluorite are present in the form of accessory minerals. Geochemical studies have shown that granites, syenites, pegmatites and greysens, as well as host carbonate rocks, are enriched in rare and radioactive elements such as Ta, Nb, W, Li, Be, Rb, Zr, Hf, Y, Yb, Sb, Sr, Ce, La, Er, Ho, Dy, Gd, Sm, Pr, Ce. Given the current demand for rare metals, especially lithium, and rare-earth elements, the development of the Karagaily-Aktas deposit can become economic.

Keywords: Karagaily-Aktas, South Kazakhstan, greisen, pegmatite, granite, lithium, tin, tungsten, rare-earth elements.

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ҚАРАҒАЙЛЫ-АҚТАС СИРЕК КЕЗДЕСЕТІН КЕН ОРНЫНЫҢ ПЕТРОГРАФИЯЛЫҚ ЖӘНЕ МИНЕРАЛОГИЯЛЫҚ ЕРЕКШЕЛІКТЕРІ (ОҢТҮСТІК ҚАЗАҚСТАН ОБЛЫСЫ)

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Аннотация. Бұл мақалада магмалық, постмагмалық және вулканогенді шөгінді кезеңдерде жаралған қалайы-вольфрам-литий минералдануы қарастырылған, Қарағайлы-Ақтас кенорнының (Оңтүстік Қазақстан облысы) сирек кездесетін грейзенделген, альбиттелген граниттерінің заттық құрамының жалпы сипаттамасы келтірілген. Интрузивті таужыныстардың петрографиялық сипаттамалары мен минералды құрамы поляризациялық микроскоптың көмегімен зерттелді, ДРОН-3 дифрактометріндегі рентгендік құрылымдық талдау, сканерлеуші электронды микроскопия (Zeiss EVO 15LS SEM) және микрозондты талдау (CAMECA-100). Негізгі сирек кездесетін

(кенді) минералдар вольфрамит, молибденит, касситерит, циннвальдит, лепидолит, шеелит, моноцит және ксенотит болып табылады. Таужыныстар түзуші минералдар-кварц, дала шпаттары (натрий және калий) мусковит, горнбленд және биотит, акцессорлық минералдар түрінде сфен, рутил, циркон, апатит және флюорит кездеседі. Геохимиялық зерттеулер көрсеткендей, интрузивті таужыныстар граниттер, сиениттер, пегматиттер және грейзендер, сондай-ақ сыйыстырушы карбонатты таужыныстар Ta, Nb, W, Li, Be, Rb, Zr, Hf, Y, Yb, Sb, Sr, Ce, La, Er, Ho сияқты сирек және радиоактивті элементтермен байытылған. Dy, Gd, Sm, Pr, Ce. Сирек металдарға, әсіресе қазіргі уақытта литийге сұраныстың жоғары екендігін ескере отырып, кешендегі Қарағайлы-Ақтас кенорнын зерттеу және игеру тиімді болу мүмкіндігі бар.

Түйін сөздер. Қарағайлы-Ақтас, Оңтүстік Қазақстан, грейзен, пегматит, гранит, литий, қалайы, вольфрам, сирек жер элементтері.

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ПЕТРОГРАФИЧЕСКИЕ И МИНЕРАЛОГИЧЕСКИЕ ОСОБЕННОСТИ МЕСТОРОЖДЕНИЯ РЕДКИХ МЕТАЛЛОВ КАРАГАЙЛЫ-АКТАС (ЮЖНО-КАЗАХСТАНСКАЯ ОБЛАСТЬ)

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Аннотация. В данной статье рассмотрена олово-вольфрамо-литиевая минерализация, приуроченная магматическому, постмагматическому и вулканогенно-осадочному этапам. Приводится общая характеристика вещественного состава редкометальных грейзенизированных, альбитизированных гранитов месторождения Карагайлы – Актас (Южно-Казахстанская область). Петрографические характеристики и минеральный состав интрузивных пород исследовались с помощью поляризационного микроскопа, рентгеноструктурного анализа на дифрактометре ДРОН-3, сканирующего электронного микроскопа (Zeiss EVO 15LS SEM), и микрозондового анализа (CAMECA-100). Основные редкометальные (рудные) минералы представлены вольфрамитом, молибденитом, касситеритом, циннвальдитом, лепидолитом и шеелитом, моноцитом, ксенотитом. Породообразующими минералами являются кварц, полевые шпаты (натриевые и калиевые), биотит, мусковит, роговая обманка и биотит, в виде акцессорных минералов присутствуют сфен, рутил, циркон, апатит и флюорит. Геохимические исследования показали, что интрузивные породы граниты, сиениты, пегматиты и грейзены, а также вмещающие карбонатные породы обогащены такими редкими и радиоактивными элементами, как Ta, Nb, W, Li, Be, Rb, Zr, Hf, Y, Yb, Sb, Sr, Ce, La, Er, Ho, Dy, Gd, Sm, Pr, Ce. Учитывая спрос на редкие металлы, особенно на литий в настоящее время, изучение и освоение месторождения Карагайлы – Актас в комплексе может стать рентабельным.

Ключевые слова: Карагайлы – Актас, Южный Казахстан, грейзен, пегматит, гранит, литий, олово, вольфрам, редкоземельные элементы.

Introduction

The territory of South Kazakhstan under consideration is characterized by a very complex geological structure, due to the presence of several structural levels, where each of them has a certain degree of metamorphism, a type of folding, and a wide range of plicative and discontinuous faults. Regionally, the territory is located on the eastern flank of the Terskey anticlinorium, intruded by a large batholith of granitoids. The described area is located within the Kungey-Bayankol structural-metallogenic zone (Shcherba, 1968; Zhang, 2009), characterized mainly by gold-rare metal-tungsten-tin, as well as lithium mineralization. The tungsten-tin-lithium deposit Karagaily-Aktas and a number of large mineral occurrences, gold and bedrock deposits of Dzharkulak, Don-Archa and alluvial deposits of Bayankol and Keskentas have been identified in the area.

The Karagaily-Aktas deposit is located within the northern spurs of the Terskey-Alatau ridge, which makes up the latitudinal chain of the Northern Tien Shan (Khromykh, 2018; Khromykh, 2022). At the beginning of the study, the object under study was classed as a rubidium-beryllium deposit. At the end of the 60s, prospecting and evaluation work was carried out by the Temirlik party, as a result of which economic concentrations of tin and tungsten were established, and beryllium and lithium have been also included (Seltmann, 2023).

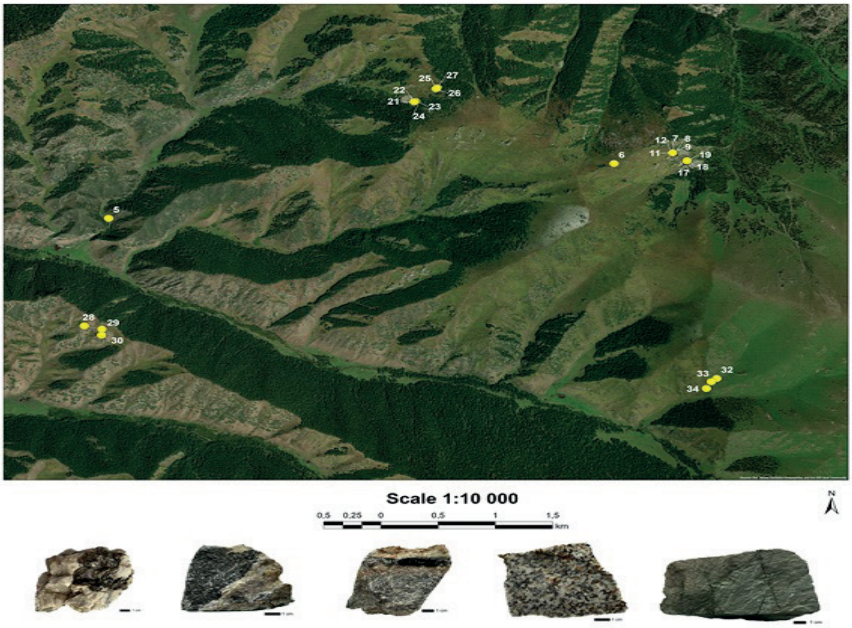


Figure-1 – Geological plan of the Eastern site of the Karagaily-Aktas ore field.

Tungsten-tin-lithium mineralization is associated with a dyke of greisenized granites intruding Lower Paleozoic shale-carbonate deposits. The ore bodies have a complex shape and are concentrated into dikes of greisenized granites and pegmatites (Kuznetsova, 2018). Metasomatic ore deposits in carbonate rocks are significantly less common. The dimensions of the ore bodies are 300-740 m along strike, thickness from 1 to 23.8 m, along the dip they are traced to 250 m.

In mid-1970s, as a result of exploration work, patterns of distribution of associated components in tin ores, such as lithium, rubidium, cesium, tantalum, niobium, beryllium, yttrium, etc., were identified.

As a result of mineralogical and geochemical work carried out in 2023, new data on rare metals and rare earth elements were obtained. The results are shown in the table.

Geological structure

The Karagaily-Aktas field with the East, Central and New sites have been discovered in 1954. The sites and mineral occurrences (Lesnoy and Dalny) constitute a single ore field, which extends from east to west for up to 10 km.

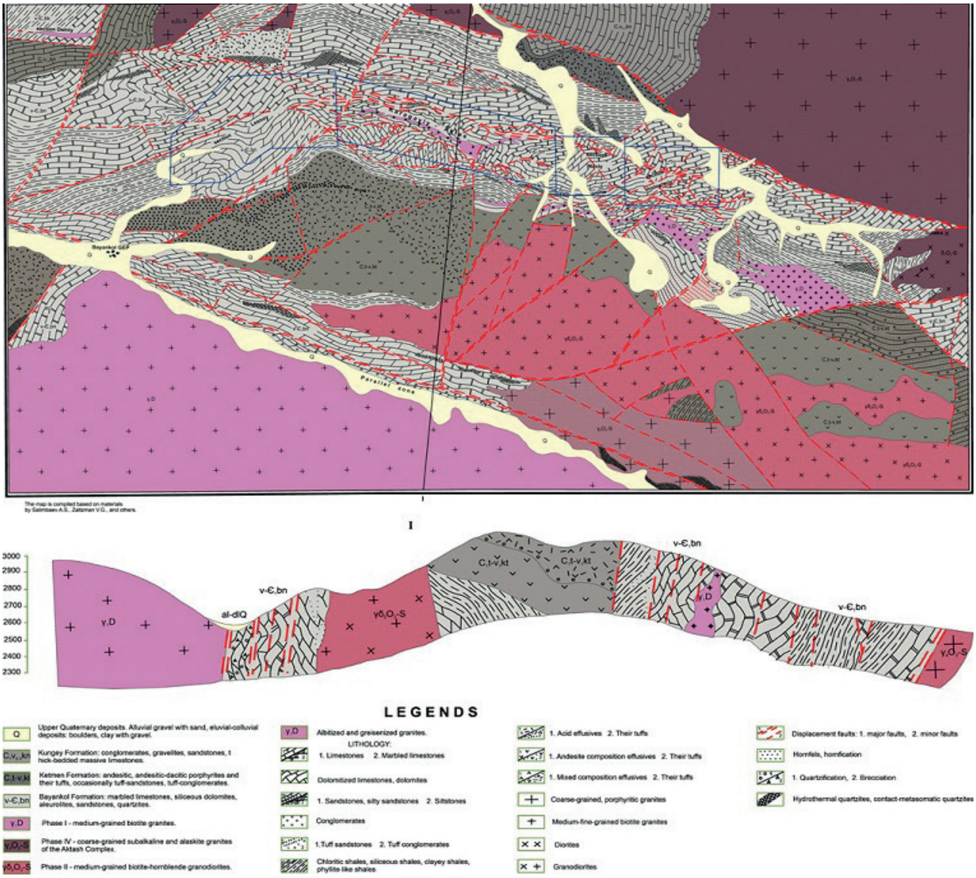


Figure-2 – Geological map and geological section (rare metal deposit Karagaily-Aktas)

Geological characteristics of the deposit area

The area of the ore field is characterized by the widespread development of intrusive rocks. The large Bayankol outcrop is closely adjacent to the ore field from the south, the Irinbay pluton from the west, and the Aktas massif from the north. In the eastern part of the field there is a small body of gabbro-diorites; in the southeastern part, granodiorites elongated in the sublatitudinal direction are exposed. The deposit is confined to a sublatitudinal albitized, greisenized granite dike (Karagaily-Aktas granites).

The Bayankol massif within the ore field is composed of medium-to-coarse-grained, locally porphyroid, biotite-hornblende granites. Granites differ in appearance and mineral composition from Aktas and Irba granites. The described granites consist of quartz, plagioclase, microcline-perthite, hornblende and biotite. The Irinbai granites are identical in petrographic composition; they differ from the Bayankol granites in the almost complete absence of plagioclase (Seltmann, 2023) .

The Karagayly-Aktas granite dyke attracts the attention of researchers due to rare-metal tungsten-tin-lithium mineralization. It extends in the sub-latitudinal direction for more than 10 km, and is confined to the central part of the block. The thickness of the dike is unstable from 10 to several tens of meters, in some places it extends up to several hundred meters. The rocks that make up the dike - granites - have undergone intensive metasomatic changes (albitization and greisenization). Pegmatoid formations in the form of schlieren and veins are also noted (Cerny, 1991).

Research results

Petrographic studies

Petrographic research shows that the intrusive rocks have different character, there are rocks of different classes from acidic to basic composition (Figure -3a, c). In addition to the listed rocks, there are post-magmatic altered greisenized granites and vein pegmatites. Mostly light-colored rocks consisting of leucocratic minerals. The structure is granitic, holocrystalline with coarse, medium, and fine grain sizes and irregularly grained porphyritic features. The rocks do not differ much in mineral composition. Thus, the main rock-forming minerals are: quartz, plagioclase, orthoclase, microcline, microperthite, muscovite, biotite, which make up more than 90% of the rock. In addition to the listed minerals, minor, accessory and ore minerals are often found: zinnwaldite, cassiterite, topaz, tourmaline, petalite, andallusite, zircon, sphene, rutile, apatite, pyrite, calcite, fluorite (Georgievskaya, 1964).

Granodiorites and plagiogranites compose small bodies elongated in the sublatitudinal direction, at a distance of 5-7 km with a width of up to 1 km. They are interconnected by gradual mutual transitions (Figure -3c). Macroscopically, they are rocks from variegated to light-colored, fine- and medium-grained, sometimes gneiss-like. Plagioclase has the composition of oligoclase-andesine, oligoclase and up to albite. Sericite, zoisite, epidote and calcite develop along them, forming the processes of sericitization and saussuritization.

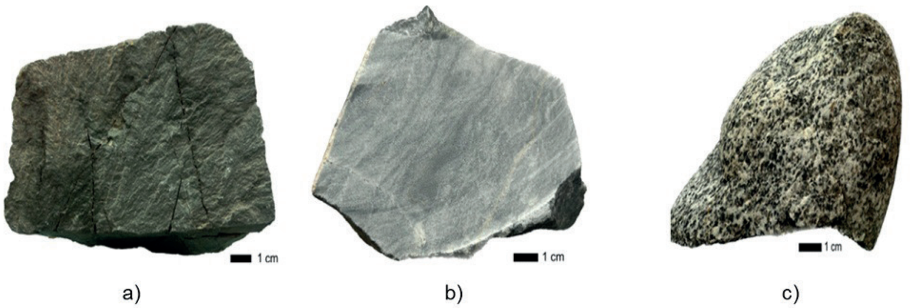


Figure-3 – Intrusive and host rocks of the Karagaily-Aktas deposit, a) gabbro-diabase; b) carbonate rock; c) grano-diorite.

Biotite, hornblende and alaskite granites are widespread in the deposit and form a single Bayankol massif. Macroscopically pinkish-gray rocks with a medium-to-coarse-grained structure, often porphyritic. They consist of microcline, plagioclase, quartz and biotite. Fluorite, zircon, apatite, sphene, rutile, and orthite are present as accessory minerals. Feldspars (plagioclase, microcline, orthoclase) form isometric tabular and more prismatic forms with sizes up to 15 mm, the minerals are weakly pelitized and sericitized (Figure -5).

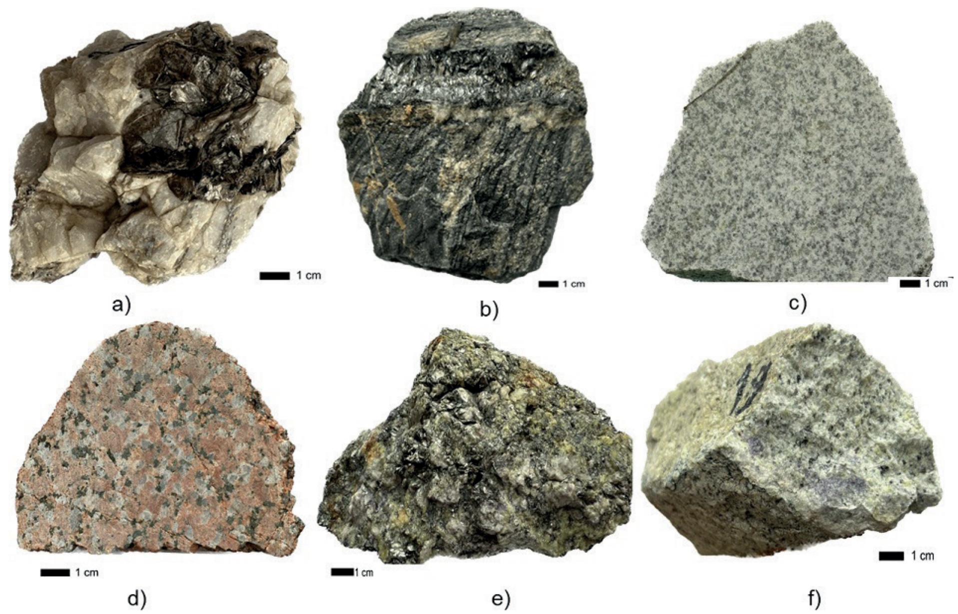


Figure-4 – Intrusive rocks of the Karagaily-Aktas deposit, a) zinnwaldite feldspathic pegmatite; b) zinnwaldite vein in carbonate rock; c) plagiogranite; d) monzogranite; e) greisen on granites; f) albitized granite

Alaskite granites form separate outcrops that can be traced in the central part of the Karagaily-Aktas deposit area. The morphology of the outcrops is complex, the thickness varies from 100-120 m to complete pinching out; often branch. They consist of a predominant amount of quartz and plagioclase, as well as potassium feldspar, muscovitized biotite and accessory apatite, and zircon.

Petrographic study of the rocks made it possible to trace all the intermediate changes in granites and greisens from weakly to highly altered (David, 2021).

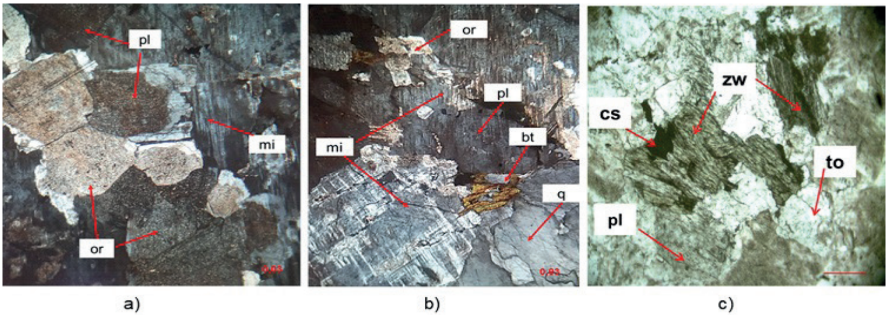


Figure-5 – The main rock-forming ore minerals: pl-plagioclase, mi-microperthite, or-orthoclase, bt-biotite, q-quartz, zw-zinnwaldite, to-topaz, cs-cassiterite (Karagaily-Aktas deposit).

Original unaltered granites are not observed within the deposit area; they are greisenized as a result of autometasomatic processes. According to the degree of greisenization, three groups can be distinguished: 1) weakly greisenized, 2) greisenized and 3) intensely greisenized granites, turning into typical greisens. The first group includes granites with an undisturbed structure and composition; only small amounts of topaz and fluorite develop in them; cassiterite and muscovite (iron-containing) appear (Figure -5c). In the group of greisenized granites, the mineralogical composition changes, the amount of quartz, muscovite and topaz increases. The rock acquires a relict hypidiomorphic granular structure. In the third group, in addition to an increase in the amount of quartz, muscovite and topaz, recrystallization of albite and quartz occurs. The granite structure is almost completely destroyed.

The most intense greisinization is observed within the Western and Central parts of the deposit, where altered rocks are localized on the hanging wall. Greisens are one of the main types of concentrations of ore components. Based on the results of the study, autometasomatic and near-vein greisens are distinguished. According to the mineral composition, it can be attributed to the quartz-zinnwaldite-topaz group; among the ore minerals, wolframite, cassiterite, zinnwaldite and pyrite are present in small quantities.

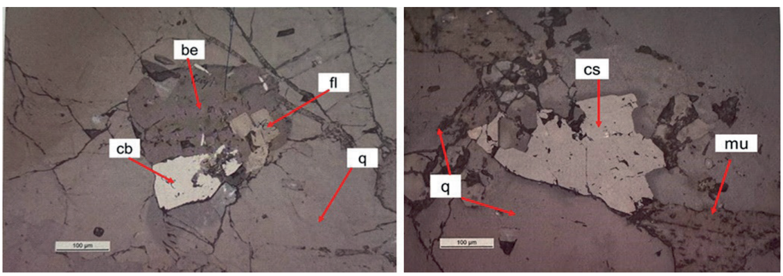


Figure 6 – Slightly greisenized granite with characteristic minerals: muscovite, beryl, cassiterite, fluorite, xenotime and quartz.

Near-vein greisens develop only in the contact parts of ore veins and in terms of the time of formation they are later than autometasomatic ones. Depending on the mineral composition, two groups are distinguished: 1) greisen from granites and other aluminosilicate rocks, 2) greisen from carbonate rocks. Near-vein greisens along aluminosilicate rocks are located in a granite dike with the subsequent release of mineral fractions: quartz-mica, quartz-mica-topaz and mica-topaz greisen. According to the results of chemical analyses, it is observed that greisenization of granites was accompanied by the removal of a significant amount of silica, sodium, oxygen and the introduction (or introduction) of fluorine, alumina, lithium, tin and tungsten.

Near-vein greisens along carbonate rocks accompany ore veins and veinlets occurring in limestones and dolomites (Figure -3b). Vein changes in limestones are characterized by the formation of rocks of mica-fluorite and mica-fluorite-tourmaline composition, thickness ranging from 2-3 to 5-7 cm.

The dike and vein series of the Caledonian intrusion complex are represented by diabase and diorite porphyrites, which appeared in both pre-ore, intra-ore, and post-ore stages.

All varieties contain, rare scattered dissemination of cassiterite, and its amount is not directly dependent on the degree of greisenization. Sometimes slightly greisenized granites show more abundant dissemination than in intensely altered varieties. In addition to cassiterite, scheelite and wolframite are also found.

The ore-bearing and ore-controlling rocks are represented by sedimentary-metamorphic rocks of the Zhaisan Formation of the Middle-Upper Cambrian, forming the wing of a large anticlinal structure complicated by steep faults of a strike-slip nature. Among the sedimentary formations that make up the deposit, the following rocks are characterized by the greatest development: quartz-feldspar-sericite, quartz-sericite shales with a thickness of 100-120 m; bituminous limestones, medium-grained, marbled, 400 m thick; quartz sandstones and siltstones up to 100 m; tuff sandstones and tuffs of andesite-dacitic porphyrites with a thickness of 150-200 m.

Mineralogical research

The Karagaily-Aktas deposit is distinguished by a wide range of minerals. To date, about 100 minerals have been studied and described, and some ore and rare earth minerals are under study. The article provides a description of main ore-forming and rock-forming minerals at the deposit.

Zinnwaldite – $KLiFeAl(AlSi_3)O_{10}(OH,F)_2$ is a lithium-containing mica, the most common in the deposit, similar in structure to biotite. It differs from lepidolite in its relatively high iron content. The mineral has a silvery, light gray color with a faint violet tint. In granite greisens, the size of mica plates ranges from tenths to 1-3 mm. Zinnwaldite in pegmatites and greisen often forms large plates up to 4 cm in size (Figure - 4a). Often includes cassiterite, ore minerals, and rare earth minerals (Figure -8).

In thin sections, zinnwaldite is colorless, slightly brownish-yellowish in color and has a distinct relief and a clear shagreen surface. The birefringence of the mineral is high from 0.025 to 0.035, biaxial, negative mineral. Weak pleochroism is observed (Figure -7).

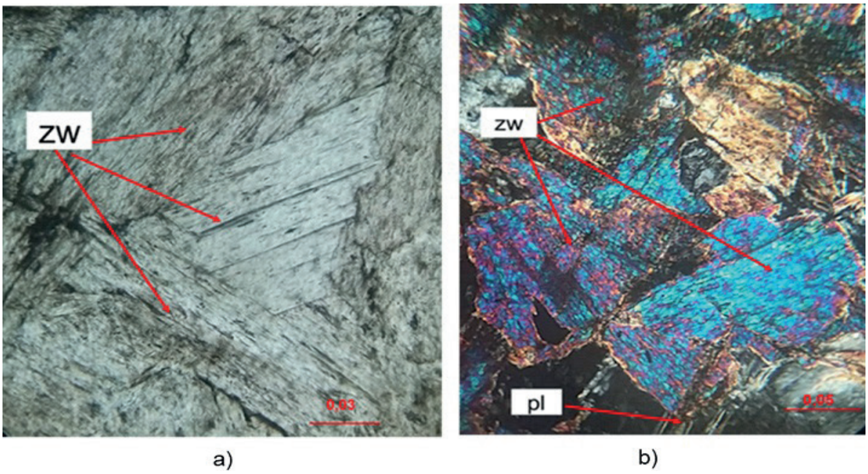
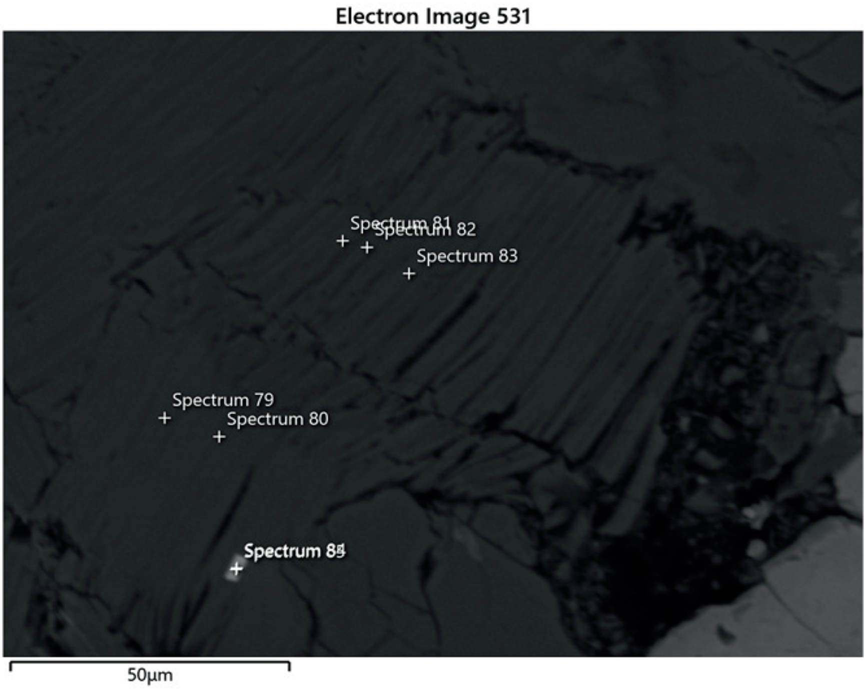
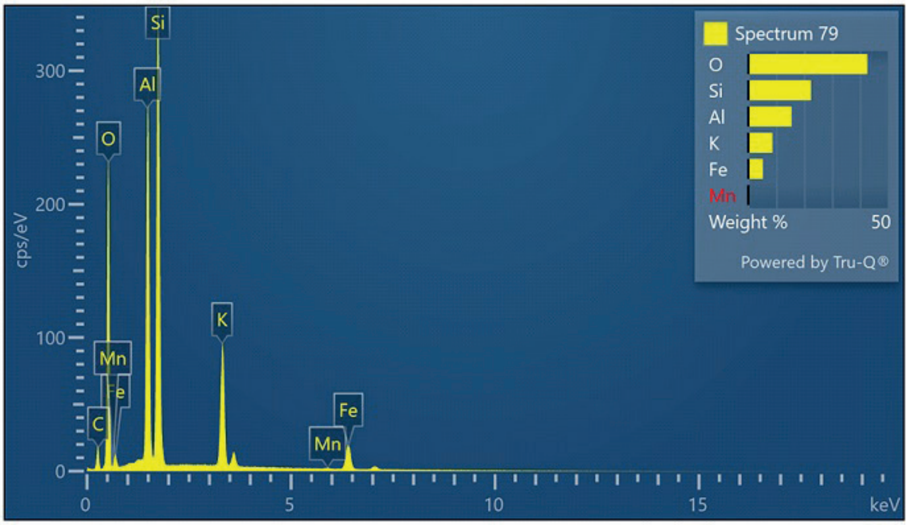


Figure-7 – Zinnwaldite plates in highly altered greisenized rock: a) parallel nicols, b) crossed nicols, magnification 10x



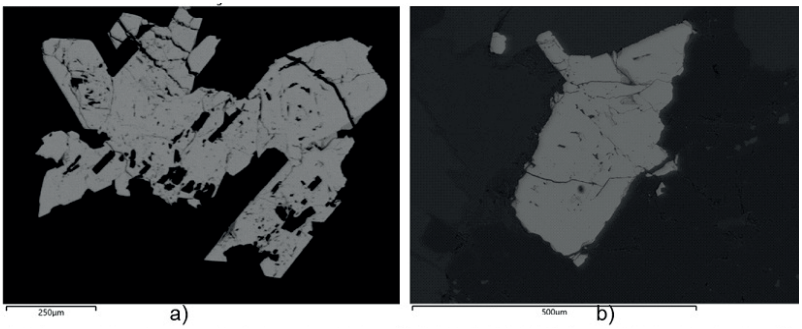
a)



b)

Figure-8 – Cataclased zinnwaldite plate in highly altered greisenized rock: a) zinnwaldite, b) semi-quantitative composition of zinnwaldite. Analyses were performed at Zeiss EVO 15LS SEM (Natural History Museum, London).

Cassiterite – SnO_2 is present in various concentration categories - magmatic, pegmatitic and post-magmatic. Igneous and pegmatite manifestations of cassiterite are in the form of accessories and are of interest only for understanding the genesis. Post-magmatic concentrations are basic in scale and relate to high-temperature pneumatolytic-hydrothermal formations. They are found in different types such as: greisen, topaz-quartz, feldspar-quartz. The sizes of cassiterite crystals vary from 0.2 mm to 0.5; larger crystals up to 3 cm are less common. Characteristic crystal shapes are often observed in weakly greisenized granites. Among the manifestations of cassiterite mineralization of the greisen type (Figure -9a), in turn, one can distinguish: greisens on granite rocks (Figure -9d), greisens on skarns, greisens on carbonate rocks - limestones and dolomites. The actual ore of them today are greisen on granites (Figure -4e, c). In greisens along skarns and carbonate rocks, cassiterite is usually present in small quantities.



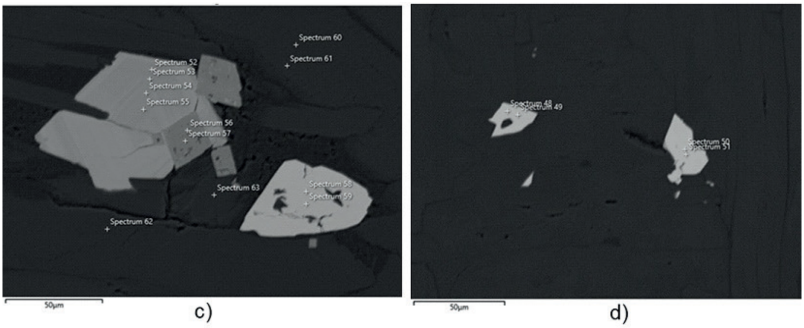


Figure-9 – Individual crystals of cassiterite in different rocks: a) from slightly greisenized granite; b) from slightly altered mica granite; c) slightly altered granite: cassiterite (white), zircon (dark gray), monocyte (gray); d) from unaltered granite. BEI. Analyses have been performed at the microprobe CAMECA-100 (Natural History Museum, London).

Table 1 - Chemical composition of cassiterite

Weight %							
	Ti	Mn	Fe	Sn	Nb	O	Total
Spectrum	0.08	0.01	0.51	77	0.38	21.13	99.11
1 / 2.	0.09	0	0.32	78.39	0.5	21.1	100.2
1 / 3.	0.24	0.04	0.98	72.99	1.43	20.75	96.44
1 / 4.	0.11	0.01	0.23	77.86	0.47	21.32	100
1 / 5.	0.16	0.02	0.23	78.28	0.43	21.47	100.6

№						
1	TiO2	MnO	FeO	SnO2	Nb2O5	Total
2	0.13	0.02	0.66	97.76	0.54	99.11
3	0.11	0.01	0.42	99.52	0.71	100.2
4	0.4	0.06	1.27	92.67	2.05	96.44
5	0.32	0.01	0.42	98.86	0.67	100
6	0.17	0.15	1.16	92	0.37	93.86
7	0.27	0.03	0.3	99.32	0.62	100.6

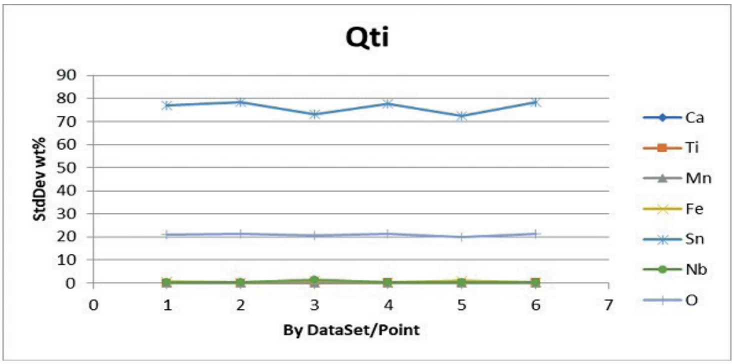


Figure-10 – The chemical composition of cassiterite is shown in the diagram

Wolframite – $(FeMn)WO_4$ is a dispersed mineral in a deposit with cassiterite. It is present in small quantities in albitized granites, greisens, and less commonly in weakly altered carbonate rocks. In greisens, the mineral forms scattered, individual well-faceted tabular crystals up to 1-1.5 mm in size. In mica and topaz veins, wolframite is distributed very unevenly. Most of the vein contains small amounts of wolframite, which forms small plates. In altered carbonate rocks, wolframite also forms individual single crystals with an internal zonal structure. The lead variety of wolframite, stolzite, is found in carbonates (Figure -11b).

Chemical analysis of tungsten (in Table -2) shows that the content of tungsten trioxide ranges from 42.61 to 57.89%. The lead content in wolframite reaches up to 32%, forming the lead variety of stolzite. Also present is ferberite, a component of a variety of wolframite.

Spectral semi-quantitative analysis in wolframite, in addition to lead, iron and manganese, often notes niobium (%), calcium - 1.5, aluminum - 0.86, potassium - 0.45, etc.

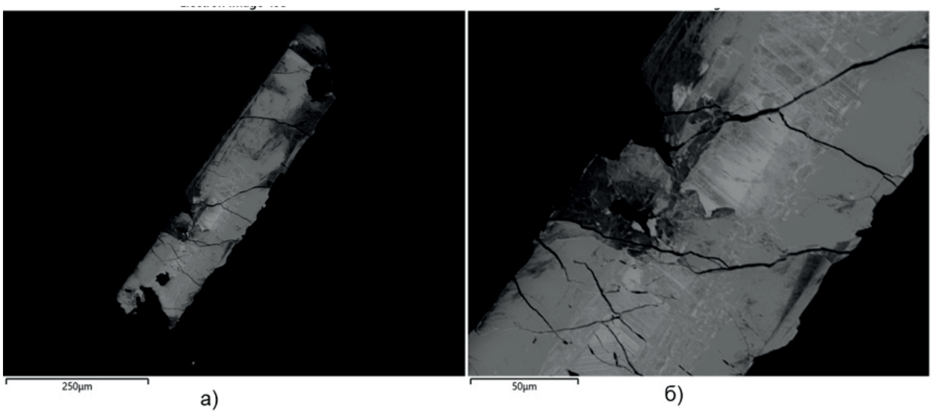


Figure-11 – A separate crystal of wolframite in a carbonate rock, a) prismatic crystal of wolframite, b) zonal structure of wolframite with lead (light zone). BEI. Analyses have been performed at the microprobe CAMECA-100 (Natural History Museum, London).

Table 2 - Chemical composition of wolframite.

№7	O	Al	K	Ca	Mn	Fe	Br	W	Pb	Total
27	17.2			0.33	6.57	11.05		57.89	0.64	93.66
28	16.82				6.68	11.52		58.78	0	93.8
29	16.55	0.71	0.49	1.44	2.32	3.91		44.29	24.44	94.13
30	15.88	0.86	0.54	1.72	1.38	2.5		42.61	29.4	94.89
31	14.23			1.31	1.63	2.63		46.1	31.07	96.97
32	14.58			1.51	2.47	3.91		47.81	26.27	96.55
35	15.55		0.2	1.78	1.58	2.84	1.06	43.47	29.57	96.06

Monazite – $CePO_4$ is a common accessory mineral of albitized granites, greisenized granites and tungsten-tin ore veins. It is also found in greisens in carbonate rocks, but in smaller quantities. The highest concentrations of monazite are observed in endocontact greisen and ore veins. Small crystals of monazite and xenotime are common in micas and topazes, less commonly in quartz. In some cases, large monazite crystals are broken by numerous small cracks and healed with violet fluorites and sellaites, less often with small mica flakes. In fluorites, brown halos of a deep dark purple color are observed around monazite and xenotime grains. In mica, only a brown halo is observed around the monocyte grains. Such halos are formed when a mineral is enriched with radioactive elements such as thorium and uranium.

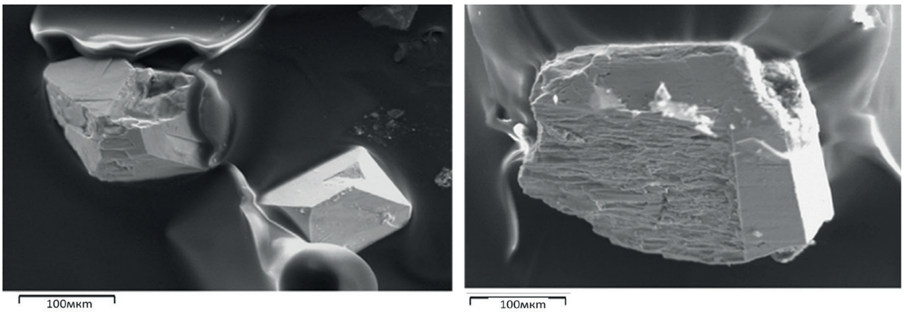


Figure-12 – Isolated bipyramidal monazite crystals, BEI.

Conclusion

1. The Karagaily-Aktas deposit belongs to the contact-metasomatic type and is genetically associated with a granite dike.

2. As a result of the study, more substantiated identification of mineralogical types of ore bodies and ore concentrations was determined, including a new sulfide-tungsten type for the deposit.

3. As a result of petrographic-mineralogical-geochemical studies, additional information was obtained on the mineral composition of rare-metal granites and greisen. Unusual varieties of minerals have been identified, such as lead variety of wolframite, stoltzite and raspite.

4. The main useful components are lithium, tin, tungsten, fluorine, yttrium, itterbium, cerium, rubidium, cesium.

5. Differences in the mineral composition and ore mineralization are explained by the different composition of the host environment. Greisens formed by granites are associated with tin and tungsten mineralization and lack fluorite and beryllium minerals: the main rock-forming minerals are quartz, light mica and topaz. Greisens formed by carbonates are associated with tungsten and lithium mineralization; in addition, fluorite, muscovite, topaz and quartz are the rock-forming minerals. From

this we can draw a conclusion about the zonal distribution of useful components (lithium, tin, tungsten and beryllium) due to the different composition of rocks that were processed under the influence of post-magmatic solutions having the same initial composition.

Acknowledgement

This research was funded by the IRN AP14870387 project " AP14870387 – "Assessment of the lithium potential of Kazakhstan, criteria controlling deposit formation and guiding exploration" funded by the Science Committee of the Ministry of Science and Higher Education of the Republic of Kazakhstan.

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Директор отдела издания научных журналов НАН РК *А. Ботанқызы*
Редакторы: *Д.С. Аленов, Ж.Ш.Әден*
Верстка на компьютере *Г.Д.Жадыранова*

Подписано в печать 15.10.2024.
Формат 70x90 1/16. Бумага офсетная. Печать – ризограф.
18,0 п.л. Тираж 300. Заказ 5.

РОО «Национальная академия наук РК»
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