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Brockite in wallrock metasomatites of the Safyanovskoe copper-sulphide deposit (Middle Urals)

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Abstract

The relevance of the work is due to the need to study ore copper-sulphide deposits in the Urals.
Purpose of the work: description of accessory brockite in metasomatites of the Safyanovskoe copper-sulphide deposit.
***Research methodology*:** the chemical composition of minerals was determined using the Jeol JSM-6390LV scanning electron microscope with an INCA Energy 450 X-Max 80 energy dispersive attachment from Oxford Instruments (Institute of Geology and Geochemistry of the Ural Branch of the Russian Academy of Sciences, Ekaterinburg).
***Results and conclusions*.** For the first time for the Safyanovskoe copper-sulphide deposit (Middle Urals), an aqueous rare earth phosphate of calcium and thorium, brockite, has been determined; it belongs to the group of rhabdophane (Ca,Th,REE)$[PO]_4 \cdot H_2O$. The mineral is rare for the Urals and was described earlier in granite pegmatites of the Middle and South Urals, as well as in dikes of metaplagiogranites of the Bazhenov ophiolite complex. Brockite was found in the rocky metasomatites of the Safyanovskoe copper-sulphide deposit after crystalline lithoclastic tuff (tuffaceous sandstone) of acid composition. The main mass of the rock consists of quartz, kaolinite (sericite), carbonates (dolomite, Fe-magnesite) with rare inclusions of pyrite. Brockite is found in the dolomite-quartz matrix of the sample in intergrowths with REE-goyazite – strontium aluminophosphate. It is assumed for the Safyanovskoe copper-sulphide deposit that an alumina association with an ore mineral association and rare earth minerals, in particular, REE-alumophosphates and phosphates, will form closely at the same time as the temperature drops and the redox conditions of the mineral formation environment change.

Keywords: brockite, goyazite, metasomatites, Safyanovskoe copper-sulphide deposit, Middle Urals.

Introduction

The Safyanovskoe copper-sulphide deposit is located 10 km northeast of the town of Rezh (Sverdlovsk region) and is confined to the southern part of the Rezhevskaya structural-formation zone. Its structure involves volcanic, volcanic-sedimentary and carbonate-terrigenous complexes of the Devonian-Lower Carboniferous age [1] (Fig. 1). The ore-bearing strata of the deposit has a thickness of about 500 m. Massive pyrite, copper-zinc and copper vein-disseminated ores are localized in metasomatically altered acidic volcanites (rhyolites, rhyodacites) and are mined in a quarry and a mine. Metasomatites occupy a regular position relative to ore bodies [2]. At the contact with ore bodies, pyrite-chalcopyrite-chlorite-quartz and alunite (pyrophyllite) -kaolinite-sericite-pyrite-quartz metasomatites are developed [3].

Objects and methods of research

In a sample of wall rock metasomatites (sample 3/17) selected in 2017 in the face of a quarry at a depth of 200 m at the contact with massive pyrite-sphalerite-chalcopyrite ore, an aqueous rare-earth phosphate of calcium and thorium - brockite was discovered, which belongs to the group of rhabdophane (Ca,Th,REE)$[PO]_4 \times H_2O$. This is the first find in the rocks of the Safyanovskoe deposit. Earlier, in metasomatites after rhyodacite (sample 2/17), a rare-earth strontium aluminum phosphate – goyazite was described [4]. Goyazite, together with brockite, was also found in sample no. 3/17. For the first time at the Safyanovskoe deposit, goyazite was described in association with barite veins in wall-rock sericite-pyrite-quartz metasomatites [5], and rare-earth goyazite in contact with Fe-magnesite was described in altered felsic volcanics [6].

The rock in sample 3/17 is metasomatite of felsic crystalline-lithoclastic tuff (tuffaceous sandstone). A green-gray sample contains fragments of an irregular shape with rounded edges up to 3 mm in size with a recrystallized main mass of kaolinite (sericite) -carbonate-quartz composition (Fig. 2, a, b). Cement is composed of kaolinite, quartz, carbonate with rare pyrite crystals. The texture of the main mass is spotty and associated with the formation of monomineralic segregations of microquartz aggregate; the structure is fine-grained lepidogranoblastic. Carbonates are represented by ferruginous dolomite and amoeba-like grains of ferruginous magnesite up to 1 mm in size (Fig. 2, a). Veins and fractures up to 3–5 mm thick, filled with pale yellow ferruginous magnesite with a distinct zonal structure. Brockite is found in a dolomite-quartz rock matrix in intergrowths with goyazite (Fig. 3).

The studies of goyazite and brockite were carried out using the JSM-6390LV (JEOL) scanning electron microscope with

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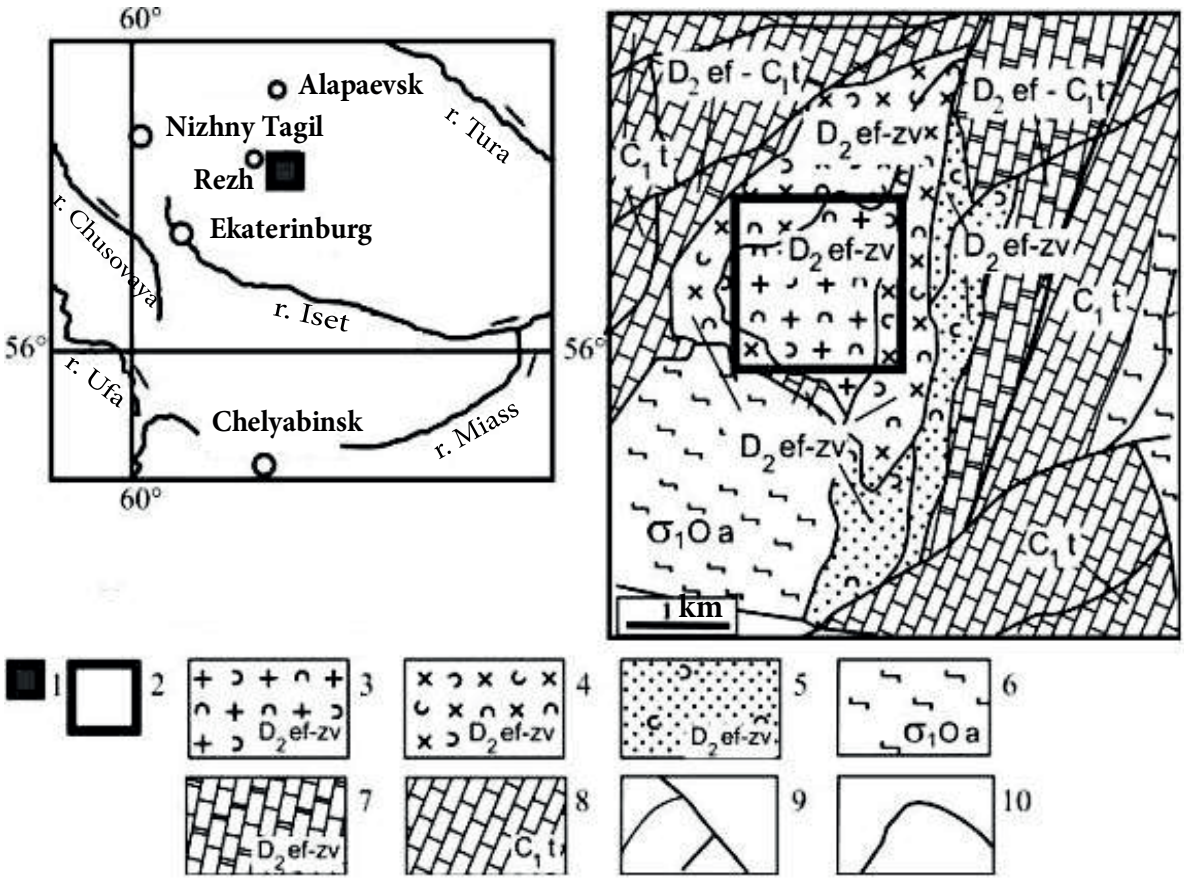

Figure 1. Areal map and geological diagram of the Safyanovskiy ore field. 1 – Safyanovskoe ore field; 2 – Safyanovsky quarry; 3 – acidic tuffs with interlayers of carbonaceous-siliceous rocks; 4 – tuffs, volcanic-sedimentary rocks with interlayers of limestone; 5 – volcanogenic-sedimentary rocks, sandstones, silty sandstones; 6 – serpentinites; 7 – marbled limestone; 8 – limestone; 9 – tectonic boundaries, faults; 10 – geological boundaries.

Рисунок 1. Обзорная карта и геологическая схема Сафьяновского рудного поля: 1 – Сафьяновское рудное поле; 2 – Сафьяновский карьер; 3 – туфы кислого состава с прослоями углеродисто-кремнистых пород; 4 – туфы, вулканогенно-осадочные породы с прослоями известняков; 5 – вулканогенно-осадочные породы, песчаники, алевропесчаники; 6 – серпентиниты; 7 – мраморизованные известняки; 8 – известняки; 9 – тектонические границы, разрывные нарушения; 10 – геологические границы.

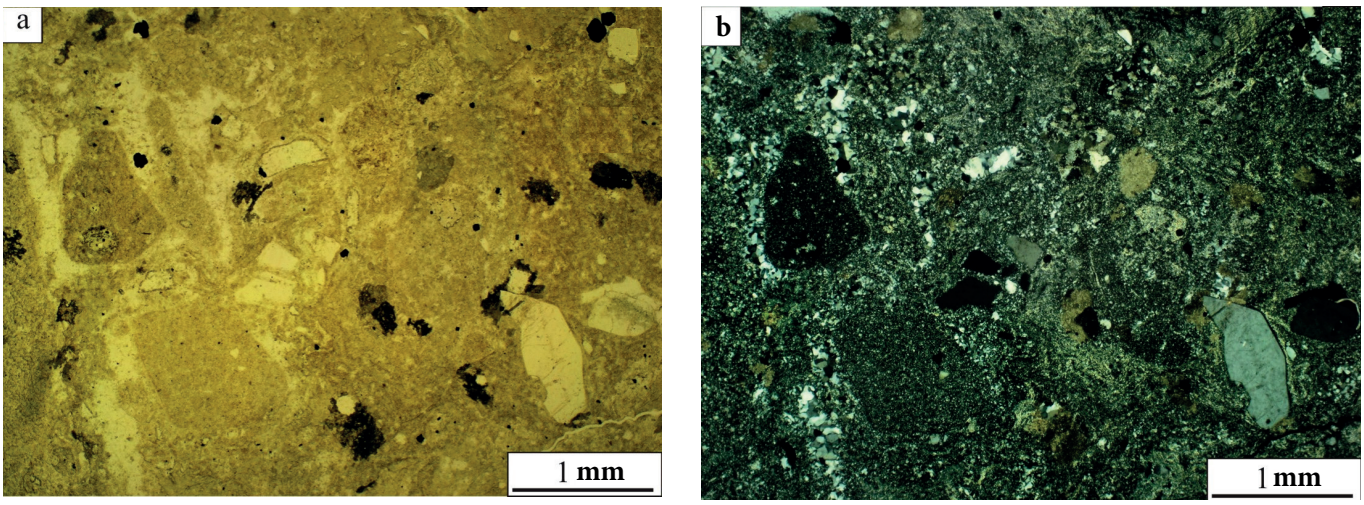

Figure 2. Photo of a transparent thin section of wallrock metasomatite on crystalline-clastic tuff (tuffaceous sandstone) of acid composition (sample 3/17) of the Safyanovskiy copper-sulphide deposit. a – without an analyzer; b – with an analyzer.

Рисунок 2. Фото прозрачного шлифа околорудного метасоматита по кристаллолито-кластическому туфу (туфопесчанику) кислого состава (обр. 3/17) Сафьяновского медноколчеданного месторождения: а – без анализатора; б – с анализатором.

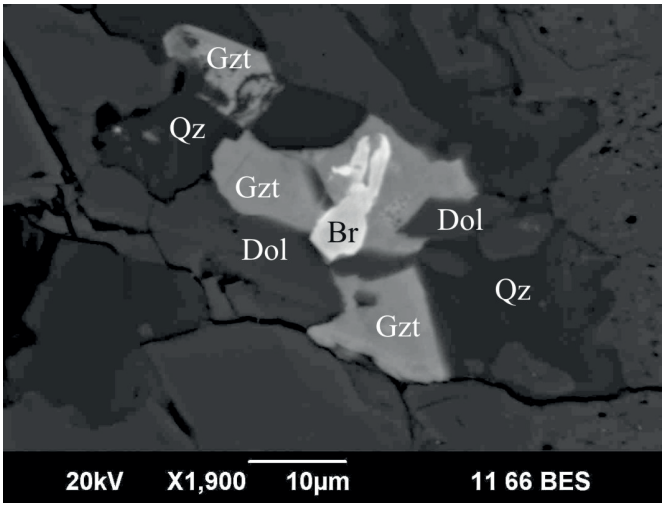

Figure 3. Brockite and goyazite in metasomatite matrix for crystalline-lithoclastic tuff. Gzt – goyazite, Br – brockite, Dol – dolomite, Qz – quartz. Photo in BSE mode, scanning electron microscope JSM-6390LV, IGG UB RAS, operator L. V. Leonova.

Рисунок 3. Броккит и гояцит в матрице метасоматита по кристаллолитокластическому туфу. Gzt – гояцит, Br – броккит, Dol – доломит, Qz – кварц. Фото в BSE-режиме, сканирующий электронный микроскоп JSM-6390LV, ИГГ УрО РАН, оператор Л. В. Леонова.

an INCA Energy 450 X-max 80 EDS spectrometer (laboratory of the FKhMI Institute of Geology and Geochemistry, Ural Branch of the Russian Academy of Sciences, Ekaterinburg). Data is shown in table.

Results and discussion

Brockite is quite rare in the Urals. It is found in the granite pegmatites of the Ilmen Mountains in the form of pseudomorphs based on xenotime crystals [7], as well as in the pegmatites of the northern part of the Aduy granite massif [8, 9] and in the Beregovaya vein within the Zenkovskiy granite massif [10]. In addition, it has been described within the Bazhenov ophiolite complex in plagiogranite dikes [11]. There it is confined to the clusters of monazite [12], overgrowing its crystals. At the Safyanovskoe deposit, monazite was found in a sample of sericitized brecciated rock (sample 78/01) [13] containing vein-disseminated copper-zinc ores represented by sphalerite, chalcopyrite, pyrite, and galena. Monazite in the form of small isometric crystals is confined to the segregations of sericite and galena along cracks and is represented by the cerium variety (Table).

The formation of brockite in plagiogranite dikes of the Bazhenov ophiolite complex is associated with low-temperature metamorphic processes of the prenite-pumpellite facies, which, according to the authors of [11], completely transformed the

Chemical composition of REE minerals in the wallrock of the Safyanovskoe copper pyrite deposit, wt%.
Химический состав РЗЭ минералов в околорудных породах Сафьяновского медноколчеданного месторождения, мас.%

oxides	REE minerals					
	Goyazite, sample 22/01	Monazite, sample 78/01	Goyazite, sample 48/2-1	Goyazite, sample 3/17	Brockite, sample 3/17	Brockite, sample 3/17
P_2O_5	25.64	21.91	28.22	26.09	25.52	25.48
SO_3	0.75	N/D	0.92	–	–	–
ThO_2	–	–	–	–	1.49	1.08
UO_2	–	–	–	–	0.52	–
SiO_2	1.97	12.27	N/D	–	–	0.31
Al_2O_3	29.84	3.69	28.51	24.58	–	–
La_2O_3	1.77	13.99	0.59	3.11	9.12	8.22
Ce_2O_3	3.27	23.88	1.51	6.20	22.56	21.53
Pr_2O_3	N/D	1.22	–	–	2.60	2.85
Nd_2O_3	1.51	9.99	–	3.44	14.76	15.67
Sm_2O_3	N/D	0.88	–	–	2.64	3.11
Gd_2O_3	N/D	1.17	–	–	1.81	2.14
Fe_2O_3	0.44	N/D	N/D	–	–	–
FeO	N/D	N/D	0.49	0.55	–	–
CaO	N/D	0.61	N/D	0.71	1.10	1.29
SrO	13.58	N/D	19.13	9.80	1.96	1.77
BaO	2.43	N/D	1.55	–	–	–
Na_2O	N/D	N/D	0.04	–	–	–
K_2O	N/D	0.84	–	–	–	–
Total	81.20	90.45	80.96	74.48	84.07	83.45

Note: N/D – element not detected; dash – element not determined.
Примечание: н. о. – элемент не обнаружен; прочерк – элемент не определялся.

rock matrix. The formation of brockite at the Safyanovskoe deposit, as well as of rare earth goyazite, is probably associated with low-temperature metasomatism, which transformed felsic volcanics and tuffs that host pyrite mineralization. It should be noted that zones with a high alumina content (up to 28 wt.% Al_2O_3), in which high-alumina minerals such as alunite, kaolinite, pyrophyllite, are identified in the near-ore metasomatites of the Safyanovskoe deposit [3]. Our studies confirm that occurrence of rare earth minerals, in particular, goyazite, are often associated with them. At alunite, porphyry copper, and epithermal gold deposits, phosphorus-aluminum sulfates and arsenates with impurities of rare earths are found in associations with luzonite and enargite [14, 15], which is also true for the Safyanovskoe deposit [2, 3].

Together with brockite and goyazite in sample no. 3/17, there are also newly formed carbonates: Fe-dolomite, Fe-magnesite. Earlier studies have shown that magnesite mineralization in the wall rocks of the Safyanovskoe deposit is a derivative of an ore-bearing solution [16]. The mineral formation temperature did not exceed 250 °C. Siderite and magnesite are associated with ore minerals (pyrite, sphalerite), as well as with barite, kaolinite, quartz, hydromica, i. e. belong to the zone of development of kaolinite- (alunite) -sericite-pyrite-quartz metasomatites. Magnesite mineralization with Fe-magnesite belongs to the zone of carbonate-kaolinite-hydrosericite-chlorite-quartz metasomatites [16]. According to [3], alunite-sericite-pyrite metasomatites were formed under reducing conditions, at log fO_2 = –38 and pH about 2.8, the kaolinite-alunite-sericite-quartz association was formed at a higher log fO_2 value, and pH – closer to 5.2, the kaolinite-sericite-chlorite-carbonate-quartz association was formed under near-neutral conditions at a higher log fO_2 value.

Conclusion

For the first time for the Safyanovskoe copper-sulphide deposit (Middle Urals), an aqueous rare earth phosphate of calcium and thorium, brockite, has been determined; it belongs to the group of rhabdophane $(Ca,Th,REE)[PO]_4 \times H_2O$, It is assumed for the Safyanovskiy copper-sulphide deposit that an alumina association with an ore mineral association and rare earth minerals, in particular, REE-alumophosphates and phosphates, will form closely at the same time as the temperature drops and the redox conditions of the mineral formation environment change.

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Броккит в околорудных метасоматитах Сафьяновского медноколчеданного месторождения (Средний Урал)

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Аннотация

Актуальность работы обусловлена необходимостью изучения рудных медноколчеданных месторождений Урала.

***Цель работы*:** описание находки акцессорного броккита в метасоматитах Сафьяновского медноколчеданного месторождения.

***Методология исследования*:** химический состав минералов установлен с помощью сканирующего электронного микроскопа JSM-6390LV фирмы Jeol с энергодисперсионной приставкой INCA Energy 450 X-Max 80 фирмы Oxford Instruments (ИГГ УрО РАН, г. Екатеринбург).

***Результаты и выводы*.** Впервые для Сафьяновского медноколчеданного месторождения (Средний Урал) установлен водный редкоземельный фосфат кальция и тория – броккит, который относится к группе рабдофана (Ca, Th, REE)$[PO]_4 \cdot H_2O$. Это редкий для Урала минерал, до настоящей находки описывался в гранитных пегматитах Среднего и Южного Урала, а также в дайках метаплагиогранитов Баженовского офиолитового комплекса. Броккит был обнаружен в околорудных метасоматитах Сафьяновского медноколчеданного месторождения по кристаллолитокластическому туфу (туфопесчанику) кислого состава. Основная масса породы состоит из кварца, каолинита (серицита), карбонатов (доломит, Fe-магнезит) с редкими вкраплениями пирита. Броккит находится в доломит-кварцевом матриксе образца в сростках с РЗЭ-гояцитом – алюмофосфатом стронция. Для Сафьяновского медноколчеданного месторождения предполагается близко-одновременное образование глиноземистой ассоциации с рудной минеральной ассоциацией и редкоземельными минералами, в частности, РЗЭ-алюмофосфатами и фосфатами при падении температуры и изменении окислительно-восстановительных условий среды минералообразования.

***Ключевые слова*:** броккит, гояцит, метасоматиты, Сафьяновское медноколчеданное месторождение, Средний Урал.

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