HYDROTHERMAL ALTERATION AND ORE MINERALIZATION OF THE NUNATAK DE CASTILLO, LIVINGSTON ISLAND, ANTARCTICA

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ABSTRACT. Nunatak de Castillo is situated in the most northeastern part of Hurd Peninsula, Livingston Island, Antarctica. In this area of the island some well exposed small plutonic bodies are cropped out. They are emplaced into the volcanic sequence, known as Mount Bowles Formation. Nunatac de Castillo is a remnant volcanic structure (volcanic plug) with typical textures - autoclastic breccias and poorly developed columnar jointing. Macroscopically the rocks are hydrothermally altered diorite porphyries. The style of alteration is propylitic. The alteration mineralogy is based on investigations using optical microscopy and XRD analyses. Epidote and potassium feldspar veins with several cm width and lenses are observed in the propylites. At the Nunatak de Castillo an ore zone is established. It is a vein structure with thickness of about 1 m. The mineral composition of the zone is represented by copper-containing minerals like chalcopyrite, chalcocite, bornite, and covellite. The supergene alteration consists of malachite and azurite.

Keywords: Antarctica, Nunatak de Castillo, hydrothermal alteration, ore mineralization

ХИДРОТЕРМАЛНО ПРОМЕНЕНИ СКАЛИ И РУДНА МИНЕРАЛИЗАЦИЯ ОТ НУНАТАК ДЕ КАСТИЙО, ОСТРОВ ЛИВИНГСТЪН, АНТАРКТИКА

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РЕЗЮМЕ. Нунатак де Кастийо се намира в най-североизточната част на полуостров Хърд, остров Ливингстън, Антарктика. В този район се разкриват няколко малки плутонични тела. Те са вместени в скалите от вулканската група, известна като формация Маунт Боулес. Нунатак де Кастийо е древна вулканска структура (вулкански нек). Типични за скалите, изграждащи постройката, са автокластичнито брекчиране и слабо проявената призматична напуканост. Макроскопски скалите са представени от хидротермално променени диоритови порфирити. Хидротермалната промяна на скалите е представена от пропилитизация. Минералният състав е определен на базата на оптична микроскопия и рентгенова дифракция. Сред пропилитите се наблюдават жили с няколко cm дебелина и лещи, изградени от епидот и калиев фелдшпат. В скалите на Нунатак де Кастийо се установява рудна зона, която представлява жилна структура с дебелина около 1 m. Зоната е изградена от медсъдържащи рудни минерали – халкопирит, халкоцит, борнит и ковелин. Супергенната минерализация е представена от малахит и азурит.

Ключови думи: Антарктика, Нунатак де Кастийо, хидротермално променени скали, рудна минерализация

Introduction

Nunatak de Castillo is situated in the most northeastern part of Hurd Peninsula, Livingston Island, Antarctica. The island is one of the South Shetland Islands, an archipelago in the Southern Ocean. It extends in a W-SW to E-NE direction to the NW coast of the Antarctic Peninsula (Fig. 1).

Previous studies of the rocks and mineralization at Nunatak de Castillo are limited and dealt with preliminary data of the petrographical characteristics of plutonic rocks (Kamenov, 1997).

The aim of this study is to present new data of the host rocks, hydrothermal alteration and ore mineralization. The results will be of great significance for the Antarctic science.

Regional settings

The South Shetland Block represents a continental fragment situated between the South Shetland Trench zone to the NW and Bransfield Back-arc Basin to the SE. There is a broad consensus that since Early Mezozoic the South Shetland Block represents a magmatic arc related to the subduction of the oceanic lithosphere of Phoenix Plate (Smelie et al., 1984).

The South Shetland Islands together with Antarctic Peninsula are part of the Andean Metallogenic Province which is the most economically important province in the world with giant Cu-Au porphyry, epithermal, Fe oxide-Cu-Au and manto-type Cu deposits (Sillitoe and Perello, 2005).

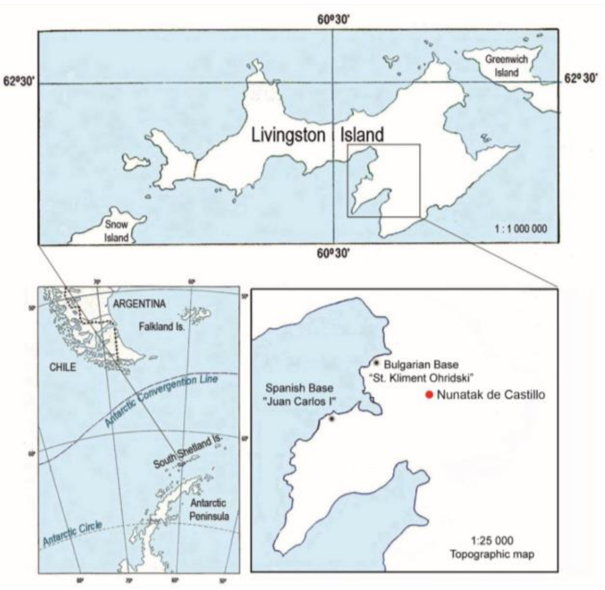

Fig. 1. Simplified map of Livingston Island as part of South Shetland archipelago. Nunatak de Castillo is situated in Hurd Peninsula SW from Bulgarian Antarctic Base.

Geology of Hurd Peninsula

The Hurd Peninsula is mainly built of the sedimentary sequence of Miers Bluff Formation (Dalziel, 1972). The successions are represented by terrigenous and aleuro-pelitic mixed rocks (mudstones) formed at different depositional environments – from turbiditic to delta and alluvial fans (Pimpirev, 2015; Stefanov, 2015). The sedimentary complex is intruded by a number of dykes. Their various ages indicate several stages of magmatic activity. The NE part of the peninsula is occupied by the rocks of the Hesperides Pluton and related diorite-porphyritic mid- to shallow-crustal sill-like bodies. Smaller quartz-dioritic bodies with island-arc affinity are emplaced within the Mount Bowles volcanic rocks in the eastern part of the peninsula near to Moores Peak (Kamenov, 1997).

Hurd Peninsula contains some well exposed small plutonic outcrops with presumed Eocene age. All these small stocks are interpreted as apophyses of the larger Barnard Point Batholith (Smellie et al., 1996; Kamenov, 1997), but weighty arguments in favor of this idea are not advanced up to know. All of the hypabysal stocks are intruded in the rocks of the Miers Bluff Formation and the Bowles Formation.

Geology of Nunatak de Castillo

Nunatak de Castillo is heterogeneous subvolcanic body. Coherent (massive) and autoclastic textures are the most common. Autobreccias form as the cooling crust of a lava or subvolcanic intrusion fragments during continued flow of the unit. These breccias comprise jigsaw-fit and rotated clasts of the same composition as the associated coherent unit (fig. 2).

Macroscopically the rocks are grey, altered, porphyroidal, fine-grained diorite porphyries.

The ore zone is about 1 m wide and is a vein structure hosted by NW-SE-striking fault. The mineralization is represented of predominantly copper- and iron-containing minerals (Fig. 2b).

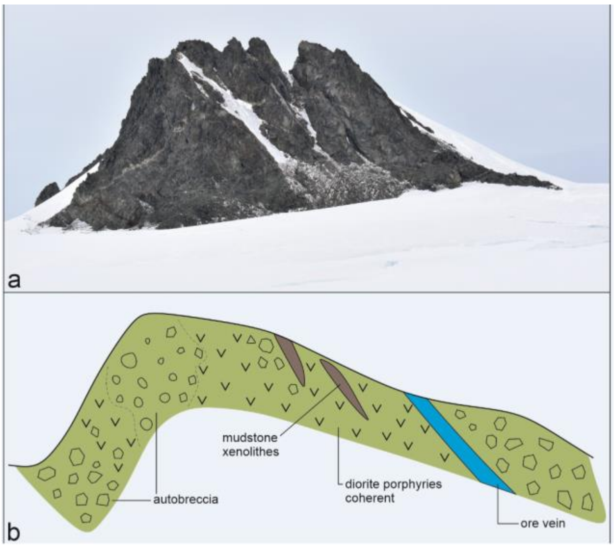

Fig. 2. (a) Nunatak de Castillo volcanic body (b) Simplified geological cross section of Nunatak de Castillo and the location of the ore zone (after Pimpirev (2001), unpublished data, with additions and modifications).

Sampling and analytical techniques

The samples from Nunatak de Castillo are collected from the host and altered rocks, and also from the ore zone.

To identify the alteration and ore mineral assemblages and to define their paragenetic relationships, polished sections and polished thin sections were prepared.

X-ray powder diffraction (XRD) analyses were done at Sofia University "St. Kliment Ohridski", Sofia, Bulgaria. TUR M62 diffractometer use filtered Co-Kα radiation in the 2Θ range 4-80°, step size 1.5°.

Host rocks and hydrothermal alteration

The rocks from Nunatak de Castillo are determine as diorite porphyries with rare, small porphyries of plagioclase and amphibole with individual crystals of porphyry quartz. A lot of xenoliths (mainly from mudstones and granitoids) are found in the rocks.

The primary mineral assemblages include plagioclase, amphibole, quartz, potassium feldspar and single zircons. The ground mass is fine to medium-grained.

The plagioclase forms subhedral to euhedral crystals usually moderately altered to sericite (fig.3). Amphiboles are subordinate to plagioclase; they form subhedral crystals and are usually altered to carbonate, epidote and chlorite (fig. 4). Quartz porphyries are only observed as single anhedral crystals in the ground mass. Potassium feldspars are rare.

Fig. 3. Altered plagioclase crystals and occurring of secondary minerals in the ground mass (CPL).

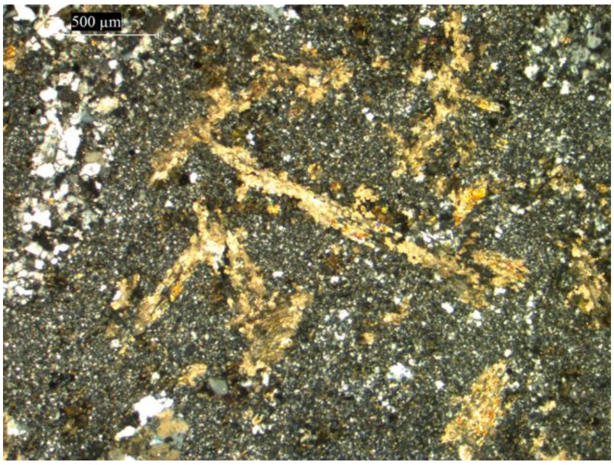

Fig. 4. Altered amphibole crystals with carbonate and chlorite (CPL).

The secondary mineral assemblages include epidote, chlorite, amphiboles, albite, carbonates, sericite, pyrite, quartz, potassium feldspar, with small quantity of apatite and zircons. Part of the minerals are also affirmed by XRD analyses (fig. 5). The alteration is unevenly distributed into the host rock. It is intensive around veins and veins with chlorite and epidote. In the host-rock away from the veins the alteration is uniformly distributed and the new-formed minerals occur in the ground mass or replacing primary minerals. The type of alteration of the host rocks in Nunatak de Castillo strongly resembles propylitic alteration.

Epidote and chlorite are the main minerals in the alterations. Epidote usually forms subhedral to anhedral crystals (fig 6), mainly occurs in veins and veinlets or is distributed into the host rock forming clusters in the ground mass with chlorite, ore minerals, and carbonates or replacing primary minerals. Chlorite occurs as anhedral and/or radial aggregates (fig 6). Amphiboles occur as fine-grained crystals with intense green color in veins or are distributed into the host rock. Carbonates and sericite are found in the ground mass or forming aggregates on plagioclase and primary amphiboles. Small subhedral crystals of albite occur in the ground mass or form thin veins with quartz. On the basis of the distribution hydrothermal zircons are determined.

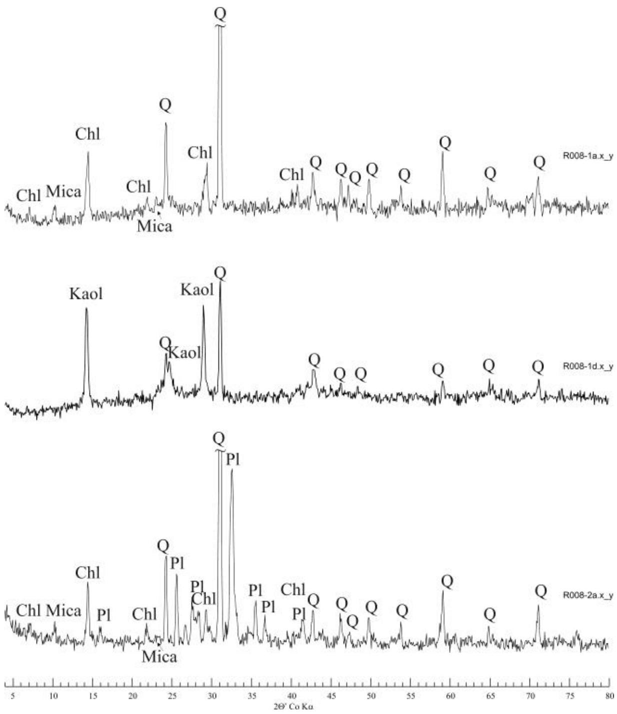

Fig. 5. X-ray diffractograms (XRD) of the alteration minerals. Chl – chlorite; Q – quartz; Mica (sericite); Kaol – kaolinite; Pl – plagioclase.

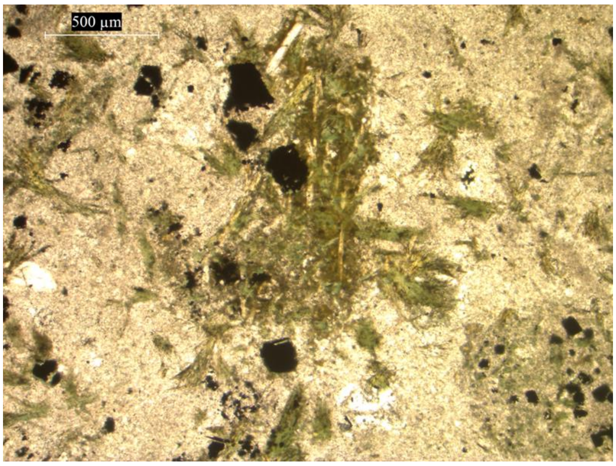

Fig. 6. Chlorite and epidote replacing primary igneous minerals (PPL).

Different veins are determined in the rocks of Nunatak de Castillo: epidote-chlorite veins; amphibole veins with quartz and chlorite; quartz veins with sericite, chlorite, kaolinite, and small quantity of epidote and carbonates; quartz veins with potassium feldspar (fig. 7.); and thin albite veins.

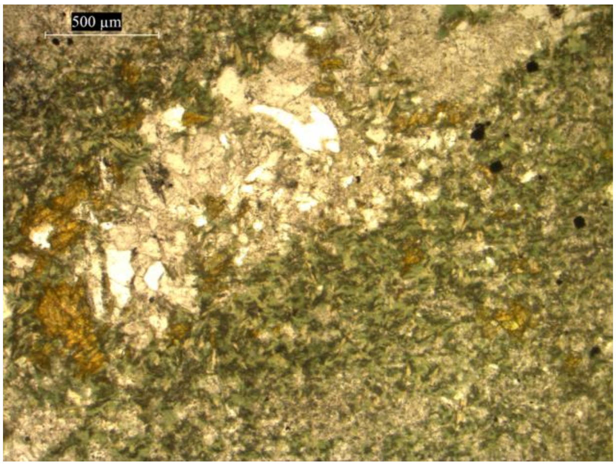

Fig. 7. Quartz-feldspar veins with intense alteration of epidote and chlorite (PPL).

Ore mineralogy

Two stages of mineralization are identified on the basis of mineral assemblages and depositional sequence.

The first stage is copper-iron bearing and is represented by primary pyrite and chalcopyrite.

Pyrite occurs as porous and fractured subhedral to anhedral single crystals and aggregates and forms nests and thin veinlets up to 100 µm (fig. 8). Rare euhedral crystals with cubic and octahedral forms can be observed. Predominantly it is replaced by iron oxide-hydroxides.

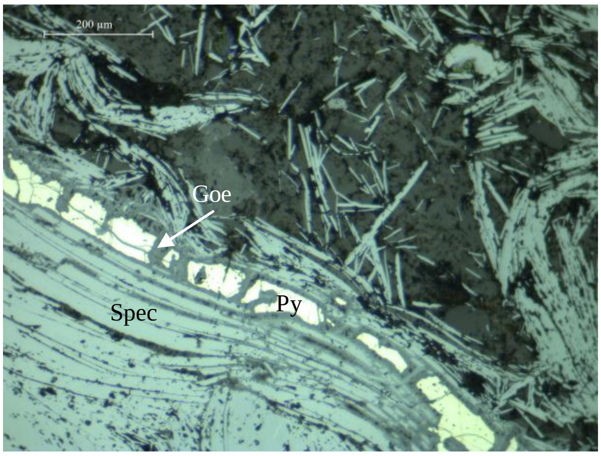

Fig. 8. Pyrite (Py) veinlet replaced by goetite (Goe) and other iron oxide-hydroxides, enclosed by specularite (Spec).

Chalcopyrite is observed as irregular grains, disseminated in the altered rock, also forms nests and rare veinlets. It encloses pyrite and probably is deposited later (fig. 9). In the most samples chalcopyrite is replaced by supergene copper sulfides (bornite, covellite, rarely chalcocite) and carbonates (malachite and azurite).

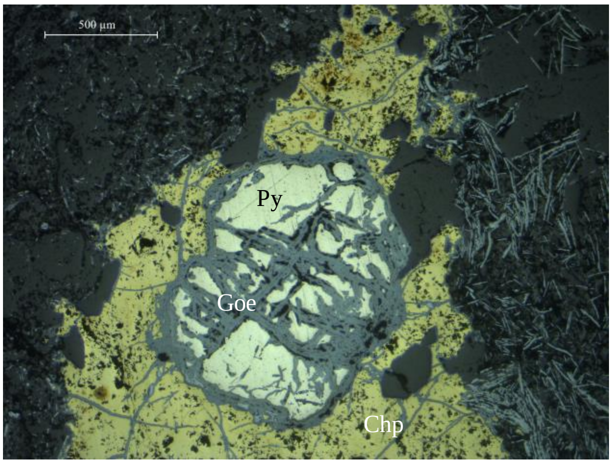

Fig. 9. Chalcopyrite (Chp) encloses single pyrite (Py) crystal. Goetite (Goe) and other iron oxide-hydroxides replaces pyrite and chalcopyrite.

The second stage is supergene and is formed under oxidizing conditions. Hematite (specularite), goetite and other iron oxide-hydroxides replace pyrite. Bornite, covellite, chalcocite, malachite and azurite are supergene alteration minerals of chalcopyrite.

Specularite is micaceous hematite and is the most abundant in supergene stage. Forms mainly veins up to 4-5 cm. Under microscope a lot of disseminated blade crystals can be observed in the groundmass (fig. 8). X-Ray analyses also affirm the presence of hematite in the samples (fig. 10).

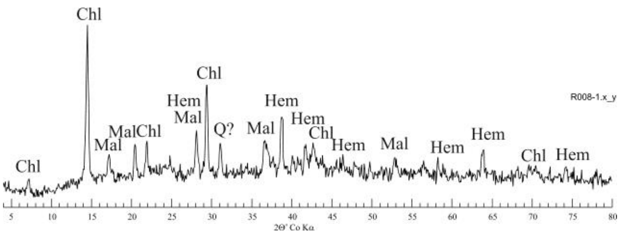

Fig. 10. X-ray diffractogram (XRD) of minerals from supergene stage. Hem – hematite (specularite); Mal – malachite; Chl – chlorite; Q – quartz.

Goetite and the other iron oxide-hidroxides replace pyrite and chalcopyrite. In some sample pyrite is completely replaced. They form net-mesh-like microstructures in both primary sulfides (fig. 9). Colloform texture is also typical.

Bornite occurs with covellite and together they form rims and infill cracks in chalcopyrite aggregates (fig. 11). Chalcocite is observed in the samples but is rare.

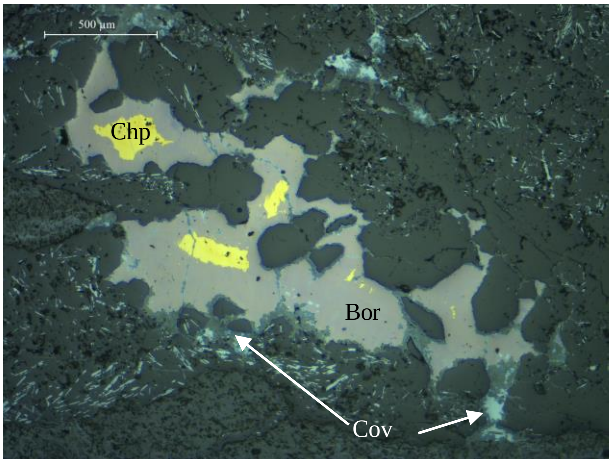

Fig. 11. Bornite (Bor) and covellite (Cov) replace chalcopyrite (Chp).

Malachite is more abundant than azurite. On the field malachite indicates the most abundant part with sulfides in the ore zone.

Discussion and conclusions

Nunatak de Castillo is located at the Hurd Peninsula, Livingston Island, Antarctica. This investigation represents a thesis that the subvolcanic body is a remnant volcanic structure (volcanic plug) with unknown age. It crosscuts the rocks of Myers Bluff formation (Upper Cretaceous). More data are needed to determine the origin of the outcrop and the volcanic facies.

The alteration mineral assemblages consist mainly of epidote, chlorite, amphiboles, albite, carbonates, sericite, pyrite, quartz, potassium feldspar and probably corresponds with propylites.

The mineralization occurs within altered diorite porphyries and is hosted by NW-SE-striking fault.

The ore minerals are Cu- and Fe-containing and their presence corresponds with the mineralization in the Andean Metallogenic Province. Chalcopyrite and pyrite together with the secondary copper sulfides (bornite, covellite, chalcocite?), copper carbonates (malachite, azurite) and iron oxide-hydroxides (specularite, goetite and others) are identified for the first time.

There is a moratorium for the prospecting and exploration of ore deposits at the Antarctic territories but the world demand for metals will continue to grow and the area could show economic potential for the future.

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