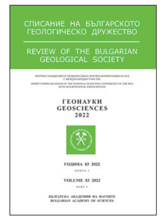
СПИСАНИЕ НА БЪЛГАРСКОТО ГЕОЛОГИЧЕСКО ДРУЖЕСТВО,
год. 83, кн. 3, 2022, с. 182–184

REVIEW OF THE BULGARIAN GEOLOGICAL SOCIETY,
vol. 83, part 3, 2022, p. 182–184



Национална конференция с международно участие „ГЕОНАУКИ 2022“
National Conference with International Participation “GEOSCIENCES 2022”

Mineral composition of quartz-polymetallic veins in Sally Rocks, Livingston Island, Antarctica

Минерален състав на кварц-полиметални жили от Сали Рокс, остров Ливингстън, Антарктика

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Abstract. The quartz-polymetallic veins from Sally Rocks, Livingston Island, Antarctica are hosted in the Miers Bluff Formation, particularly in the sedimentary sequences of the Sally Rocks member, consisting of thin bedded alternation of mudstone and sandstone. The veins consist of chalcopyrite, sphalerite, galena, pyrite, and arsenopyrite. Chalcopyrite and sphalerite predominate, galena is second in distribution, and pyrite and arsenopyrite are in a subordinate amount. According to the geological setting, textures, and mineral assemblages, the ore mineralization in Sally Rocks can be determined as hydrothermal which corresponds to the genesis of the other ore occurrences in the Hurd Peninsula.

Keywords: mineral composition, quartz-polymetallic veins, Livingston, Antarctica.

Introduction

The purpose of this study is to document the ore mineral composition, crosscutting relationships, and mineral chemistry of quartz-polymetallic veins in the Sally Rocks area, located in the most southwestern bay of the Hurd Peninsula, where the Hurd Glacier is ending in the South Bay. These new data supplement the information about the ore mineralization on the Hurd Peninsula, Livingston Island, Antarctica.

Materials and methods

The samples are collected from ore veins and host rocks during the Antarctic season 2019/2020. Polished sections and thin sections are prepared to determine the paragenetic relationships of the ore minerals and to characterize the host rocks. Ore samples are observed by optical microscope Leica DM750. X-ray powder diffraction (XRD) analyses are carried out at Sofia University St. Kliment Ohridski. TUR M62 diffractometer use filtered Co-Kα radiation in the 2Θ range 4–80°, step size 1.5°. Electron microprobe analyses (EMPA) and back-scattered electron imaging are implemented on carbon-coated polished sections in the certified laboratory “Eurotest-Control”. Analyzes were performed according to ISO 22309:2011 “Microbeam analysis – Quantitative analysis using energy dispersive spectrometry (EDS) for elements with atomic number 11 (Na) or higher”. The equipment used is based on a SEM – Jeol JSM 35 CF, upgraded with a digital scanning system for SEM – “DISS5+”, an energy dispersive X-ray system – “IDFIXe” with software for qualitative and quantitative analysis, and an energy dispersive detector with a resolution of 129 eV of Mn- Ka and analytical range from Boron to U. For quantitative analysis using MAC standards – microanalysis consultants – natural minerals – chalcopyrite, galena, pyrite, arsenopyrite, antimonite, zinc selenide, lead telluride and pure substances – gold, silver, cadmium, nickel, cobalt, manganese. The operating conditions of the apparatus are: accelerating voltage 20 keV, probe current 4.10-9 A, spectrum acquisition time 100 s, without “dead time”.

https://doi.org/10.52215/rev.bgs.2022.83.3.182

Geological settings

Livingston Island is one of the South Shetland Islands which in a regional aspect belongs to the South Shetland Block. It 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 the early Mesozoic, the South Shetland Block represents a magmatic arc related to the subduction of the oceanic lithosphere of the Phoenix Plate (Smellie et al., 1984).

Sally Rocks as a part of the Hurd Peninsula is mainly built up of rocks from sedimentary sequences of the Miers Bluff Formation (MBF), which consists of five members. The MBF sedimentary sequences consist of terrigenous and aleuro-pelitic mixed rocks (mudstones) formed at different depositional environments – from turbiditic to delta and alluvial fans (Pimpirev et al., 2015; Stefanov, Pimpirev, 2015).

Characteristics of the host rocks and ore veins

The ore veins are hosted by the rocks of MBF, mostly by the sedimentary sequences of the Sally Rocks member, consisting of thin bedded alternation of mudstone (mostly) and sandstone. The sandstone is fine-grained. Parallel and cross laminations as well as convolutions are observed. These sediments probably originated due to the bottom currents dynamics (Pimpirev et al., 2015).

Petrographic studies shown that the host rocks are predominantly polymictic sandstones. Their structure is clastic, and according to the grain size, is psammitic to aleuritic. The fragments are subrounded to angular. Cement is in small quantity or almost absent, determining the clast-supported structure. Rocks consist of crystaloclasts, lithoclasts, and cement material in low amounts. The crystaloclasts are of quartz, potassium feldspar, and plagioclase, in the presence of altered mafic minerals that cannot be determined. Less often, lithoclasts represented by volcanic fragments can be observed. Quartz grains vary in size and shape. The majority of plagioclase crystaloclasts show well-defined intergrowth lamellae. The sandstones are cut by quartz and quartz-polymetallic veins. The veins have sharp contacts with the host rocks. Some of the veins show zoning of the quartz grains. In the periphery, smaller quartz crystals occur, while in the central part they are significantly larger. Locally, fragments of the host rocks are found in the veins.

A number of quartz-polymetallic veins with a thickness of about 5–6 cm are exposed in the Sally Rocks area. The veins have similar features to those exposed in the area of the Bulgarian Antarctic Base (BAB) (Sabeva et al., 2020) and Caleta Argentina. The veins are structurally controlled, probably following strike-slip faults. They mainly consist of quartz and ore minerals. Primary ore minerals are chalcopyrite, galena, and sphalerite, while less common are arsenopyrite and pyrite. In the weathering zone, malachite and covellite are observed.

Mineral composition of quartz-polymetallic veins

Ore minerals mostly occur as nests and veins. Their composition is similar to that of BAB and Caleta Argentina – pyrite, chalcopyrite, galena, sphalerite, but only in this research area of Hurd, arsenopyrite is found. Chalcopyrite and sphalerite predominate, galena is second in distribution, and pyrite and arsenopyrite are in a subordinate amount. The depositional sequence is: 1, pyrite and arsenopyrite; 2, galena; 3, chalcopyrite and sphalerite. The gangue minerals are quartz, potassium feldspar, clinochlore, dickite, calcite and sericite (proven also by XRD).

Chalcopyrite is the most common in the studied samples. It is observed as anhedral grains with small size <5 μm to aggregates up to 5 mm. It encloses arsenopyrite (Fig. 1A) and galena, and is probably deposited together with sphalerite. Chalcopyrite is porous and in most of the samples is replaced by secondary copper minerals (covellite, malachite, azurite, brochantite; proven by XRD), which form net-mesh-like microstructures in it.

EMPA analyses of chalcopyrite show chemical composition close to stoichiometry $(Cu_{1.00}Ag_{0.01})_{1.01}Fe_{1.01}S_{1.98}$. Silver (0.34 wt%) is the trace element most commonly reported in chalcopyrite and typically structurally-bonded in the lattice (George et al., 2018).

Sphalerite is also anhedral. Its aggregates reach several mm, but it also occurs as smaller and irregular inclusions in chalcopyrite up to about 150 μm in size. It encloses galena, and its close relationship with chalcopyrite causes their simultaneous deposition. Chalcopyrite inclusions (as “chalcopyrite disease”) are mostly randomly distributed, but regular orientation is also observed in individual grains (Fig. 1B).

Electron microprobe analyses indicate the presence of Fe, Ni, Cu, Ag, Cd, and Sb as trace elements. Iron (4.65 wt%) and copper (4.51 wt%) have the highest concentrations of all the elements, which is due to the chalcopyrite inclusions in sphalerite. Silver (0.37 wt%) most commonly presents in sphalerite as microinclusions of Ag-bearing minerals (Cook et al., 2009).

Galena is next in distribution. It occurs as small anhedral inclusions in chalcopyrite and aggregates up to 3 mm. It is enclosed by chalcopyrite and sphalerite. Galena has alteration rims composed by corkite $PbFe_3(PO_4)(SO_4)(OH)_6$, proven by XRD.

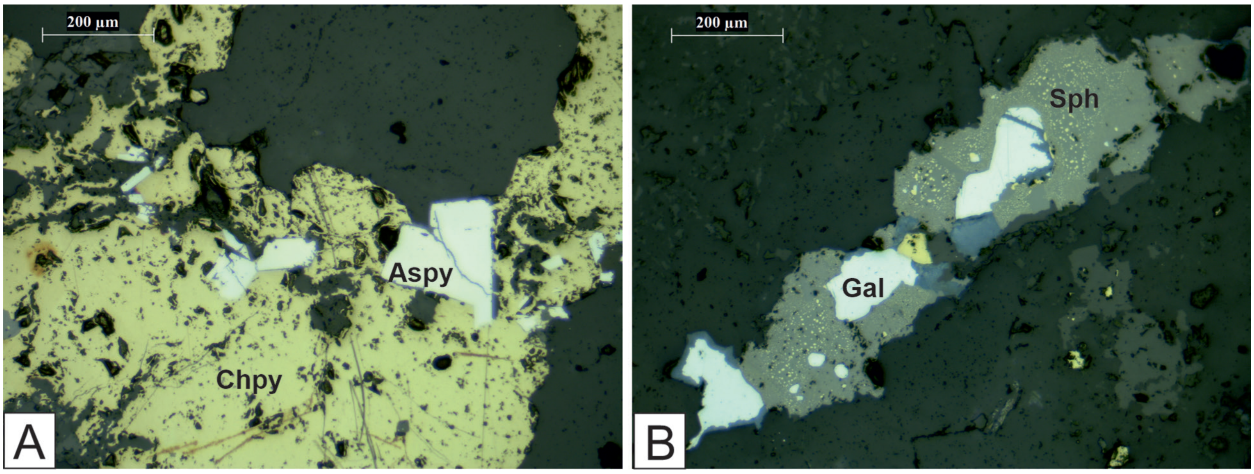

Fig. 1. Mineral assemblages of the quartz-polymetallic veins in Sally Rocks. *A*, Arsenopyrite (Aspy) twinning enclosed by chalcopyrite (Chpy); *B*, Sphalerite (Sph) with "chalcopyrite disease" encloses galena (Gal).

Arsenopyrite is more common than pyrite and is enclosed by chalcopyrite. From all the ore occurrences in the Hurd Peninsula, it is observed only in the Sally Rocks area. It occurs mostly as euhedral crystals with rhombic and rectangular forms and less commonly as subhedral crystals. It is whiter than pyrite, anisotropic, and forms twinning (Fig. 1A). Small inclusions of pyrrhotite and thin alteration rims, probably of secondary Fe oxides and hydroxides, are observed in some samples.

Arsenopyrite is characterized by a composition close to stoichiometric $Fe_{0.99}As_{1.07}S_{0.93}$ but analyses also show very low contents of elements such as Mn, Ni, Cu, Ag, and Sb. It is one of the main hosts of structurally-bound gold, but Au contents have not been established.

Pyrite is the rarest and occurs mainly as single euhedral to subhedral crystals ranging in size from < 5 µm to 50 µm. It is enclosed by chalcopyrite.

Conclusions

According to the geological setting, textures, and mineral assemblages, the ore mineralization in Sally Rocks can be determined as hydrothermal, probably epithermal which corresponds to the genesis of the other ore occurrences in the area of the Hurd Peninsula (Willan, 1994; Velev et al., 2016; Sabeva et al., 2020) as a part of the Andean metallogenic province (Guild et al., 1998). Further detailed field and analytical work is necessary to clarify spatial and genetic relationships between the veins from the BAB area, the Bulgarian Beach, and Caleta Argentina and to constrain the ore-forming environment.

Acknowledgments: Sincere thanks to Prof. Christo Pimpirev for the opportunity to do research on Livingston Island. This work has been carried out in the framework of the National Program of Polar Research supported by the Ministry of Education and Science of Bulgaria (Agreement No 70.25-176 from 22.11.2019). We are grateful to the logistic team for the support and our safe arrival and stay in Antarctica.

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