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Mineralogical Study of the vein style Cu-Pb-Zn-Bi-As-Au mineralization hosted in the carbonates of Myriofyto, Vertiskos Unit, N. Greece

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Introduction

The long-debated Serbo-Macedonian Massif belongs to the complex tectonomagmatic terrain which forms the northern part of the Hellenides or the North Aegean Domain and is represented by the Vertiskos Unit (Kydonakis *et al.*, 2015). It is dominated by a Paleozoic sequence of gneiss and mica gneiss and rarely some marble exposures. A Mesozoic two-mica and generally deformed granite with fine grained aplitic offsets to the north, outcrops at Myriofyto. According to Christofides *et al.* (2007), the Myriofyto granite belongs to the Kerkini Granitic Complex, and is enriched in Zr, Nb, Y, Ga and REE but not in metallic elements. These plutonic rocks are chemically associated with the Arnaia granite which displays low metallic content. Vertiskos Unit was intruded by Oligocene-Miocene magmatic rocks which were strictly related to an extensional regime set in back-arc environment conditions (Stergiou *et al.* 2018). Extended complex shear and fault structures as well as incorporating fragmented sequences of metamorphosed mafic and ultramafic rocks are found in the Vertiskos Unit (Sidiropoulos, 1991; De Groot *et al*., 1996).

The strongly sheared marble-gneiss contact zones and the post-shear subvertical faults and related breccia zones in gneisses of the northern part of Vertiskos, host several gold-bearing sulfide mineralizations in Drakontio, Koronouda, Stefania, Laodikino, and Myriofyto (Melfos and Voudouris, 2017). These deposits are part of the Kilkis ore district which includes porphyry, carbonate-replacement and vein style mineralizations enriched in gold. Herodotus and other ancient writers mention the importance of this area, around Dysoron mountain, for the gold rich deposits since the times of Alexander I (6th century B.C.)

According to Melfos and Voudouris (2017) the gold-bearing sulfide deposits of the Vertiskos Unit are associated with the Cenozoic magmatism. The present paper focuses on the study of the gold-bearing sulfide mineralization in the Myriofyto area.

Materials and Methods

For the purposes of optical microscopy, a total of 17 thin, 8 polished and 4 thin-polished sections were prepared and studied under a Leitz LABLORLUX 12 POL dual reflected-transmitted light polarizing microscope at the Department of Mineralogy, Petrology, Economic Geology of the Faculty of Geology, Aristotle University of Thessaloniki. The chemical composition of the non-metallic and the metallic minerals was determined by Scanning Electron Microscopy (SEM), using a JEOL 840 equipped with an ISIS 300 OXFORD energy dispersive spectrometer (EDS) at the Scanning Electron Microscopy Laboratory of Aristotle University of Thessaloniki. The study of the fluid inclusions was carried out at the Aristotle University of Thessaloniki, using the freezing-heating stage of LINKAM THM 600, attached at a LEITZ SM-LUX-POL microscope and a temperature control system TMS 90. Finally, to identify the major elements content of the mineralization and the host rock, six samples were analyzed by X-ray fluorescence (XRF) at the School of Sciences, Aristotle University of Thessaloniki.

Results

The rocks of the Myriofyto area consist mainly of marbles intruded by hydrothermal quartz veins with a thickness of 30-40 cm. The marbles appear white, coarse-grained, massive and folded at some places due to shear. On the basis of the petrographic study, three types of marbles are recognized: i) slightly impure calcitic marble, ii) dark grey laminated calcitic marble, and iii) very coarsely-crystalline, white calcitic marble. The mineralogical composition of the marbles consists mainly of calcite, with minor dolomite and ankerite. The carbonate minerals are accompanied by traces of quartz, white mica, chlorite, amphibole, epidote, clinozoisite, zircon and apatite.

The mineralization is hosted by the marbles and the quartz veins which intrude the marbles. The ore minerals form disseminations mostly in the quartz veins and include pyrite, chalcopyrite, sphalerite and galena with minor magnetite, tennantite, pyrrhotite (Fig. 1a, b). Arsenopyrite, galenobismutite and native gold are found in traces. Pyrite is the most dominant sulfide and demonstrates euhedral crystals including various inclusions of the other sulfides (Fig. 1a,b). Chalcopyrite appears in crystals and often as inclusions in pyrite. Sphalerite and galena form overgrowths over pyrite crystals and galena appears either with the other sulfides or as the dominant ore mineral in the host rocks. Other ore minerals are magnetite which occurs in characteristic euhedral crystals and accompanies the other sulfides (Fig.1b), tennantite and pyrrhotite which are relevant to chalcopyrite, arsenopyrite which is associated mostly with galena, chalcopyrite and galenobismutite. Galenobismutite is relevant to arsenopyrite and often carries Ag. Finally native gold appears at the margins of chalcopyrite grains included in pyrite. The primary mineralization has been replaced by chalcocite, covellite, malachite and goethite in the oxidized zone.

Chemical analysis of the host marble shows that the MgO content varies among the three different types of the marbles and is higher in the samples of the second type (dark grey laminated calcitic marble). The first type displays high concentrations of FeO and Al_2O_3 because of the amphiboles and the phyllosilicate minerals which are possibly attributed to the hydrothermal alteration. The third type of the marble appears pure and mostly consists of CaO. The enrichment of MgO in the second type of marble is possibly attributed to the grey layers alternating with the white calcitic ones. The high concentration of SiO_2 reflects the presence of the quartz veins associated with the ore mineralization. The study of the fluid inclusions showed homogenization temperatures between 200 and 240 ºC, with a peak at 220 ºC, and salinities from 7.11 to 14.36 wt% NaCl eq. These conditions are attributed to post mineralization processes, e.g. tectonics with the development of extended shear zones, which affected the primary fluid inclusions.

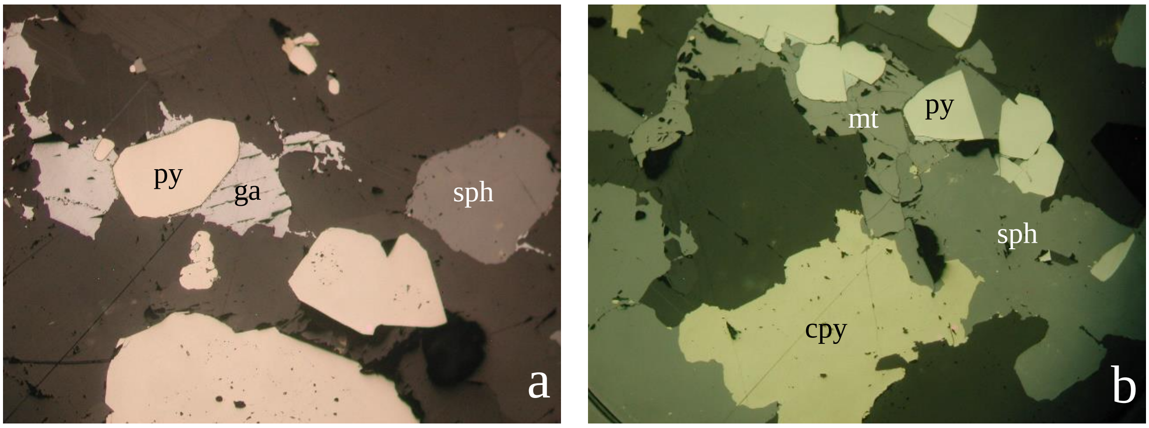

Figure 1. Photomicrographs of the primary ore mineralization. a. Pyrite (py), galena (ga) and sphalerite (sph). b. Chalcopyrite (Cpy), pyrite (py), sphalerite (sph) and magnetite (mt).

Discussion

The ore mineralogical composition and the fluid inclusions in the mineralization of the Myriofyto area are very similar to the Stanos Cu-Au-Bi-Te deposit at the southern part of Vertiskos. According to Bristol et al. (2015) this mineralization in Stanos is dated in early Miocene (19 Ma) and is probably related to a magmatic event which was developed along a shear zone. It was affected by the subsequent metamorphic processes of greenschist to lower amphibolite grade, due to shear, and is characterized by the lack of any magmatic rocks exposure. Magmatic related deposits with elevated Te-Bi-Au are found also at the northern part of Vertiskos, in the Kilkis ore district, and are possibly related to shear zones and normal and strike-slip faults which enhanced the hydrothermal fluids circulation derived from the Oligocene-Miocene magmas (Gilg, 1993; Bristol et al., 2015; Melfos and Voudouris, 2017; Stergiou *et al.*, 2018). It is very probable the shear-related Cu-Pb-Zn-Bi-As-Au mineralization in Myriofyto, hosted in quartz veins and the marbles of the Vertiskos Unit, to have a genetic affiliation to a magmatic rock of a possible Oligocene-Miocene age, not exposed in the area. The ore bodies are mainly associated with quartz veins that were emplaced along shear and strike-slip zones, operated under ductile-to-brittle conditions. This is the reason that the measured fluid inclusions in Myriofyto are not representatives of the primary mineralized fluids but of the subsequent fluids circulated along the tectonic structures.

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