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FLUID INCLUSION SYSTEMATICS OF THE OKOŠKA GORA POLYMETALLIC DEPOSIT

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Introduction

The Okoška Gora mineralization is located in the southern part of the Pohorje Mountains in northern Slovenia. The Pohorje Mountains in its southern part consist of metasedimentary series belonging to the Eastern Alps, more precisely to the eclogite-bearing part of the Koralpe-Wöltz unit, which represents the upper (or middle) part of the Austroalpine imbricated stack (Schmid et al., 2020 and references therein). The metasedimentary sequence consists of micaschist, gneiss, marble and quartzite, which underwent amphibolite grade metamorphism during the Cretaceous. The Pohorje series was emplaced by several episodes of magmatic activity, which can be roughly divided into pre- and post-metamorphic events. Preceding the metamorphism are Permian (Chang et al., 2020) granitic orthogneisses (pegmatitic gneisses *sensu* Mioč, 1972) and amphibolites of unknown age. Post-metamorphic magmatism is characterised by the intrusion of the Pohorje granodioritic pluton during the Miocene (Fodor et al., 2021).

The Pohorje Mountains host numerous dispersed and localized mineralizations and mineral occurrences in its southern part, of which Okoška Gora is the largest. Other polymetallic deposits with similar mineral paragenesis are reported from the vicinity of Vitanje, Slovenska Bistrica, Oplotnica, Polskava (Mioč, 1972) and in the vicinity of the Rogla ski resort (Mihael Ravnjak, verbal comm.). The timing and genetic conditions of the Okoška Gora deposit have been hotly debated (Drovenik et al., 1980 and references therein), with metamorphosed and intrusion-related hydrothermal models proposed. Berce (1963) argued for a hydrothermal origin of the deposit associated with emplacement of the Miocene Pohorje pluton. Based on the sulfur isotope signature of the sulfides, Drovenik et al. (1980) agreed with Berce (1963) on the intrusion-related hydrothermal model, but proposed an Early Paleozoic time of mineralization associated with emplacement of the Pohorje "keratophyre" (granitic orthogneiss; now Permian). Their interpretation was based on petrographic observations of euhedral pyrite and galena, which they attributed to blastic recrystallization during the Cretaceous metamorphic event. This paper presents the first fluid inclusion-based microthermometric data in an attempt to decipher the genetic conditions of the Okoška Gora deposit. This work is part of a larger multidisciplinary project aimed at deciphering the formation conditions and establishing fact-based genetic models for Slovenian mineral deposits.

Okoška Gora mineralization

Okoška Gora is a high-grade and highly localized Zn-Pb-Cu exploration target located in the southern part of the Pohorje Mountains between the towns of Oplotnica and Slovenska Bistrica. Three exploration shafts were dug at the mineralization site, one of which is still accessible today. The main ore minerals are pyrite, sphalerite, galena and chalcopyrite, whereas the gangue is primarily quartz, sericite and adularia. The predominant mineralization style is stockwork breccia with open-space veins and abundant druse-lined cavities filled with terminated crystals of gangue and ore minerals. Ore disseminations are minor and mostly restricted to pyrite. Ore minerals have not been observed to replace the host-rock. In the area east of the Okoška Gora mineralization, silica-chalcedony rhythmically banded sinters were reported (Mihael Ravnjak, verbal comm.), however it is not clear whether they represent breccia infill or paleosurface deposition. The mineralized stockworks contain transparent quartz, often in the form of sceptre, and amethyst, which is slightly pleochroic under the polarised light of the optical microscope. On the thin-section level, the two quartz types do not appear to cross-cut, but at the outcrop scale veins of transparent quartz intersect veins of amethyst (Janez Zavašnik, verbal comm.), suggesting the later's earlier paragenetic position.

Fluid inclusion systematics

A total of 100 fluid inclusions in sphalerite and quartz from five samples of ore breccia were investigated in this study. Both types of quartz form well-developed euhedral crystals, whereas sphalerite forms euhedral crystals or fills the open spaces between pre-existing ore and gangue minerals. Sphalerite is honey yellow or dark brown in color and its relative transparency makes it suitable for fluid inclusion analysis.

The fluid inclusions are usually 10–50 μm in size. All of the analyzed inclusions are liquid-rich and contain about 60–80 % liquid and 20–40 % vapour phase. In quartz crystals, secondary low-temperature assemblages (Q1) and primary inclusions assemblages (Q2) have been identified (Fig. 1). Primary Q2 inclusions are elongated, rounded or they occur in the form of negative crystals. It can be concluded that they are primary, based on the fact that assemblages follow the growth zones of the host crystal. Secondary (Q1) inclusions are round or irregularly ameboid and their assemblages are generally oriented in linear forms, regardless of the crystal shape. Inclusions in both assemblages are generally two-phase, rarely three-phase, the latter containing unknown transparent solids, which are probably not salt crystals. Two types of inclusion assemblages have been identified in sphalerite (Fig. 1). Inclusions in the first assemblage (S2) occur as negative crystals and sometimes contain an unindentified transparent solid mineral, similar to the one in primary quartz inclusions. Type 2 assemblage in sphalerite (S1) is characterised by needle-like, elongated inclusions.

Conclusions and final remarks

Based on the observed characteristics of the fluid inclusions, some conclusions can be drawn regarding the formation conditions of the Okoška Gora deposit. The fluid inclusions in both studied mineral phases are liquid-rich indicating non-boiling conditions and rather slow precipitation of ore and gangue minerals. Assemblages S2 and Q2 are characterised by fluid inclusions consisting mainly of negative crystal shaped inclusions, which have larger vapour-phase bubbles compared to assemblages S1 and Q1. These features indicate precipitation under higher temperature conditions. In addition, the S2 and Q2 inclusions follow the growth zones of the crystals, indicating the simultaneous crystal growth and fluid inclusion entrapement. Conversely, the irregular, needle-like, and ameboid inclusions of Q1 and S1 occur in linear, subparallel structures and have a higher proportion of liquid phase, indicating that they formed from a lower temperature fluid and are likely secondary compared to the negative crystal assemblages. The petrography data for the fluid inclusions suggest the presence of two mineralizing fluids in the system, raising questions about their origin and metallogenetic fertility. The transition from a higher-temperature to a lower-temperature fluid in the system could indicate two mineralizing pulses or mixing and dilution of the primary mineralizing fluid by seawater or meteoric water. In order to clarify the genetic relationships between the fluid inclusion assemblages, we will perform microthermometry and Raman analysis, which will provide indisputable evidence of the formation conditions of the Okoška Gora deposit.

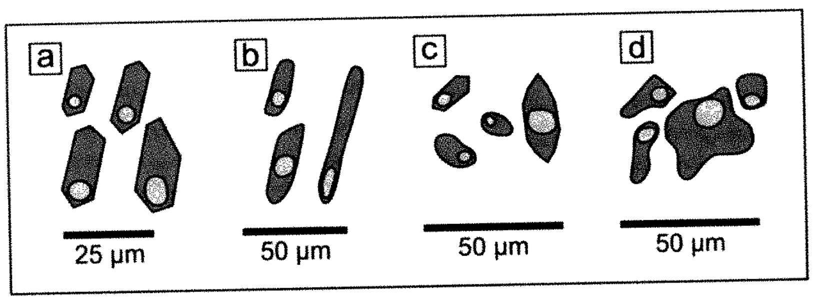

Figure 1 – Fluid inclusion systematics (a–d). Characteristic fluid inclusion assemblage for sphalerite S2 (a) and sphalerite S1 (b). Primary fluid inclusion assemblage in quartz (c) and secondary assemblage in quartz (d).

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