

## **Enargite from the Lahóca high-sulphidation epithermal gold deposit at Recsk, Hungary: joint application of infrared microscopy – microthermometry and orientation imaging microscopy**

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Most of the ore minerals are opaque in the 400-700 nm wavelength (visible light) range and this sets limitations for routine microscopic methods for fluid inclusion studies of ore deposits. On the other hand, a number of opaque minerals are quite transparent to near-infrared (NIR) radiation (Campbell et al., 1984). The IR radiation has lower energy than the visible light and therefore its energy is not large enough to excite an electron from the valence band to the conduction band. Thus the light is not absorbed by the mineral, consequently the mineral is transparent in IR light (Shuey, 1975). Several opaque minerals, such as pyrite, enargite, stibnite, molybdenite, hematite, etc. have been found to be transparent in IR light (Campbell et al., 1984). Microthermometric studies on these minerals showed that their fluid inclusions preserved such stages of the ore forming processes which otherwise could not be reconstructed on the basis of conventional studies of fluid inclusions in transparent minerals (Campbell and Robinson-Cook, 1987; Lüders, 1996).

In the vicinity of Recsk in NE-Hungary, an intrusive-volcanic complex of Palaeogene age contains the Lahóca high sulphidation type epithermal Cu-As-Au ore deposit. The deposit consists of stocks of massive enargite-luzonite. Under the epithermal zones, porphyry copper deposit occurs at about 500 - 600 m depth.

Conventional fluid inclusion petrography and microthermometry of quartz-hosted fluid inclusions were completed on Olympus BX51 microscope with IR filters and Linkam FTIR 600 type stage. Infrared fluid inclusion petrography were carried out on enargite crystals using wide infrared radiation sensitive camera (Hamamatsu C2500) mounted on Olympus BX51 microscope without any light filter and using special objectives

(Olympus MIRPlan) which are optimized for transmitting the infrared radiation. Infrared microthermometry on enargite was performed by using Linkam FTIR 600 type stage with sapphire windows together with the above described infrared microscopic system. The reproducibility of the measurements was  $\pm 1$  °C at high temperatures and below 0 °C. The calibration measurements to avoid and eliminate IR radiation, which were carried out on quartz-hosted and enargite-hosted fluids, caused problems during fluid inclusion microthermometry which has been described by Moritz (2006). Results of calibration measurements proved that the “green house effect” has no significant effect on the measured homogenization and final ice melting temperatures by using the setup of our laboratory described above.

Our observations in the infrared microscope collude with the previous studies (Mancano and Campbell, 1995; Molnár et al. 2008), where enargite crystals show various transmittances under the IR microscope. Several times the crystals remained opaque in periodic zones or in inhomogeneous patches. The thickness of the sample and differences in the chemical composition (for example replacement of As by Sb in the structure) can influence the IR transmittance, but we couldn't explain the remained opacity by these effects. Because optical properties of minerals are highly influenced by the orientation of the crystal structure in relation to the incident beam, we investigated the IR transmittance in the connection to the crystal's orientation of enargite. Orientation imaging microscopy (OIM) is a powerful technique used to obtain crystallographic orientation from single and polyphase crystalline materials, based on the electron backscatter diffraction (EBSD) patterns in the scanning electron microscope (SEM). Results

of the comparison of the crystal orientation maps produced by the SEM-EBSD method with the IR transmittance of the samples under microscope suggest the validity of our approach. Further mapping the IR transparency of enargite crystals extended with NIR micro-spectrophotometric reflectance/transmittance measurements is in progress in order to define the exact relationship between the crystal orientation and absorption coefficients in near-infrared light.

The results of microthermometry for enargite-hosted primary fluid inclusions suggest that the ore forming stage in the Lahóca deposit took place in a temperature range between 170 and 230 °C. There is no quartz or other transparent mineral which precipitated synchronously with enargite and data for quartz which precipitated before crystallization of enargite indicate temperatures of 250 - 300 °C for the early stage of hydrothermal activity. Fluid inclusions in late stage quartz, formed during a syn-hydrothermal tectonic stage, homogenized between 130 and 170 °C. The defined decrease of the temperature between the hydrothermal phases is associated with an increase of fluid salinity, which probably reflects the increasing proportion of magmatic water in the epithermal zone of the intrusion-related hydrothermal system (Molnár et al., 2008). Data for enargite-hosted fluid inclusions also suggests that the decreasing temperature and increasing salinity (from ~1 to ~8 eq mass% NaCl) of the ore forming stage shows spatial changes from the NNW part to the SE part of the deposit. This direction does not point towards to the position of the porphyry copper ore bearing intrusion of the system.

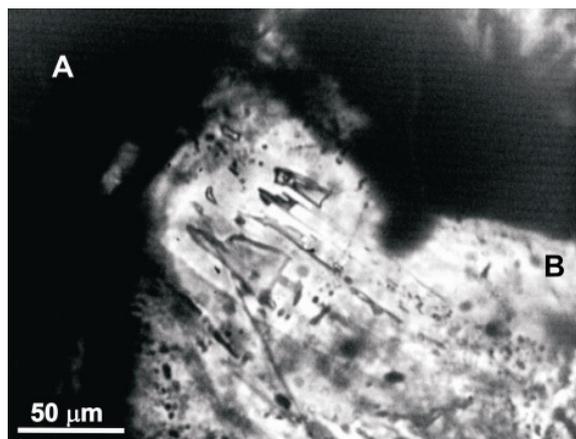


Fig.1. IR microscopic image of transparent (B) and opaque (A) enargite-crystals. The IR transmitting crystal contains secondary, mostly necked-down fluid inclusions.

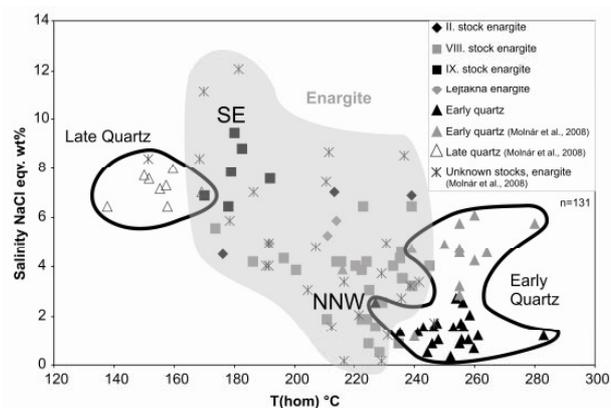


Fig.2. Fluid inclusion homogenization temperature-salinity data for the Lahóca epithermal gold deposit.

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Artikel/Article: [Enargite from the Lahoca high-sulphidation epithermal gold deposit at Recsk, Hungary: joint application of infrared microscopy - microthermometry and orientation imaging microscopy 190-191](#)