Petrographical and geochemical study of the magmatic phases and hydrothermal vein types of the Bolcana porphyry Cu-Au mineralization

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The Bolcana porphyry Cu-Au mineralization is located in the southern part of the Apuseni Mountains (Romania), where Miocene calc-alkaline intrusive and volcanic units host numerous porphyry Cu-Au and epithermal Au-Ag (Pb-Zn) mineralizations *(*Neubauer *et al.,* 2005*)*. The Bolcana ore deposit is located in the central part of the Bolcana-Troiţa-Magura volcanic structure and is hosted by the Neogene Hondol-Faerag Andesite and the Bolcana Intrusive Body. The porphyry copper mineralization is represented by chalcopyrite, pyrite, bornite, magnetite, hematite, molibdenite and subordinate native gold ore minerals. This mineral assemblage is associated with potassic, sericitic, sericite-chlorite, propylitic and intermediate argillic hydrothermal alterations. The porphyry-style mineralization is cross cut by the late stage low sulphidation type epithermal veins *(*Milu *et al.,* 2003*)*.

Three exploration drill holes were investigated, which are located along a NW-SE profile across the mineralized porphyry intrusion and expose the system to the depth of 250 m from the surface. The cores represent distinctive parts of the porphyry system, with variable intrusive phases, alteration types, Cu/Au ratio and epithermal overprinting. Our scope was a detailed documentation of the magmatic phases, their specific mineral assemblages, the alteration features and the crosscutting relationships of the hydrothermal veins.

Based on the petrographical results, the studied zone of the Bolcana prospect is formed by successive porphyry phases of dioritic composition, which is locally associated with hydrothermal breccias, too. Considering the time relationships, there are two early phases, the medium grained porphyry (MGPO) and the coarse grained porphyry phases (CGPO), both suffered potassic alteration, overprinted by sericite(-chlorite) alteration. The medium grained porphyry (QMGPO) occurs as an intermediate phase, which was affected by a moderate sericite alteration. The late porphyry phase is the fine grained porphyry (FGPO) which suffered from a potassic alteration overprinted by a sericite-chlorite alteration and locally caused brecciation of the earlier intrusions. Locally the QMGPO suffered argillic alteration associated with hydrothermal brecciation. The host rock of the intrusions is a monomictic intrusive rock containing breccia (MXI) with propylitic alteration.

The hydrothermal alteration zones developed during the porphyry phases are accompanied by different vein types: M-type (magnetite), A1-type (quartz-magnetite), A2-type (quartz-magnetite-pyrite-chalcopyrite-bornite), A3-type (quartz-pyrite-chalcopyrite), D1-type (chalcopyrite), D2-type (pyrite) and E-type (sphalerite, chalcopyrite, pyrite, calcite) veins. Veinlet nomenclature follows (Gustafson & Quiroga 1975) and (Arancibia & Clark, 1996).

Fluid inclusion study was done on the quartz of the A2-type veinlets, as those veins contained appropriate host minerals and well preserved fluid inclusion assemblages. Four types of fluid inclusions were identified: (1) halite-bearing polyphase fluid inclusions (S_H+L+V), (2) fluid inclusions with other solid phase (S+L+V), (3) two phase liquid+vapor with highly variable phase ratio (L+V), (4) two phase (L+V) fluid inclusions with fairly constant phase ratios arranged in plains. Types 1-3 occur in assemblages of primary inclusions, thus suggesting an inhomogeneous parent fluid, i. e. a boiling system, while type 4 is a secondary generation trapped from a homogeneous fluid. As the trapping of the primary fluid inclusions happened heterogeneously from an inhomogeneous system, the minimum homogenization temperatures (Th) of the aqueous liquid rich inclusions correspond to the formation temperature *(*Roedder, 1981*)*. Thus, measurements done on the inclusions with V=10 area% were taken into consideration.

Based on the results, the formation temperatures of the (L+V) inclusions cover a wide range (140-280°C) while the (L+V+halite) inclusions homogenized at temperatures > 350°C. The calculated salinities form two well distinguishable groups (0.5-5 NaCl equiv. wt% in L+V inclusions and ~ 33 NaCl equiv. wt% in L+V+halite inclusions).

This deviation can be explained most likely by the fluidmixing, though the CO_2-clathrate formation upon cooling and the salinity increase during boiling may have also a slight effect on the calculated salinities.

The hematite in the inclusions proven by the Raman spectroscopy suggests the magmatic origin and oxidizing character of the mineralizing fluids *(*Henley *et al.,* 1984*)*. The presence of $CaSO_4$ as a solid phase in polyphase fluid inclusions shows the oxidizing character of the fluids and that the magma was saturated in sulphur *(*Lickfold *et al.,* 2003*)*. The CO_2 measured in the vapor rich inclusions is a typical component of the vapor phase after the boiling event *(*Webster & Mandeville, 2007*)*.

The hydrothermal alteration types observed in the magmatic phases together with the occurrence of intermediate argillic type alteration zones suggest that the studied part represents most likely a shallow zone of a porphyry mineralization, though the observed low formation temperatures rise further questions, too.

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