

Veining and mineralization history of Bor porphyry copper–high sulfidation Cu-Au deposit (Serbia)

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The origin of massive sulfide deposits with high sulfidation Cu±As±Au assemblage and their link to the porphyry copper systems has been debated for more than 50 years, with the role of seawater, submarine vs subaerial deposition and stratovolcanoes vs collapsed calderas being the central questions (Sillitoe 1983, Stix 2003 etc.). Massive enargite- or covellite-bearing sulfide bodies are formed within the zone of advanced argillic alteration, vuggy silica caps or at the boundary between propylitic to argillic alteration zones, in proximity to fault structures and breccia pipes. The Bor deposit is the largest example of an ore system where both porphyry copper mineralization (Borska reka deep underground) and high-sulfidation orebodies are present both as veins and as massive sulfide orebodies.

The Bor metallogenic zone is hosted within the Timok magmatic complex, which is located in the Serbian part of the Apuseni-Banat-Timok-Srednogorie belt. It contains 16 ore fields with porphyry copper, high- and low-sulphidation epithermal deposits. Resources are estimated to 20 million and 1000 tons of Cu and Au, respectively (Jelenković et al., 2016). Volcanic activity that formed the Timok magmatic complex occurred during the Turonian age of the Late Cretaceous epoch and is sub-divided into three stages.

The orebodies at Bor are hosted entirely by Timok andesites of the first stage, including lavas and pyroclastic rocks. Diorite porphyry dykes 50-150 m wide were documented at deeper levels of Borska reka (Jelenkovic 1980).

Mineralization at Bor is contained in veins and in massive sulfide ore bodies of up to several tens of meters size in all directions (Tilva Ros, T, T1 and T2) with pyrite, covellite, enargite, as well as bornite and chalcopyrite in the lower part. Orebodies of native sulfur are present in the vicinity of massive sulfide bodies and indicate maximum possible sulfur fugacity conditions (Jelenkovich 2002), and native sulfur is present as a part of the high-sulfidation assemblage in late-stage epithermal veins.

Alteration in the closest proximity of the massive sulfide orebodies is advanced argillic, grading into sericitic and propylitic with chlorite further away. Earliest stage of vein formation is represented by A-type sinuous veins containing very small amount of sulfides, followed by B-type quartz-pyrite/chalcopyrite veins and pyrite paint veins. D-type quartz veins with euhedral pyrite cross-cut the A, B, and paint veins. Massive sulfide veins with mineral assemblage similar to massive sulfide orebodies cross-cut all other vein types and represent the latest stage of mineralization.

Based on ore textures, the following sequence of mineral assemblages is established for the high-sulfidation epithermal veins and massive sulfide orebodies:

1. Early pyrite, sometimes with chalcopyrite (\pm bornite) inclusions, that later gets brecciated and resorbed. Chalcopyrite and pyrite co-exist in equilibrium in the lower levels of the T orebody.
2. Chalcocite does not show an equilibrium texture but overgrows early pyrite and is present as inclusions in later stage pyrite.
3. Covellite overgrowing earlier brecciated pyrite and displaying equilibrium textures. Early, Cu-poor pyrite overgrown by rims of Cu-rich pyrite.
4. Latest stage - covellite and fine-grained pyrite overgrowing covellite blades.