Geology and Polymetallic Mineralization of the Tsagaan Tolgoi Skarn Deposit, South Mongolia

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The Tsagaan Tolgoi skarn deposit in southern Mongolia is a polymetallic site rich in zinc, lead, and iron. It lies at the boundary between the Neoproterozoic Oortsog Formation limestone and Late Triassic to Early Jurassic granitic intrusions of the Bor-Under Complex.

In this study, we examine the geological framework, mineralogy, alteration features, and geochronology of the skarn system, with a focus on the evolution of ore-forming processes.

Petrographic and mineralogical analyses of skarn samples reveal a complex mineral assemblage that includes garnets (andradite and grossular), wollastonite, hedenbergite, diopside, epidote, carbonates, and quartz. These minerals exhibit hypidioblastic to microgranoblastic textures, indicating thermal metamorphism associated with magmatic intrusion. The skarn bodies display a massive structure with variable ore mineral content (ranging from 5% to 60%), suggesting heterogeneous ore distribution. The mineralization in the skarn evolved through both prograde (with minerals such as pyroxene and wollastonite) and retrograde (including chlorite, epidote, and calcite) stages.

X-ray diffraction (XRD) and scanning electron microscopy (SEM-EDS) analyses identify three main alteration zones: argillic (featuring kaolinite and illite-smectite), propylitic (containing chlorite, epidote, calcite, and quartz), and skarn (with pyroxene, quartz, and calcite). The primary ore minerals comprise magnetite, pyrite, pyrrhotite, chalcopyrite, sphalerite, galena, and bornite, alongside secondary oxidation products such as hematite, goethite, limonite, zincite, and chalcocite. Zoned textures and intergrowths of chalcopyrite and sphalerite indicate multiphase mineralization.

U-Pb dating of zircon grains from the intrusive rocks reveals ages ranging from 250 to 257 million years ago, aligning with post-collisional magmatic events in the region. The timing and composition of hydrothermal events indicate a magmatic-hydrothermal genesis closely associated with granitoid emplacement.

We present a comprehensive analysis of the skarn mineralization, alteration assemblages, and metallogenic implications of the Tsagaan Tolgoi deposit, South Mongolia.