Economic Geology, v. 103, pp. 909–938

The Empire Cu-Zn Mine, Idaho: Exploration Implications of Unusual Skarn Features Related to High Fluorine Activity

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Abstract

The Empire Cu-Zn skarn deposit is unusual because of the proximal position of Zn mineralization, abundance of endoskarn, and the extremely vermicular texture of quartz phenocrysts in the related intrusive rocks. Cu-Zn skarn occurs at the contact between Upper Mississippian White Knob limestone and the granite porphyry phase of the Mackay Stock which consists, from early to late, of quartz monzodiorite, granophyre, granite porphyry, porphyritic granite, and many dikes. The late phases have high F and also extremely vermicular quartz phenocrysts. Endoskarn is more abundant than exoskarn. The earliest alteration of the intrusive rocks consists of disseminated diopsidic pyroxene ($Di_{64}Hd_{36}$ to $Di_{88}Hd_{12}$), actinolite, and titanite. This assemblage was cut by early scapolite (Me_{18} to Me_{35}, mostly $Me_{18\text{-}26}$) and/or green pyroxene ($Di_{14}Hd_{80}$ to $Di_{20}Hd_{77}$) veinlets, with or without wollastonite halos. These early veins were then cut by main-stage endoskarn veins that typically have a garnet + minor pyroxene inner zone, a wollastonite and/or pyroxene ± Ca-rich plagioclase (An_{56} to An_{89}) envelope, and a halo containing disseminated, fine-grained alteration minerals of the same assemblage as the envelope. Some veins contain only the envelope assemblage and are interpreted to represent the alteration front. The inner zone locally contains vesuvianite. Where many veins intersect, endoskarn is massive. Pyroxene is zoned around fluid conduits; the distal pyroxene is Fe rich (hedenbergitic) whereas the proximal pyroxene is Fe poor (diopsidic). The garnet changes in the opposite way, being Fe poor-Al rich (grossularitic) in locations distal to the fluid conduits, and Fe rich (andraditic) in proximal locations. In contrast, in the exoskarn, all pyroxene is diopsidic and garnet is andraditic. Weak, retrograde alteration composed of quartz + calcite + chlorite with minor fluorite, talc, and epidote overprinted both endoskarn and exoskarn. Magnetite precipitated after garnet-pyroxene in both endoskarn and exoskarn. Sphalerite precipitated together with chalcopyrite in proximal locations and is associated with retrograde alteration. Other ore minerals include minor molybdenite, bornite, pyrite, galena, arsenopyrite, native Au, as well as supergene minerals such as chrysocolla, malachite, azurite, native Cu, and limonite.

Fluid xenoliths from pyroxene in early endoskarn veinlets homogenize at >600°C. Massive endoskarn and exoskarn replacing limestone inclusions in granite porphyry formed at 500° to >700°C, whereas the highest temperature inclusions, >700°C, occur in narrow garnet + minor pyroxene veins. Fluid inclusions in exoskarn replacing wall rock have homogenization temperatures of 500° to 650°C. Retrograde alteration and Cu-Zn mineralization occurred at 250° to 300°C. Fluid inclusions in prograde minerals contain daughter minerals, whereas fluid inclusions in retrograde minerals do not, indicating a decrease in salinity with time. Late-stage fluids have low eutectic temperatures, indicating the possible presence of KCl, NaCl, $FeCl_2$, $CaCl_2$, $MgCl_2$, K_2CO_3, and/or Na_2CO_3.

Formation of the unusually abundant endoskarn, the proximal position of Zn mineralization, and the extremely vermicular texture of quartz phenocrysts are all believed to have been promoted by the high F content of the magmatic fluid. These features may serve as exploration indicators of associated high F mineralization such as buried porphyry Mo deposits.

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0361-0128/08/3757/909-30