

Mineral chemistry of greenrock alteration associated with the porphyry Cu-Mo mineralization at the Gibraltar deposit, south central British Columbia, Canada

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The Gibraltar deposit with the geological reserves (past production plus reserves) of 2.8 Mt Cu is hosted by Granite Mountain batholith of late Triassic age in the Quesnellia terrane. The batholith, which has the surface exposure of 15 km x 10 km, is mostly composed of tonalite with minor variation in modal abundances of felsic and mafic minerals. Igneous minerals are plagioclase, quartz, biotite, hornblende, with minor amounts of titanite, zircon, apatite and magnetite. Bulk rocks show a typical subduction-related geochemical signature with negative anomalies of high field strength elements, such as Nb, Ta and Ti, with minor positive and negative Eu anomalies ($Eu/Eu^*=0.09-1.2$). The mineralization is accompanied by extensive alteration in the tonalite, which produced illite, quartz, rutile, titanite, magnetite, apatite, chlorite and epidote. The high-temperature potassic alteration zone was likely present in the centre of the current mining operation, but the alteration has been obscured by the replacement of secondary biotite by chlorite. Among alteration minerals, epidote and chlorite are ubiquitous in the tonalitic rocks in and around the mine, producing green rock alteration. Epidote group minerals primarily replace plagioclase. Chlorite is also common after hornblende and biotite, and a mixture of titanite and rutile replaces biotite and hornblende. Epidote minerals are light grass green in hand specimens and also thin sections. They show a large compositional variation even within one sample from Al-rich (high clinozoisite component) to Fe-rich epidote, suggesting multiple alteration events or reflecting varying fluid composition within a hydrothermal system. Some are yellowish in thin sections and they contain significant allanite component with high La_2O_3 (up 9.54 wt%) and Ce_2O_3 (up to 14.7 wt%). These Ce-La-rich epidote grains contain higher concentrations of other REEs, Mn, Y and Th than Fe-rich epidote. These LREE-rich epidotes form isolated grains within chlorite aggregates in epidote-rich tonalities. In contrast, Fe-rich, REE-poor epidote is abundant and preferentially replaces plagioclase. Igneous titanite (up to 2 mm) is low in Al_2O_3 (~1.2 wt%) whereas hydrothermal titanite contains high Al_2O_3 ranging from 2 to 6 wt%. Hydrothermal titanite is more abundant than igneous, and shows a wide compositional variation of Mg and Fe. Rocks with greenrock alteration show high abundances of

U, Pb and K in bulk rocks compared to epidote-poor samples. The enrichment of U and Pb in bulk rocks is likely due to their incorporation in epidote as minor components.