Bulk Rock and Melt Inclusion Geochemistry of Bolivian Tin Porphyry Systems

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Abstract

The Miocene tin porphyry systems of Llallagua, Chorolque, and Cerro Rico have a moderately fractionated rhyodacite to dacite bulk rock composition. Ta, Zr, and TiO_2 concentrations are close to average upper crustal values. Hydrothermal overprint is reflected by strong enrichment of B, Bi, and Sn (>100 times upper crust) and by moderate enrichment of Sb, Pb, Ag, As, Au, and W (10-100 times upper crust). Melt inclusions in quartz phenocrysts have been analyzed by electron and proton microprobe techniques. The melt inclusions are characterized by highly fractionated rhyolitic composition with strong depletion of compatible components (0.02-0.14 wt % TiO_2, 15-85 ppm Zr). The trace element pattern with strong enrichment of incompatible elements (5-17 ppm Ta, 7-85 ppm As, 35-643 ppm B, 20-194 ppm Cs, 13-623 ppm Li, and 5-43 ppm Sn) is similar to tin granite systems. The compositional gap between melt inclusion and bulk rock geochemistry and the large compositional variations of trace elements among melt inclusions cannot be explained by crystal-liquid fractionation in a closed system alone.

We propose a scenario of selective quartz crystallization in a compositionally zoned magma chamber ranging from intermediate to highly fractionated melt portions. Influx of primitive melt into the magma chamber is thought to have resulted in mixing and to have triggered volcanic activity that led to the intermediate degree of fractionation of the exposed tin porphyry systems. Unexposed tin granitic portions released magmatic vapor phases that followed the volcanic vents and resulted in hydrothermal alteration and mineralization. Supply of magma and metals from different portions of compositionally zoned magma chambers can explain the exceptional metallogenic association of Bolivian tin porphyry mineralization with only moderately fractionated igneous rocks. It is probably those portions of a general tin granite composition that are chemically linked to tin mineralization, whereas the exposed rhyodacitic stocks essentially provide the structural focusing for magmatic vapor phases from a deeper stratified magma reservoir.