No tin deposits in Chile? Focus on one exception: the Belén -Tignamar district, Arica

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The Central Andes are rich in metal deposits associated with magmatism arising from subduction of oceanic lithosphere under South America. Bolivia, southern Peru and northwestern Argentina are rich in tin deposits associated with Paleozoic to Pliocene igneous rocks; yet coeval magmatic centres in immediately adjacent Chile rarely contain tin. One anomaly is the polymetallic Capitana deposit, Belén-Tignamar district, in the high Andes of Arica (18°35'S; 69°30'W). A unique specimen collected by M. Zentilli in the abandoned mine in 1963 is being used as a focus to review the question of why tin is so rare in Chile. Reportedly, a Capitana vein contained 7% Sb, 0.1% Ag, 5% Cu, 2.5% Pb, 11.8% Bi, and 4.7% Sn.

There have been many different hypotheses concerning the contrast between tin-rich Bolivia and tin-deprived Chile. Workers suggested that granitophile tin originated in anomalously tin-rich crust, or was remobilized from pre-existing tin concentrations. Differences in elevation and depth of erosion were considered to play a role. In the 1970s a popular hypothesis proposed that during subduction, tin was selectively distilled from subducted lithosphere, deeper and farther (east) than copper. More recently, experimental studies and chemical modeling have shown that when magmas evolve with low oxygen fugacity, such as when interacting with reducing carbon in the crust, Sn^{2+} behaves as incompatible element and becomes enriched in hydrothermal fluids, whereas in oxidized magmas Sn^{4+} gets incorporated in rock-forming minerals, and is thus dispersed. If the reduced stannous fluids encounter oxidizing conditions, tin is precipitated as cassiterite (SnO_2); in the presence of S, As, and Sb, for example in epithermal Capitana, tin goes into sulphosalts.

The mineralogy and geochemistry of the ore specimen have been studied using reflected light microscopy, XRD, electron microprobe and bulk chemical analysis. The specimen has quartz, pyrite, sphalerite, (covellite), tetrahedrite-tennantite ($Cu_{12}Sb_4S_{13}$ -$Cu_{12}As_4S_{13}$) and other sulphosalts. Chemically it contains 6.1% Cu, 0.5% Zn, 10% Pb, 4.8% Bi, 0.7% Ag, 0.05% Sn (predominantly in sphalerite), 3.5% Sb, 3.1% As, and is enriched in Hg (46 ppm) and U (57 ppm; Th/U = 0.01).

The geological map may hold the clue to the existence of this unique tin deposit in Chile. Capitana is hosted by Mesozoic to Cenozoic volcanic rocks, and associated with a Tertiary porphyritic intrusive. A most unusual fact is that within the Belén-Tignamar district there are outcrops of an isolated, fault bounded inlier of the Belén Schist, a Proterozoic-Paleozoic gneissic complex of metamorphosed igneous and sedimentary rocks similar to those known from the crystalline basement of the Bolivian tin province.

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