METALLOGENY OF TIN - REVISITED

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About 80-85 % of all historically mined tin of about 25 Mt Sn is from a few tin ore provinces only (100 to 1000 km scale). These are, in decreasing importance, the Southeast Asian tin belt (Indonesia, Malaysia, Thailand, Burma) with 45 %, South China with 16 %, Andean tin belt (Bolivia, southern Peru) with 14 %, and Cornwall with 8 %. Primary tin ore deposits are part of magmatic-hydrothermal systems invariably related to late granite phases (tin granites, pegmatites, tin porphyries), and may become dispersed by exogenic processes and then eventually form placer deposits within 10-20 km from their primary source, due to the density of cassiterite (7.4 g/cm^3) and its hardness and chemical stability. Alluvial placer deposits were usually the starting point for tin mining, and have provided at least half of all tin mined by a variety of mostly artesanal and semi-industrial techniques. They have been by far the most important tin source in the Southeast Asian tin belt, and even today nearly all Indonesian tin production is from deep dredging of drowned alluvial tin placers in the Sunda shelf.

The small-volume and late granitic phases in spatial, temporal and chemical relationship to tin ore deposits are highly fractionated. Systematic element distribution patterns in these granitic phases and their associated much larger multiphase granite systems suggest fractional crystallization as the main petrogenetic process controlling magmatic evolution and magmatic tin enrichment. Oxidation state seems to control the bulk tin distribution coefficient, with low oxidation state favoring incompatible behavior of divalent tin in felsic systems, also mineralogically expressed by accessory ilmenite ($FeO^{\cdot}TiO_2$) as opposed to accessory magnetite ($FeO^{\cdot}Fe_2O_3$) in more oxidized melt systems. This difference in the accessory mineralogy, and hence metallogenic potential, can be easily detected in the field by a hand-held magnetic susceptibility meter.

The hydrothermal system is a continuation of the magmatic evolution trend and necessary consequence of the crystallization of a hydrous melt. The exsolved highly saline aqueous fluid phase, enriched in boron and/or fluorine plus a wide metal spectrum, can be accomodated and stored by the intergranular space in some crystallized melt portions, or accumulate in larger physical domains, accompanied by focused release of mechanical energy (brecciation). The hydrothermal mobility of tin is largely as Sn^{2+}-chloride complexes; the precipitation of tin as cassiterite involves oxidation. Tin typically characterizes the inner part of much larger km-sized zoned hydrothermal systems with the chemical signature Sn-W-Cu-As-Bi in the inner part (greisen, vein/stockwork/breccia systems, skarn) and a broader halo with vein- or replacement style Pb-Zn-Ag-Sb-Au-U mineralization. This zoning pattern may also occur telescoped on each other.