Ore minerals as accessory magmatic phases: The products of extreme fractionation or metasomatism?

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Highly evolved granitic systems may contain disseminated Ta-Nb-Sn-W ore minerals. It has long been debated whether the mineralization is the result of magmatic or hydrothermal processes. There is little doubt that some of the mineralization is hydrothermal in origin, evident from the common occurrence of wolframite and cassiterite in veins in the wallrocks surrounding these highly evolved granites and pegmatites. However disseminated columbite-tantalite, and to a lesser extent cassiterite are intergrown with magmatic silicate minerals and thus are interpreted to have crystallized from silicate melts.

Where magmatic Ta-Nb(-Sn) mineralization is interpreted to occur, it is typically associated with granites or pegmatites with high concentrations of fluxing elements such as Li, F, P and B. However, experiments show that these elements have a minor or no effect on the solubilities of Ta-Nb-Sn-W minerals in melts. Solubilities are strongly related to the molar Al/(Na+K) (ASI) composition of the melt and temperature. Thus the dominant affect of the fluxing elements is to lower the solidus temperature of the melt, which allows melts to undergo extreme fractionation, i.e., to attain trace element concentrations high enough for accessory phase saturation.

There is a general consensus that pegmatite textures result from rapid crystal growth. The rapid crystal growth in turn may be related to the high concentrations of fluxing compounds, which decrease melt viscosities and increase diffusivities. Accessory phases such as columbite-tantalite also display rapid growth textures such as skeletal crystals. An important question is: “what process causes the supersaturation that results in the rapid crystal growth?” One possibility is undercooling, however rapid growth textures are not necessarily related to the borders of pegmatites where the temperature gradients would have been highest. Another important texture observed in tantalum mineralization is that the ore minerals commonly occur as multi-mineral clusters, e.g., tantalite±wodginite±cassiterite±tapiolite±apatite. This texture suggests that crystalization may not be controlled by the concentrations of high field strength elements (Ta, P etc.) in the melt, rather, metasomatism of bivalent cations, e.g., Mn, Fe, Ca, Sn may trigger accessory phase/ore deposition in a volatile-saturated silicate melt.