Metal enrichment in granitic melts: the role of protolith chemistry and partial melting conditions

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The mobilization of ore elements during partial melting of metasedimentary rocks critically influences the potential of granitic melts to develop mineralizations. We present data from migmatite samples together with thermodynamic modeling results to highlight the importance of protolith chemistry, melting conditions and mode of melt extraction during the generation of Sn-enriched granitic melts.

The distribution of elements between melt and restite is controlled by the stability of element-sequestering minerals during melt generation. The stability of a phase with high affinity for a certain element in the restite prevents enrichment of the corresponding element in the melt and leads to its enrichment in the restite. For Sn, muscovite, biotite, titanite and magnetite represent such sequestering phases in metasedimentary rocks. As muscovite and biotite are involved in dehydration melting at different conditions, those two minerals play a key role for the distribution and mobilization of Sn during partial melting. Release of Sn during the breakdown of muscovite at lower temperatures does not necessarily lead to Sn-rich melts, as large quantities of Sn can be redistributed into restitic biotite, leading to Sn-enrichment in the restite. Further heating, eventually resulting in biotite dehydration melting of Sn-enriched restitic rocks leads to Sn-rich melts, if no other Sn-sequestering phase is stable. Biotite dehydration melting starts at elevated temperatures (>800 °C). Crust internal heat production alone is not sufficient to reach such high temperatures. Therefore, there must be additional advective heat input to reach biotite stability limits. Such heat input may originate from input of mantle melts in subduction zones (e.g. South China, Malaysia), crustal extension (e.g. Cornwall) or the emplacement of UHT metamorphic units in settings of continental collision (e.g. Variscan orogen, in particular the Erzgebirge).

Strongly weathered Paleozoic shales represent an ideal protolith for the generation of Sn-enriched granitic melts. Due to the intense weathering they show a depletion in the feldspar-bound elements Ca, Na, Sr and Pb and a relative enrichment in Al, K, Rb and Sn. The distinct chemical composition (low Ca, Na and high Al, K) leads to a very specific mineral assemblage with high modal amounts of hydrous minerals during prograde metamorphism. These high amounts of muscovite and biotite lead to high amounts of melt during partial melting. The concentration of Sn in the melt is not only a function of Sn concentration in the protolith but also of the melt volume and removal of low-T melts. If Sn is released into large amounts of low Sn-melt from muscovite dehydration melting, the overall concentrations will remain low. Thus, melt extraction prior to the decomposition of biotite and the resulting release of Sn
enhances Sn concentration in late melts. The high modal abundance of muscovite leads to high melt volumes at low temperatures, which facilitates the extraction of melt before the breakdown of biotite. Partitioning of Sn into small melt volumes results in elevated concentrations in the melt, even before further enrichment by fractional crystallization starts.

Figure 1. Equilibrium phase diagram for a deeply weathered shale. The red line represents the solidus of the system and the melt generation by muscovite breakdown at elevated pressures. The green line denotes the biotite stability limit. Melts generated before the breakdown of biotite are unlikely to be Sn-enriched as much of it is redistributed into restitic biotite.