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Enrichment and mobilization of tin during metamorphism

OWISHI SARKAR[1], ROLF L. ROMER[1], UWE KRONER[2] AND CLAUS LEGLER[3]

[1]GFZ Helmholtz Centre for Geosciences
[2]TU Bergakademie Freiberg
[3]Freiberg

This study presents an atypical example of tin (Sn) enrichment from the Erzgebirge area, a Variscan metamorphic complex in Central Europe known for its major tin deposits associated with post-orogenic granites and minor strata-bound mineralization within metasedimentary rocks. Specifically, the phyllites and mica schists from the Bockau area in the Western Erzgebirge contain 50-200 ppm Sn (locally up to 5000 ppm). These rocks are derived from Early Ordovician feldspar-free shales, characterized by low concentrations of Na, Ca, Sr and Pb indicating intense chemical weathering, and Sn contents (~15-20 ppm) that are higher than those typically found in siliciclastic sediments (~5-10ppm). These data indicate that Sn addition and mobilization occurred during metamorphism of the shales. The high Sn contents are sequestered in prograde metamorphic minerals and cassiterite (SnO_2) inclusions, with a second generation of cassiterite forming during post-peak chloritization of the schists. This study addresses the enrichment and remobilization processes of Sn in the shales. Compositional comparison between the un-metamorphosed shales and schists reveals significant increases in Si, Fe, and Sn contents. Later chloritization of biotite led to a decrease in K, Rb, and Ba contents, while Ti and Sn were released, forming ilmenite inclusions ($FeTiO_3$) and a second generation of metamorphic cassiterite, respectively. Lighter elements, like Li and B were mobilized during metamorphism, preferentially incorporating into biotite and chlorite, respectively. Despite the open-system behavior and substantial changes in elemental composition, the radiogenic isotopic ratios of Sr, Nd, and Pb show no evidence of contributions from an isotopically contrasting reservoir. This suggests that the mobilization and enrichment of elements, particularly Sn, primarily represent internal redistribution within the meta-sedimentary units rather than contributions from external fluids.

Partial melting of such enriched rocks is likely to produce Sn-rich melts. This has important implications for tin deposit formation, as it suggests that (i) source rock composition is a critical factor, and (ii) extreme magmatic fractions typically required for melts derived from normal siliciclastic sediments may not always be necessary to form a deposit. Therefore, redistribution of Sn during metamorphism may play a potentially significant role in the later formation of primary tin deposits.