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Tracking sources of mineralising fluids using tourmaline compositions: A case study from the Ardlethan tin deposits, Eastern Australia

Carr, P.A.¹, Bennett, V.C.¹, Norman, M.N.¹ and Blevin, P.L.²

¹ Research School of Earth Sciences, The Australian National University, 142 Mills Rd., Canberra ACT 2601 Australia, Patrick.Carr@anu.edu.au

² Geological Survey of NSW, Maitland, NSW 2320 Australia.

Multiple generations of tourmaline commonly accompany cassiterite-bearing Sn deposits, both within the source granite and associated with mineralization in veins, breccia pipes and greisens. This results from the incompatible behaviour, and consequent enrichment, of boron in late-stage melts and fluids. To explore the use of tourmaline for determining primary compositions and subsequent evolution of melts and fluids leading to Sn mineralization, we measured the major, minor, trace element and Sm-Nd and Rb-Sr isotopic compositions of tourmaline associated with the Ardlethan tin deposits, Lachlan Orogen, eastern Australia. The samples are from four settings: two porphyry-style breccia pipes (Mine Breccia Pipe, MBP; White Crystal Breccia Pipe, WCBP) hosted by the Mine Granite (MG) [1], and two minor greisen deposits (Little Bygoo and Big Bygoo) hosted in the Ardlethan Granite (AG). The age of the MG is 426.6 ± 3.1 Ma, but magmatic fluids contributing to the mineralization are thought to have originated from the younger 415.0 ± 2.5 Ma AG [1,2] or possibly a volumetrically minor 412.0 ± 1.9 Ma 'cassiterite porphyry' [1,3]. U-Pb cassiterite geochronology indicates mineralization occurred 411-405 Ma, but cannot distinguish the source intrusion.

Tourmaline samples were collected from within granites (occurring interstitially and within quartz-tourmaline nodules) and in deposits (as breccia infill and within greisen assemblage, and where possible from samples containing cogenetic cassiterite). Major and minor elements were determined by EMP, trace elements by LA-ICP-MS, and Rb-Sr and Sm-Nd isotopic compositions by isotope-dilution thermal ionisation mass spectrometry. All tourmaline samples have schorl compositions, being rich in Fe and Na. Median Sn concentrations of tourmaline in the AG increase from 33 ppm in interstitial tourmaline to 74 ppm in nodular tourmaline, highlighting the incompatible nature of Sn in reduced, peraluminous felsic melts and recording a primary enrichment process. Median Sn concentrations increase to 395 ppm in breccia infill tourmaline associated with cassiterite in the MBP. REE concentrations of tourmaline from the AG and MG are similar, with LREE-enriched ($La_{CN}/Sm_{CN} = \sim 20$) and flat HREE patterns, and are consistent with whole rock values for those units. Whole rock Eu anomalies are all strongly negative, whilst in all tourmalines they are strongly positive. This difference is likely due to redox conditions within the fluids [4] and tourmaline partitioning effects [5]. The two greisen deposits have REE patterns similar to their host granite and indicate that fluids derived from the AG were responsible for Sn mineralization. Tourmaline occurring within both breccia pipes is characterised by negative HREE slopes ($Tb_{CN}/Lu_{CN} = \sim 0.3$), indicating input from the 'cassiterite porphyry', which also has a negative HREE slope. Initial $^{87}Sr/^{86}Sr$ tourmaline compositions (calculated using zircon and cassiterite crystallisation ages) are variable (0.708-0.729) whereas relatively constant initial ϵNd (≈ -3) characterise the AG, MBP and Little Bygoo tourmaline. The Nd-Sr isotopic relationships may reflect increasing incorporation of radiogenic Ordovician sediments through AFC processes although contamination with high Rb/Sr phases within tourmaline (e.g. mica) is also plausible. The WCBP tourmaline is distinct with lower initial $\epsilon Nd = -10$ and lower initial $^{87}Sr/^{86}Sr = 0.716$, and is similar in composition to the MG, indicating significant fluid-rock

interaction. Tourmaline geochemistry identifies at least two magmatic sources to mineralization at Ardlethan and subsequent fluid-rock interactions at some sites of deposition. Tourmaline is shown to record primary enrichment processes whilst also withstanding secondary pervasive alteration.

References:

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