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Tin granites: Multiple pathways toward ore formation

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Recent years have seen tin largely overlooked as a pivotal critical metal for the technological revolution and the green energy transition. Its demand is soaring as it powers a diverse array of modern applications, sparking renewed scientific interest. The term “tin granite” has been traditionally used for more than 2 centuries[1], referring to the close association between specific granite and tin occurrences, yet, the term lacks a clear definition, raising fundamental questions. What is a tin granite? Does a single archetype truly account for all tin-bearing systems? Driven by economic interest, research has largely focused on defining optimal conditions required to form a “tin granite”. Yet, for instance, cordierite-bearing granites, genetically associated with the world’s largest tin deposit of San Rafael (Sn-Cu, Peru), have nothing special[2], and differ markedly from biotite granites associated with the world-class Sn>>W Cornish province. This underscores the inherent complexity of natural systems and challenges the idea of a single, universal route to economic mineralisation. It is crucial to move beyond the classical “source-transport-deposition” framework and explore the multiple pathways toward ore formation. Developing comprehensive metallogenic models is essential for guiding exploration and future discoveries, and requires innovative approaches coupled with cutting-edge analytical techniques.

Among the many interacting processes and intensive parameters that can enrich tin by over three orders of magnitude relative to average crustal levels, redox conditions - particularly reducing environments - have long been recognised as critical[3]. However, largely due to analytical limitations, no study has systematically documented the oxidation state of tin in crustal rocks involved in ore formation. Our recent work[4] demonstrates that X-ray Absorption Near Edge Structure (XANES) spectroscopy enables direct assessment of tin oxidation state at concentrations as low as 30 ppm. Our findings challenge the classical view and the scenarios proposed represent a step toward a better understanding of the natural variability of “tin granites”.

[1]Humboldt, 1823. *Essai Géognostique Sur Le Gisement Des Roches Dans Les Deux Hémisphères*.

[2]Harlaux et al. 2021. *Lithos* 400–401, 106409.

[3]Lehmann, 1990. *Metallogeny of Tin*. Vol. 32.

[4]Michaud et al. 2025. *Scientific Reports* 15, 34476.