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The volcanic-plutonic connection and fertility of highly evolved magma systems: A case study from the Herberton Sn-W-Mo mineral field, Queensland, Australia

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To discern differences between “fertile” and “non-fertile” igneous rocks associated with Sn, and W + Mo mineralisation, synchronous plutonic and volcanic rocks from the world-class Herberton Mineral Field of North Queensland have been studied in detail.

Whereas previous studies discerned the existence of two distinguishable suites of intrusive rocks from geochemical analyses (as summarized by Champion and Bultitude, 2012), the latest research into the whole rock geochemistry of extrusive rocks, and the U / Pb isotopes, Hf isotope and trace element signatures of zircons extracted from the region’s igneous rocks has (a) more precisely defined the geochemical and geochronological characteristics of the two synchronous intrusive-extrusive suites; and (b) revealed the genetic links between the intrusive suites and coeval extrusive rocks.

According to the results, the younger intrusive rocks crystallized at 303-310 Ma, formed less reduced magmas that moderately fractionated to produce intra-plutonic W-Mo mineralisation. The geochemical and isotopic features of the coeval volcanic succession can be best reconciled utilising the volcanic-plutonic connection model of Bachmann (2008), whereby the volcanic rocks represent fractionated derivatives of the intrusive rocks.

The older sequence of intrusions emplaced at 317-330 Ma, formed relatively low $f(O_2)$ magmas that strongly fractionated to produce late-stage differentiates from which hydrothermal fluids, enriched most significantly in Sn, were released. Although their Hf isotope demonstrates similar features, the synchronous volcanic rocks of this suite are compositionally less evolved than the Sn-mineralised intrusive rocks, thereby requiring formulation of a model entailing separate sequences of development for the breached eruptive magma chambers that produced sunken calderas, and the constrained intrusions that released copious mineralising fluids at the end of a protracted fractionation process.

To explain the formation of these two igneous regimes in a 30 million year period, we propose the Herberton region transitioned from a compressive tectonic environment with a thicken crust, to conditions of crustal thinning and lithospheric extension due to progressive slab rollback between the mid-Carboniferous and early Permian.