

Fingerprinting Intrusion-Related Versus Orogenic Gold, Western Lachlan Orogen, Tasmanides, Australia

Helen McFarlane^{1,2}, Fariba Kohan Pour^{1,2}, Cameron Cairns³, Helen McFarlane^{1,2}, Ross Cayley³, Zsanett Pinter⁴, Michael Verrall¹, Colin MacRae⁴, Jacob Walmsley¹, Steven Boger⁴, James Lewis¹

¹CSIRO Mineral Resources, Kensington, Australia, ²MinEx CRC, Bentley, Australia,

³Geological Survey of Victoria, Melbourne, Australia, ⁴CSIRO Mineral Resources, Clayton, Australia

The Western Lachlan Orogen (WLO) of southeastern Australia hosts one of the world's largest gold provinces, with multi-million-ounce Ordovician orogenic deposits in the Bendigo and Stawell zones. According to the Lachlan Orocline model, the under-explored Tabberabbera Zone, a potential along-strike extension of the Bendigo Zone, comprises potential for both orogenic-style and intrusion-related gold deposits. However, efforts to constrain the mineralisation style and implementing effective exploration strategies are hindered by the close spatial relationship of Devonian plutons and orogenic-style deposits. To address this challenge, we investigate eight gold deposits located in the WLO, using a macro- to micro-scale analytical approach, integrating micro-XRF MAIA mapping, automated mineralogy, EPMA-CL mapping, and apatite chronochemistry.

Gold mineralisation near the Devonian I-type Beechworth Granite, in the northern Tabberabbera Zone, occurs as free gold in quartz veins, accompanied by native bismuth, Bi-tellurides, lollingite, and hydrothermal apatite coeval with Devonian intrusions, suggesting an intrusion-related style. High Ti-in-quartz and U-Pb thermal reset of detrital apatite further indicate temperatures above 375°C. Conversely, gold at Haunted Stream is locked within sulphides and lacks Bi and Te, indicating a classic orogenic style. Apatite compositions differ between intrusion-related and orogenic-style mineralisation with the latter exhibiting higher Sr/Y, Th/U, HREE/MREE, positive Eu anomaly and lower Mn/Fe inferring crystallisation from oxidising fluids. Hydrothermal apatite ages suggest: (1) gold remobilisation during the emplacement of the Upper Devonian Harcourt Granodiorite overprinting orogenic-style mineralisation at Gill Reef, Bendigo; (2) Triassic mineralisation at Happy Valley driven by distal magmatism; and (3) Jurassic reactivation of the Haunted Stream Fault during the opening of the Otway Basin.

Our findings demonstrate that apatite is a potential indicator for fingerprinting ore-forming fluids and constraining gold mineralisation styles. This study provides new insights for refining mineral exploration models and improving deposit classification and mineral exploration targeting in regions of overlapping intrusion-related and orogenic signatures.