Expanding the Chronological Evolution of Winu Cu-Au Deposit (Western Australia): Insights from Modern In Situ Titanite-Apatite-Calcite Petrochronology

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Mineral systems evolve through a protracted process with multiple stages of fluid activity and mineral alteration. Such scenario promotes mineral recrystallisation and fluid-temperature driven isotopic resetting of key geochronometers, challenging to establish the chronology of mineral systems and its genetic model. Modern petrochronology opens a new avenue to elucidate the chronological evolution of mineral systems. We present novel in situ titanite, apatite and calcite U-Pb dates from the concealed Winu Cu-Au deposit located in the Great Sandy Desert, Western Australia. Winu is hosted in metamorphosed massive sandstones and siltstones, with mineralisation associated with numerous thin, brittle veins and breccias. Although molybdenite Re-Os model ages suggest chalcopyrite precipitation between 658-655 Ma, the timing of vein formation is uncertain. Medium-to fine-grained anhedral titanite disseminated in polymineralic fine-grained matrix (quartz, alkali feldspar, micas, chlorite and zoisite) yield U-Pb ages of 668 ± 3 and 666 ± 3 Ma, whereas medium- to fine-grained anhedral apatite disseminated in the matrix yield U-Pb ages spanning 670–600 Ma. These data suggest that both phases record the regional high-temperature metamorphism and ductile deformation in the Paterson Orogen, which promoted early hydrothermal fluid activity as identified in the Nifty Cu deposit. Yet, fine-grained, disseminated calcite grains in polymineralic matrix yield the oldest U-Pb date of 522 ± 17 Ma, whereas calcite veins yield Carboniferous to Permian dates spanning 375–270 Ma. Although often associated with mineralised assemblages, the calcite U-Pb dates apparently record the timing of large-scale intracontinental reactivation of craton margins coeval with the development of the Canning Basin. The study reinforces a multi-stage evolution, with early hydrothermal activity associated with Neoproterozoic tectonism and later overprints coinciding with intracontinental extension events. These integrated datasets provide new constraints on the timing of structurally controlled mineralization at Winu, refining exploration models for orogenic-related ore systems in the region.