Archaean hydrothermal fluid modified zircons at Sunrise Dam and Kanowna Belle gold deposits, Western Australia: Implications for post-magmatic fluid activity and ore genesis

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**Abstract**

To further our knowledge of ore genesis in one of Australia’s preeminent ore districts, we have completed a comprehensive geochemical study of ore-related porphyritic intrusions from the Archaean Kanowna Belle and Sunrise Dam gold deposits (both >10 Moz), Eastern Goldfields, Western Australia. Zircon samples (including samples from the newly developed Velvet mine) with ages ranging from 2.8 to 2.2 Ga, were investigated for O-OH isotopic signatures, trace element abundance, and U-Th-Pb compositions to elucidate the nature of the magmatic source and ore-related fluid. These intrusions have similarly high Sr/Y and La/Yb ratios to adakites from the Aleutian and Cook Islands, but lower Mg# values and higher K2O contents, suggesting they were derived from partial melts in a thickened crust. The modern analogs are post-collisional, high-Sr/Y granitoid porphyries in southern Tibet. Magmatic zircons have intermediate δ18O values (+5‰ to +6.3‰), and estimated magmatic crystallization temperatures (Ti-in-zircon) in between 660–760 °C. They are interpreted as having crystallized from positive δ18O magmas during water-fluxed melting of juvenile lower crust. Hydrothermal fluid modified zircons are texturally indistinguishable from magmatic zircons, but their trace element, OH, and isotopic compositions are distinct. The involvement of hydrothermal fluid in zircon growth is evidenced by a negative correlation between OH content and δ18O. In addition, the studied hydrothermal fluid modified zircons are characterized by high La contents, flat rare earth element patterns, weak Ce anomalies, and low-pH hydrothermal fluid. Such fluids are common in eastern Yilgarn gold camps.

**Keywords**: Hydrothermal fluid modified zircon, fluid, OH, O isotope, gold mineralization, Archaean; From Magmas to Ore Deposits

**Introduction**

The Eastern Yilgarn Craton is one of the largest gold camps in the world, with many giant gold deposits (e.g., Blewett et al. 2010; Goldfarb and Groves 2015; Wang et al. 2017). To improve our understanding of gold genesis in the Eastern Yilgarn Craton, we need more precise geochronological and isotopic data. Zircon is generally resistant to post-crystallization alteration, so the timing of gold mineralization can be either directly determined on hydrothermal zircon or indirectly constrained using magmatic zircon (Claoue-Long et al. 1988; Pelletier et al. 2007; Zhou et al. 2012). Zircon O-Hf isotopic signatures are widely used to indicate magmatic source composition. However, the effect of fluids on the U-Th-Pb and O isotope systems in pre-Proterozoic zircons has been only sparsely studied (Pidgeon et al. 2013). Pidgeon et al. (2017) proposed that low-temperature fluids affected both the U-Th-Pb ages and O-OH isotopic compositions of zircons from Jack Hills. However, the effect of higher temperature ore fluids or post-magmatic fluids on Archaean zircons has not been well investigated.

Two Archaean gold deposits (Sunrise Dam and Kanowna Belle) that formed at sub-amphibolite metamorphic facies conditions (~greenschist) in the Eastern Goldfields of Western Australia show a close association with Archaean felsic intrusions (Wang et al. 2017) and were subjected to a significant number of hydrothermal events. Zircons from these deposits were selected for detailed elemental and isotopic study to better understand the nature of post-magmatic fluids and their effect on zircon growth. This approach has enormous potential for determining the fluid source and constraining the timing of mineralization.

**Geological setting of the Eastern Yilgarn Craton (EYC)**

The Yilgarn Craton is composed of six tectonostratigraphic terranes (Narryer, South West Gneiss, Youanmi, Kalgoorlie, Kurnalpi, and Burtville; Cassidy et al. 2006). The last three of these terranes constitute the EYC or Eastern Goldfields superterrane (Fig. 1), which is bounded by interconnected, north-northeast-striking and east-dipping crust-penetrating structures (Ida, Ockerburry, and Hootanui faults; Swager et al.