

## A Multi-platform Microanalysis Approach to Unravelling Geological Problems: a Case Study from Olympic Dam South Australia

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The ca. 1.6 Ga iron-oxide-Cu-Au (IOCG) Olympic Dam (OD) deposit in South Australia is considered the archetypal example of IOCG formation. It is the largest known IOCG system on Earth, with a Cu-U-Au-Ag resource in excess of 10 Bt [1]). Like other IOCG systems worldwide, the OD ores record an extended complex formation history that is expressed in a diverse package of preserved mineral assemblages [2]. Pulling apart both the chemical and temporal complexity at the micro/nano scale is key to understanding the evolution of the deposit.

Iron-oxides (dominant hematite  $\alpha$ -Fe<sub>2</sub>O<sub>3</sub> and subordinate magnetite Fe<sub>3</sub>O<sub>4</sub>) are the most dominant minerals within the deposit, and the most visible expression of hydrothermal alteration of the host granite. These iron-oxides can be directly related to the mineralizing process thus information contained within them such as chemical composition, crystal structure, and age of formation, provides direct information on the processes responsible for the genesis of the OD IOCG deposit [3,4,5].

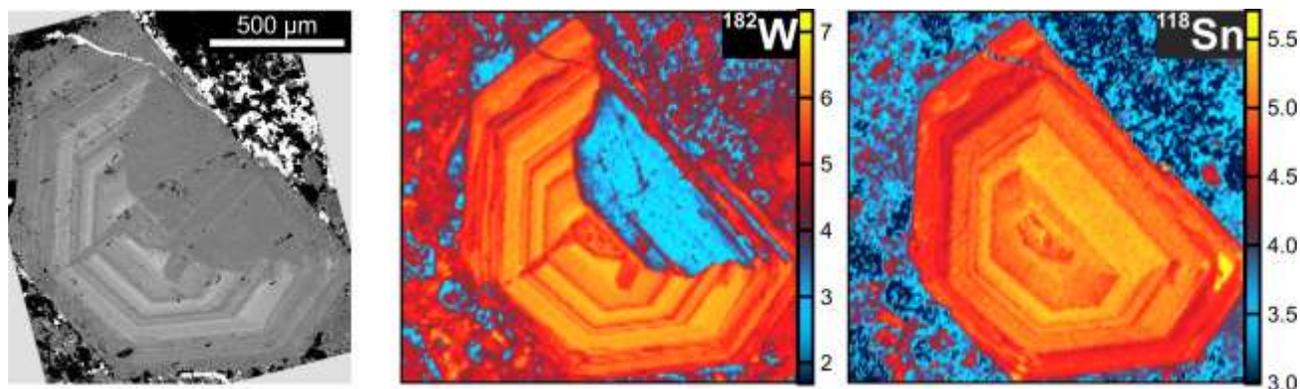
Imaging and microanalysis of hematite using complimentary techniques that bridge scales of observation from the millimetre to Angstrom scales, such as FIB-SEM, EPMA, LA-ICP-MS, and HR-TEM, have been used to better understand into the OD deposit. Distinct chemical signatures are found to be preserved at the micro and nanoscale, indicating that whereas some primary iron-oxides are well preserved, others have passed through replacement, reworking, and recrystallization events during multiple cycles of interaction with fluids [3-6].

An example of this complex relationship of preservation vs overprinting is displayed in Figure 1. Primary oscillatory zoned hematite displays embayments of hematite replacement as evidenced by the dark area on the grain in BSE. This overprinting is characterised by decoupling between the granitophile elements W and Sn evident in the LA-ICPMS maps. Selective removal of trace elements can be invoked by evolving redox conditions, resulting in disequilibrium of the fluid involved affecting elements with differences in the stability of cationic oxidation states (Sn<sup>4+</sup> vs W<sup>6+</sup>; [5]).

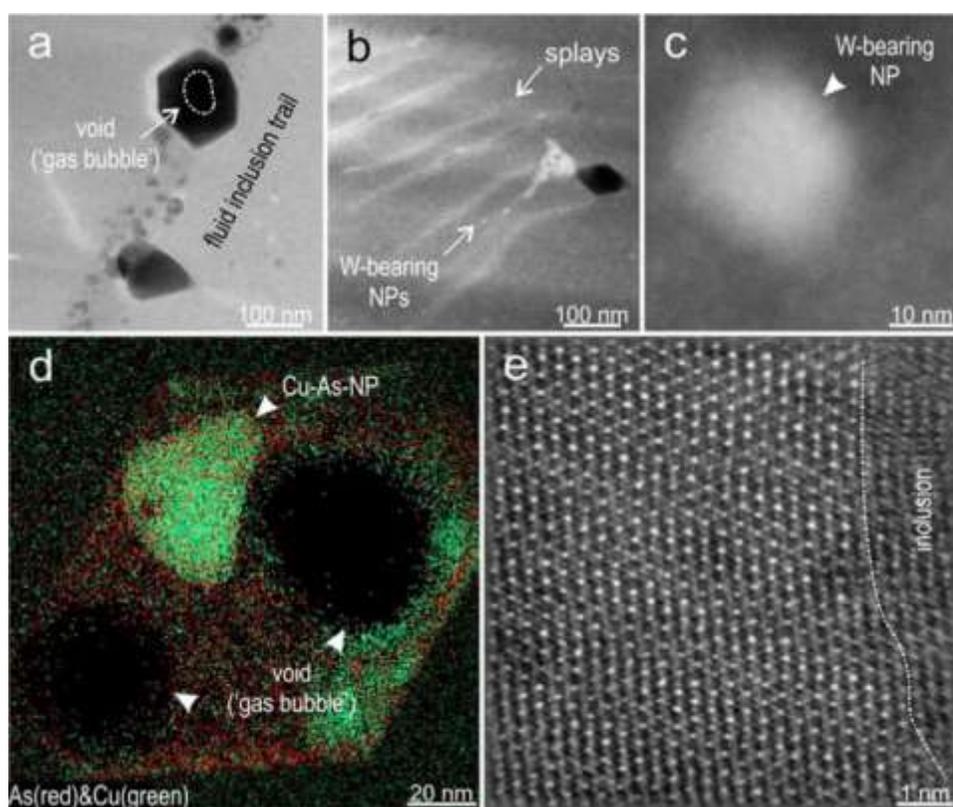
This is further evidenced in HR-TEM images of FIB-SEM foils of overprinted hematite (Figure 2). Overprinted areas display extensive inclusion trails comprising voids, silica bearing nanoparticles, and a range of metallic nanoparticles (W, Cu, As). In addition to this wispy splays of WO<sub>3</sub> (Ferberite) were present. Atomic resolution HAADF-STEM imaging of hematite immediately adjacent inclusion trails show nanodomains of dense twin sets, indicating localised reprecipitation of hematite. Combined with the diverse complex inclusion population, and gross scale elemental zonation in LA-ICPMS maps, a mechanism of *in-situ* combined dissolution reprecipitation reaction (CDRR [7]) is concluded as the primary replacement mechanism for hematite at Olympic Dam.

## References

- [1] BHP Billiton, 2016. Annual Report 2016.  
 [2] Hitzman *et al.*, *Precambrian Research* 58 (1992), p. 241-287.  
 [3] Ciobanu *et al.*, *Precambrian Research* 238 (2013), p. 129-147.  
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 [5] Verdugo-Ihl *et al.*, *Ore Geology Reviews* 91 (2017), p. 173-195.  
 [6] Verdugo-Ihl *et al.*, 15<sup>th</sup> Quadrennial IAGOD, 189-190.  
 [7] Putnis, *Mineralogical Magazine* 80 (2002), p. 689-708.



**Figure 1.** BSE image and LA-ICP-MS maps of zoned hematite grain. Scale in cps (log 10<sup>n</sup>) [5]



**Figure 2.** (a-c,e) HAADF-STEM images of metal bearing nanoparticles and voids inside hematite; (d) EDS-STEM map of metal bearing nanoparticle [6]