

Ore minerals at the nanoscale

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Like most minerals, sulfides and oxides are compositionally heterogeneous at the smallest scale. Application of different techniques is necessary to fully understand their crystal-chemistry, each with its own inherent advantages and disadvantages, and each with limited ranges of observational scale. Focused Ion Beam Scanning Electron Microscopy (FIB-SEM) opens up new avenues for *in-situ* sampling of small volumes of material characterized by other techniques, including SEM, EPMA and LA-ICPMS. Slices lifted from the surface of a sample, can be imaged and prepared for Transmission Electron Microscopy (TEM). This permits bridging of micro- to nanoscale observations on a site of petrogenetic interest. Constraints on ore-formation can be related to crystal-structural modifications via super-structuring or nanoscale characterization of mineral inter-growths that can be tied to crystallization from higher-temperature solid solutions. Recognition of the latter, as opposed to replacement processes, is a topic of much debate.

Here we show examples from Cu-(Fe)-sulfides and Fe-oxides, two mineral groups that define iron oxide-copper-gold deposits such as Olympic Dam (OD), South Australia. Cu-Fe-sulfides (chalcocite and related Cu_{2-x}S species, bornite and chalcopyrite) display distinct lamellar or symplectitic intergrowths throughout three of the four ore zones at OD. Compositional data (EPMA) combined with TEM analyses on FIB-prepared foils shows that their nanoscale intergrowths, superstructuring and antiphase boundary domains can be interpreted as due to exsolution, coarsening and phase transformation, leading to meaningful cooling paths relative to phase diagrams. Such information backs up a vertical zoning that is due to primary ore precipitation rather than replacement.

Inter-conversion between magnetite and hematite is a phenomenon attributed to redox changes. However, this can also occur via pH variation, in particular when maghemite, a transitory transformation phase occurs during replacement of primary magnetite by secondary hematite, as noted in BIF deposits. We show such transformation in samples from the deposit edges at OD. This helps constrain the origin of Fe-oxide intervals within granite as BIF-related blocks from older lithologies which the granite (host for mineralization at OD) has intruded.