Apatite in the Olympic Dam IOCG System and Adjacent Prospects: Insights into Magmatic and Hydrothermal Evolution

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The utility of apatite-group geochemistry in gaining insights into evolving physiochemical conditions during mineralization in a magmatic-to-hydrothermal environment is a topic of expanding research. Apatite is a widespread pre-, syn- and postmineralization accessory in the Olympic Dam (OD) IOCG-system and in nearby Wirrda Well (WW) and Acropolis prospects (25 km SW and SE of OD, respectively). Although broadly tied to the same 1.6 Ga IOCG mineralization event, differences exist in the tenor of Cu-Au mineralization and host lithologies.

Magmatic apatite in the ~1.6 Ga Roxby Downs Granite (RDG) displays core-to-rim ΣREE-zoning. Monazite inclusion-rich cores are overgrown by REE-rich rims; both are depleted along hematite-sericite–filled fractures crosscutting apatite. REE loss and SO_4 increase, with nucleation of florencite inclusions, accompany apatite destruction during hematite-sericite alteration of the RDG.

Halogen variation, in terms of an increase in Cl relative to F, is seen in altered picrite dikes within the deposit area and the less-evolved Horn Ridge granite ~5 km SE of the deposit. Both igneous rocks are broadly coeval with the RDG, which hosts mineralized hematite-sericite breccias at OD. Irregular grain-scale zoning in apatite from picritic dikes is geochemically expressed by increased F and corresponding drop in ΣREE and Cl. These zones coincide with domains of monazite inclusion-nucleation and subsequent overprint during hematite-sericite alteration of host picrite.

Hydrothermal apatite within Cu ± Mo ± Zn mineralization ~5 km NE of OD, as well as in mineralization at ~2 km depth, ~1 km E of the deposit, occurs as aggregates interstitial to Fe-oxides; similar apatite is observed at Acropolis. Two types of apatite are observed at WW in veins and breccias hosted by deformed and altered 1.85 Ga Donington granite and Fe-oxide–altered mafic dikes. Apatite associated with magnetite-pyrite-chlorite-siderite ± sericite breccia displays equant to irregular morphologies and contains magnetite and REE-mineral inclusions. Second generation apatite occurs along late calcite veins crosscutting all lithologies. Vein apatite contains lower SO_4 and ΣREE than the first type.

Changes in apatite morphology, textures, REE, halogen, and newly formed REE-minerals show the magmatic-to-hydrothermal transition throughout igneous lithologies undergoing hematite-sericite alteration at OD. Hydrothermal apatite in deep-proximal and distal satellites at OD shows similarities to apatite from WW and Acropolis in terms of morphology, REE-zoning, and mineral inclusions, and importantly, in terms of SO_4 and Cl content. In all these prospects, sulfide stability is at f_{O2} conditions defined by magnetite + hematite coexistence, albeit lower than the main OD deposit (hematite-stable). Higher SO_4 in apatite under increasing f_{O2} is attributable to transition from magnetite to hematite stability. In contrast, Cl increase, pronounced in the deep-proximal satellite and Acropolis, but less so in the distal satellite and at WW, indicates either different fluid sources or variation in main metal ligands. WW vein-apatite is distinct from all other hydrothermal apatite, and may relate to post-1.6 Ga fluids.

Results will be tested against apatite from mineralized hematite-stable breccias at OD. Variation in apatite chemistry among more- or less-evolved IOCG systems should discriminate Fe-oxide-Cu-Au mineralized from barren Fe-oxide–dominated hydrothermal systems.