SPATIAL-TEMPORAL EVOLUTION OF SKARN ALTERATION IN IOCG SYSTEMS: EVIDENCE FROM PETROGRAPHY, MINERAL TRACE ELEMENT SIGNATURES AND FLUID INCLUSION STUDIES AT HILLSIDE, YORKE PENINSULA, SOUTH AUSTRALIA

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ABSTRACT

Hillside is a newly-discovered, undeveloped copper resource related to Mesoproterozoic Hiltaba Suite intrusives along the crustal-scale Pine Point fault on the eastern margin of the Yorke Peninsula, South Australia. Mineralogical and petrographic study was undertaken on ~100 samples representative of all lithologies, parts of the deposit, and evolution from magmatic through prograde and retrograde skarn to late-stage hydrothermal overprint. Emphasis was placed on distributions of REE+Y and other trace elements in main minerals, and on the constraints these patterns provide for processes associated with alteration and mineralization.

Alteration at Hillside is defined by diverse skarn assemblages. Most are readily interpreted as exoskarns formed onto (Moonta-Wallaroo Group) sedimentary protoliths. Two granitoids and associated pegmatites are indicative of composite (multiphase?) felsic magmatism. Granitoid emplacement and alkali-metasomatism pre-date skarn formation; the same initial alteration is recorded in coeval gabbros. The main prograde and retrograde associations [garnetite, garnet-(epidote-allanite-(Ce)) skarn, garnet-feldspar skarn and (pyroxene-dominant) multi-component skarn] are defined by mineral associations and replacement relationships among calc-silicates and replacement of calc-silicates by secondary calcite±quartz±chlorite assemblages. Andradite-dominant garnet and diopside-dominant pyroxene are prograde minerals in this (magnetite-pyrite stable) association. Clinozoisite and amphibole are retrograde and co-exist with sulphides. Hematite-chalcopyrite+pyrite assemblages and advanced replacement of skarn minerals by calcite+quartz are associated with the late-retrograde stage. Skarnoid, at the skarn margin, contains the main skarn minerals, feldspars, grossular-rich garnet and minor wollastonite.

LA-ICP-MS trace element datasets show that skarn minerals are rich in REY, Sn, HFSE and incompatible elements. Temporal (prograde-to-retrograde) evolution is recognised in terms of chondrite-normalised REY fractionation trends for garnet, with predictable patterns from sample to sample. Trace element concentrations in garnet represent the best guide to deposit-scale zonation patterns: Sn increases in garnet from N to S, and ΣREY increases from E to W. Trends for retrograde garnet are more varied, attributable to cycles of replacement, overgrowth and recrystallization. Nanoscale FIB-SEM-TEM investigation of feldspar and garnet allows distinction of whether key trace elements are lattice-bound or occur as nanoscale mineral inclusions.

Preliminary fluid inclusion data provide evidence for early high-T, high-salinity fluids (~23 wt.% NaCl equiv., ~600 ºC, ~2 kbar) and the destructive influence of retrogression and reaction with later fluids tied to skarn collapse during uplift/fault reactivation (~1 wt.% NaCl equiv., <300 ºC, ~0.15 kbar).

The study shows the potential value of LA-ICP-MS trace element signatures in garnet and accessories as petrogenetic tools and, potentially, as exploration vectors. The extraordinary petrographic and geochemical complexity implies that routine application of these patterns as an exploration tool is dependent upon recognition of underlying trends specific to protolith and spatial-temporal evolution.

Hillside is defined as a Fe-Cu-(Au)-skarn that includes key features of an IOCG system. The deposit formed in a deep skarn setting (~6 km) and records a late-stage overprint during uplift and fault reactivation. The data can underpin sustainable genetic models for the Hillside deposit and contribute towards a metallogenic framework for the Olympic Cu-Au province, particularly with respect to the diversity of mineralization styles as an expression of ore formation at different crustal levels.

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