

**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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A thesis submitted to The University of Adelaide in fulfilment of the
requirements for the degree of Doctor of Philosophy

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November 2015

DECLARATION

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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 Σ REY 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 °C, ~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 °C, ~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.

ACKNOWLEDGEMENTS

First, thanks to God for this wonderful journey and the valuable experience of travelling overseas and learning new things.

I would like to express my deepest appreciation to my wonderful supervisors, Cristiana L. Ciobanu and Nigel J. Cook, for always supporting me and for being there with your guidance and help. Thank you so much for always being patient with me and never giving up on me to complete this project. I feel so grateful to have been chosen to work under your supervision and learn so much about geology, ore deposits, microanalysis and research. Millions of thanks to you for letting me stay at your house while completing this thesis for submission. A big thank you also goes to Andreas Schmidt Mumm, who supported my initial application for graduate studies at the University of Adelaide, but moved to Saudi Arabia and couldn't supervise me.

Thanks also to Mark Twining and Rex Minerals for permission to access the Hillside deposit, and for all the information. I also appreciate help and samples from Graham Teale, Alan Mauger and Christine Warwick during the course of the research.

Millions of thanks to the Adelaide Microscopy staff, especially Ben Wade, who trained me with use of the microanalytical instrumentation. This project would not have been possible without your patience and advice, often well into the night. Thanks also to Ben Vanderhoek for his assistance with Leapfrog software.

By no means forgotten are Lin Ye, Tan Boa, Ha' and Su for helping me during my stay in Guiyang, China. I gratefully acknowledge the Institute of Minerals, Guiyang Science Academy for sponsoring the fluid inclusion part of the project carried out there.

I would like to acknowledge the Ministry of Education Malaysia and Universiti Malaysia Kelantan for sponsorship of my time in Adelaide (tuition fees and living allowance), as well as CRC DET for supporting my research expenses, conferences and travel during my candidature.

Last but not least, I extend very special thanks to my family in Malaysia who always been there for me, listening to my problems, and always comforting me to stay strong despite the challenges I was facing. I appreciate your prayers and continuous moral support. Special thanks also to all of my friends in Adelaide, who were always there for me through thick and thin, and who gave meaning to my life in Adelaide beyond the research.

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