Hydrothermal processes in barren and mineralized systems

Insights using fluid inclusion microanalysis and geochemical modelling

Thesis Submitted by Martina Bertelli B.Sc. (Hons), Padova

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ABSTRACT

The study of fluid inclusions in this thesis was used as a research tool to characterize fluids associated with specific types of deposits and related hydrothermal systems and to investigate ore deposition processes with the ultimate aim of addressing key questions relating to ore genesis. Two magmatic-hydrothermal systems were investigated. The first part of the thesis focuses on the study of the Suicide Ridge Barren Breccia Pipe (SRBP; ~ 1527 ± 4 Ma), located in the Snake Creek area, in the Cloncurry district, Australia. The pipe is one of numerous breccia systems that characterize the Cloncurry District and is temporally and spatially associated with a granite that outcrops at its southwestern boundary and which is ascribed to the Williams and Naraku magmatic event (ca 1550-1500 Ma). The breccia is characterized by clasts of variable dimensions, degree of rounding and composition that includes dominant calc-silicate clasts of the Corella Formation that underlie rocks of the Soldiers Cap Group that host the pipe. This indicates a dominant upward transport of the fragments. Other breccia fragments include granite bodies characterized by albite-quartz rocks that have textures typical of the magmatic-hydrothermal transition. These rocks likely formed in a fractionated carapace of a granite during the exsolution of volatiles associated with the cooling magma. Two dominant types of inclusions have been identified in these textures and include early primary and pseudosecondary CO_2-rich and secondary sodic-calcic brine inclusions. The CO_2-rich fluid inclusions represent fluid released from the crystallizing magma and variable homogenization temperatures in the primary and pseudosecondary inclusions indicate that they were trapped under different pressure conditions. Pressures estimated from the primary CO_2 fluid inclusions suggest that they were trapped at 4.2 kbar, at least 1 kbar above the inferred lithostatic

pressure. This likely represents the overpressuring produced by release of CO_2-rich volatiles during the crystallization of magma and which ultimately caused the subsequent brecciation. Sodic-calcic fluid inclusions represent a later influx of fluids in the breccia system that produced widespread albitization. Bulk crush leach analysis suggests that the carbonic fluid inclusions in the granite clasts have either a magmatic origin or formed from the dissolution of evaporites (or mixing of the two), whereas the sodic-calcic inclusions may have been sourced from bittern brines.

The study also included LA ICP MS analysis of fluid inclusions from the SRBP and the Eloise Cu-Au deposit in order to address the key differences between barren and mineralized hydrothermal systems in the Cloncurry district. The major difference between the barren breccia pipe and IOCG deposits is the absence in the former of multisolid high salinity, high temperature fluid inclusions, suggesting that these were critical for the formation of IOCG deposits. Fluid mixing was a key deposition mechanism at Eloise as indicated by the general abundance of Ba in multisolid fluid inclusions, that possibly suggests S-poor fluid, the variable chemistry of fluid inclusions consistent with a mixing trend and the significant lower of salinity that characterize later fluids compared to the ore forming fluid that can not be attributed to precipitation of Cl-bearing phases. The preferred model for ore deposition at Eloise is fluid mixing between hot, ultrasaline Cu-bearing, S-poor fluid, evolving as the result of cooling and wall rock reaction as it migrated in a northern direction and a S-bearing fluid cooler fluid. Possible sources of sulphur include the later halite-bearing fluid inclusions and CO_2-rich fluid inclusions.

The second part of the study focused on the base metal-rich, high-temperature, carbonate-replacement Bismark deposit in northern Mexico. Previous fluid inclusion studies based on microthermometry and PIXE showed that the Zn-rich, Pb-poor

Bismark deposit formed from a moderate salinity magmatic fluid but the exact precipitation mechanisms were unclear. Furthermore, PIXE data suggested that Pb and Zn concentrations were comparable and inconsistent with the Zn-rich nature of the ore. In this study LA ICP MS analysis of the same fluid inclusion populations was carried out to compare with the PIXE data and the new results were used to model possible ore deposition mechanisms. The new laser ablation data revealed overall lower concentrations of Pb in the ore fluid (average value ~336ppm) than previously indicated by PIXE analysis (average value ~713ppm). Chemical modeling using this new data tested the following processes: 1) cooling; 2) fluid-rock reaction at constant temperature; 3) cooling and simultaneous fluid-rock interaction. Modeling results show that the gangue and ore minerals observed at Bismark are best reproduced by fluid-rock interaction with simultaneous cooling. Results from the simulations strongly indicate that ore deposition was mainly driven by a pH increase due to the neutralization of the acidic ore fluid (pH = 3.9) through reaction with the limestone.

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