Evolution of the Saxby and Mt. Angelay Igneous Complexes and their role in Cloncurry Fe Oxide-Cu-Au ore genesis

Thesis submitted by

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STATEMENT ON THE CONTRIBUTION OF OTHERS

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ABSTRACT

The Saxby and Mt. Angelay Igneous Complexes represent the volatile rich, post ~1530 Ma granitoids of the Williams Batholith, and have been considered to be a possible source of magmatic-hydrothermal fluids that produced IOCG deposits in Cloncurry district. The evolution of these igneous complexes is studied in this thesis with the ultimate aim to understand the chemistry of magmatic fluids and their involvement in ore genesis. These igneous complexes contain a variety of intrusions including mafic, intermediate and felsic members and their fluid evolution was examined by several bulk and micro-analytical techniques.

The distribution of rock units and their contact relations were obtained from field observations and regional and detailed mapping. The Saxby (SIC) and Mt. Angelay (MAIC) Igneous Complexes are dominated by metaluminous, potassic, magnetite-bearing intrusive rocks, which intruded into the calc-silicate rocks of the Mary Kathleen Group and psammo-pelitic rocks of the Soldiers Cap Group between 1530 and 1500 Ma. The major rock types in the SIC include granites and a large number of mafic intrusions, with limited pulses of intermediate magmas, typically observed at the magma mixing/mingling locations. The MAIC apparently represents a more evolved pluton, which has limited mafic intrusions with more intermediate rock types and abundant felsic rocks. Other major rock types and structures include magmatic-hydrothermal transition veins and 'brain rocks' of Mt. Angelay, mixed/mingled rocks and explosive breccias of the SIC, and late igneous phases of pegmatites and aplites. Intense sodic/ sodic-calcic alteration is abundant in both complexes, complicating geochemical interpretation.

Petrographic and geochemical studies were used as tools to distinguish various rock types and magmatic crystallization processes from sub-solidus hydrothermal processes. The major and trace element studies together with rare earth element (REE) patterns and field observations suggest different magma sources for the mafic and felsic rocks. The REE patterns, depletion in Eu, Sr, P and Ti, and Y-undepleted nature of K-rich, abundant felsic intrusions suggest a crustal source which is more likely depleted in garnet, titanite, apatite, pyroxenes and/or amphiboles and enriched in plagioclases. In mafic and intermediate intrusions, the decrease in CaO, Nb, Sr, Sc, V and TiO_2 with increasing SiO_2, together with negative Eu anomalies, suggested that fractional crystallisation of plagioclase and amphibole were prominent processes involved in the formation of the more silicic phases from mafic magmas. REE patterns also suggest that this mafic source region was enriched in pyroxenes, amphiboles, apatite and titanite and depleted in garnet.

The volatile evolution of the SIC and MAIC intrusions was particularly estimated from halogen (F/Cl) abundances and ratios of hydrous minerals including biotite, hornblende and apatite, and from calculated halogen activities of magmatic fluid in equilibrium with biotite. The F and Cl concentrations of ferromagnesian minerals highly depend on Fe and Mg contents; however, they show variable rates of compatibility with fractionation that may have influenced the halogen concentration of the final magmatic-hydrothermal fluid. The halogen contents of both whole rocks and minerals show high F and Cl contents in mafic rocks and gradual loss in Cl with crystallization. The majority of F analyses in the whole rocks are below detection, but the minerals show major increase in F contents from mafic to intermediate rocks. The halogen variability in intrusions depends on a number of factors including bulk rock chemistry, wall rock alteration and Fe-Mg avoidance.

Fluid inclusions were used as a tool to understand the magmatic-hydrothermal evolution of the SIC and MAIC and the intrusions contain a variety of primary and secondary fluid inclusions. The primary magmatic fluids of the SIC and MAIC include a common, abundant CO_2 rich fluid phase, which may have been sourced from mafic magma. High salinity, primary, multisolid inclusions of Mt. Angelay brain rocks represent magmatic-hydrothermal fluids; in which their magmatic origin is also confirmed by PIXE halogen ratios. The multisolid inclusions show very high salinities (38-60wt% NaCl equivalent) and high homogenization temperatures ranging from 450-600°C and more. Secondary inclusions of L+V+S (16-46wt% NaCl equivalent) and L+V (1-30wt% NaCl equivalent) are present in all the SIC and MAIC rocks including granites, brain rocks and breccias, and they homogenize in between 140-300°C and 100-250°C respectively.

The field and analytical studies suggest that the Saxby breccia pipes and Mt. Angelay brain rocks represent the release of magmatic fluids at the final stages of magma evolution (Chapter 2 & 6). It is suggested that the process of magma mingling and the variable CO_2 input from mafic intrusions have played major role in the formation of breccias and brain rocks. The fluid inclusion P-T estimations from these magmatic-hydrothermal locations together with geochemical and mineral chemical observations also provide clues to the overall volatile evolution of the mafic and felsic magma, and their possible role in IOCG genesis.

The metal and element budget of some Cloncurry ore deposits and SIC and MAIC intrusions are compared as the fluid inclusions provide a direct correlation. The primary fluid inclusions assemblage in Mt. Angelay brain rocks (CO_2 inclusions + multisolid inclusions) is similar to that found in the most obviously granite-related IOCG deposits (especially Ernest Henry), and is verified in detail by PIXE and LA-ICP-MS analysis. The element concentrations, ratios and Fe, Cu, Mn and Zn contents of multisolid inclusions from these two settings show similarities, which suggest a magmatic involvement in the IOCG ore genesis of Cloncurry. However, fluid mixing is also suggested as a major process for the formation of ore deposits.

Although many previous studies supposed that granites were crucial in the magmatic-to-IOCG connection, the data collected during this study suggest that mafic intrusions played major roles in the evolution of Saxby and Mt. Angelay Igneous Complexes and in the formation of some of the Cloncurry ore deposits.

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