MYSTERY ISLAND INTRUSIVE SUITE AND ASSOCIATED ALTERED AND MINERALIZED ROCKS, ECHO BAY, DISTRICT OF MACKENZIE, NWT

N.C. Reardon
Ottawa-Carleton Geoscience Centre, Ottawa

R.S. Hildebrand and B.E. Taylor
Geological Survey of Canada, Ottawa

Introduction

The Mystery Island intrusive suite comprises several sheet-like plutons of intermediate composition which intrude andesitic stratovolcanoes within the 1.87 Ga Great Bear Magmatic Zone of Wopmay orogen. The plutons have haloes of altered wallrock comprising three zones: albite, magnetite-actinolite-apatite, and pyrite. Interest in magnetite-actinolite-apatite deposits has increased significantly in recent years due to the discovery and development of the Olympic Dam and related deposits, South Australia. Magnetite-actinolite-apatite mineralization in the Echo Bay area and elsewhere in the Great Bear Magmatic Zone is a current exploration target for silver and uranium.

Pitchblende and native silver (Ag)-bearing veins in the Echo Bay area are spatially associated with plutons of the Mystery Island intrusive suite and their altered wallrocks. Although more than two million ounces of silver and over 14 million pounds of U_3O_8 have been mined from the Echo Bay area, the origin of the mineralization remains obscure. Spatial and temporal relationships between the Mystery Island intrusive suite, altered and mineralized wallrocks, and pitchblende-native Ag-nickel (Ni)-cobalt (Co) arsenide-bearing veins, as outlined during this project, are essential in understanding the geological history of mineralization in the Echo Bay area. These relationships provide an empirical guide for further mineral exploration.

Objectives

The principal objectives of this study were: 1) to map and sample the plutons of the Mystery Island intrusive suite and associated alteration haloes in the Echo Bay area, 2) to understand the formation of the alteration haloes, and 3) to determine the relationship between the plutons, alteration haloes and pitchblende - native Ag-Ni-Co arsenide-bearing veins. This was accomplished by:

- compilation and assessment of available geological information for the Echo Bay area.
- 1:15 000 scale mapping of the Mystery Island intrusive suite, associated alteration haloes, and quartz veins in the Echo Bay area.
- determination of mineral textures, paragenesis and composition in altered and mineralized (magnetite-actinolite-apatite) zones of the alteration haloes.
- characterization of the nature and origin of hydrothermal fluids, and estimation of the extent of water-rock interaction during alteration using oxygen and hydrogen stable isotope data for both whole-rock samples and mineral separates.
- determination of spatial and temporal relationships among the plutons, associated alteration haloes, and pitchblende - native Ag - Ni-Co arsenide-bearing veins.

Methods

Fourteen weeks of field mapping at 1:15 000 scale and sampling of the plutons of the Mystery Island intrusive suite, altered and mineralized wallrocks, and quartz-carbonate veins in the Echo Bay area was completed during 1988 and 1989 (Reardon, 1989; 1990). In appropriate areas, outcrop scale mapping of actinolite-magnetite-apatite vein/altered wallrock relationships was completed. A map of the area at 1:25 000 scale, showing the distribution of alteration in the Echo Bay area, and an accompanying report will be released as a GSC Open File during 1992 (Reardon, 1992).

Forty whole-rock hydrogen and 150 whole-rock oxygen isotope analyses of the plutons of the Mystery Island intrusive suite and their altered wallrocks were completed. In addition, mineral separates were prepared for representative magnetite-actinolite-apatite zone veins and breccias. Nineteen hydrogen isotope analyses of amphibole, talc, epidote, and biotite; 35

oxygen isotope analyses of quartz, feldspar, magnetite, amphibole, apatite, epidote, talc, and biotite. Thin sections were prepared for all samples for which isotopic analyses were completed.

Results

Excellent exposure of the plutons and their altered wallrocks in oblique cross-section allowed a unique assessment of geologic, geothermal and geochemical variations with depth. The results of this study are the first of their kind for intermediate magmatic - hydrothermal systems.

All of the plutons of the Mystery Island intrusive suite are characterized by alteration haloes, primarily above their roofs, but also within and below the plutons locally. Three zones of altered rock were mapped:

1) an albite zone within and adjacent to the plutons characterized by pervasive replacement of the rocks by albite;

2) a magnetite-actinolite-apatite zone generally present at some distance above the pluton roofs and characterized by actinolite-magnetite-apatite veins, pods, hydrothermal breccias and replacement; and

3) an outer pyrite zone of disseminated pyrite, and pyrite veins and pods.

A chalcopyrite subzone, beyond the pyrite zone, was mapped in the Port Radium area. The zones are somewhat irregular, and overlap of two or all of the zones is common. Alteration is generally more pronounced within sedimentary units, which may be due to differences in composition and permeability. The greatest concentration of pitchblende - native Ag - Ni-Co arsenide-bearing veins is found where the magnetite-actinolite-apatite and pyrite zone overlap, within sedimentary units. However, although pitchblende - native Ag - Ni-Co arsenide-bearing veins are *spatially* associated with the plutons of the Mystery Island intrusive suite and their altered wallrocks, they are not related temporally. Both the plutons and their alteration haloes are displaced by the faults in which both unmineralized and mineralized veins occur. Cross-cutting relationships indicate two periods of activity in these fault systems, the later veins being mineralized (Jory, 1964; Robinson, 1971). This younger period of veining postdates the 1.67 Ga (Bowring and Ross, 1985) Hornby Bay Group (Furnival, 1939), and thus is much younger than the plutons and alteration haloes (Hildebrand, 1988; Reardon, 1990).

Mapping also revealed new outcrops of the Cameron Bay Formation at Contact Lake. Above a local unconformity, a pebbly conglomerate contains fragments of altered and mineralized andesite and as much as 5% 1 to 2 mm rounded quartz grains.

This indicates that the altered and mineralized rocks, and possibly a pluton of the Mystery Island intrusive suite (a source for the quartz), were exposed before deposition of part of the Cameron Bay Formation, a relationship found elsewhere in the area by Hoffman et al. (1976) and Hildebrand (1981).

Paragenesis of the minerals in veins and breccias indicates that magnetite was deposited first, but possibly in two generations: before and during actinolite deposition. Apatite, where present, is typically a late mineral. Textures observed in altered and mineralized zones indicate that alteration occurred by replacement, veining, and brecciation. Magnetite is invariably altered either partly or entirely to hematite. Actinolite is chloritized and, in at least two veins, altered to talc. Minor amounts of sphene and carbonate were present in all vein and breccia samples studied in thin section.

Petrographic studies indicate that pervasive propylitic alteration of wallrocks; feldspar is altered to sericite, secondary albite and epidote; ferromagnesian minerals are altered to chlorite with lesser calcite and magnetite. Saussuritization of feldspars within the plutons occurs locally. Within the albite zone, the rocks are replaced by granular albite. Regional metamorphism is subgreenschist.

Whole-rock $\delta^{18}O$ range from +5.3 to +11.7 for altered andesitic lavas, volcaniclastic rocks and intrusive porphyries, and from +5.7 to +12.3 for the plutons. δD range from -56 to -92 for andesitic lavas, volcaniclastic rocks and intrusive porphyries, and from -57 to -83 for the plutons. These data indicate that the rocks are hydrothermally altered, and rule out a *dominantly* meteoric geothermal system and high water/rock ratios, since most $\delta^{18}O$ and δD are higher than +6.0 and -70, respectively. The data are comparable to those from geothermal systems in which the fluids are magmatic water and evolved seawater or highly-evolved meteoric water (see Taylor, 1987), although lower δ-values indicate a

higher meteoric input locally. Stable isotope data for mineral separates of actinolite -80.3 to -53.4; biotite -112.2; epidote -98.1; and talc -55.05 support these conclusions. Sulphur isotope data, yet to be completed, will indicate the significance of magmatic input to the system.

The determination of pressure, temperature and fluid composition during alteration and mineralization, and of the effects of late quartz-carbonate veins on pluton-related alteration is in progress.

Conclusions

Field and laboratory studies carried out in this project indicate that:

1) all of the plutons of the Mystery Island intrusive suite have alteration haloes.

2) three zones of altered rock are present: 1) an inner albite zone; 2) a intermediate magnetite-actinolite-apatite zone; and 3) an outer pyrite zone (and chalcopyrite subzone in the Port Radium area).

3) the presence of hydrothermal breccias, zoned alteration haloes, wallrock replacement and the stable isotope data indicate formation of actinolite-magnetite-apatite mineralization by hydrothermal processes. Isotope data also indicate that the fluids involved were magmatic and evolved seawater or evolved meteoric water.

4) pitchblende - native Ag - Ni-Co arsenide-bearing veins are spatially, but not temporally, associated with the plutons and their altered wallrocks.

5) the greatest concentration of pitchblende, native Ag, Ni-Co arsenide veins is present where the magnetite-actinolite-apatite and pyrite zones overlap, particularly within sedimentary units.

Acknowledgements

Isotope analyses and sample preparation were supported by an NSERC research grant to Bruce Taylor. Thanks is extended to DIAND and many of the staff at the GSC in Ottawa, especially Richard Lancaster, Guy D'Arcy and Gerry Gagnon for their invaluable assistance; to John Sekerka for mass spectrometer analyses of isotope samples; to CEGB for, well, lots of things; and to my assistant, Stéphane Lagacé.

References

Bowring, S.A. and Ross, G.M.

1985: Geochronology of the Narakay Volcanic Complex: Implications for the age of the Coppermine Homocline and Mackenzie igneous events; Canadian Journal of Earth Sciences, v. 22, p. 774-780.

Furnival, G.M.

1939: A silver-pitchblende deposit at Contact Lake, Great Bear Lake, Canada; Economic Geology, v. 34, p. 739-776.

Hildebrand, R.S.

1981: Early Proterozoic LaBine Group of Wopmay Orogen: remnant of a continental volcanic arc developed during oblique convergence; in Proterozoic Basins of Canada, F.H.A. Campbell, (ed.); Geological Survey of Canada, Paper 81-10, p. 133-156.

1988: Ore deposits in the Great Bear Magmatic Zone, an Early Proterozoic arc terrane in Wopmay Orogen, northwestern Canadian Shield; International field conference on the tectonic setting of Proterozoic volcanism and associated ore deposits, Turku, Finland, abstract volume, August 1988, p. 12.

Hoffman, P.F., Bell, I.R. and Tirrul, R.

1976: Sloan River map area (86K), Great Bear Lake, District of Mackenzie; Geological Survey of Canada, Paper 76-1A, p. 353-358.

Jory, L.T.

1964: Mineralogical and isotopic relations in the Port Radium pitchblende deposit, Great Bear Lake, Canada; PhD thesis, California Institute of Technology, 275 p.

Reardon, N.C.

1989: The Mystery Island intrusive suite and associated alteration haloes, Great Bear Lake, District of Mackenzie, NWT; in Current Research, Part C; Geological Survey of Canada, Paper 89-1C, p. 37-42.

1990: Altered and mineralized rocks at Echo Bay, N.W.T., and their relationship to the Mystery Island intrusive suite; in Current Research, Part C; Geological Survey of Canada, Paper 90-1C, p. 143-150.

1992: Altered rocks and magnetite-apatite-actinolite deposits associated with the Mystery Island intrusive suite, Echo Bay, District of Mackenzie, NWT; Geological Survey of Canada, Open File (in press).

Robinson, B.W.

1971: Studies on the Echo Bay silver deposit, NWT, Canada; unpublished PhD thesis, University of Alberta.

Taylor, B.E.

1987: Stable isotope geochemistry of ore-forming fluids; in Short Course in Stable Isotope Geochemistry of Low Temperature Fluids, T.K. Kyser (ed.); Mineralogical Association of Canada Short Course Handbook, v. 13, p. 337-445.