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PROTEROZOIC GRABEN-CONTROLLED HYDROTHERMAL FIELD ASSOCIATED WITH THE SULLIVAN STRATIFORM ZN-PB-AG DEPOSIT

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The Sullivan-North Star Corridor is a north-trending 7 km by 1-2 km belt of altered and mineralized disrupted strata and fragmentals adjacent to the Sullivan mine. The Corridor is interpreted to represent a rift-controlled hydrothermal field within the Middle Proterozoic syn-rift turbidite basin of the Aldridge Formation. This study is part of the Sullivan Project, a joint GSC-BCGS-Cominco Ltd.-USGS-university appraisal of the geological environment and origin of the Sullivan deposit. Our Corridor research has benefited greatly from the generous assistance of Cominco staff and access to company reports and data.

The Corridor is a simple north-trending graben that broadens and becomes more structurally complex at its north end adjacent to the east-trending Kimberley fault. North-trending synsedimentary faults are recognized by stratigraphic offset across clastic dike zones and lack of offset of Proterozoic age gabbro sills that cut the faults. Fragmental rocks occur throughout the Corridor. Disrupted bedding, breccia and clastic dikes are overlain by extensive locally-derived bedded conglomerate at the base of the Sullivan horizon, the stratigraphic level of the Sullivan deposit.

Hydrothermal centers (Sullivan, Stemwinder and North Star sulphide deposits) are associated with tourmalinite altered upflow zones along north-trending synsedimentary faults. Muscovite alteration (after feldspar) is widespread throughout the Corridor; it forms discordant zones that merge upward into a sub-concordant body most extensive along the Sullivan horizon. Sodium-depletion and elevated Zn, Pb, As, Sb and Hg characterize extensive muscovite alteration; enrichment in main stage hydrothermal upflow zones includes B, Fe, S, Cu, Sn, Pb and Zn.

Extensive geochemical enrichment/depletion, rock alteration and fragmentals represent a large-scale anomaly that can be incorporated into exploration models for Sullivan-type deposits.

Evolution of hydrothermal field

Fault release of geopressured fluids, and liquefaction of sediments led to eruption of sand and gravel volcanoes that marked the onset of activity in the hydrothermal field. Subsequent low temperature hydrothermal activity resulted in tourmalinite alteration along upflow zones and minor stratiform Mn garnet and Zn-Fe sulphides. Upflow of hot hypersaline metalliferous brines marked onset of Main stage hydrothermal activity that included seafloor sulphide deposition and expansion of tourmalinite alteration pipes. Collapse of Main stage hydrothermal activity led to widespread low temperature muscovite alteration along non-Main stage faults and laterally within permeable fragmental units.

Emplacement of a gabbro sill complex underlying the Sullivan deposit (>1000 m aggregate thickness of sills) is interpreted to have been concurrent with Corridor hydrothermal activity; shallow level intrusion of the uppermost sill in the sill complex was accompanied by boiling, formation of granofelsic fragmentals and albite-biotite alteration along sill contacts.

Basinal structural controls

Paleogeographic facies reconstruction and isopach maps of cumulative sill thickness of the northern (Canadian) Aldridge-Prichard basin indicates a north-trending depositional trough and magmatic axis.

A series of major Proterozoic age NE-trending faults transverse to the Aldridge basin may have segmented the rift basin. The Sullivan deposit sits at the intersection of the Kimberley fault, a transverse structure, and the Sullivan-North Star Corridor, a rift axis structure that lies just east of the magmatic axis.

The fundamental controls on the siting of the hydrothermal upflow that formed the Sullivan deposit is the intersection of rift axis structures with this transverse fault.

Hydrothermal model

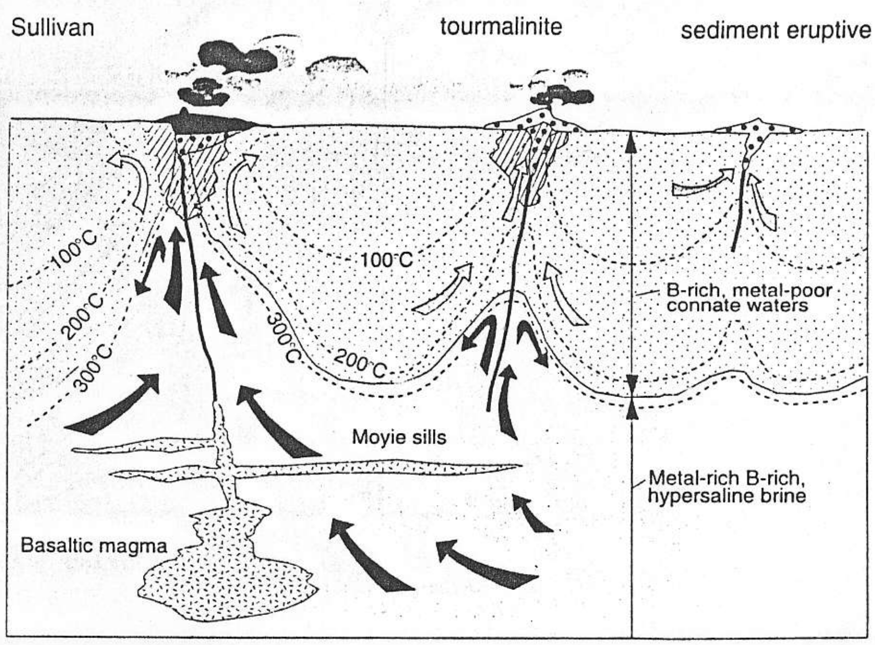
A model for the hydrothermal reservoir zone and formation of saline brines associated with the Sullivan-North Star hydrothermal field is based on comparison with the Salton Sea geothermal system (SSGS), California (*e.g.* McKibben *et al.*, 1988). Though the SSGS is not a submarine system, both are syn-rift feldspathic clastic sequences with high heat flow due to magma emplacement. †SSGS basinal fluids are salinity stratified; deep hypersaline brine (T=260-365°C; TDS >20%) are overlain by less saline partially evolved meteoric waters (T <260°C; TDS = 1-13%). Most relevant to the Aldridge story is that the shallower waters have low concentrations of metals but significant boron (Zn <15 ppm; Pb <5 ppm; B =100 ppm); hot hypersaline brines have both high metal and boron concentrations (Zn >300 ppm; Pb >60 ppm; B >200 ppm). At the geothermal field, a diapir of hot hypersaline brine rises buoyantly to shallow depths due to magmatic heating at depth. McKibben *et al.* (1988) suggest that initial ascent of the brine diapir would drive convective circulation and discharge of overlying less saline waters.

A model for hydrothermal activity within the Corridor and Aldridge basin needs to explain:

- the greater abundance of clastic eruptive deposits versus tourmalinite prospects, and the scarcity of sulphide deposits;
- evolution of hydrothermal centers from early fragmental eruption to tourmalinite formation to (in rare cases) sulphide deposition;
- hypersaline fluids associated with sulphide deposition; and marine siliciclastic sediment source for boron (Palmer *et al.*, 1994).

We propose the following model (Figure 1). Salinity stratified formation waters within the basin sediments were heated by magmatic intrusion that provided the thermal energy for buoyant ascent of dense saline brines out of the deep basin and resulted in three deposit types within the Aldridge Basin. Small off-rift axis faults that intersected shallow geopressured fluids would produce clastic eruptions

SULLIVAN-ALDRIDGE BRINE DIAPIR MODEL



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William Harvey Gross Award - Call for Nominations

The William Harvey Gross Award is presented annually by the Mineral Deposits Division to a young geologist (less than 40 years of age on December 31, 1995) who has made outstanding contributions to the field of economic geology in a Canadian context.

The recipient may be a Canadian or a non-Canadian who has made a contribution in Canada or with a distinctively Canadian flavour. The contributions on which the award is base may relate to mineral exploration or development, scientific research either applied or fundamental, and field-based studies, that is to include all aspects of what is generally referred to as economic geology and which represents the broad spectrum of fields to which Bill Gross contributed.

The award consists of a medal and a cash supplement supported through an endowment fund provided by Corona Corp. Donations by the friends and family of Bill Gross provide a contribution toward the travel expenses for the recipient and spouse to attend the annual luncheon of MDD to receive the award.

Nominations for the William Harvey Gross Award must be made by a member of MDD and supported by 4 additional MDD member signatures and letters of support.

Nominations should be submitted in triplicate to the Chairperson of the selection committee:

H. Scott Swinden
Geological Survey Branch, Department of Mines and Energy
P.O. Box 8700, St. John's, Newfoundland, A1B 4J6
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and weak hydrothermal alteration. Along more permeable larger faults, or faults closer to the magmatic axis, partial ascent of a brine diapir would drive overlying lower temperature B-rich formation waters to the seafloor, forming tourmalinite alteration. Where highly permeable zones along major faults were coincident with higher level emplacement of magma, heating would be sufficient to drive a brine diapir to the seafloor, forming a sulphide body. At such sulphide deposits all three stages would be represented (early faulting and clastic eruption, followed by tourmalinite formation and later sulphide deposition) reflecting the progressive evolution of faulting, release of geopressured fluids, venting of shallow level B-rich fluid driven by ascent of brine diapir, and intersection of brine diapir with seafloor.

References

McKibben, M.A., Andes, Jr., J.P. and Williams, A.E., 1988, Active Ore-formation at a Brine Interface in Metamorphosed Deltaic-lacustrine Sediments: The Salton Sea Geothermal System, California. *Economic Geology*, v. 83, p. 511-523.

Palmer, M.R., Jiang, S. and Slack, J.F., 1995, Boron Isotopic Composition of Tourmaline-rich Rocks and Tourmalinites from the Middle Proterozoic Belt and Purcell Supergroups, Rocky Mountains, *GAC/MAC Victoria '95, Final Program & Abstracts*, A-79.

Duncan R. Derry Medal Call for Nominations

The Duncan R. Derry Medal is the highest award bestowed by the Mineral Deposits Division (MDD) of the Geological Association of Canada.

It is awarded annually to an outstanding economic geologist who has made contributions to the science of economic geology in Canada. Candidates should be recognized for their skill and stature as professional economic geologists, and also by their public contributions to the science.

It is acknowledged that publication is the prime, but not the only method, of disseminating scientific information in any discipline. Candidates should be members of the GAC, and preferably, but not necessarily, members of the MDD.

Nominations for the Duncan R. Derry Medal are to be made by 3 members of the MDD, jointly or by independent submission

Nominations should be submitted in triplicate to the Chairperson of the Selection Committee:

Jennifer Pell
Indian and Northern Affairs Canada
P.O. Box 1500, Yellowknife, NWT, X1A 2R3
Tel: 403-920-8216
FAX: 403-873-5763

GAC - Mineral Deposits Division Newslette

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Palabora Mining Company, a a member of the international RTZ Group, is situated near the town of Phalaborwa in the remote part of the north-eastern Northern Province, Republic of South Africa (Fig. 1). It is a mine unique amongst the world's major copper operations in its geology and mineralogy, diversity of by-products, technical innovation and performance efficiencies, financial performance and its dedication to social development and environmental care. It is also one of the largest open cast mining operations in the world and is the largest in Africa.

The exploitation of the orebody by Palabora Mining Company started in 1956, although artifacts found in the area prove that copper of remarkable purity was produced in the Phalaborwa area as early as the 8th century AD. In 1963, construction began on site, and two years later, mining operations began. In February 1966, the first Cu anodes were cast.

The mine operates as a high tonnage, low copper grade (average of 0.5% Cu) venture producing about 100 000 tons of broken rock per day on a 7-day week basis to feed a milling operation continually at a nominal rate of 82000 tons per day. The average stripping ratio is approximately 0.173:1 where waste material includes dolcrite and material below 0.1% Cu.

The current pit dimensions are 1800m E-W, 1400m N-S and 450m deep. The pit is designed to achieve a final depth of 762m below average surface elevation in the year 2002 with final pit dimensions of 388.69m E-W and 143.88m N-S at bench 58. The ore is, however, known to extend far deeper than the final pit depth and feasibility studies are being conducted into underground mining to extend the life of the mine well into the next century.

At present, Palabora mines three pipelike bodies in the Palabora Igneous Complex, those being the northern and southern pipes for its vermiculite and apatite (apatite goes to Foskor) and the central, or Loolekop pipe for its copper. Mining does however alternate between the two vermiculite deposits, depending on the market requirements.

By-products of the copper mining venture include, magnetite, baddeleyite **(Z1O2),** uranium, nickel sulphate and sulphuric acid and account for approximately 20% of the total revenue. The ultramafic rocks of the complex are host to economic deposits of vermiculite, and Palabora supplies approximately 30% of the world's requirements.

PALABORA IGNEOUS COMPLEX

The Palabora Igneous Complex is in Archean Shield and covers an elongated, kidney-shaped area roughly 6.5km north-south and 2.5km east-west in extent. The Complex resulted from an alkaline intrusive cycle, which emplaced, in successive stages, a suite of rocks ranging from ultramafic to pcralkaline in character, (geological and mineralogical staff, 1976). The geology of the Complex is shown in Figure 2 (modified after Hanekom ***el. al.*** 1965). According to Hanekom ***el. al*** three successive stages in the intrusive cycle are distinguishable.

PHASE I

The first phase of the intrusive cycle resulted in the emplacement into the Archean granite gneisses of a massive ultramafic, vertical, pipelike body consisting mainly of pyroxenite, consisting of variable proportions of phlogopite, diopside and apatite. A corona of feldspathic pyroxenite around the pyroxenite, formed as a result of the interaction of the pyroxenite with the Archean granite gneisses.