

Base and Precious Metals Indicator Mineral Research at the Geological Survey of Canada

INTRODUCTION

The application of indicator mineral methods to diamond exploration is well established because much research has focused on the visual recognition of indicator minerals and their chemical characteristics in diamondiferous kimberlites. In Canada, kimberlite indicator mineral methods have been successfully applied to till and stream sediment sampling (McClenaghan & Kjarsgaard 2007) and contributed to the discovery and development of several diamondiferous kimberlites. This method relies, at least at the early exploration stage, on detecting the presence of 10s to 100s of oxide and silicate indicator mineral grains in till or stream sediments that have survived pre- and postglacial weathering as well as glacial transport. In contrast to kimberlites, base and precious metal exploration generally targets much larger mineralized or altered zones which will yield precious and sulphide minerals as well as oxide and silicate indicator minerals. These indicator minerals might not survive pre- or postglacial weathering or glacial transport. Limited research and case studies have been conducted that document the abundance and chemistry of indicator minerals characteristic of base and precious metal deposits and how these minerals survive weathering and glacial transport. The Geological Survey of Canada (GSC) is addressing this knowledge gap through indicator mineral studies of known base metal deposits of various types across Canada, including magmatic Ni-Cu-PGE, Cu-Pb-Zn VHMS, Pb-Zn sedex and Fe-oxide Cu-Au/U (Fig. 1). Additional studies are being carried out on base and precious metal indicator minerals in areas with potential for porphyry, epithermal, volcanic hosted mineralization and sedimentary hosted Zn deposits. The objectives of the GSC research are: 1) to specify the indicator minerals that are indicative of various base and precious metal deposit types and to describe their properties; 2) to establish practical methods for their recovery from glacial and stream sediments and for their identification that can be routinely applied in exploration in glaciated terrain; 3) to apply these methods for establishing the mineralization

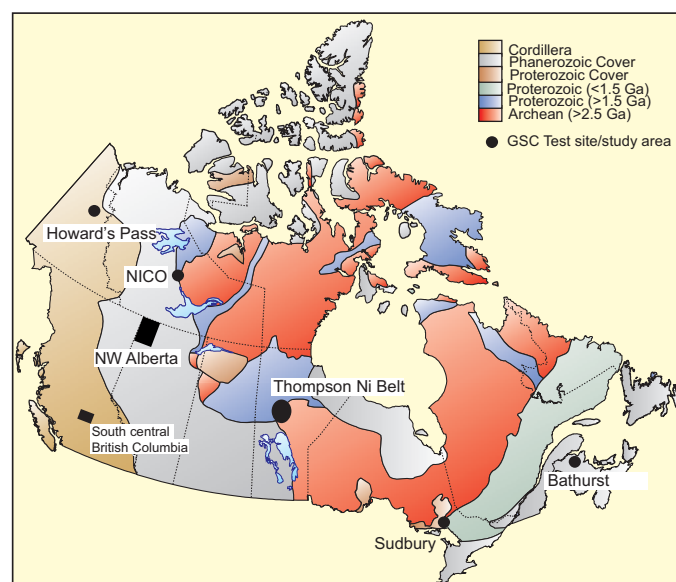


Figure 1. Location of Geological Survey of Canada base and precious metal indicator mineral test sites and study areas in Canada.

potential of regions that are in need of new exploration; and 4) to transfer this knowledge base to the mineral exploration industry. This research is being funded by the GSC's Targeted Geoscience Initiative TGI-3 (2005-2010) in partnership with CAMIRO, and by the Mountain Pine Beetle Project (2007-2009) centered in British Columbia. A study in northern Alberta was funded by the GSC's Northern Resource Development Program (2003-2007). The purpose of this article is to provide an overview of the ongoing base and precious metal indicator mineral research at the GSC.

METHODS

The test sites chosen are known deposits that are accessible, where the ore zones subcrop beneath till, the local area is till covered, and in some cases, previous work indicates there is metal-rich debris in the till. Bedrock samples of ore and host rocks (~5 kg) and till samples (10-30 kg) at varying distances up- and down-ice of several known deposits have been collected at various test sites across Canada (Fig. 1). In addition, regional reconnaissance till sampling was conducted in northwest Alberta and south central British Columbia. In those two areas, till samples were collected at an average spacing of 2 to 5 km. All bedrock and till samples are processed at Overburden Drilling Management Ltd. (ODM), Nepean, Ontario to recover heavy mineral concentrates for counting and selection of potential indicator minerals, some of which have been previously specified by Averill (2001, 2007a, 2007b). Concentrates are prepared using a combination of tabling and heavy liquids (Averill & Huneault 2006) to ensure recovery of the silt (Fig. 2) to sand sized indicator minerals. ODM is working in close collaboration with the GSC on samples from all the test sites to document the indicator mineral suites for the various deposit types. Selected grains are photographed, examined using a scanning electron microscope (SEM),

continued on page 13

Base and Precious Metals Indicator Mineral Research... *continued from page 12*

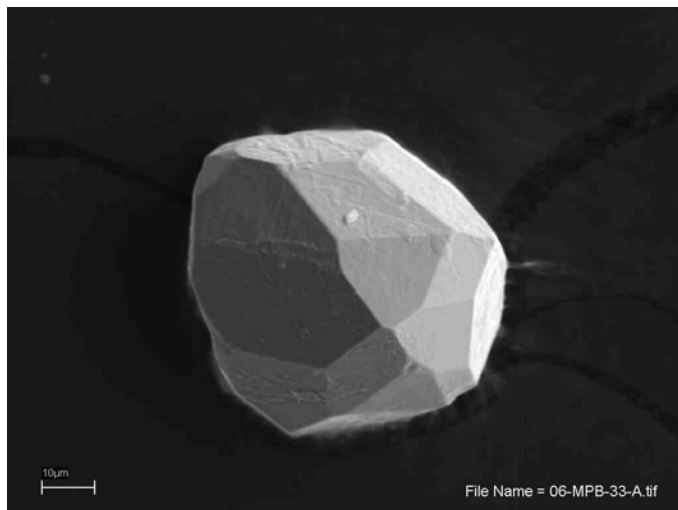


Figure 2. SEM backscattered image of a silt-sized sperrylite (PtAs_2) grain from till 250 m down-ice of the Broken Hammer Cu(Ni)-PGE zone, Sudbury.

analyzed by electron microprobe (EMP) to confirm the visual identifications and document their major and trace element signatures, and in some cases, further analyzed by laser ablation-ICP-MS to characterize their trace element signatures.

TEST SITES

Magmatic Ni-Cu-PGE

The world class magmatic Ni-Cu (PGE) deposits in the Thompson Nickel Belt (TNB) in north central Manitoba, Canada, were selected to address knowledge gaps about Ni-Cu-PGE indicator minerals, especially chromite (Fig. 3). This test site is also one of four test sites

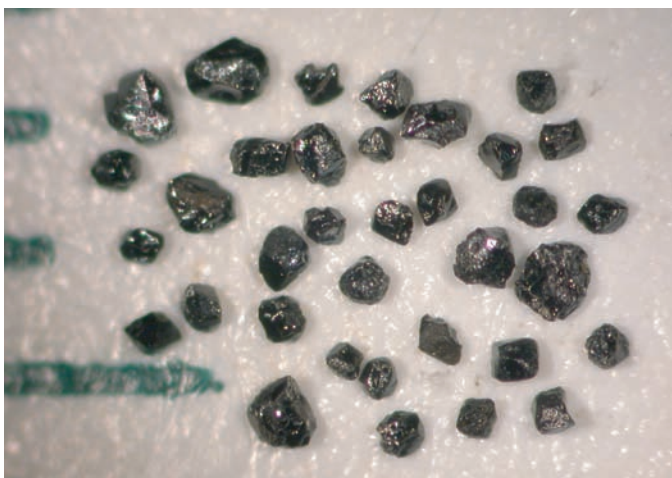


Figure 3. Fresh, angular chromite grains from the 0.25-0.5 mm fraction of till 50 m down-ice of South Pit ore zone, Thompson Ni Mine. Scale bars are spaced 1 mm apart.

for the Canadian Mining Research Organization (CAMIRO) Project 04E01 focused on magmatic Ni-Cu-PGE indicator minerals. The three other test sites included in this CAMIRO project include West Musgraves, Australia, Jinchuan, China and Noril'sk,

Russia. Bedrock and till samples were collected across the northern TNB in 2005 and 2006. GSC archived heavy mineral concentrates were also used. This site was selected because a 400 km long Cr-diopside dispersal train in till was known (down-ice) from the TNB (Fig. 4)

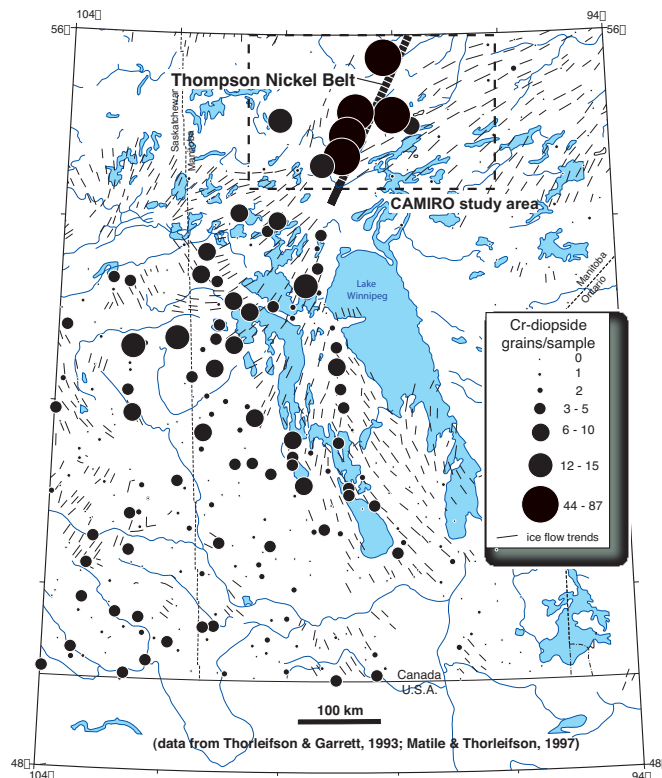


Figure 4. Distribution of low (>0.5 % Cr_2O_3) Cr-diopside in the 0.25-2.0 mm fraction of till from reconnaissance-scale till samples across western Manitoba and eastern Saskatchewan. Data from Thorleifson and Garrett (1993) and Matile and Thorleifson (1997).

suggesting that the ultramafic host rocks have a strong signature in the till and the potential of Cr-diopside to be an indicator mineral of this deposit type. Closely spaced bedrock and till sampling was focused around the open pits at CVRD-INCO's Thompson and Pipe Mines and surface areas around the Birchtree Mine in the north part of the belt. Widely spaced bedrock and till samples were also collected along the NE-SW trending TNB, as well as west (down-ice) and east (up-ice) of the belt. The belt is covered by till which is overlain by thick glaciolacustrine

continued on page 14

Note: This EXPLORE article has been extracted from the original EXPLORE Newsletter. Therefore, page numbers may not be continuous and any advertisement has been masked.

Base and Precious Metals Indicator Mineral Research... *continued from page 13*

sediments. Thus sampling was carried out using a combination of hand dug holes, till exposed in river sections and backhoe excavation. This study is a collaborative effort by CAMIRO, ODM, B. McClenaghan (GSC), G. Matile (Manitoba Geological Survey), D. Layton-Matthews (Queen's University), W. Griffin (GEMOC), G. Beaudoin (Laval University) and CVRD-INCO.

Magmatic/hydrothermal Cu-(Ni)-PGE

In 2006, a suite of bedrock and till samples were collected from sites up-ice, overlying and up to 5 km down-ice from Wallbridge Mining Company Ltd.'s magmatic-hydrothermal Broken Hammer Cu-(Ni)-PGE footwall mineralized zone on the North Range of the Sudbury Basin, Ontario. This site was selected because the mineralized zone (Big Boy vein) is well exposed by recent trenching, is known to contain visible sperrylite (PtAs₂), and is located on the north side of the Sudbury Basin and thus up-ice of the major Sudbury deposits. The deposit area is covered by thin (<3 m) discontinuous till. This study is a collaborative effort by B. McClenaghan and D. Ames (GSC), G. Budulan (B.Sc. student, University of Ottawa), A. Bajc (Ontario Geological Survey), Wallbridge Mining Company Ltd. and ODM.

Cu-Pb-Zn Volcanogenic hosted massive sulphide

Bedrock and till samples were collected in 2007 from sites up to 2 km down-ice from Xstrata Zinc's volcanogenic hosted Half Mile Lake Zn-Pb-Cu massive sulphide deposit in the Bathurst Mining Camp, New Brunswick. This test site was selected because the deposit was known to have a well defined metal-rich dispersal train characterized by anomalous concentrations of Cu, Pb, Zn, Sn, In, As, Ag, Bi, Au, and Sb in the <0.063 mm sized fraction of till extending at least 500 m down-ice (Parkhill & Doiron 2003). The deposit area is covered by a continuous till blanket that is 1-3 m thick. Collaborators for this test site include B. McClenaghan, G. Budulan (M.Sc. student, Queen's University), M. Parkhill and J. Walker (New Brunswick Dept. Natural Resources), D. Layton-Matthews, Xstrata Zinc and ODM.

Pb-Zn Sedimentary exhalative (SEDEX)

A small suite of till samples was collected in the Howard's Pass area of the Selwyn Basin, Yukon, in the summer of 2007. These samples were collected up-ice, overlying and down-ice of the Zn-Pb-rich XY Zone to document indicator minerals around a Zn-Pb sedimentary exhalative (SEDEX) deposit in an alpine glacial setting with thin, locally derived till and complex ice flow patterns. This research is a collaborative effort by D. Turner (M.Sc. student, Simon Fraser University), B. Ward (Simon Fraser University), B. McClenaghan, Selwyn Resources Ltd. and ODM.

Fe-oxide-Cu-Au/U

The Co-Au-Bi NICO deposit in the Great Bear magmatic zone (central NWT) was selected as a test site to

characterize the indicator mineral and alteration geochemical signature of Fe-oxide Cu-Au/U (IOCG/U) deposits in glaciated terrain. IOCG/U deposits can host significant resources in base, precious and strategic metals as well as energy and are under-explored in Canada. This site was selected because the mineralized zones and alkali-altered host rocks are well exposed, ore mineralogy is well known, and active resource evaluation by Fortune Minerals Ltd. provides logistical support in an otherwise remote, poorly-accessible area (Corriveau et al. 2007). In 2007, bedrock and C-horizon till samples were collected over and down-ice from mineralization, host rocks and alteration zones, and up-ice in background terrain. The NICO deposit area is dominated by bedrock and by thin, discontinuous till which is overlain at many sites by veneers of winnowed till and glaciolacustrine sediments. Additional test sites will be selected in the Great Bear magmatic zone for further sampling in 2008. This study is a collaborative effort by I. McMartin and L. Corriveau (GSC), G. Beaudoin, Fortune Minerals Ltd., NWT Geoscience Office and ODM.

Porphyry, epithermal, and volcanic hosted mineralization

A regional till sampling program, including indicator mineral sampling, was completed in 2007 in south-central British Columbia in a region with a high potential to host porphyry, epithermal, and volcanic hosted mineralization. This region was selected because its forest industry is under threat following the recent mountain pine beetle infestation which has destroyed a high percentage of the pine forest. The objective of the till sampling program is to evaluate the mineral potential of this region which ultimately could help diversify its resource economy. The exploration challenges in this region include the thick and nearly continuous glacial sediment cover and thick accumulation of Tertiary flood basalt that overlie prospective rocks. The current hypothesis is that windows through the basalt to underlying mineralized rocks might be concealed by the extensive glacial sediment cover. Surficial geology mapping is conducted in parallel with the till sampling to better define the regional ice-flow history. This research involves the participation of A. Plouffe and J. Bednarski (GSC) and C.A. Huscroft (Thompson Rivers University).

Undiscovered sedimentary hosted Zn mineralization

A surficial geology and regional till sampling project conducted from 2003 to 2007 in northwest Alberta has identified the potential for the area to host sedimentary-hosted Zn mineralization. Plouffe et al. (2006) reported a significant sphalerite (ZnS) anomaly in till in northwest Alberta, including a till sample containing >1000 sphalerite grains in 30 kg (Fig. 5). Galena grains accompany some of the sphalerite grains in till. Current research includes S and Pb isotopic analyses of the sphalerite and galena grains in till, which should provide additional information on the type of mineralization in bedrock and potentially the source of the mineralizing fluids. R. Paulen (Alberta Geological Survey), A. Plouffe, R. Smith and S. Paradis (GSC) have been involved with this project.

Base and Precious Metals Indicator Mineral Research... continued from page 14

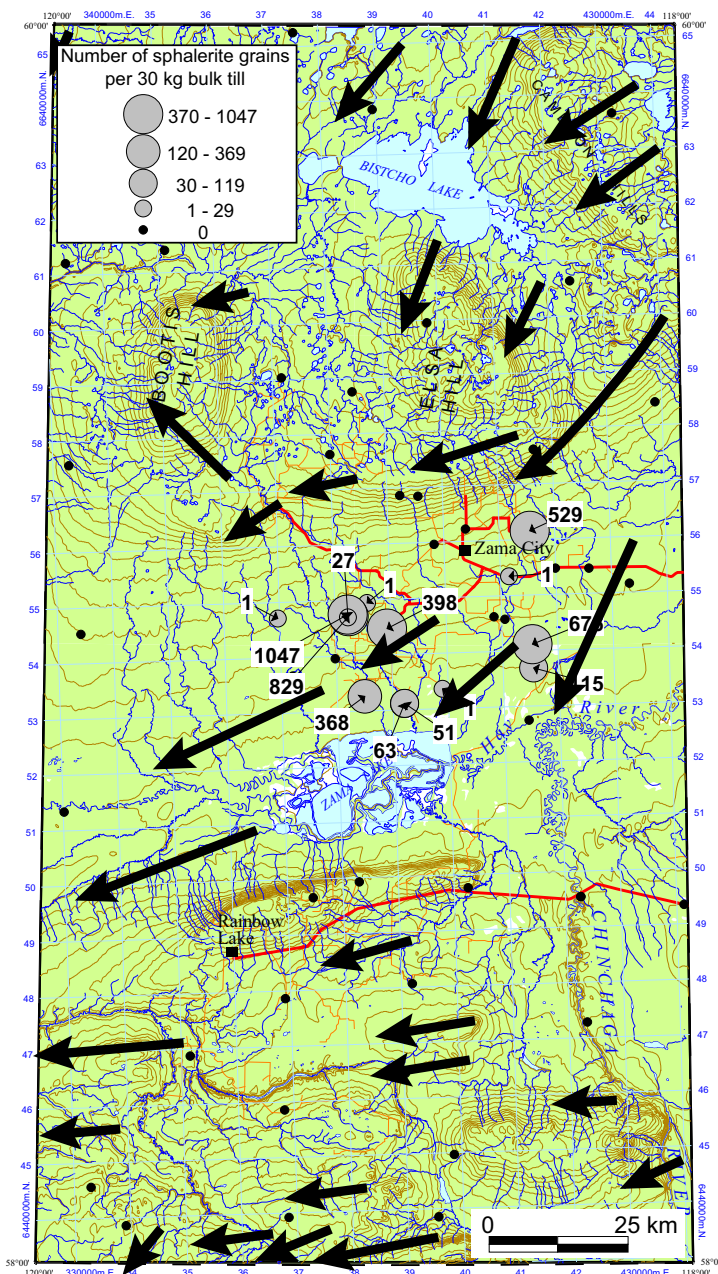


Figure 5. Number of sphalerite grains in till normalized to 30 kg, from northwest Alberta. Ice-flow directions (grey arrows) are from the recent surficial geology maps produced as part of this project.

REFERENCES

- Averill, S.A. 2001. The application of heavy indicator mineralogy in mineral exploration with emphasis on base metal indicators in glaciated metamorphic and plutonic terrains. In: McClenaghan, M.B., Bobrowsky, P.T., Hall, G.E.M. & Cook, S.J. (eds) *Drift Exploration in Glaciated Terrain*. Geological Society of London, Special Publication **185**, p. 69-81.
- Averill, S.A. 2007a. Useful Ni-Cu-PGE versus kimberlite indicator minerals in surficial sediments: similarities and differences. In: Geological Association of Canada, Short Course Notes, 105-118.
- Averill, S.A. 2007b. Recent Advances in Base Metal Indicator Mineralogy: An Update from Overburden Drilling Management Limited. EXPLORE, Newsletter of the Association of Applied Geochemists, No. **134**, 2-6.
- Averill, S.A. & Huneault, R. 2006. Overburden Drilling Management Ltd: Exploring heavy minerals. EXPLORE, Newsletter of the Association of Applied Geochemists, No. **133**, 1-5.
- Corriveau, L., Ootes, L., Mumin, H., Jackson, V., Bennett, V., Cremer, J.-F., Rivard, B., McMartin, I. & Beaudoin, G. 2007. Alteration vectoring to IOCG(U) deposits in frontier volcano-plutonic terrains, Canada. In: Proceedings of Exploration 07: Fifth Decennial International Conference on Mineral Exploration, edited by B. Milkereit, 2007, p. 1171-1177.
- Matile, G.L.D. & Thorleifson, L.H. 1997. Till geochemical and indicator mineral reconnaissance of northeastern Manitoba. Manitoba Energy and Mines, Open File 97-3.
- McClenaghan, M.B. & Kjarsgaard, B.A. 2007. Indicator mineral and surficial geochemical exploration methods for kimberlite in glaciated terrain, examples from Canada. In: Mineral Resources of Canada: A Synthesis of Major Deposit-types, District Metallogeny, the Evolution of Geological Provinces and Exploration Methods. Geological Association of Canada, Special Publication No. **5**, 983-1006.
- Parkhill, M. A. & Doiron, A. 2003. Quaternary geology of the Bathurst Mining Camp and implications for base metal exploration using drift prospecting. In: Goodfellow, W.D., McCutcheon, S.R. & Peter, J.M., eds., *Massive Sulfide Deposits of the Bathurst Mining Camp, New Brunswick, and Northern Maine*, Economic Geology Monograph **11**, 631-660.
- Plouffe, A., Paulen, R. C. & Smith, I. R. 2006. Indicator mineral content and geochemistry of glacial sediments from northwest Alberta (NTS 84L, M): new opportunities for mineral exploration. Geological Survey of Canada, Open File 5121, Alberta Energy and Utilities Board, Special Report 77.
- Thorleifson, L.H. & Garrett, R.G. 1993. Prairie kimberlite study- till matrix geochemistry and preliminary indicator mineral data. Geological Survey of Canada, Open File 2745.

Beth McClenaghan, Isabelle McMartin, Alain Plouffe
 Geological Survey of Canada
 601 Booth Street
 Ottawa, ON
 CANADA K1A 0E8
 Email: bmcclena@nrcan.gc.ca

