Drift Prospecting for Mississippi Valley-Type (MVT) Deposits Using Indicator Mineral Methods: An Example from Pine Point, Northwest Territories, Canada

Oviatt, N.M. [1, 2], Paulen, R.C. [3], Gleeson, S.A. [1, 4], McClenaghan, M.B. [3]

1. Department of Earth and Atmospheric Sciences, University of Alberta
2. DeBeers Canada Inc. Exploration
3. Geological Survey of Canada, Natural Resources Canada
4. GFZ Helmholtz-Zentrum Potsdam

ABSTRACT

A glacial dispersal study was conducted around a subcropping Pb-Zn deposit (O28) in the Pine Point Mississippi Valley-type (MVT) district, Northwest Territories, Canada. The intent of this study was to characterize and document the associated indicator minerals and their dispersal from a known Pb-Zn orebody. Surficial mapping of striae and glacial stratigraphy indicate that at least three phases of ice flow have affected the Pine Point area, each of which had access to the orebodies. Sulphide mineralization at deposit O28 included sphalerite, galena and pyrite, of which sphalerite and galena were recovered from the sand fraction of till samples up to 500 m from the mineralized subcrop. The majority of sphalerite and galena from till samples down-ice of the deposit were 0.25 to 0.5 mm in size; however, in samples closest to the subcropping mineralization most of the 1 to 2 mm fraction was recovered. The geomorphology of sphalerite grains was more rounded with increased distance from the orebody indicating that size and morphology can demonstrate relative proximity to an orebody. The major element chemistry as well as the Pb and S isotopic signature of the sphalerite and galena grains recovered from bedrock samples were compared to the sphalerite and galena grains recovered from till samples. In general, the major element concentrations of sphalerite recovered from till samples were similar to those of the honey-brown and cleiophane varieties of sphalerite identified in bedrock samples. Major element geochemistry of galena grains recovered from till samples was most similar to the cubic and the late-stage fracture-filling varieties identified in bedrock. The S isotopic values for sphalerite grains recovered from till samples, for the most part, fell within the range of those recovered from bedrock samples. Lead isotopic ratios for both till and bedrock samples showed very little variation, which is characteristic of the Pine Point deposit. The results of this study present criteria and highlight additional methods for exploration of MVT deposits in glaciated terrain by defining which minerals associated with MVT deposits survive glacial comminution, transport and deposition.

INTRODUCTION

Repeated glaciations over most of Canada during the Quaternary period have resulted in the deposition of glacial deposits of varying thickness. This drift cover presents a significant hurdle for exploration companies working in prospective terrains. Extensive work has been completed in defining and documenting indicator mineral and till geochemical methods for numerous deposit types (e.g., Shilts, 1996; McClenaghan, 2005; McClenaghan et al., 2015), though the applicability of these methods to the exploration of Mississippi Valley-type deposits is unknown.

Location and geological setting

The Pine Point mining district is located on the southern shore of Great Slave Lake, Northwest Territories on the eastern margin of the Western Canada Sedimentary Basin (Figure 1). The district consists of 100 drill-defined, tabular and prismatic orebodies that are dispersed over an area of approximately 1600 km^2.

Glacial sediments (till), derived from the Keewatin Sector of the Laurentide Ice Sheet, generally increase in thickness from the east (~3 m) to the west (~25 m) across the district. Previous studies in the area identified striations that indicate ice flow to be in a general southwest direction (Lemmen, 1998). Striations on bedrock surfaces exposed during open-pit mining examined during this study and others (Rice et al., 2013) indicate a minimum of three directions of ice flow. Cross-cutting relationships observed from these striations reveal an earliest ice flow to the southwest, followed by an intermediate northwest flow, and lastly a west-southwest direction.

METHODS

A total of 96 till and 76 bedrock samples were collected across the district throughout the duration of the project. Of the 96 till samples, a total of 83 samples were collected in the vicinity of deposit O28 (Figure 2). Bedrock samples were collected from five different deposits (O28, HZ, L65, M67 and R190) to determine the range of sulphide minerals present. Bedrock and till samples were processed for indicator minerals, which were analyzed by microprobe for major element chemistry and subjected to additional isotopic analyses of Pb and S. Furthermore, the till samples were processed for geochemistry of the fine fraction (silt + clay). For further details on the field and analytical methods, the reader is directed to GSC Open File 7320 (Oviatt et al., 2013a) and GSC Open File 7423 (Oviatt et al., 2013b).

In "Proceedings of Exploration 17: Sixth Decennial International Conference on Mineral Exploration" edited by V. Tschirhart and M.D. Thomas, 2017, p. 867–870

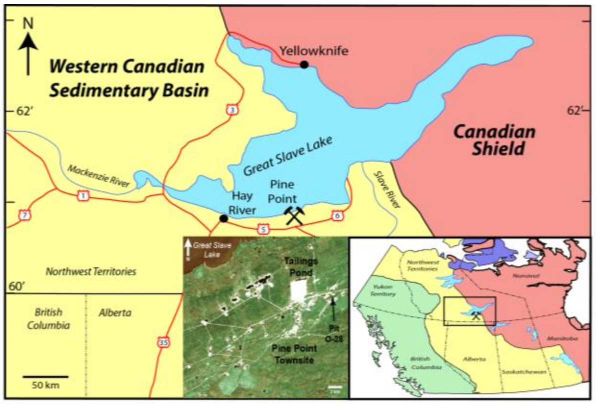

Figure 1: Location map of the Pine Point mining district. A detailed study was conducted at deposit O28.

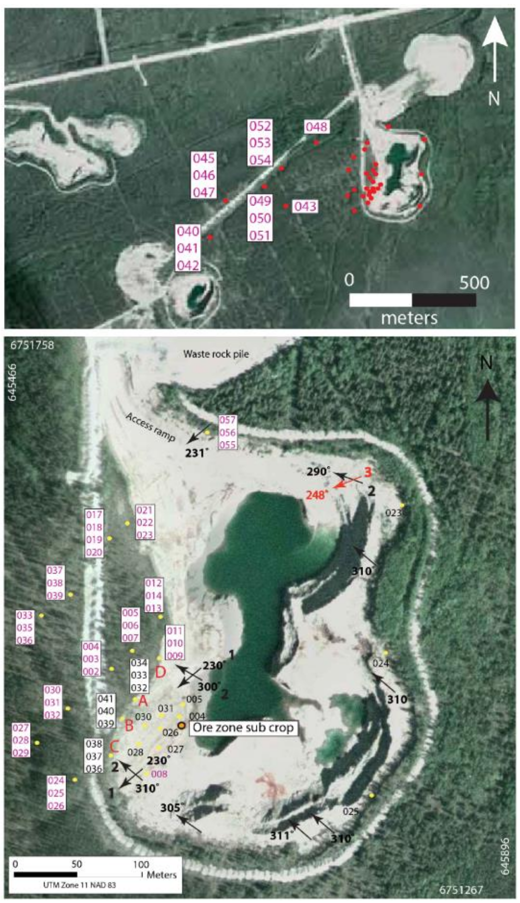

Figure 2: Locations of till samples collected: (A) in the O28 study area and (B) proximal to the deposit. Different coloured sample numbers indicate two phases of field work conducted in 2010 (black) and 2011 (pink). Stacked sample numbers indicate samples that were collected at 1, 2, and 3 m depth. Striation measurements are indicated with arrows delineating the relative ages, from the oldest (1) to the youngest (3).

RESULTS

Different varieties of sphalerite, galena and pyrite were identified within the bedrock samples (Figure 3). Two different growth habits were identified in thin section for galena, cubic (as fracture and vug fills, or banded ores) and skeletal (dendritic crystals). Sphalerite is present as four distinct varieties: honey-brown, blackjack, colloform and cleiophane.

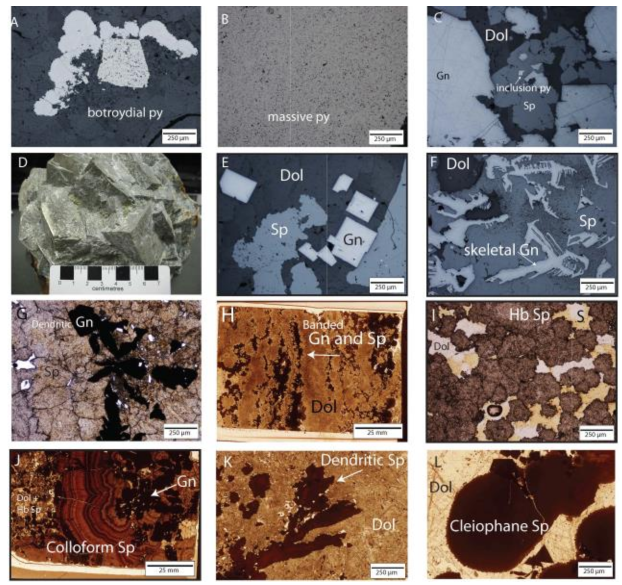

Figure 3: Photomicrographs of ore minerals in thin section or hand sample: (A) botryoidal pyrite (py) in dolomite host; reflected light; (B) massive pyrite; reflected light; (C) inclusion pyrite in sphalerite (Sp) with galena (Gn) and dolomite (Dol); reflected light; (D) massive, 3 cm, cubic pyrite from deposit S65; (E) cubic galena and sphalerite in dolomite; reflected light; (F) skeletal galena in colloform sphalerite; reflected light; (G) dendritic galena; plane-polarized light; (H) banded galena and sphalerite; plane-polarized light; (I) subhedral, honey-brown sphalerite with native sulphur; plane-polarized light; (J) colloform sphalerite with galena; plane-polarized light; (K) dendritic sphalerite; plane-polarized light; (L) cleiophane sphalerite in dolomite; plane-polarized light.

Indicator minerals recovered from till samples

Sphalerite and galena were recovered from the 0.25 to 2.0 mm size fractions though some samples also contained these minerals in the pan concentrate (~25 µm). The majority of honey-brown, blackjack and colloform sphalerites were recovered from the 0.25 to 0.5 mm fraction though samples collected in close proximity to the deposit contained the highest grain counts (0–265) recovered from the 1.0–2.0 mm fraction (Figure 4) (Oviatt et al., 2013b). The grains in close proximity to the deposit were more angular than those collected at larger distances (~250 m). Major element analysis was completed by an electron microprobe analyzer (EMPA) on grains recovered from both bedrock and till. These analyses indicate that sphalerite grains from till samples have similar concentrations to those from bedrock samples (Oviatt et al., 2015) with respect to Zn and S. The $\delta^{34}S$ values for sphalerite in bedrock from all five deposits range from 20.6‰ to 24.2‰. Conversely, $\delta^{34}S$ values for sphalerite grains recovered from till range from -5.3‰ to 24.4‰. The $\delta^{34}S$ values did not vary across the different varieties of sphalerite.

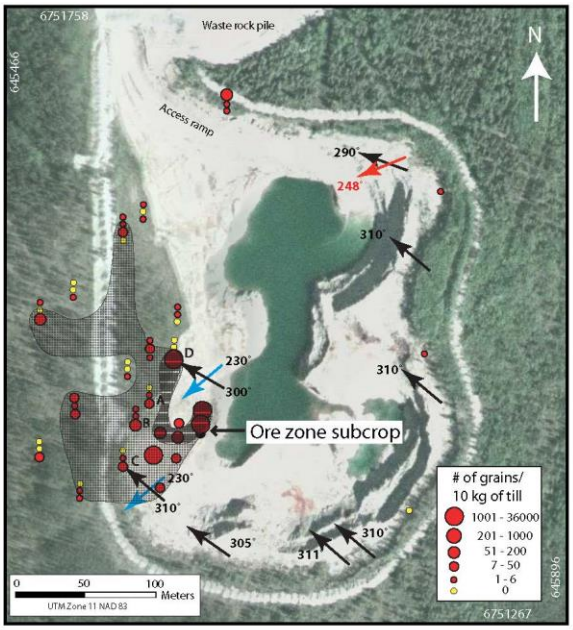

Figure 4: Distribution of sphalerite grains in the 0.25–0.5 mm fraction of till. The cross-hatched pattern shows samples that contain sphalerite grains in the 0.5–1.0 mm fraction, and the thick-lined pattern shows samples containing sphalerite grains in the 1.0–2.0 fraction that tend to be closer to the orebody.

The majority of galena grains were recovered from the 25 µm to 0.5 mm fractions of till in samples that were located in close proximity to the ore zone (Figure 5). These grains were typically cubic though some grains had a more rounded appearance. All galena crystals from bedrock and till samples have homogeneous $^{208}Pb/^{204}Pb$, $^{207}Pb/^{204}Pb$ and $^{206}Pb/^{204}Pb$ values, which is characteristic of Pine Point.

DISCUSSION

Sphalerite, galena and pyrite were detected in till down-ice of the O28 deposit at the surface at least 500 m from the deposit. The coarsest sphalerite and galena grains were recovered from till samples <50 m from the O28 orebody indicating that indicator mineral grain size can indicate proximity to a deposit. The morphology of sphalerite grains changes with glacial transport distance from source, with angular grains occurring in samples proximal to the deposit source while more rounded grains are located in samples distal from the deposit. Galena grain morphology is not conducive to determining glacial transport distance from a deposit. This is due to the very strong cubic cleavage exhibited by galena crystals, which causes galena grains to fragment along cleavage planes rather than clastic erosion of the grain itself during glacial comminution. Some galena grains recovered from till samples also had acquired a secondary coating of anglesite on them, producing a grain morphology that was, in part, formed *in situ* after glacial transport (Figure 6).

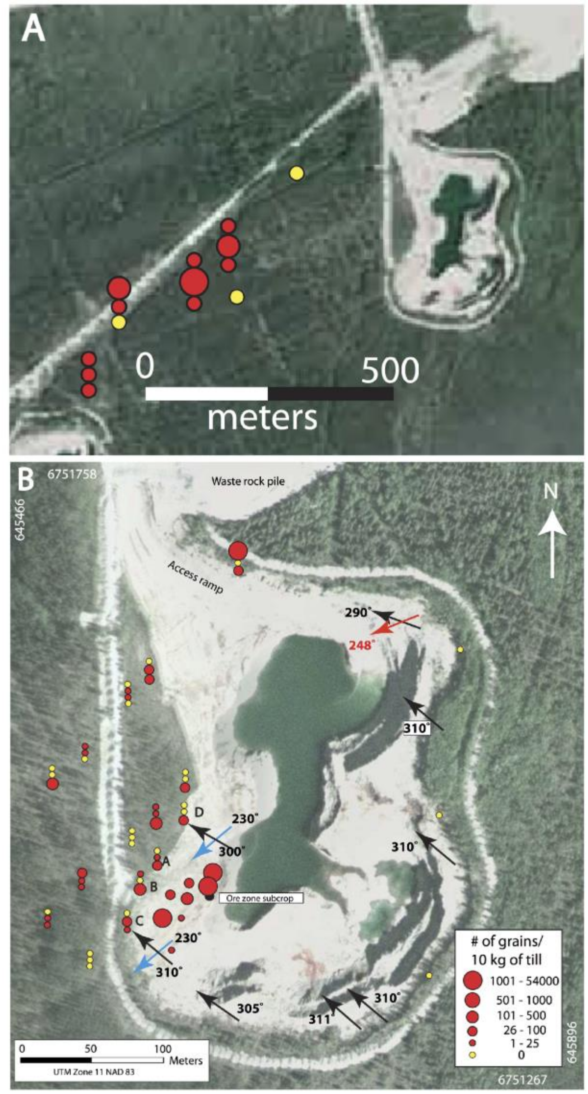

Figure 5: Distribution of galena grains in the 0.25–0.5 mm fraction of till samples (A) in the O28 deposit area, and (B) proximal to the O28 ore zone.

The majority of indicator mineral dispersal appears to be in the direction of the first two ice flow trajectories, to the southwest and northwest, indicating that the deforming bed of the glacier (cf., Alley et al., 1986; van der Meer et al., 2003) during the last ice flow phase to the north-northwest did not have direct access to the surface of the mineral deposits. Only metal-rich material previously dispersed by the earlier two ice flow events would have been further reworked and diluted during the last ice flow phase. The absence of these late phase striations on bedrock surfaces covered by more than 3 m of till supports the explanation of the net indicator mineral dispersal. In other words, the O28 orebody was covered by >2 m deposit of till at some time during the first two ice-flow phases, essentially cutting off the orebody from being glacially eroded and dispersed by the final west-southwest ice-flow phase. This observation is significant for Pb-Zn exploration in the region, because the glacially streamlined landforms observed at surface, produced from the last phase of ice flow, are not parallel to the mapped glacial dispersal train of sphalerite and galena (~270°).

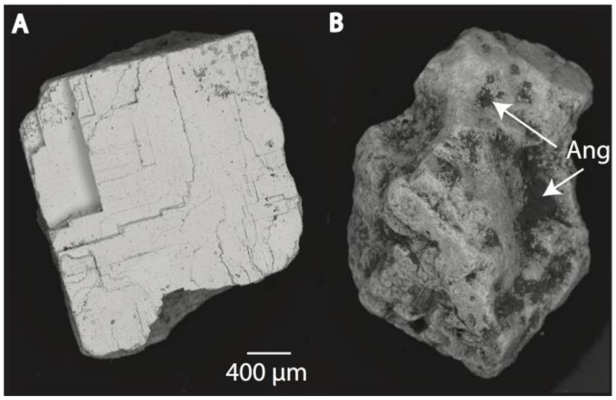

Figure 6: Secondary electron images of galena grains from a till sample collected approximately 250 m from ore zone. The grains are cubic (A) to sub-rounded (B). The sub-rounded appearance may be due to the coating of anglesite (Ang) on this grain which is absent from the grain in (A).

Elemental concentrations for major elements in sphalerite grains recovered from till samples were similar to those of the honey-brown and cleiophane varieties analyzed in the bedrock samples. The majority of grains recovered from till samples appear to have the same concentrations of Zn, Fe and S as the honey-brown variety, indicating that this variety was either the most abundant in deposit O28 or that this type of sphalerite was more resistant to glacial transport. In general, Fe concentrations in sphalerite grains recovered from till samples are slightly lower than those in bedrock samples (Oviatt et al., 2015). Some till samples show an enrichment in Fe in the till matrix geochemistry (Oviatt et al., 2013a), which could be from matrix-grain interaction.

SUMMARY

We have shown that galena and sphalerite are preserved in till as indicator minerals, particularly when derived from carbonate bedrock. In this study indicator mineral methods using surface till were able to detect the presence of a MVT deposit covered by approximately 3 m of till, at least 750 m down-ice in the direction (~290°) that reflects the net dispersal from the three ice-flow trajectories.

Based on the results of this study, some recommendations of exploration techniques for MVT deposits in glaciated terrain can be made. First, it is important to obtain detailed, property-scale data on glacial flow history. Secondly, in areas with multiple ice-flow trajectories, a sampling strategy should be used that will capture possible dispersal vectors for each trajectory. Grain size and morphology of sphalerite grains can be used to determine proximity to a MVT deposit. The bedrock source, and potential deposit type, can be ascertained from isotopic analysis of individual galena and sphalerite grains, specifically their Pb and S isotopic signatures.

ACKNOWLEDGEMENTS

This research was funded by the Geological Survey of Canada Geo-Mapping for Energy and Minerals (GEM) Program (2008–2013) under the Tri-Territorial Indicator Mineral Project. This activity is a contribution to N.M. Oviatt's M.Sc. thesis at the University of Alberta, which was supported by a NSERC CRD grant in partnership with Tamerlane Ventures Limited, Teck Resources Limited and Overburden Drilling Management Limited.

REFERENCES

Alley, R.B., D.D. Blankenship, C.R. Bentley, and S.T. Rooney, 1986, Deformation of till beneath ice stream B, West Antarctica: Nature, 322, 57-59.

Lemmen, D.S., 1998, Surficial geology, Buffalo Lake, District of Mackenzie, Northwest Territories: Geological Survey of Canada, Map 1906A, scale 1:250 000.

McClenaghan, M.B., 2005, Indicator mineral methods in exploration: Geochemistry: Exploration, Environment, Analysis, 5, 233–245.

McClenaghan, M.B., R.C. Paulen, D. Layton-Matthews, A.K. Hicken, and S.A. Averill, 2015, Glacial dispersal of gahnite from the Izok Lake Zn-Cu-Pb-Ag VMS deposit, northern Canada: Geochemistry: Exploration, Environment, Analysis, 15, 333–349.

Oviatt, N.M., M.B. McClenaghan, R.C. Paulen, and S.A. Gleeson, 2013a, Till geochemical signatures of the Pine Point Pb- Zn Mississippi Valley-type district, Northwest Territories: Geological Survey of Canada, Open File 7320.

Oviatt, N.M., M.B. McClenaghan, R.C. Paulen, S.A. Gleeson, S.A. Averill, and S. Paradis, 2013b, Indicator minerals in till and bedrock samples from the Pine Point Mississippi Valley-type district, Northwest Territories: Geological Survey of Canada Open File 7423.

Oviatt, N.M., S.A. Gleeson, R.C. Paulen, M.B. McClenaghan, and S. Paradis, 2015, Characterization and dispersal of indicator minerals associated with the Pine Point Mississippi Valley-type (MVT) district, Northwest Territories, Canada: Canadian Journal of Earth Sciences, 52, 776–794.

Rice, J.M., R.C. Paulen, J.M. Menzies, M.B. McClenaghan, and N.M. Oviatt, 2013, Glacial stratigraphy of the Pine Point Pb-Zn mine site, Northwest Territories: Geological Survey of Canada, Current Research 2013-5, 1-14.

Shilts, W.W., 1996, Chapter 15: Drift exploration, in J. Menzies, ed., Past Glacial Environments, Sediments, Forms and Techniques: Butterworth Heinemann, 411-439.

van der Meer, J.J.M., J. Menzies, and J. Rose, 2003, Subglacial till: the deforming glacier bed: Quaternary Science Reviews, 22, 1659-1685.