ISOTOPIC AND GEOCHEMICAL SIGNATURES OF BASE-METAL INDICATOR MINERALS IN THE SOUTHERN NORTHWEST TERRITORIES

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Introduction

Heavy indicator minerals recovered from stream sediment and till samples are commonly used for mineral exploration in glaciated terrain. The geochemical and isotopic composition of recovered heavy minerals can be used to determine provenance, deposit type, and guide exploration programs to prospective areas. As part of the Geological Survey of Canada's Geo-mapping for Energy and Minerals (GEM) Program, till samples and stream sediments were collected across a 100,000 km² region in the southern Northwest Territories, including three regions where previous surficial sampling programs under the Protected Area Strategy (Watson 2011a, b; 2013) program recovered high counts of base metal indicator minerals, including sphalerite, galena, chalcopyrite, and arsenopyrite. The Pine Point Mississippi Valley-type (MVT) district is present in the eastern part of the study area and is the only known potential up-ice source of sphalerite and galena mineralization exposed at surface. Despite the potential of the region to host additional mineral resources, very little exploration has been undertaken outside of Pine Point. Sulphur ($\delta^{34}S$= -14 to 40‰) and lead ($^{207}Pb/^{204}Pb$= 15.57 to 15.70; $^{206}Pb/^{204}Pb$= 18.00 to 18.20) isotope determinations by secondary ion mass spectrometry, and trace element geochemistry by laser ablation-inductively coupled plasma-mass spectrometry (low Ag, Sb, and Bi; LA-ICP-MS) indicate galena grains were sourced from MVT occurrences distinct from Pine Point, likely being sourced from within 1 km of peak galena abundance sample sites. LA-ICP-MS and electron probe micro analysis (EPMA) of sphalerite grains (high Ge and Zn, low Fe and In) suggest they originated from MVT mineralization that is distinct from Pine Point. Sulphur isotopes ($\delta^{34}S$ = -44 to +30‰) from chalcopyrite grains show potential for manto/Kipushi and/or sediment-hosted Cu sources. Arsenopyrite grains are less abundant than other recovered indicator minerals and have $\delta^{34}S$ signatures (±6‰) similar to orogenic Au systems 380 km northeast of the study area in the Canadian Shield.

Sample Locations

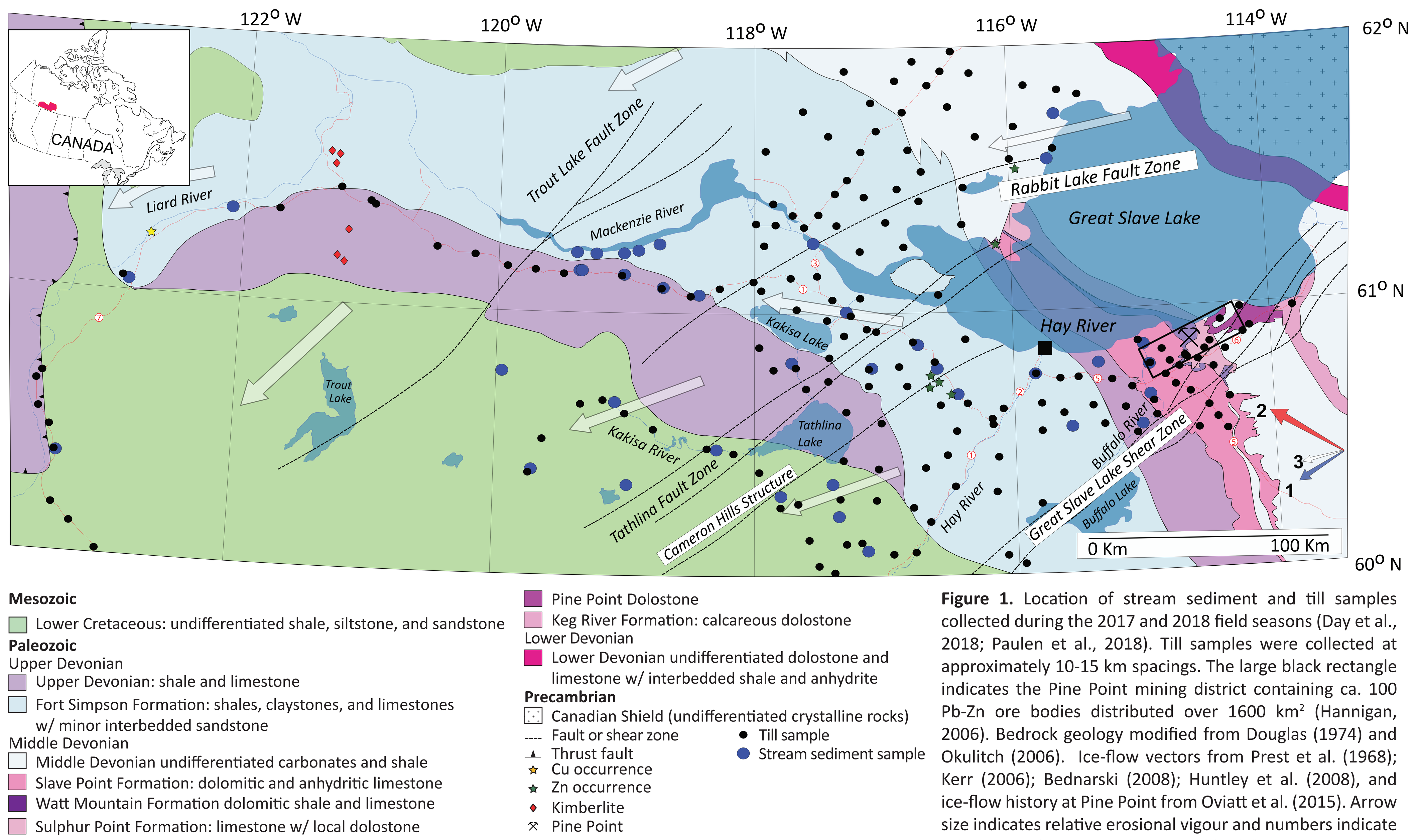


Figure 1. Location of stream sediment and till samples collected during the 2017 and 2018 field seasons (Day et al., 2018; Paulen et al., 2018). Till samples were collected at approximately 10-15 km spacings. The large black rectangle indicates the Pine Point mining district containing ca. 100 Pb-Zn ore bodies distributed over 1600 km² (Hannigan, 2006). Bedrock geology modified from Douglas (1974) and Okulitch (2006). Ice-flow vectors from Prest et al. (1968); Kerr (2006); Bednarski (2008); Huntley et al. (2008), and ice-flow history at Pine Point from Oviatt et al. (2015). Arrow size indicates relative erosional vigour and numbers indicate relative ice-flow chronology. Modified from Paulen et al. (2018)

Protected Area Strategy Survey

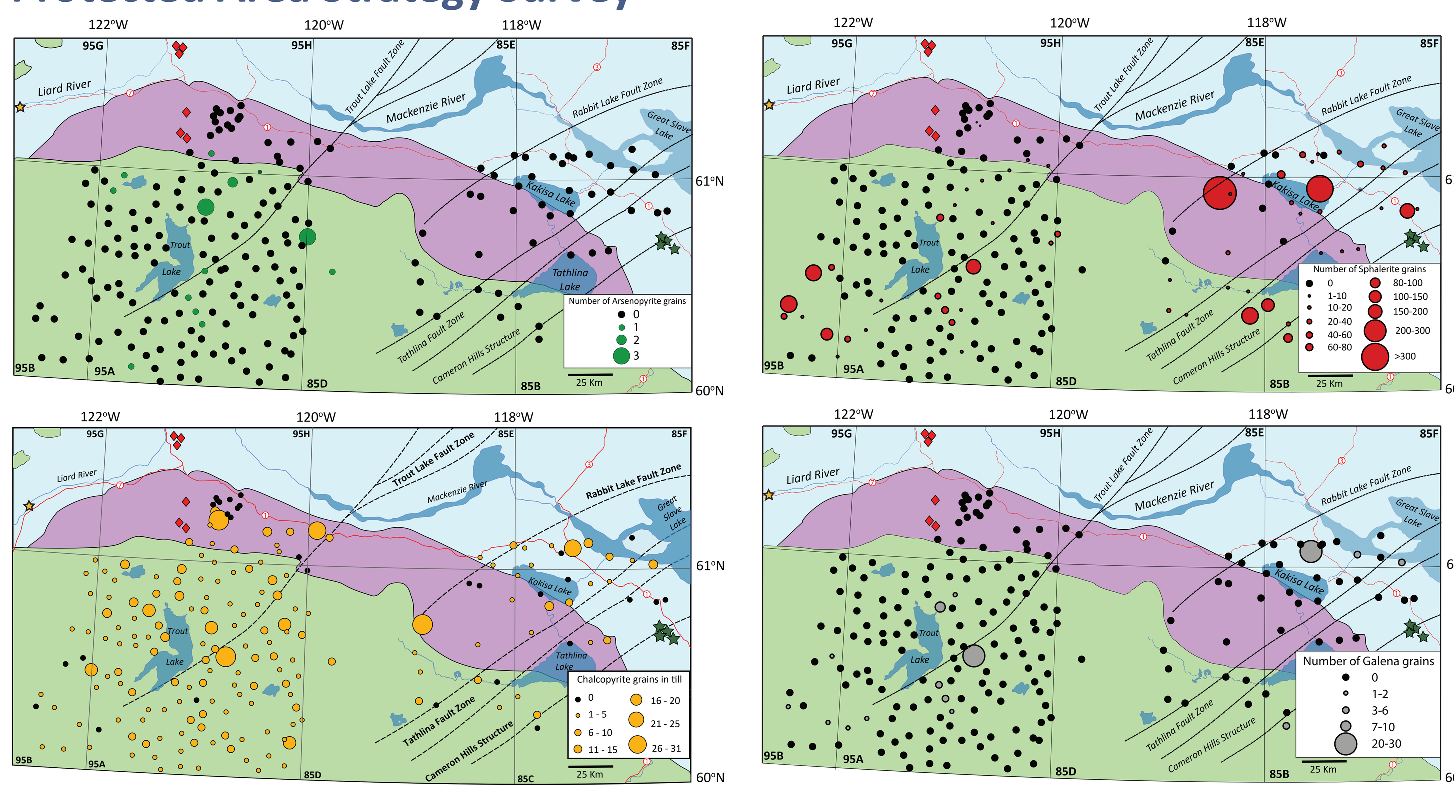


Figure 2. Proportional dot plots of arsenopyrite, sphalerite, chalcopyrite, and galena abundances in the 0.25-2.0 mm heavy mineral fraction (normalised to 25 kg of <2mm table feed weight) recovered from till samples during PAS surveys (Watson, 2011a, b; 2013). General ice flow direction was from northeast to southwest (Fig. 1). Classification intervals were arbitrarily assigned to control variation in the number of grains per sample. Bedrock geology modified from Douglas (1974) and Okulitch (2006). Note same legend as Figure 1. Samples collected in this region were analyzed as part of this study.

$^{206}Pb/^{204}Pb$ versus $^{207}Pb/^{204}Pb$

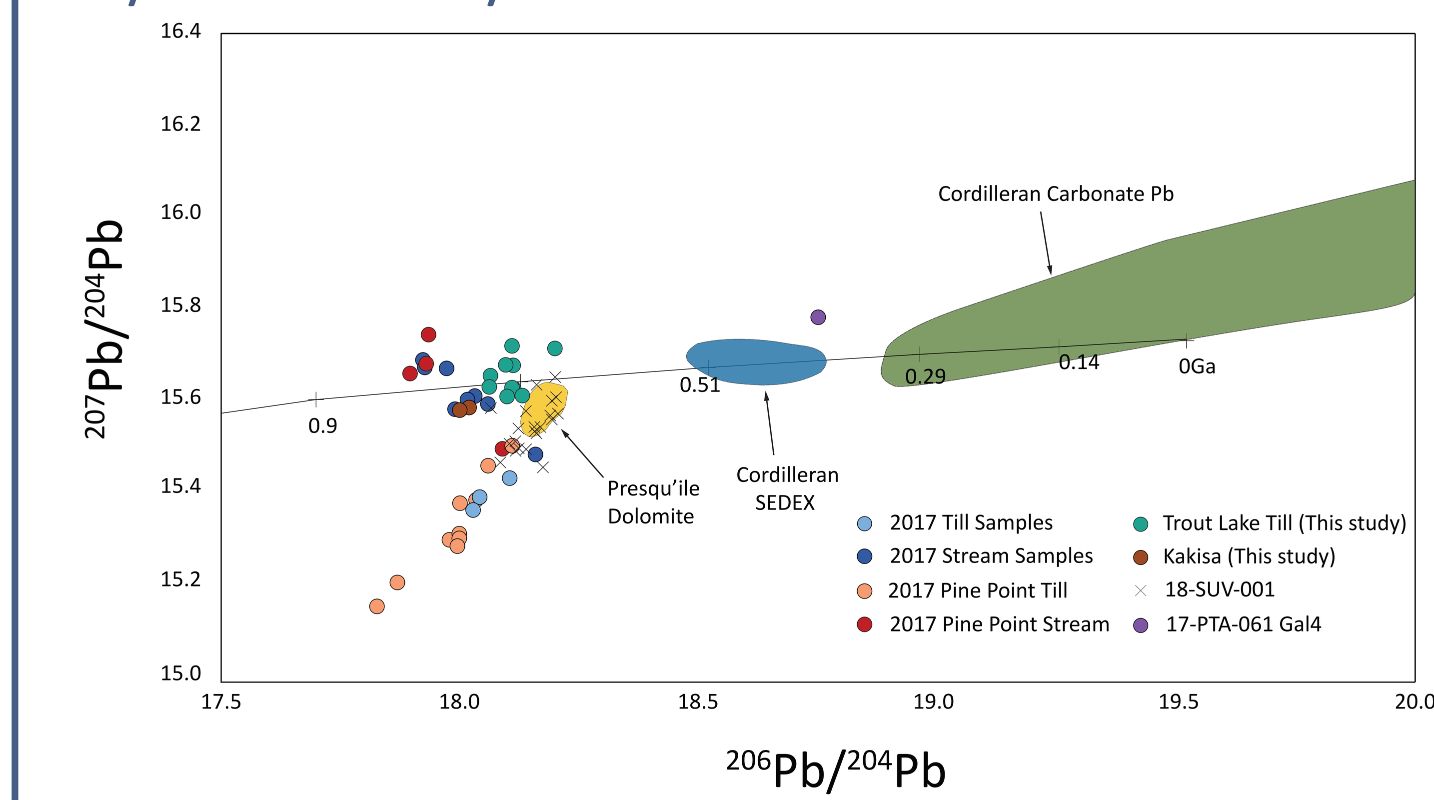
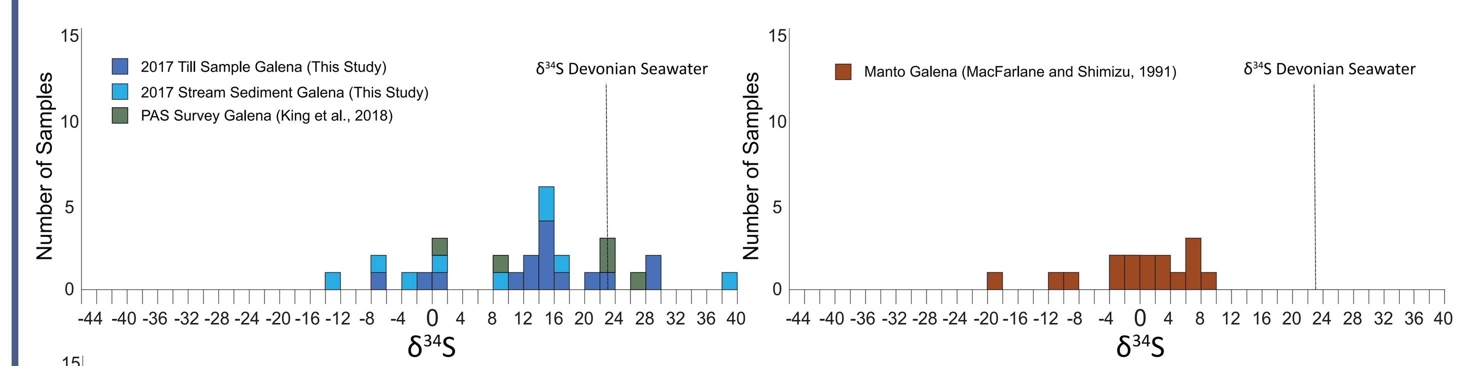


Figure 3. Lead isotope bivariate plot of $^{206}Pb/^{204}Pb$ versus $^{207}Pb/^{204}Pb$ for galena grains from PAS samples in the Trout Lake and Kakisa regions and 2017 till and stream samples. Values are compared to data from previous studies at Pine Point and in other Presqu'ile-hosted occurrences (yellow field; Cumming et al., 1990; Paradis et al., 2006; Oviatt et al., 2015). Data are plotted in reference to the shale curve of Godwin and Sinclair (1982). Also shown are data from other SEDEX Pb-Zn deposits (blue field) in Yukon Territory and carbonate-hosted Pb-Zn deposits in northern British Columbia, as well as values from the Western Canada Sedimentary Basin in northern British Columbia (green field; Godwin et al., 1988; Paradis et al., 2006). PAS survey and 2017 stream samples plot proximal to the shale curve with $^{206}Pb/^{204}Pb$ and $^{207}Pb/^{204}Pb$ indicative of Pb derived from evolved upper crustal sources (e.g., Zartman and Doe, 1979; Zartman and Haines, 1988; Krammers and Tolstikhin, 1997). 2017 till samples appear to define a mixing line with a lower crustal source(s), similar to reported sources at Pine Point, indicating that lead in these samples was likely derived from basement rocks (Paradis et al., 2006; Paulen et al., 2011; Oviatt et al., 2015).

Galena $\delta^{34}S$ Histograms



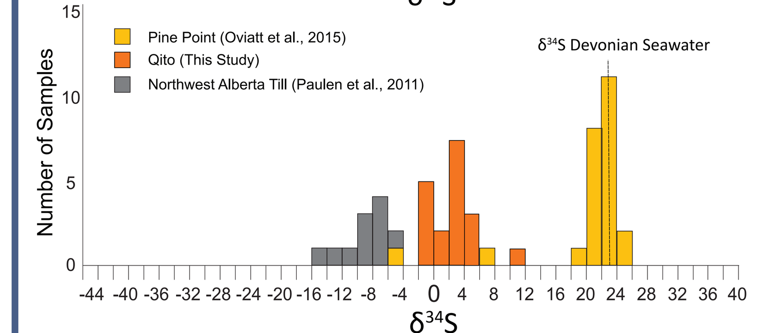
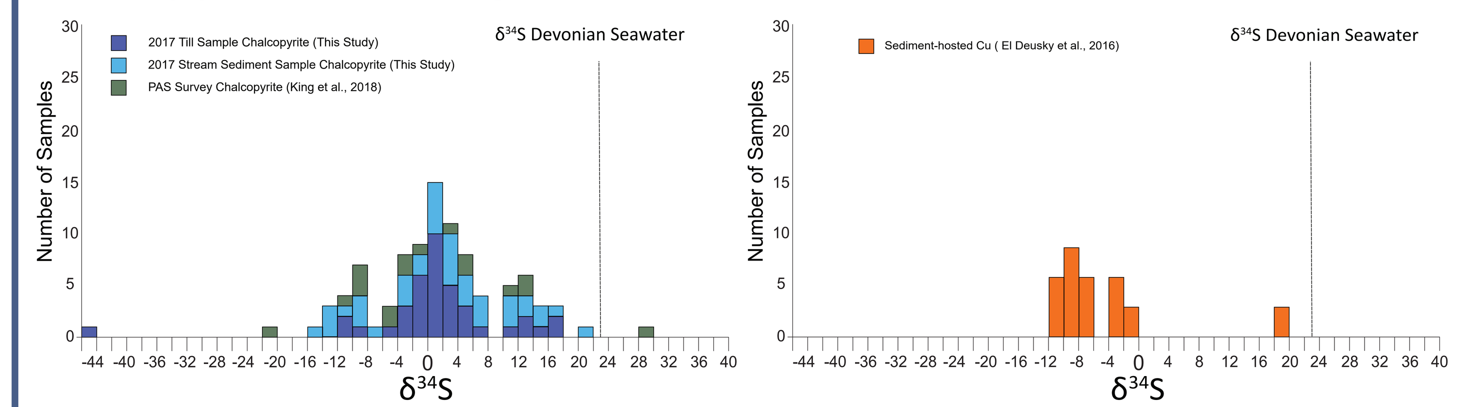


Figure 4. Histograms of $\delta^{34}S$ values from secondary ion mass spectrometry (SIMS) analysis from galena grains re-covered from 2017 till and stream sediment samples as well as PAS survey galena grains. Values are compared to values from deposits hosted in Presqu'ile dolomite, and manto systems in Peru (MacFarlane and Shimizu, 1991; Paulen et al., 2011; Oviatt et al., 2015).

Chalcopyrite $\delta^{34}S$ Histograms



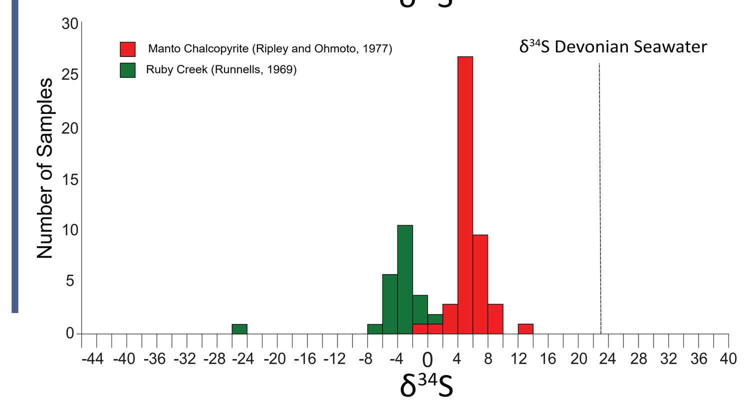


Figure 5. $\delta^{34}S$ composition of chalcopyrite grains recovered from 2017 till, stream sediments, and PAS survey samples. Values are compared to data from sediment-hosted Cu deposits in Africa, manto deposits in Peru and the Ruby Creek Kipushi-type deposit (Runnels, 1969; Ripley and Ohmoto, 1977; El Desouky et al., 2010).

Arsenopyrite $\delta^{34}S$ Histograms

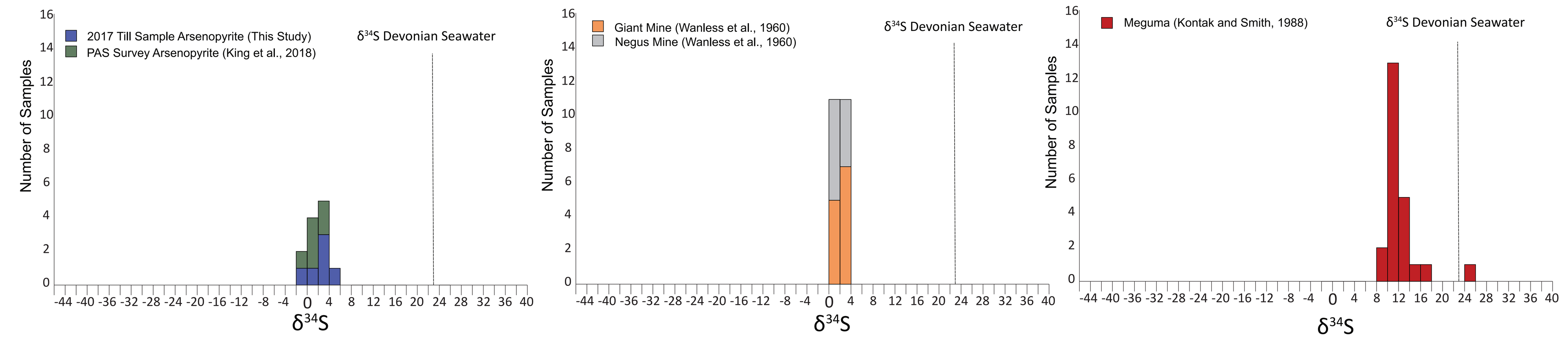


Figure 6. Histograms of $\delta^{34}S$ values from arsenopyrite grains recovered from 2017 till and PAS survey samples. Values are compared to data from two orogenic Au systems near Yellowknife, NWT (Wanless et al., 1960) and arsenopyrite found in Meguma-type Au systems (Kontak and Smith, 1988).

Sphalerite Geochemistry

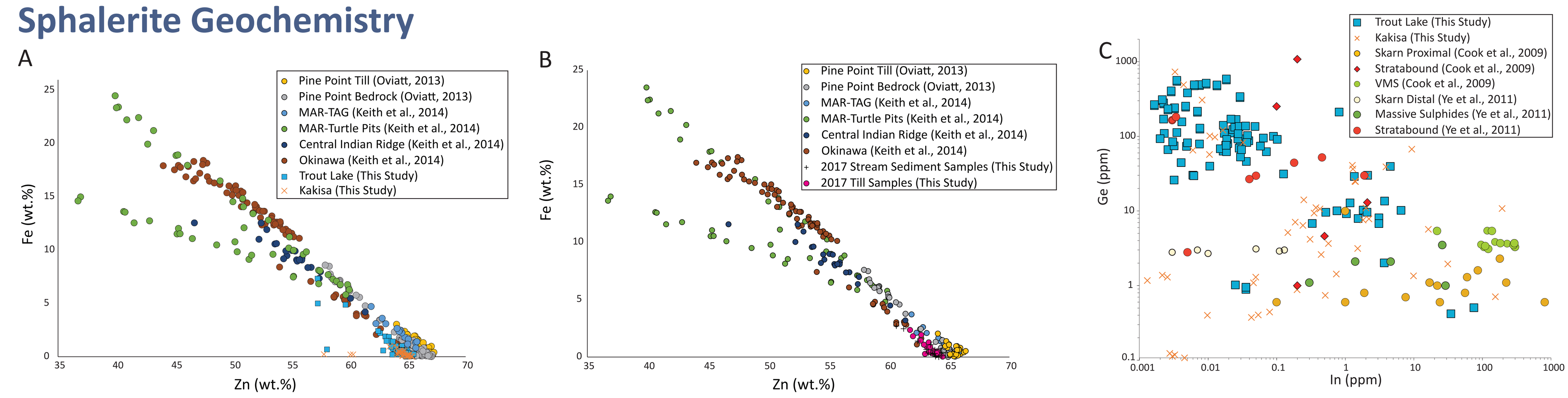


Figure 7. Geochemistry of sphalerite from PAS survey samples (A and C) and 2017 till and stream sediment samples (B). In Figures 7A and 7B, samples are compared to Fe/Zn ratios from sphalerite found in various seafloor hydrothermal systems around the world (Keith et al., 2014) as well as sphalerite collected from bedrock and till samples in the Pine Point mine area (Oviatt, 2013). In Figure 7C, the parts per million (ppm) of Ge and In in PAS survey samples are plotted against values from various deposits, covering a temperature range 300-410°C, studied by Cook et al. (2009) and Ye et al. (2011). The incorporation of Fe and In in sphalerite is most efficient at higher temperatures (T>250°C; Cook et al., 2009; Ye et al., 2011; Keith et al., 2014). Note logarithmic scale in Figure 7C.

Galena Geochemistry

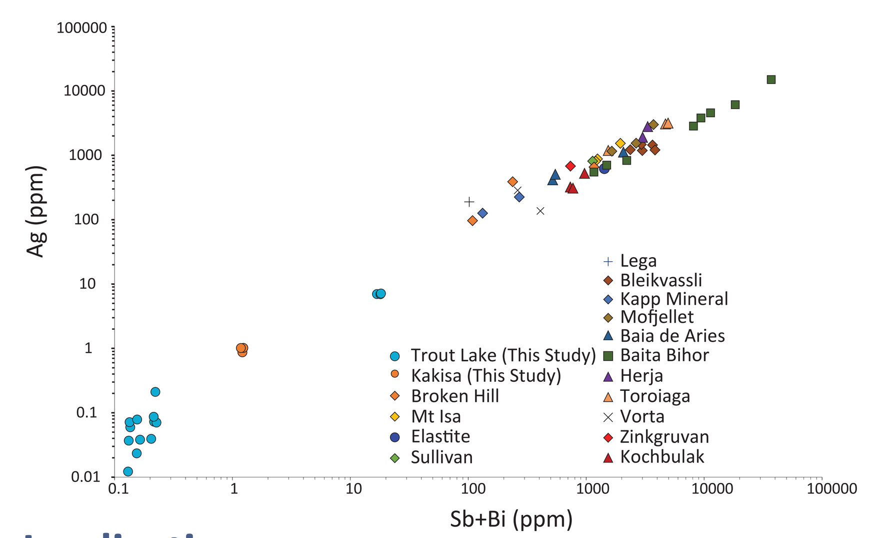


Figure 9. Scatterplot of Ag versus Sb+Bi in galena grains from PAS survey samples compared to data from various deposits around the globe (George et al., 2015). The incorporation of Ag, Sb, and Bi is most efficient at temperatures between 350°C and 400°C; at these temperatures galena can incorporate several wt.% Ag (George et al., 2015). Note, the high values from Baita Bihor are the result of Bi enrichment in the host rocks (George et al., 2015).

Implications

- Sphalerite and galena grains were not likely sourced from Pine Point;
- Low Fe and In, high Zn and Ge in sphalerite and low Ag, Sb and Bi in galena indicate that grains likely formed in low temperature environment, possibly MVT-style setting
- $\delta^{34}S$ of chalcopyrite grains indicates potential for manto/Kipushi-type and/or sediment-hosted Cu in the region;
- $\delta^{34}S$ signatures of arsenopyrite are similar to those of orogenic Au deposits near Yellowknife and were likely sourced from similar orogenic Au-systems up-ice of study area in the Canadian Shield
- Previous provenance studies in Pine Point region (Oviatt, 2013) showed that within 700 m down-ice transport, till samples generally contain at most tens of galena grains therefore, it is suggested that galena grains have travelled < 1 km from their source;
- Recommended future exploration should be focused in carbonate units proximal to the faults in the region including the Cameron Hill Structure, Trout Lake, Rabbit Lake, and Tathlina Lake fault zones (Fig. 1)

Acknowledgements

Protected Area Strategy samples were provided by the Northwest Territories Geological Survey as part of a collaborative project with the Geological Survey of Canada's Geomapping for Energy and Minerals GEM-2 program, Southern Mackenzie Surficial activity. Additional funding to support this work was provided by Dr. Stephen J. Piercey (NSERC Discovery Grant). The authors would like to acknowledge Glenn Piercey and Dr. Graham Layne (Memorial University) for SIMS Pb and S isotopic analysis. Dr. Wanda Aylward (Memorial University) is acknowledged for assistance with preliminary SEM imaging and EPMA analysis. Additionally, field assistants Grant Hagedorn, Matt Pyne, Joeli Plakholm, and Jamie Sapera are thanked for all their help with sample collection. Research was conducted under NWT Scientific Research Licence #16226.

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Permanent link: https://doi.org/10.4095/315440

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Presented at: Geological Association of Canada–Mineralogical Association of Canada–International Association of Hydrologists conference, Quebec 2019
Date presented: May 2019

Recommended citation
King, R.D., Piercey, S.J., Paulen, R.C., Day, S.J.A., Smith, I.R., and Petrus, J.A., 2019. Isotopic and geochemical signatures of base-metal indicator minerals in the southern Northwest Territories; Geological Survey of Canada, Scientific Presentation 107, 1 poster. https://doi.org/10.4095/315440