

Kimberlite and Base Metal Indicator Minerals in Glacial Sediments of Northern Alberta, Canada

Introduction

Historically, most heavy mineral surveys conducted by Geological Surveys and the Exploration industry primarily focused on either anticipated recovery of gold grains or kimberlite indicator minerals (KIMs). Indicator mineral surveys applied to base metal exploration rely on heavy, coarse-grained and chemically stable, magmatic and metamorphosed oxide and silicate minerals since most sulphide minerals are susceptible to degradation in the near-surface environment (Averill, 2007).

In northwestern Alberta, Canada, the Alberta Geological Survey (AGS) and the Geological Survey of Canada (GSC) conducted reconnaissance-scale sampling of glacial sediments to assess the potential occurrence of KIMs and other indicators of economic minerals (Fig. 1).

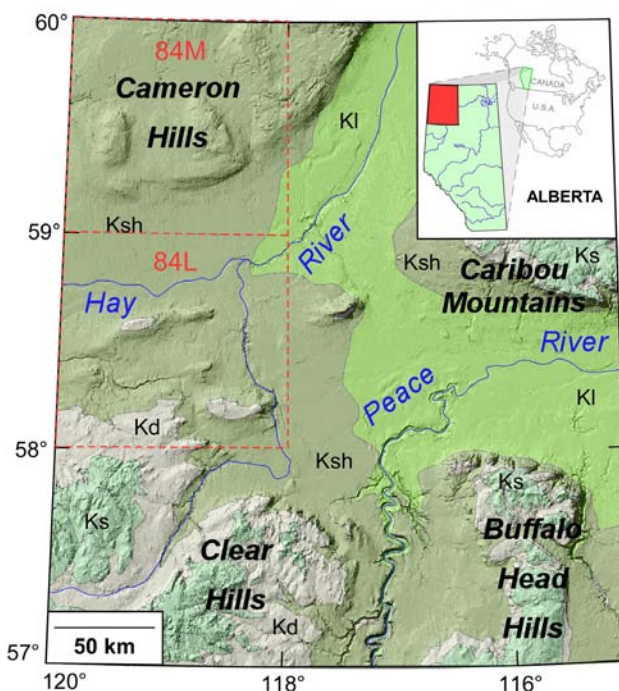


Figure 1: Physiography and bedrock geology of northwest Alberta in which the glacial sediment survey was undertaken. Cretaceous bedrock units listed from oldest to youngest (after Hamilton et al., 1998): Loon River Formation (KI), Shaftesbury Formation (Ksh), Dunvegan Formation (Kd) and Smoky Group (Ks). The Loon River and Shaftesbury formations occur within the upper part of the Fort St. John Group. The sample survey was conducted in National Topographic System (NTS) sheets 84M and 84L.

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This sampling program represents the first systematic regional geochemical and mineralogical survey of northwestern Alberta to be undertaken by the government. The Cretaceous sedimentary rocks of the Western Canada Sedimentary Basin, renowned for their hydrocarbon resources, are seldom considered to have potential to host base metal mineralization. These sedimentary rocks, deformed in the eastern Cordillera of the Rocky Mountains and Foothills and relatively flat-lying in the Interior Platform of Alberta, have also discouraged those who presumed that the Precambrian rocks of the Canadian Shield are more favourable hosts of base metal mineralization (cf., Edwards, 1988; Macqueen, 1997). Therefore, reconnaissance surveys for heavy minerals and geochemistry of stream and glacial sediments have not been conducted in the northern part of the Western Canada Sedimentary Basin.

Quaternary deposits are the unconsolidated surface materials that blanket virtually all of northern Alberta. Bedrock, occurring as remnant uplands which control the broad elements of the physiography, rarely crops out. Elsewhere, the flat nature of most of the region is a reflectance of the horizontal to gently dipping sedimentary bedrock. The region is poorly drained; secondary streams are not deeply incised and organic deposits in the form of fens and bogs abound. The physiography of northern Alberta consists of a number of uplands including the Buffalo Head Hills, Cameron Hills, Caribou Mountains, and Clear Hills separated by broad lowlands through which the Peace and Hay rivers and their tributaries drain (Pettapiece, 1986). These rivers are part of the Mackenzie River drainage basin which empties northward into the Beaufort Sea.

The underlying bedrock in northwest Alberta are a Cretaceous succession of nearly horizontal and poorly-indurated marine shales of the Fort St. John Group (Loon

River and Shaftesbury formations) and Smoky Group, separated by deltaic to marine sandstones of the Dunvegan Formation (Green et al., 1970; Okulitch, 2006). The transition from Lower to Upper Cretaceous strata occurs within the Shaftesbury Formation.

Northwest Alberta is covered by an extensive cover of unconsolidated glacial and nonglacial sediments varying greatly in thickness from 0 to 450 m (Pawlowicz et al., 2005, 2007). These sediments were deposited during glacial and interglacial periods of the Quaternary. For the most part, the surficial materials and present-day landforms are a result of the last glacial event, the Late Wisconsin (25 000 to 10 000 radiocarbon years before present). Ice derived from the Keewatin Sector of the Laurentide Ice Sheet flowed west and southwest across northern Alberta towards the Rocky Mountains. Ice retreated from the study area between 12 000 and 11 000 radiocarbon years before present (Dyke, 2004), at which time extensive glacial lakes developed over the lowland areas as a result of damming of the regional eastward drainage by the retreating glaciers. Thus, fine-grained glacial lake sediments overlie till in the lower portions of the Hay and Peace river drainage basins.

Results of the glacial sediment survey reported here are outputs of a collaborative project between the AGS and the GSC under GSC's Northern Resource Development Program (NRD Project 4450) with additional support through the GSC's Targeted Geoscience Initiative (TGI-2). Heavy mineral and geochemical results released in 2006 (Plouffe et al., 2006) resulted in significant mineral staking and exploration activity. This article outlines the presence of low concentrations of KIMs and high concentrations of sand-sized sphalerite grains in till from northwest Alberta and highlights the potential for the area to contain primary bedrock-hosted deposits of Zn.

Sample Survey and Methods

Bulk sediment samples (~30 kg) of predominantly till (but also including a few glaciofluvial samples) were collected. Samples were collected from the C soil-horizon (>1 m depth) from road exposures, natural bluffs, hand-dug pits, and borrow and sump pits dug for road construction or oil and gas drilling operations. Samples were sent for heavy mineral and gold grain analyses to a commercial laboratory to provide a preliminary overview of the mineral potential for the region. The heavy mineral fraction was isolated in a two step process involving a shaking table and heavy liquids (specific gravity of 3.2). KIMs, gold grains and other heavy indicator minerals were identified in the 0.25 – 2 mm sand-sized fraction under binocular microscopes by staff mineralogists at the laboratory. To monitor the accuracy of the heavy mineral separation and mineral identification procedures, several blank and spiked till samples were inserted by GSC (Plouffe et al. 2006, 2008). Picked KIMs and low Cr-diopside grains were then analyzed by electron microprobe to determine their chemistry.

The silt and clay-sized fraction (<0.063 mm or -250 mesh) was separated by dry sieving at the AGS lab.

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Duplicate and analytical standard samples were introduced into the sample set, which was then submitted to a commercial laboratory for analyses. Analyses were conducted on a 15 g split of the <0.063 mm sized fractions and included an *aqua regia* digestion followed by determination of major elements by ICP-ES and minor elements by ICP-MS, and LiBO₂ fusion/dilute nitric acid digestion followed by ICP-MS. Detailed field sampling methods, laboratory procedures for heavy mineral separation and identification, electron microprobe details, and analytical quality control and reproducibility are described in Plouffe et al. (2006).

Results

Approximately 90 glacial sediment samples in northwestern Alberta contained low numbers of KIMs consisting of 1 to 9 indicator grains. KIMs dominantly

consist of pyrope, chromite and Cr-diopside with lesser amounts of forsterite and ilmenite (Figure 2) (Plouffe et al. 2006, 2007, 2008). Most of these minerals were detected in the 0.25 to 0.5 mm size fraction but a limited number of grains were found in the 0.5 to 1 mm size range. No potential KIMs were detected in the 1 to 2 mm size fraction. A large percentage of the till samples containing KIMs are located in the region north of Zama and Hay lakes and south the Cameron Hills (Fig. 2). Most noteworthy are two anomalous samples containing 6 and 9 grains respectively.

However, of particular significance, and the focus of recent collaborative research, is the discovery of a significant sphalerite dispersal train in the south-central sector of the Bistcho Lake (NTS 84M) and north central sector of the Zama Lake (NTS 84L) map sheets (Fig. 3). Dark grey to black, angular, brittle grains of sphalerite, with rare grains of orange to honey sphalerite, were found

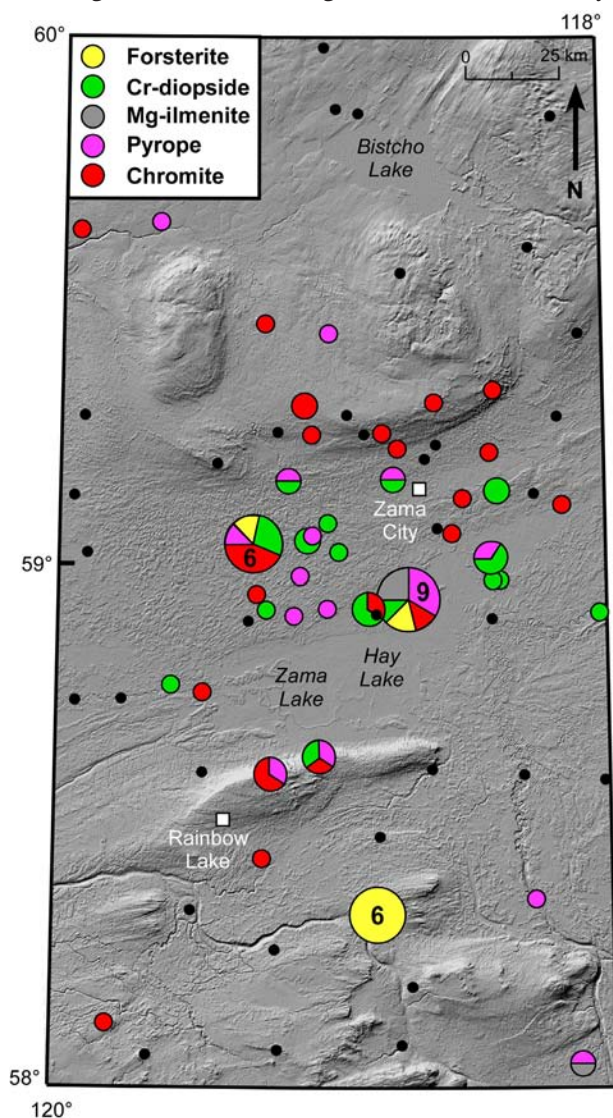


Figure 2: Number of kimberlite indicator mineral grains recovered from glacial sediments, normalized to 30 kg sample weights, plotted on Shuttle Radar Topography Mission (SRTM) generated digital elevation model. The small circles represent a single grain count; larger grain counts indicated by number; small solid black circles indicate samples with no recovered KIMs.

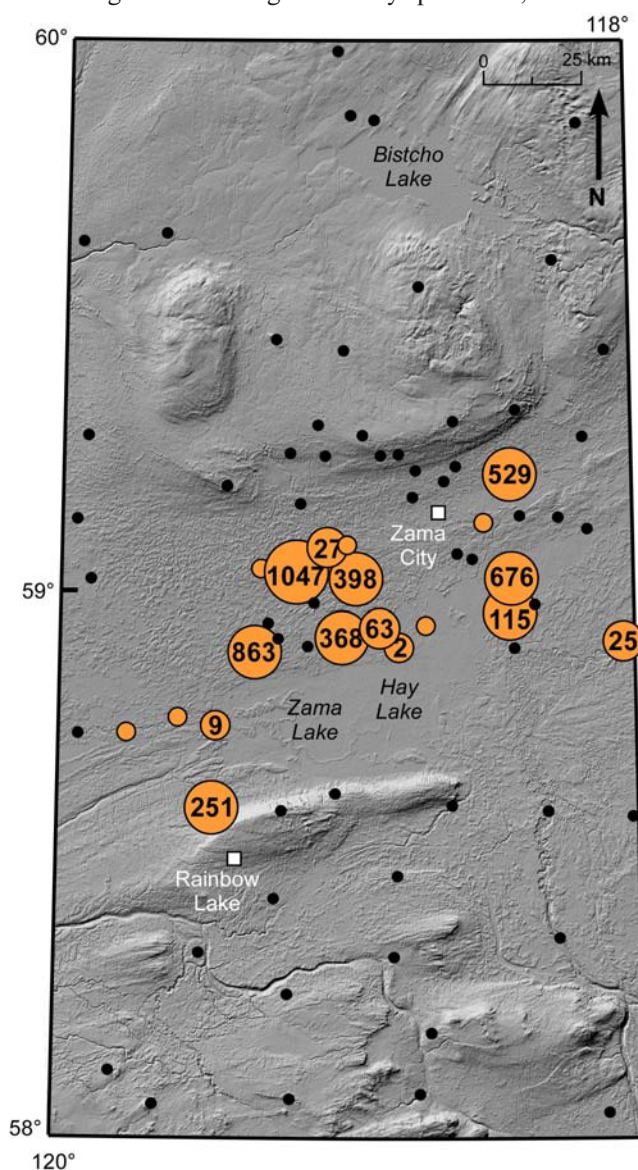


Figure 3: Number of sphalerite grains recovered from glacial sediments, normalized to 30 kg sample weights, plotted on SRTM generated digital elevation model. Small orange circles represent a single grain count; small solid black circles indicate samples with no recovered sphalerite.

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in high concentrations (>100 grains) in nine till samples including the highest concentration of 1047 sphalerite grains (normalized to 30 kg sample weight) in one till sample (Plouffe et al., 2006, 2008). Background concentrations in local till are zero grains. The grains exhibit pristine morphology with angular to sub-angular edges (Fig. 4). The mineralogical anomaly extends over an area of approximately 4000 km². One to four grains of galena were reported in eight of the till samples obtained from the anomalous region. The galena grains are also angular to sub-angular.

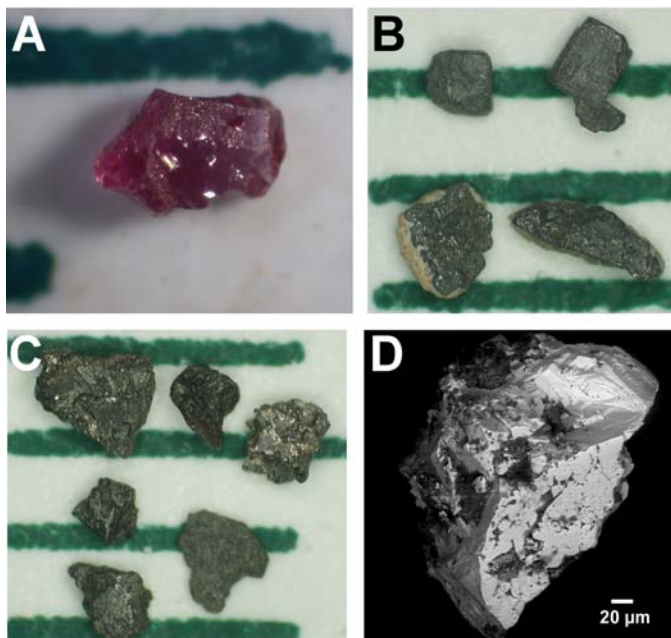


Figure 4: Microphotographs of the various indicator mineral grains recovered from till samples, divisions between green scale bars is 1 mm for images A-C. A) purple Cr-pyrophe garnet; B) galena grains exhibiting cubic crystal structure; C) dark grey to black Zn-rich sphalerite, a majority of the grains recovered were of this nature; D) scanning electron microscope image of an angular sphalerite grain.

Fifteen of the dark black sphalerite grains were submitted for electron microprobe analyses to confirm their mineralogy (Plouffe et al., 2007). The average composition of the sphalerite is 33.4 wt % S, 65.4 wt % Zn, 0.7 wt % Fe and 0.43 wt % Cd with traces amounts (0.3 to 0.1 wt %) of Cu, Ag, Se, and In. Compared to the composition of sphalerite at the world class Pine Point Mississippi Valley Type Zn-Pb deposit located 330 km to the northeast (Kyle, 1981), sphalerite from this study contains on average lower levels of Pb and Fe coupled with higher Cd concentrations. Furthermore, sphalerite colour from the Pine Point deposit varies from tan, yellow, light red-brown, dark red-brown to dark brown (Kyle, 1981). In contrast, the majority of sphalerite grains recovered from the northwestern Alberta till samples are dark grey to black (Fig. 4). Geochemistry of the till samples collected in the survey area show that till samples with high sphalerite content in the sand-sized fraction did not yield high anomalously high Zn concentrations in the silt plus clay-sized fraction (<0.063 mm). However, at a

regional scale, Zn concentrations in till are slightly elevated (<200 ppm) in a broad band oriented NE-SW extending subparallel to the Great Slave Shear Zone (Fig. 5) (Plouffe et al., 2006). For more detailed information the reader is referred to Plouffe et al. (2006, 2007, 2008).

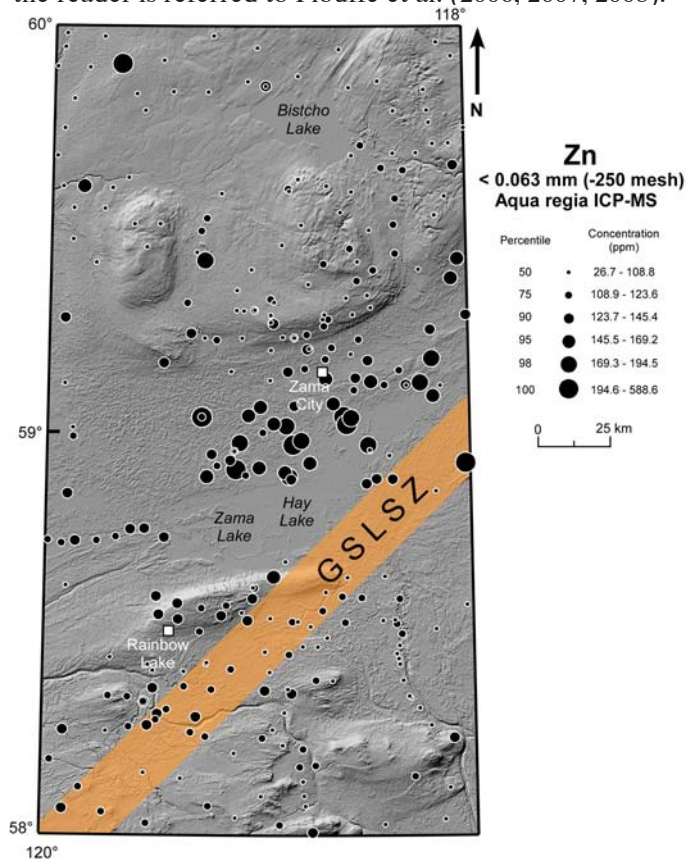


Figure 5: Zn content of the silt plus clay-sized fraction (<0.063 mm or -250 mesh sieve) of till as determined by aqua regia / ICP-MS, plotted on SRTM generated digital elevation model. The orange thick line cutting obliquely across the southeast portion of the study area marks the approximate location of the Great Slave Lake Shear Zone (GSLSZ) projected to surface (from Eaton and Hope, 2003). Modified from Plouffe et al. (2006).

Glacial Dispersal and Ice-flow History

Surficial mapping and ice flow studies in the region indicate that the sphalerite anomaly is not likely derived from the Pine Point Zn-Pb deposit 330 km to the northeast (Fig. 6). The survey area was inundated by ice emanating from the Keewatin Sector of the Laurentide Ice Sheet during Late Wisconsin glaciation (Dyke, 2004). At the onset of glaciation, topographically confined lobes of ice advanced in a general southwestward to westward direction into the region probably in a direction similar to the small arrows on Figure 6. At glacial maximum, ice flowed westward across the region towards the Rocky Mountains where it abutted the Cordilleran Ice Sheet and was deflected north and south along the mountain front. The Zama Lake area lies almost 300 km east of the confluence of both ice sheets. During the full-glacial period, ice-flow trajectories across the Pine Point Pb-Zn deposit were westward (255°) north of the Cameron Hills as indicated by striations observed at the abandoned Pine

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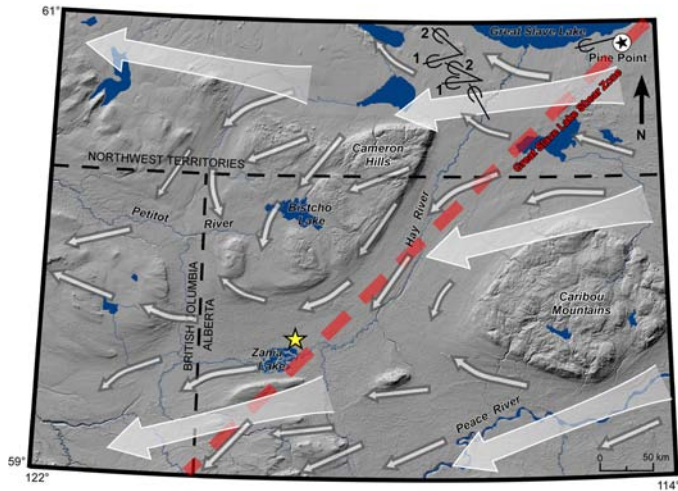


Figure 6: Summary of Late Wisconsin regional ice-flow patterns for northwest Alberta and southwester Northwest Territories depicted on SRTM generated digital elevation model (from Paulen et al., 2007). The large arrows indicate ice flow during maximum extent of the western sector of the Laurentide Ice Sheet and small arrows indicate younger, late glacial ice-flow trajectories. Striation measurements are shown, numbers refer to the relative age of ice flow (1=oldest). The Great Slave Lake Shear Zone (red dashed line) (from Eaton and Hope, 2003) and the Pine Point Pb-Zn mine (black star in white circle) are also indicated.

Point mine, well north of the Zama Lake sphalerite anomaly (yellow star, Figure 6). Extensive fluted and otherwise glacially-sculpted terrain (smaller arrows,

Figure 6) exhibit evidence of a number of crosscutting, and at times topographically confined ice flows (Paulen et al., 2007). Many of these streamlined landforms formed during deglaciation when the ice sheet retreated as a series of lobes. Similarly, during initial ice advance, at the onset of the last glaciation, topographically confined lobes advanced across the region. Thus, it is possible that material from the Pine Point region was transported for short distances towards Zama Lake during either early or late stages of the last glaciation. However, sphalerite minerals were recovered from basal till sampled from >3 m depth, suggesting that they were deposited during full glacial, as opposed to deglacial time.

Aside from the regional ice-flow history, there are several factors that argue against the sphalerite anomalies being the product of long-distance glacial transport, comminution, and deposition of erratic material from the Pine Point area, and instead favour a proximal bedrock source. First, the nine sample sites with high sphalerite grain counts (and eleven with lesser concentrations) are situated within a geographically restricted area north of Zama Lake. Second, geochemical analyses of the silt plus clay-sized fraction of the tills does not reveal proportionally elevated concentrations of lead and zinc, suggesting that glacial comminution of sand-sized sphalerite and galena has been limited. Third, close examination of the mineral grains shows that some grains have strong primary crystal structure and sub-angular to angular morphologies which would not have likely survived extensive glacial erosion and transport. Lastly,

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the sphalerite grains have dissimilar optical and chemical properties than the ore studied at Pine Point by Kyle (1981).

Summary

The bedrock source(s) of the KIMs in northwest Alberta is unknown. Plouffe et al. (2007) suggested that samples with 1 or 2 KIMs within the Zama Lake-Zama City region may represent background concentrations for a region located 100's of kilometres southwest of known kimberlites in the Lac de Gras region of the Northwest Territories. On the other hand, samples containing 6 to 9 KIMs are considered anomalous and might reflect the presence of an unknown kimberlitic source closer to this region.

The bedrock source(s) of the sphalerite and galena grains in till in northwest Alberta remain unknown. This mineralogical anomaly in till is not thought to be derived from the Pine Point Mississippi Valley Type Zn-Pb deposit located 330 km northeast in the Northwest Territories, but rather, is interpreted to be the result of glacial erosion of undiscovered proximal sedimentary hosted Zn mineralization, suggesting that we have identified a potential for Zn mineralization in the Cretaceous shale of northwest Alberta. The anomaly is situated in close proximity to the Great Slave Lake Shear Zone (Eaton and Hope, 2003; see also Fig. 6). Recent research on Pb and

Zn in northern Alberta formation waters (Hitchon, 2006) concluded that exploration should focus on these shear zones and faults, up which geothermal fluids might have migrated. Future Pb and S isotopic analyses of the galena and sphalerite grains in the till may resolve their provenance and shed further light on mineral potential in the study area, and which may eventually lead to the discovery of one or more Zn-rich base metal deposits hosted within Cretaceous shale of northwestern Alberta.

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Roger C. Paulen

*Alberta Geological Survey
Alberta Energy Conservation Board
4th Floor, 4999 – 98 Avenue
Edmonton, AB, Canada, T6B 2X3
roger.paulen@gov.ab.ca 780-427-2851*

Alain Plouffe

*Geological Survey of Canada
Natural Resources Canada
601 Booth Street,
Ottawa, ON, K1A 0E8
aplouffe@NRCan.gc.ca 613-995-4390*

I. Rod Smith

*Geological Survey of Canada
Natural Resources Canada
3303 - 33 Street NW,
Calgary, AB, T2L 2A7
rodsmith@NRCan.gc.ca 403-292-7132*

