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SPECIAL REPORT 77

Indicator mineral content and geochemistry of glacial sediments from northwest Alberta (NTS 84L, M): new opportunities for mineral exploration

A. Plouffe, R.C. Paulen, and I.R. Smith

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Abstract

This report presents the results of heavy mineral and geochemical analyses conducted on glacial sediment samples collected in northwest Alberta. This study was undertaken as part of a collaborative project between the Alberta Geological Survey (Alberta Energy and Utilities Board) and the Geological Survey of Canada (Natural Resources Canada) originally designed to assess the regional occurrence of kimberlite indicator minerals (KIMs) in glacial deposits. Results indicate that KIMs are absent, or rare, and generally consist of trace contents of pyrope and chromite, the composition of which remains to be assessed with electron microprobe analyses. Gold grains are generally absent from all samples with a some exceptions where they are present in only small amounts. Of particular significance, and the focus of this report, is the presence of anomalous concentrations of sphalerite grains with secondary galena (up to 1000 sphalerite grains in the 0.25-0.5 mm size fraction from a bulk till sample) from the south-central sector of the Bistcho Lake (NTS 84M) and north central sector of the Zama Lake (NTS 84L) map sheets. The source of the sphalerite grains in till is unknown. However, given its geographically restricted presence in the regional sample set, it may point to undiscovered sedimentary hosted zinc deposits in this region, and therefore, represents new opportunities for mineral exploration.

Introduction

In 2003, the Alberta Geological Survey (AGS) and the Geological Survey of Canada (GSC) initiated a four year collaborative project in northwest Alberta to create surficial geology maps and provide geoscience information in support of exploration for (1) shallow gas reservoirs in unconsolidated Tertiary/Quaternary sediments, (2) granular aggregate resources, and (3) kimberlitic bedrock. This project is part of the Northern Resources Development Program of the GSC, and received additional funding from the GSC's Targeted Geoscience Initiative-2. The project area also extends into northeast British Columbia where additional studies have been conducted in collaboration with the British Columbia Ministry of Energy, Mines and Petroleum Resources (BCMEMPR, Fig. 1; Levson et al., 2004). To evaluate the potential for kimberlitic bedrock within the Alberta study area, large (~25 kg) bulk glacial sediment samples were collected during surficial geology mapping fieldwork, following a methodology which has been developed in the Western Canada Sedimentary Basin (Fenton and Pawlowicz, 1993; Thorleifson and Garrett, 1993; Garrett and Thorleifson, 1996). These methods are similar to those proven effective at detecting kimberlites in areas underlain by the Canadian Shield (McClenaghan and Kjarsgaard, 2001; McClenaghan, 2005). The objective of this report is to present the results from heavy mineral analyses, gold grain counts, and geochemical analyses conducted on glacial sediment samples with an emphasis on anomalous concentrations of sphalerite grains discovered in bulk till samples. Minimum interpretation of the results is provided, as the intent of this report is to make the resource exploration community aware of the results in the most expeditious manner possible. A follow-up report will contain more in-depth analyses of the results, including an examination of the nature and geochemistry of the recovered sphalerite grains.

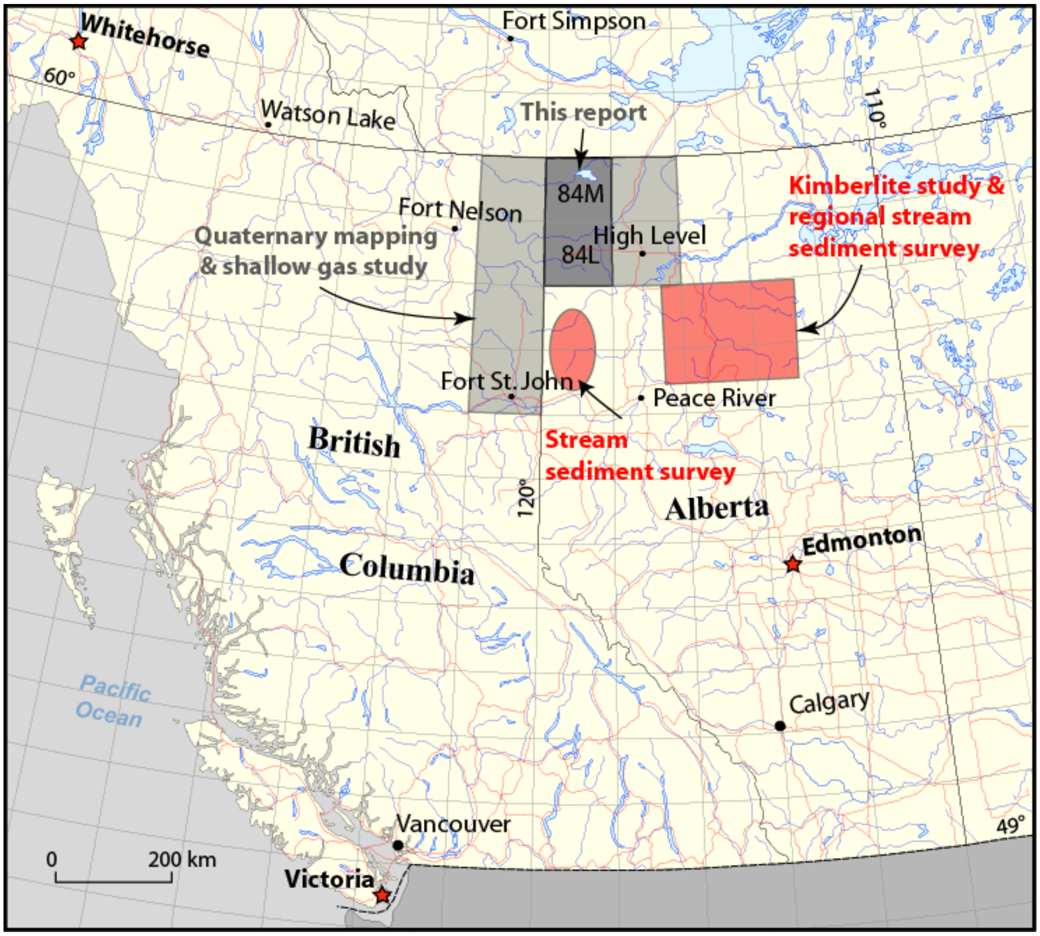

Figure 1. Map of British Columbia and Alberta with project study area (pale grey and red) and region covered as part of this report (dark grey).

Study area: physiography and geology

The data provided in this report extend across the Zama Lake and Bistcho Lake map sheets (NTS 84 L and M, respectively) which lie within the Fort Nelson Lowland , a sub-division of the Alberta Plateau physiographic region (Bostock, 1967). Cameron Hills (760 m above sea level-asl), situated in the northeastern sector of map 84M, lie within the Alberta Plateau. The flat surface over most of the region is a result 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 southern sector of the study area drains to the east and northeast through Hay River. The northwestern sector drains to the west through the Petitot River. Both of these rivers are part of the Mackenzie River drainage basin which empties into the Beaufort Sea.

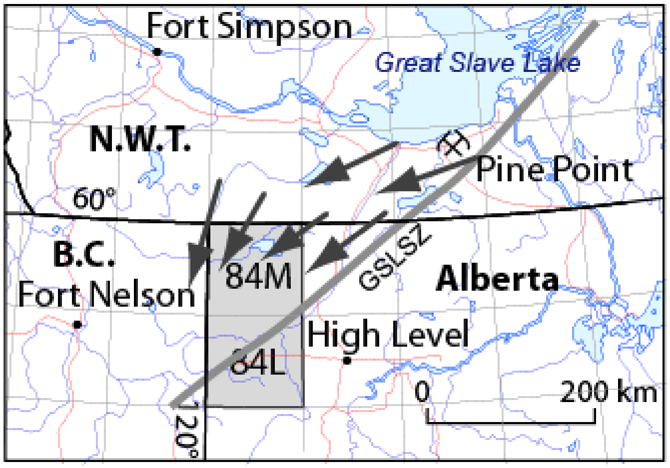

Figure 2. Location of Pine Point deposit with regional ice-flow directions derived from Prest et al. (1967). The Great Slave Lake Shear Zone (GSLSZ) is shown (approximate location).

The region was covered by ice during the Late Wisconsinan glaciation. Ice derived from the Keewatin Sector of the Laurentide Ice Sheet flowed west and southwest across the area (Fig. 2). Glacial lakes developed at the ice front where the glaciers advanced up-slope, impounding drainage. A nearly continuous till cover consisting of a diamicton with a fine grained matrix (on average 27% sand, 60% silt, and 12% clay) and low clast content (< 5 %) blankets most of the region. The ice retreat scenario was similar to that of ice advance, with development of glacial lakes where the meltwater drainage was blocked, and deposition of glaciofluvial sand and gravel in meltwater channels flowing directly from the glacier, or at the outlets of glacial lakes (Mathews, 1980; Smith et al., 2005a). Surficial geology maps, produced as part of this project, depict the distribution of surficial deposits and west and southwest regional ice-flow directions (Plouffe et al., 2004; Paulen et al., 2005a; 2005b; Smith et al., 2005b). A large portion of the area is covered by organic bog and fen deposits generally in excess of 1 metre. Till is exposed at surface in raised areas, but generally underlies most of the organic deposits. Glaciofluvial sand and gravel accumulations are often found in association with meltwater channels. The overall granular aggregate resource potential of the region was assessed by Smith et al. (2005a).

Bedrock is exposed in meltwater channels, along modern stream valleys, and on hilltops. It consists of Cretaceous Shaftesbury Formation shale overlain at an elevation of ~700 m asl by Cretaceous Dunvegan Formation sandstone. Underlying the Shaftesbury Formation are shales, sandstones and other strata of the Fort St. John Group, then a Late Carboniferous to Early Cretaceous unconformity, followed by Late and Middle Devonian shale, siltstone and limestone strata (Hamilton et al., 1999; Morrow et al., in press). The limestone units are of particular relevance to this study (potential Mississippi Valley-type (MVT) Pb-Zn deposits) and include Slave Point, Sulphur Point, Muskeg, and Keg River formations. In places, the Presqu'ile Dolomite has replaced parts of the Sulphur Point and Slave Point formation limestone. In Morrow et al.'s (in press) reconstruction of formation tops from northern Alberta and southern NWT, the top of the Middle Devonian Slave Point Formation (the uppermost limestone unit) underlying the present study area is ~1000 m. Local well reports indicate depths of Keg River Formation exceeding 1700 m (Pana, in press). The regional basement is the Paleoproterozoic Hottah terrane (Hoffman, 1989; Gehrels and Ross, 1998). The Great Slave Lake Shear Zone crosses the study area, where it is intersected by a pair of northwest and northeast trending faults (Pana et al., 2001).

Methodology

Access for sampling of glacial sediments was by truck, all terrain vehicles, and helicopter. Samples were predominantly till but also included a few glaciofluvial samples (Appendix 1). Samples were collected on road exposures, natural bluffs, hand-dug pits, and borrow pits dug for road construction or oil and gas drilling operations. In hand-dug pits, samples were collected below the most intensely oxidized soil horizons at an average depth of about 1 metre (Fig. 3). In deep pits dug by excavators, samples were taken from the lowest portion of the pit, often below 4 metres (Fig. 4). Two sizes of bulk glacial sediment samples were collected: large samples filling a 5 gallon rock pail (~25 kg) and smaller 1-2 kg bagged samples. In areas with reasonably good road access, large samples were collected on average 10 km apart, and smaller ones every 5 km. However, most of the study area has minimal or no road access, so sampling density is typically much less. The sample distribution is shown in Figures 5A and B.

Figure 3. Example of sample collected in a hand-dug pit.

Figure 4. Example of a borrow pit; site RP03-211, sample 2923.

A limited number of large (~25 kg) samples (50), from the two map areas, were sent for heavy mineral and gold grain analyses to provide a preliminary overview of the mineral potential for the region. Glaciofluvial samples were prioritized along with a regional selection of basal till samples. They were shipped to Overburden Drilling Management (ODM) Ltd. laboratories (Nepean, Ontario) for heavy mineral separation and identification in two batches (March and November 2005). The heavy mineral fraction was isolated in a two step process involving a shaking table and heavy liquids (specific gravity 3.2) (Fig. 6). The exact weight of sediment processed is provided in Appendix 2 on the sheet entitled Tabling data. The total weight of processed sample (table feed) corresponds to the bulk sediment weight minus the character sample (Fig. 6) and the clasts >2mm. Kimberlite indicator minerals, gold grains and other heavy minerals were identified in the 0.25 – 2 mm sized fraction under binocular microscopes, by staff mineralogists at the laboratory.

As part of the quality assurance and quality control measures, a sample spiked with KIMs was introduced in the sample set. Grains for the spiked samples were selected in the size range 0.25 to 1.0 mm by the staff at the AGS with the aid of a binocular microscope. A total of 40 grains were selected from mantle xenolith material collected from the K6 kimberlite (Buffalo Head Hills) and from the heavy mineral fractions of till samples collected in the Buffalo Head Hills (Prior et al., 2005). The spike consisted of 10 pyrope grains, 11 Mg-rich olivine grains (forsterite), 9 chromite grains and 10 Cr-diopside grains. These grains were placed in a 25 kg sample of till from Brownvale, Alberta. Till from this location is known to be barren of pyrope, eclogitic garnet, olivine and ilmenite (Prior et al., 2005), and is commonly used by the AGS as a blank sample for kimberlite indicator mineral quality control.

One pail of the Brownvale till, assigned number 2443, was spiked with the 40 grains. The spiked sample was then placed within the large batch of samples sent for analysis in early 2005. After the samples were tabled and picked, it was noted that very few olivine grains were identified in the spiked KIM sample. This information was communicated to the laboratory and re-picking was completed for the entire suite of samples and extra effort was placed on picking and identifying other minerals of economic interest.

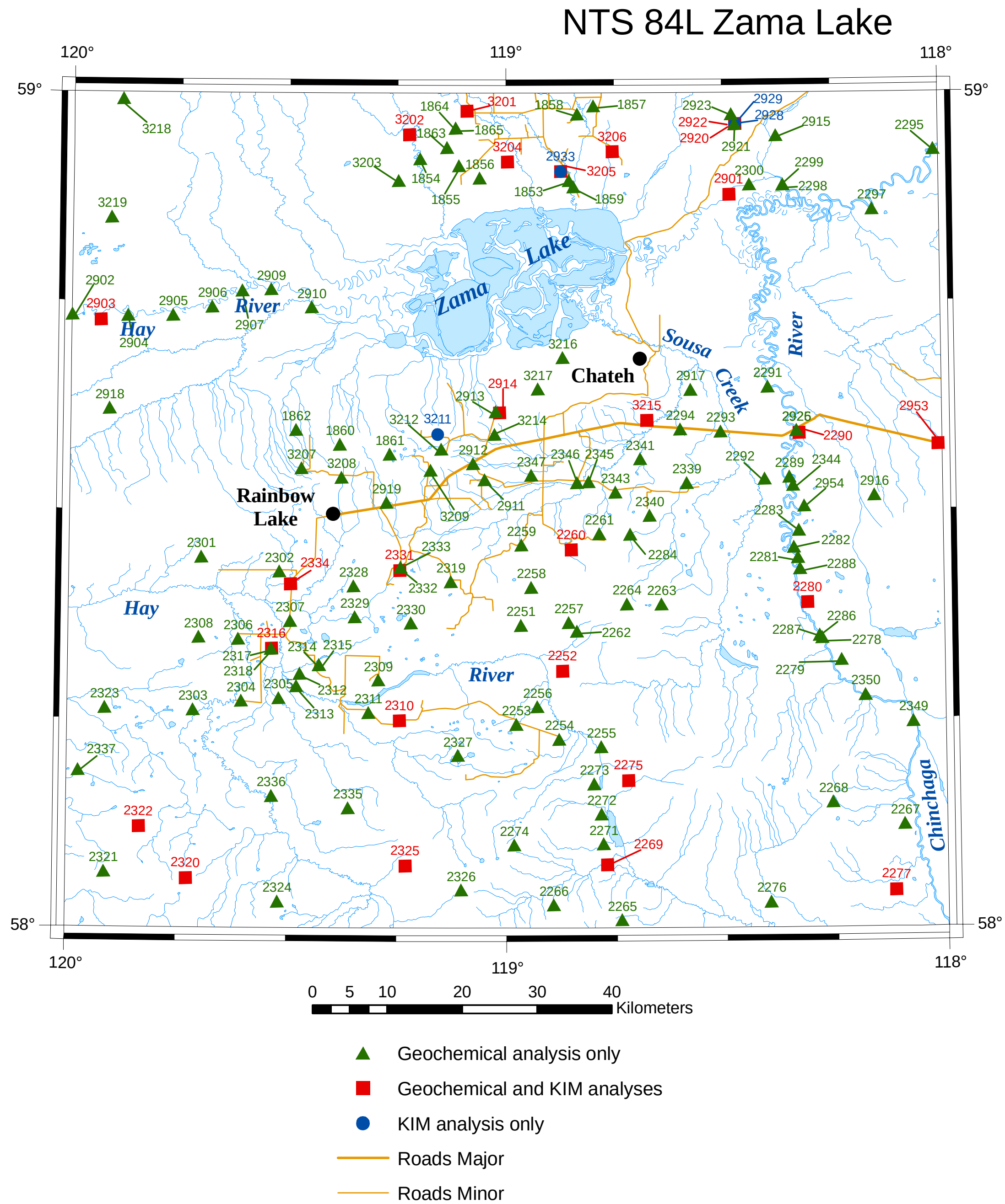

Figure 5A. Sample distribution over the Zama Lake (NTS 84L) map sheet. Note: geochemical analyses have been conducted on all samples indicated. However, only 71 of the 175 KIM samples have thus far been analysed.

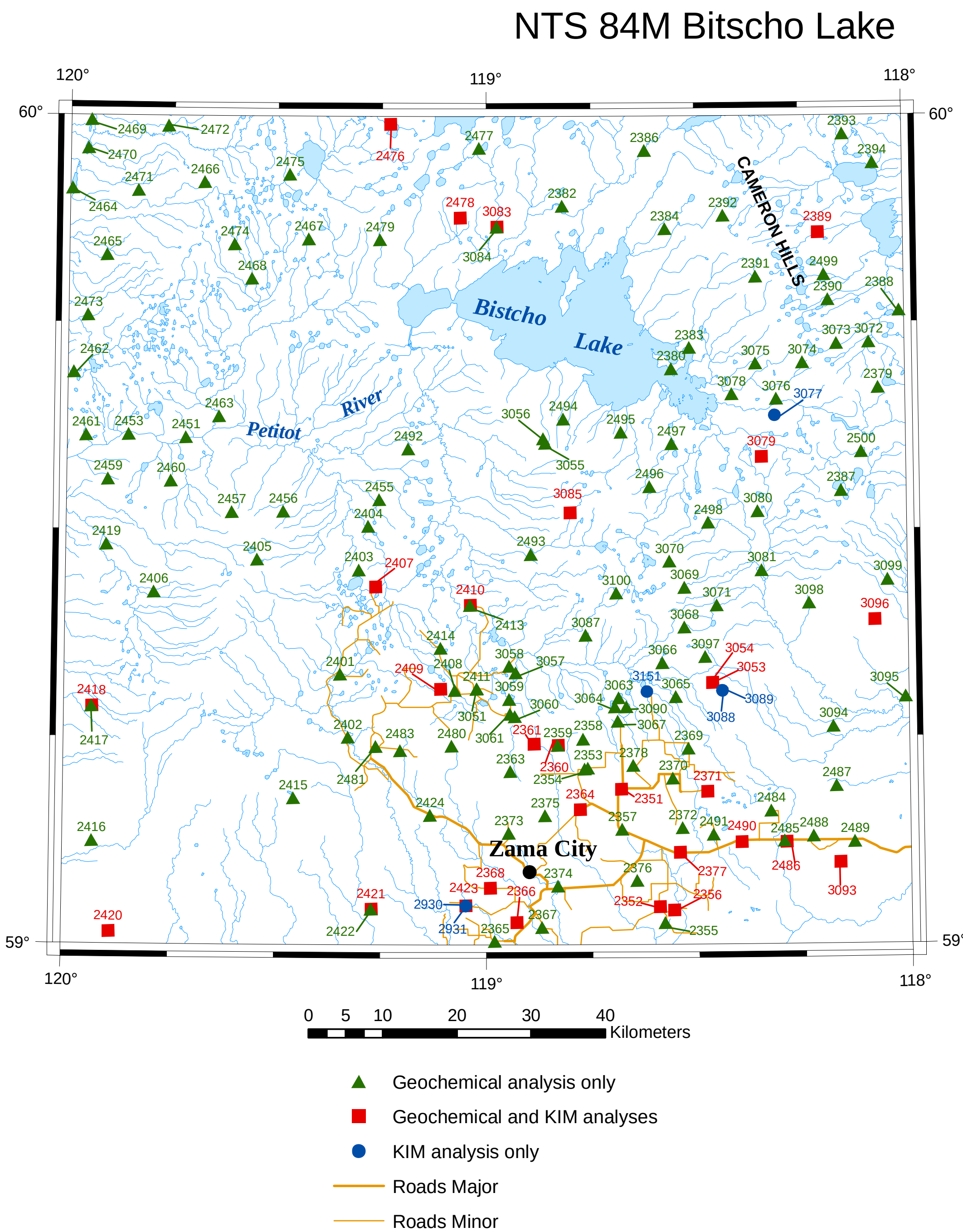

Figure 5B. Sample distribution over the Bistcho Lake (NTS 84M) map sheet. Note: geochemical analyses have been conducted on all samples indicated. However, only 71 of the 175 KIM samples have thus far been analysed.

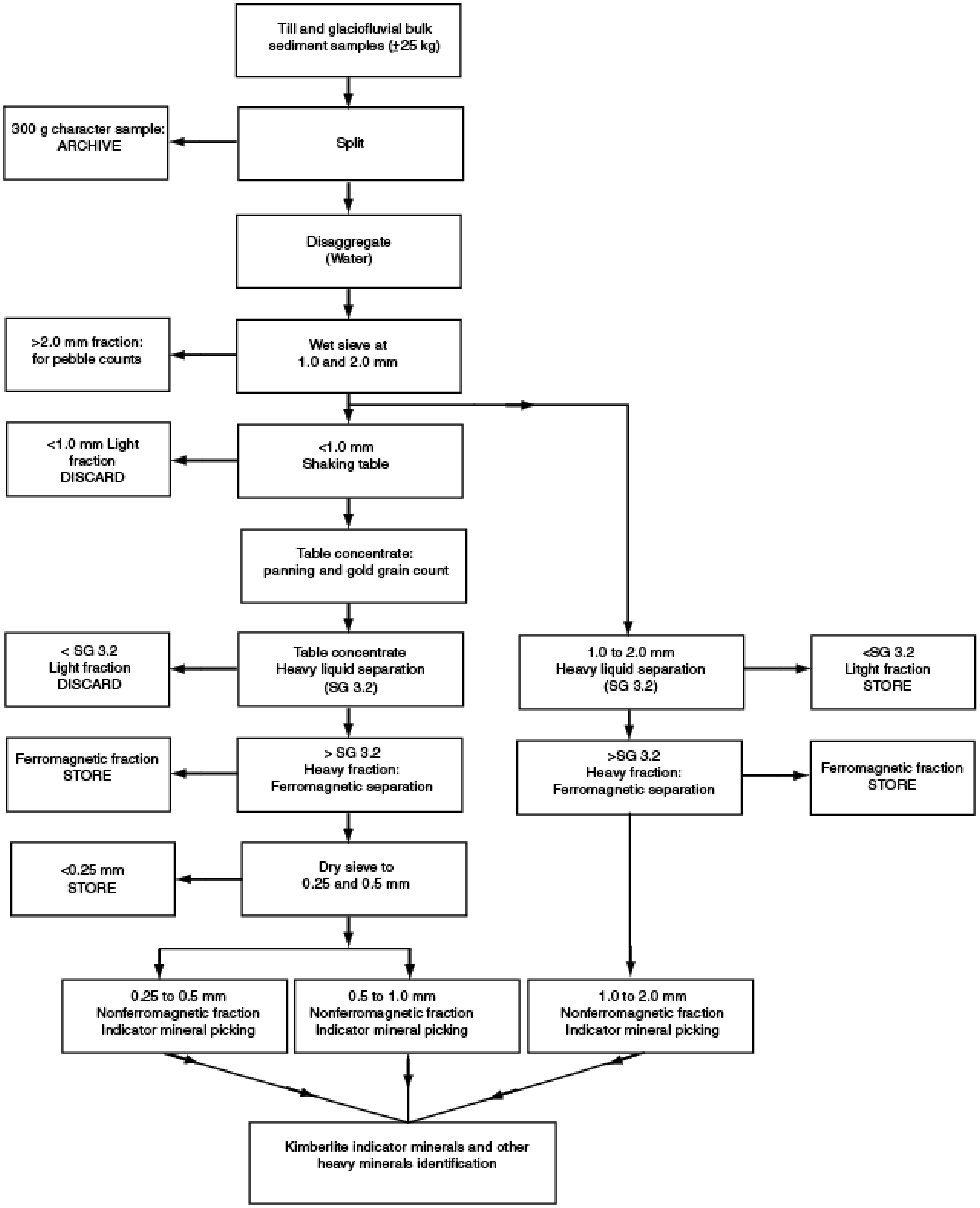

Figure 6. Sample processing flow diagram for the preparation of heavy mineral concentrates (modified from McClenaghan et al., 1999).

Following the discovery of anomalous concentrations of sphalerite grains in till samples (spring 2005: see details below), the original sites (five in total) with high sphalerite counts were resampled in the summer of 2005. Samples were collected from the same borrow pit and the same depth. In order to further confirm the magnitude of the elevated grain counts and to constrain the geographic extent of the anomaly, additional samples were collected in proximity to the original sphalerite anomaly. These samples, along with regional samples near the anomaly that had not been analyzed previously (21 in total), were submitted for analysis. These additional samples were submitted for the same type of analyses at ODM Ltd. plus a count of metamorphosed/magmatic massive sulphide indicator minerals (MMSIM).

Only till samples were submitted for geochemical analyses because of the general lack of fines in glaciofluvial sediments. The smaller bagged till samples (1-2 kg) were prepared at the Alberta Geological Survey laboratory where the silt and clay-sized fraction (<0.063 mm or –250 mesh) was separated by dry sieving. Duplicate and analytical standard samples were introduced, and then the material was sent for analyses at Acme Analytical Laboratories Limited (Vancouver, B.C.) in two batches (March and November 2004). Three analyses were conducted on the <0.063 mm sized fractions: 1) 15 g sub-samples were submitted for inductively coupled plasma mass spectrometry (ICP-MS) analysis for a suite of 37 minor elements following an *aqua regia* digestion (ICP-MS Aqua Regia sheet in Appendix 3), and 2) 0.2 g sub-samples were analyzed for major elements by ICP emission spectrometry (ICP-ES) (ICP-ES $LiBO_2$ fusion sheet in Appendix 3) and 3) for minor elements by ICP-MS (ICP-MS $LiBO_2$ fusion sheet in Appendix 3) both after a $LiBO_2$ fusion and dilute nitric acid digestion. Detection limits are provided in Appendix 3.

Quality assurance, quality control and results reproducibility

As indicated above in the methodology section, to ensure the reproducibility of the sphalerite anomaly in till (see results below), five sites with the highest number of sphalerite grains were re-sampled at the beginning of the 2005 field season.

Duplicate and standard samples were introduced in the analytical sample set to monitor accuracy and precision of the geochemical analyses. Results of this testing are provided in Appendices 4 and 5. Blind duplicates and blind standards refer to samples introduced in the sample set during sample preparation completed at the AGS laboratory. Laboratory duplicates and laboratory standards were included during analyses by the analytical laboratory (ACME Labs.) as part of the normal procedures. Results from this testing indicate that the analytical precision and accuracy of the geochemical analyses are satisfactory.

Results

Gold grain results

Thirty samples contain at least one gold grain (Appendix 6). Two samples (2418 and 3151) contain 3 gold particles. Most of the gold grains are in the silt-sized range with estimated gold concentration in the heavy mineral concentrates varying between <1 to 39 ppb (calculated based on the size of the gold particles and the weight of the heavy mineral concentrates – see Appendix 6 Detailed visible gold sheet). The two samples with the highest estimated gold concentration are glaciofluvial sediment samples [3089 (18 ppb) and 3211 (39 ppb)]. No samples in this data set are valued as significant gold exploration targets.

Kimberlite indicator minerals

Counts of kimberlite indicator minerals (KIMs) in the bulk sediment samples are provided in Appendix 2. Except for one spiked sample (2443) the number of KIMs varies from 0 to 6. Most of the KIMs consist of purple garnet and chromite. The composition of all of these potential KIMs remains to be evaluated using an electron microprobe. Note, sample 2443, with a greater number of KIMs, represents the spiked sample introduced for quality assurance measures (see Quality assurance, quality control and results reproducibility, above). The significance of these KIMs remains to be fully evaluated once results of the electron microprobe analyses will be available.

Sphalerite and associated mineral occurrences

The general assemblage of heavy minerals, concentrated from the 2 – 0.25 mm size fraction, was evaluated as part of the KIM picking process for the samples analysed in March 2005 and as part of a MMSIM analysis for the samples analysed in August 2005 (Appendix 2). Consequently, for the samples analysed in March 2005, the sphalerite counts are reported on the sheet entitled “Other heavy minerals” and on the “MMSIM” sheet for those analysed in August 2005 (Appendix 2).

An anomalously large number of sphalerite grains (>1000) were identified in till sample 2423 dominantly in the 0.25 t o0.5 mm size fraction. This is the highest concentration of sphalerite grains ever detected in a till sample by ODM Ltd. (Stu Averill, personal communication 2005). The sphalerite is found in association with abundant marcasite and smaller amounts of siderite. Sphalerite grains (up to 400 grains) are also present in 7 other till samples from the same region (2368, 2366, 2371, 2377, 2421, 2920, 3205; Fig. 7). In Figure 7, the number of sphalerite grains has not been normalized to the bulk sediment weight because for a number of samples the number of sphalerite grains only represents an estimate. Galena, often found in association with sphalerite in certain types of mineral deposits (e.g., Mississippi Valley Type), was detected in trace amounts in till samples 2290, 2371, 2929, 2930 , 2933, 3204, and 3205, but not in sample 2423 (Appendix 2; Fig. 8).

Till samples with the largest number of sphalerite grains were collected from the deepest portion of borrow pits in unoxidized till at a depth exceeding 3 metres. Given the high compaction of the till in the lower part of the pits and the strong clast fabric measured in a limited number of localities (unpublished data), it most likely reflects transport and deposition at the base of the ice sheet (i.e. basal till), rather than long-distance englacial transport.

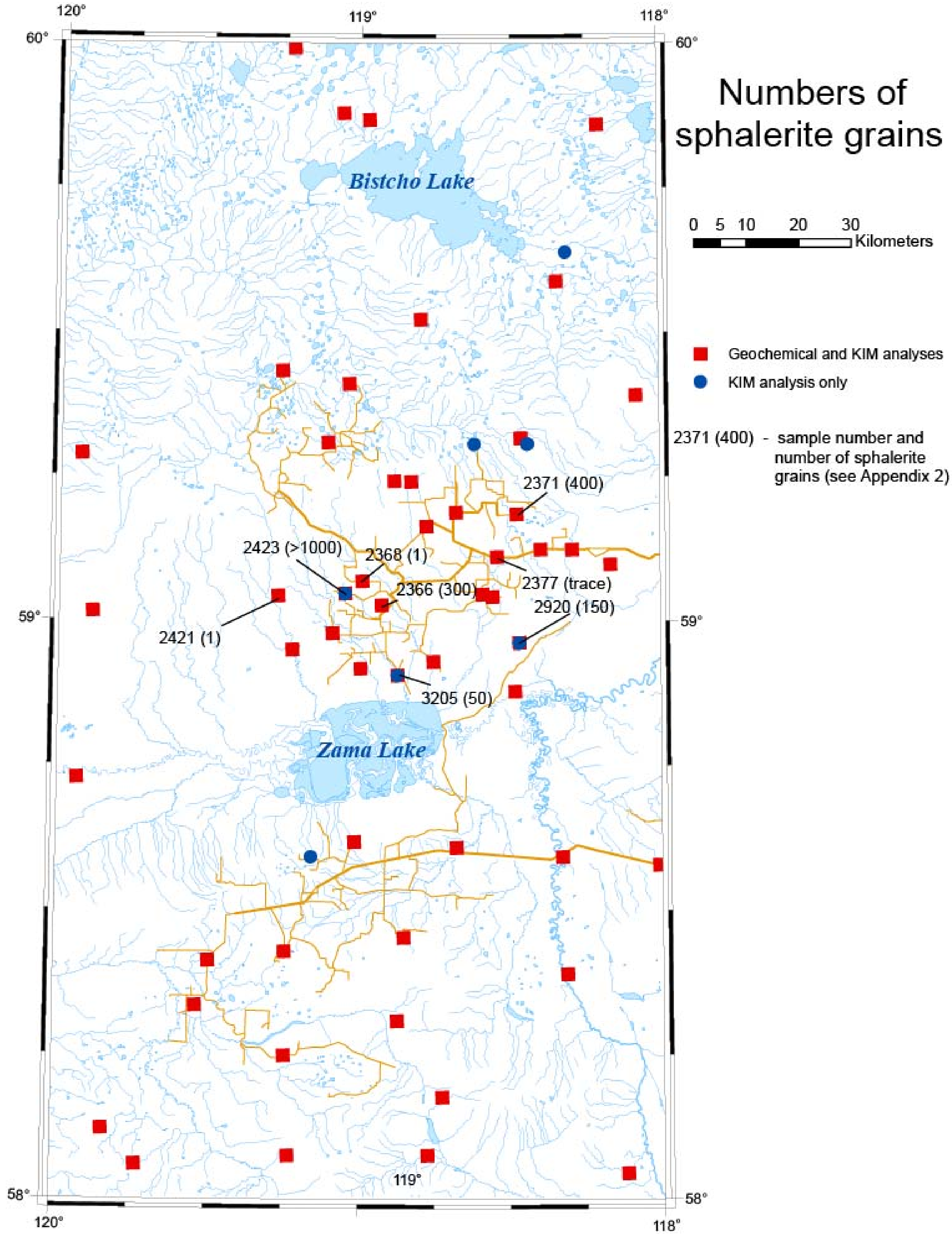

Figure 7. Map showing the distribution of samples containing sphalerite grains.

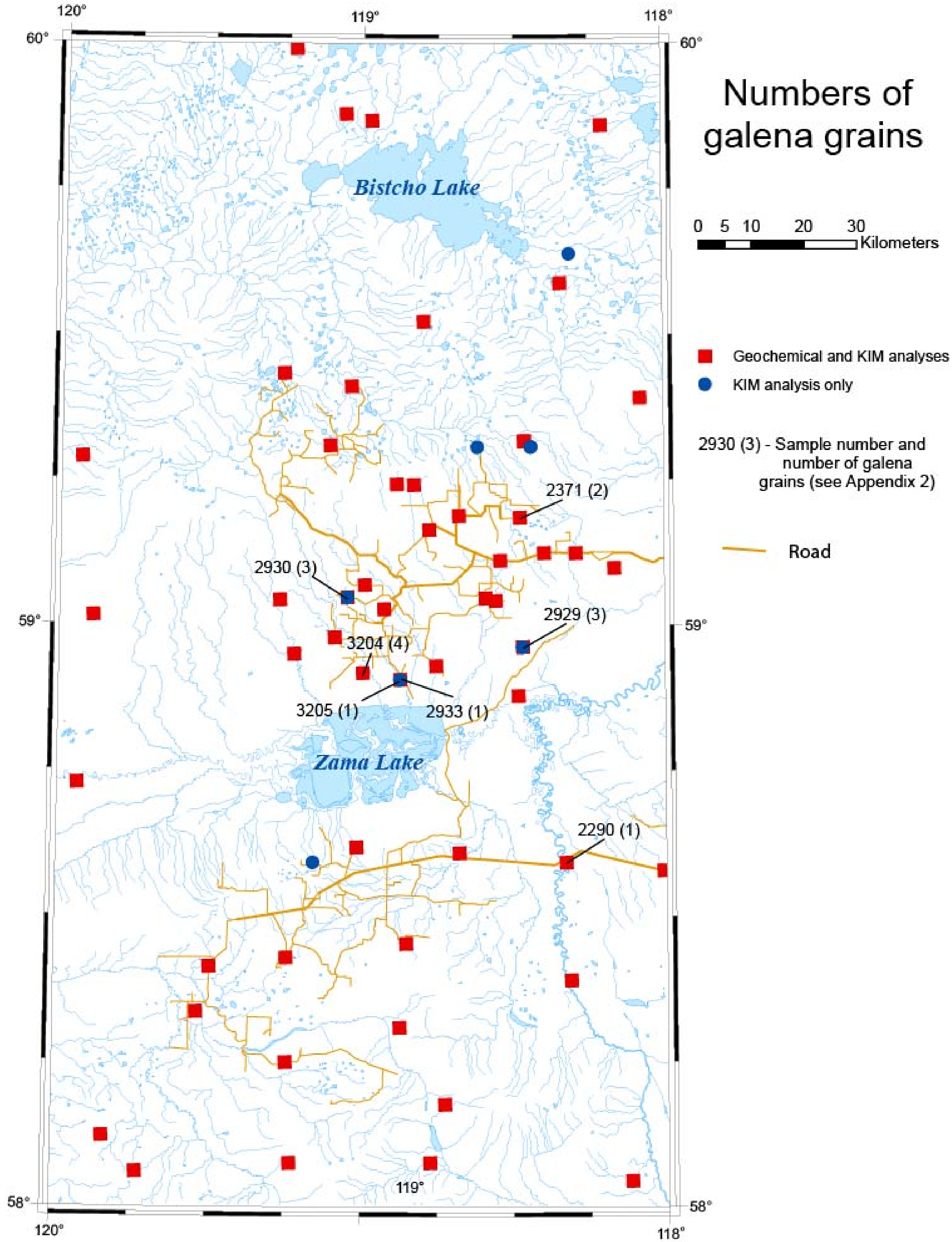

Figure 8. Map showing the distribution of samples containing galena grains.

Geochemistry

Geochemical results are presented in Appendix 3 which is divided into three parts (3 sheets) reflecting the different digestions and analytical methods (see Methodology section). Geochemical results for the samples collected during the 2005 field season (2928, 2929, 2930, 2931, 2933) were not available at the time of publication and are thus not included.

Zinc concentrations in the silt and clay-sized fraction of the till samples range from 26.7 to 588.6 ppm with an average concentration of 114 ppm and a standard deviation of 39 ppm. Till samples with high sphalerite content in the sand-sized fraction did not yield high zinc concentrations in the silt and clay-sized fraction. For example, sample 2423 with a sphalerite grain content exceeding 1000 grains only contains 150 ppm zinc which is well within the zinc background concentrations in tills from this region estimated to be 153 ppm (mean plus 1 standard deviation; Appendix 3). Only the sulphur level in sample 2423 is slightly elevated (1.73 %) compared to the rest of the samples (mean: 0.34 %).

Regional zinc concentrations in till are elevated in a broad band oriented NE-SW (> 95th percentile) extending from north of Zama Lake to the southeastern sector of 84M map sheet (Fig. 9). This band is sub-parallel and in proximity to the Great Slave Lake Shear Zone (Burwash et al., 1994; Fig. 9). The highest zinc concentration is outside of this corridor and is located approximately 40 km northwest of Bistcho Lake (sample 2466, Figs. 5, 9, and Appendix 3).

Lead concentrations in the silt and clay-sized fraction of the till samples range from 5.1 to 28.0 ppm with an average concentration of 15 ppm and a standard deviation of 2 ppm. Samples with trace amounts of galena in the heavy mineral picks do not contain high lead levels in the silt and clay-sized fraction. For example, sample 3205 with one galena grain yielded a lead concentration of 14 ppm which is close to the average lead concentration of 15 ppm in the rest of the till samples. Elevated lead concentrations (> 98th percentile) principally occur in a region extending from south of Zama Lake to approximately 30 km north of the hamlet of Zama City (Fig. 10). There is some overlap between the region with high lead and zinc levels (Figs. 9 and 10). The highest lead concentration is in the same till sample with the highest zinc concentration located northwest of Bistcho Lake (sample 2466, Figs. 5 and 10, and Appendix 3).

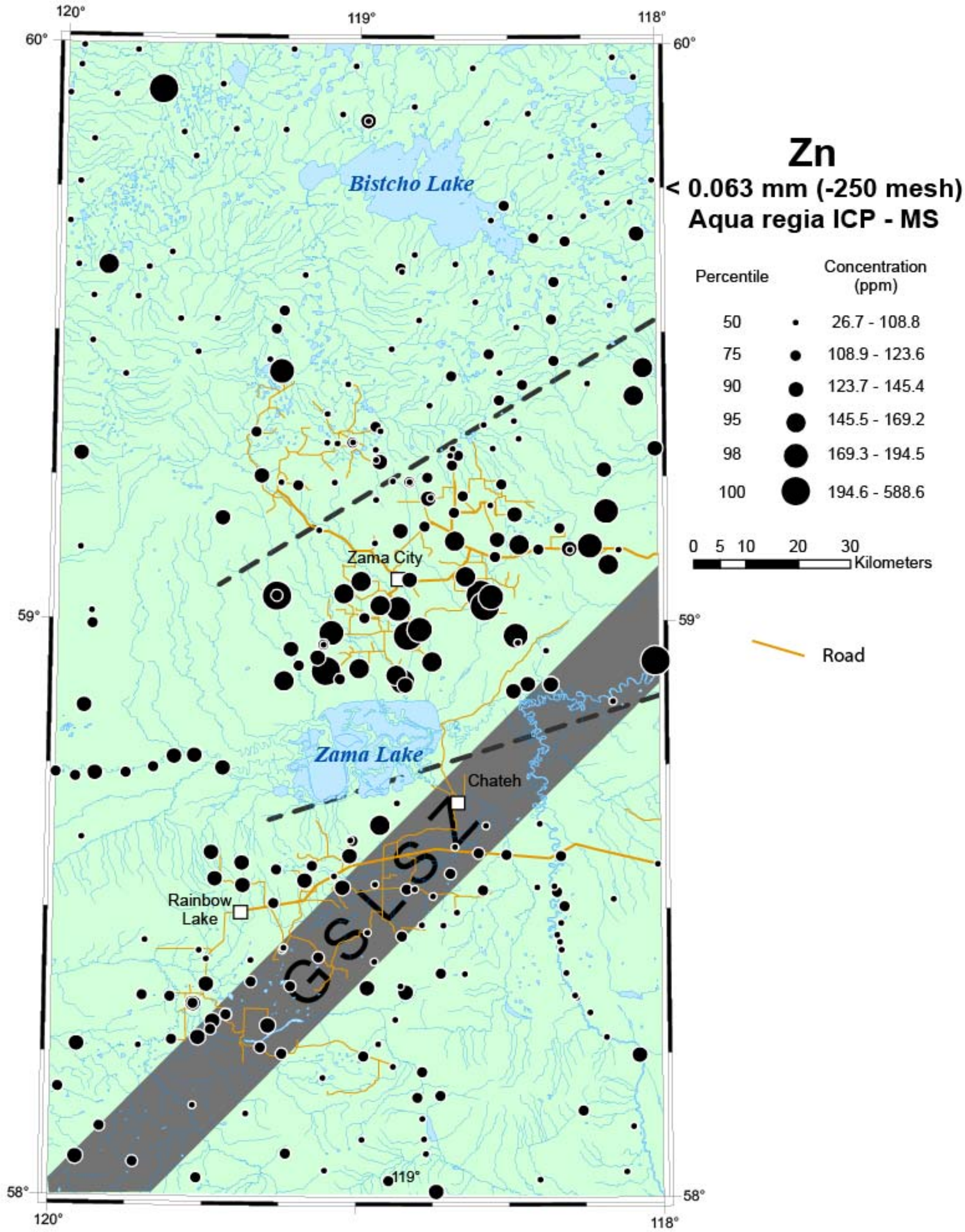

Figure 9. Zinc content of the silt and clay-sized fraction (<0.063 mm or -250 mesh) of till as determined by aqua regia / ICP-MS. The dashed lines depict the NE-SW corridor with the high zinc levels. GSLSZ-Great Slave Lake Shear Zone.

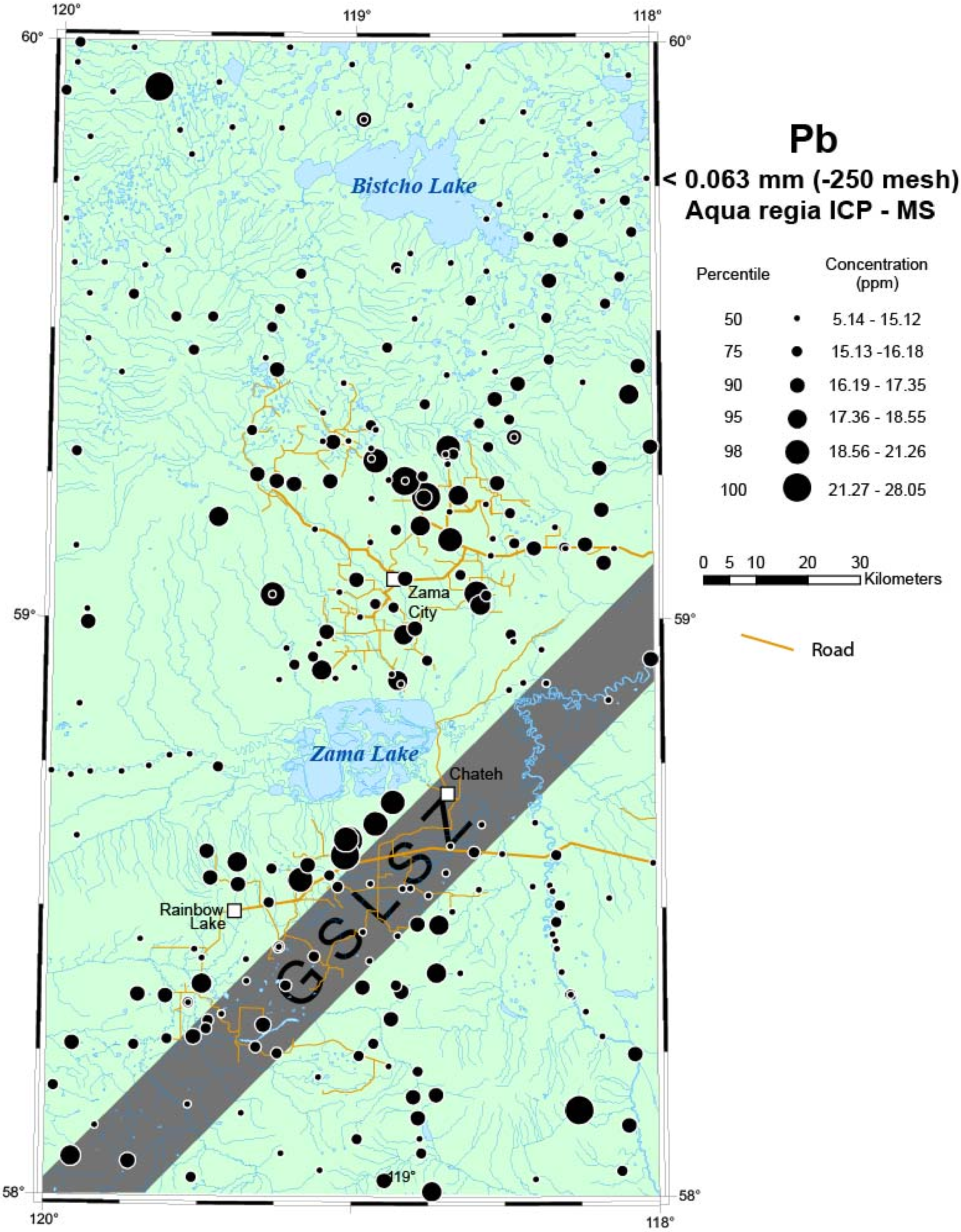

Figure 10. Lead content of the silt and clay-sized fraction (<0.063 mm or -250 mesh) of till as determined by aqua regia / ICP-MS. GSLSZ-Great Slave Lake Shear Zone.

The absence of geochemical anomalies in the silt and clay-sized fraction of till samples that contain abundant sphalerite and galena in the medium sand-sized fraction might be related to the proximity of a bedrock source and the lack of glacial comminution of the sphalerite and galena into particles smaller than sand size. Sphalerite and galena in the host bedrock are most likely in the sand-sized range with no geochemical enrichment in fine grained minerals. In addition, the unoxidized nature and elevated carbonate content in some of the till samples (0 to 30% carbonate in the silt and clay-sized fraction, unpublished data) might have prevented the leaching of zinc and lead from the sulphide minerals and the scavenging of these metals by fine grained phyllosilicates, oxides, and hydroxides (Shilts, 1984). Understanding why this anomaly is only reflected in the mineralogy of the sand-sized fraction of tills and not in the geochemistry of the silt and clay-sized fraction will be the subject of future research. These results indicate that a soil and glacial sediment geochemical survey alone, commonly used in exploration for sulphide deposits, would not yield satisfactory results within the study area. Any follow-up surveys will need to include heavy mineral analyses of glacial sediments collected from the C horizon as opposed to simply conducting drift geochemical analyses.

Interpretation

As no chemical or other analyses have been performed on the sphalerite grains recovered, the possible source of these grains in till is unknown. However, the samples collected as part of this study can be placed in the geographical context of known regional Pb-Zn deposits. Readers interested in a more thorough understanding of existing and potential Pb-Zn mineralization in the region are referred to GSC Bulletin 591 (Hannigan, in press) and the various papers and references contained therein, and to Hitchon (2006).

Regionally, the most significant Pb-Zn occurrences are found at the world class Pine Point deposits which outcrop 330 km northeast of the study area, and where between 1964 and 1988, 50 of 93 defined ore bodies were mined (Hannigan, in press). The Pine Point Pb-Zn deposits are MVT-type, formed within Middle and Upper Devonian carbonates. Northeastern Alberta is considered an area of prime MVT exploration potential because the same Middle Devonian carbonate strata found at Pine Point, outcrop, or are found near the surface (Godfrey, 1985; Hannigan, in press). The fact that much of the region lies within the bounds of Wood Buffalo National Park, however, negates much exploration interest. Gulf Minerals Ltd. (1975) reported a minor zinc anomaly of 0.1% in carbonate strata outcropping at Vermilion Chutes (~250 km east-southeast of the study area). West of Vermilion Chutes, carbonate-bounded Pb-Zn deposits would be too deeply buried to be considered of economic potential.

The proximity of Pb-Zn bearing carbonate strata and potential for glacial transport must be considered as a possible source of the sphalerite anomalies reported here. It is conceivable that boulders and other debris could have been transported west and southwesterly into the study area, eventually becoming disaggregated in the till and yielding small pockets of sediment enriched in sphalerite. However, the presence of a number of samples with high sphalerite counts situated within a geographically restricted area, and the fact that the anomalies are not found in the silt and clay-sized fraction, would argue against long-distance glacial erosion, comminution and deposition of erratic material. This scenario though cannot be ruled out altogether.

In addition to known Pb-Zn bearing strata outcrops in northern Alberta and southern Northwest Territories, well records proximal to the study site have documented Pb-Zn bearing carbonate strata (reviewed by Pana, in press). Documented Pb-Zn bearing strata include the Chevron Lutose well (16-34-118-21W5) which reported 3.7% Zn (37633 ppm) in the faulted and dolomitized Keg River Formation between 1265 – 1304 m depth interval; well 10-22-120-01W6 which reported 4707 ppm Zn and 5187 ppm Pb in the Slave Point Formation at 1234 m depth; well 09-05-114-08W6 which reported 1435 ppm Zn in the Keg River Formation at 1698 m depth; and well 06-33-113-07W6 which simply reported the presence of Zn in the Keg River Formation (depth unknown; Dubord, 1987; Turner and McPhee, 1994).

Drift Exploration Implications

The overall trend of the region with high sphalerite counts and high zinc levels (Figs. 7 and 9) parallels the latest mapped ice-flow history for the region, that is to the west to southwest, as determined from landform analysis and recent surficial mapping (Fig. 2, see also Paulen et al., 2005b; in press; Smith et al., 2005b; in press). Drift prospecting should continue to use large (25 kg) samples to recover the heavy mineral concentrates and, if possible, samples should be collected in the C soil horizon, preferably below the limit of oxidation. It is also preferable to sample basal till which was transported at the base of the ice and reflects a more local source than material transported in englacial position. From field observations made in a number of borrow pits, basal till is usually found at depths >3 metres, and often has an unoxidized dark to medium grey colour, as opposed to the overlying till facies which appears more brown.

Conjecture that the sphalerite grains found in this study do not represent long-distance transport of erratic material, and instead were eroded from a proximal bedrock source could suggest that we have identified the potential for hydrothermal fluid remobilization of minerals from the underlying Pb-Zn bearing carbonate strata into the overlying shale bedrock. Fluid remobilization could have occurred along deep-seated faults. The anomaly is situated in close proximity to the Great Slave Lake Shear Zone (Burwash et al., 1994). Recent research on lead and zinc in formation waters (Hitchon, 2006) concludes that exploration should focus on the location of these shear zones and faults, up which geothermal fluids might have migrated. Future chemical, isotopic, and physical analyses of the recovered sphalerite grains will hopefully resolve their possible origin, and shed further light on mineral potential in the study area.

Shallow gas occurs in unconsolidated sediments of buried valleys within the study area (Pawlowicz et al., 2004; 2005a; 2005b). Some gas wells are producing from a depth less than one hundred meters. An important natural resource, shallow gas also represents a natural hazard in this region and has been implicated in a number of blowouts (cf. Clare, 1988). Consequently, extra safety precautions are required for any type of drilling in this region.

Acknowledgements

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Geological Survey) picked and provided the indicator mineral grains used in the spike sample. L. Robertson (GSC Ottawa) helped construct the maps presented in this report. This project was in part funded by the Targeted Geoscience Initiative-2.

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