

# Drift prospecting in the region of the Yukon-Tanana Terrane, southern Yukon<sup>1</sup>

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## ABSTRACT

Regional till geochemistry surveys were conducted in the Finlayson Lake, Glenlyon and eastern Carmacks map areas. Detailed till sampling was completed at the Kudz Ze Kayah and Clear Lake massive sulphide deposits to evaluate glacial dispersal near mineralized rock in a mountainous region and a plateau, respectively. A comparative evaluation of the silt-and-clay-sized fraction versus the clay-sized fraction geochemistry indicates that the clay-sized fraction presents higher metal concentrations than the silt and clay, but both size fractions generally delineate the same base metal exploration targets. The correlation between the high gold concentrations in both size fractions is not as good as for base metals because gold occurrences are only reflected in the silt- or clay-sized particles of till. The beryllium content of till might provide an indication of the occurrence of beryl in bedrock but the low analytical precision of beryllium analyses limits this approach.

## RÉSUMÉ

Des levés géochimiques du till ont été effectués dans les régions des feuillets topographiques de Finlayson Lake et Glenlyon ainsi que de la partie est du feuillet de Carmacks. Un échantillonnage plus détaillé du till a été réalisé près des gîtes de sulfures massifs de Kudz Ze Kayah et de Clear Lake pour évaluer la dispersion glaciaire près d'une minéralisation connue dans une région montagneuse et sur un plateau. L'étude comparative de la composition géochimique de la fraction argileuse et de la fraction silteuse-argileuse du till montre que la fraction argileuse contient de plus fortes teneurs en métaux que la fraction silteuse-argileuse. Par contre, de façon générale, la géochimie des deux fractions granulométriques permet de définir les mêmes cibles d'exploration pour les métaux de base. La corrélation entre les concentrations élevées en or des deux fractions granulométriques n'est pas aussi bonne que pour les métaux de base probablement parce que les indices d'or ne s'observent que dans la fraction silteuse ou argileuse du till. La teneur en béryllium du till pourrait donner une indication de la présence de béryl dans la roche en place mais la faible précision des analyses du béryllium limite la portée de cette approche.

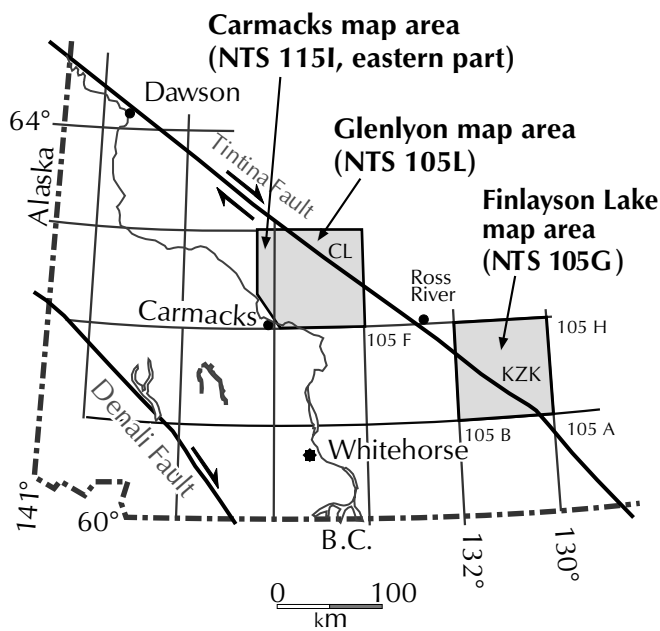
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## INTRODUCTION

The discovery of volcanogenic massive sulphide deposits in the mid-1990s (Schultze, 1996; Tucker et al., 1997) and an emerald occurrence in 1998 (Groat et al., 2002; Neufeld et al., 2003), both in the Yukon-Tanana Terrane (YTT) of southeastern Yukon, has demonstrated the potential of this terrane to host such mineral deposits (Hunt, 1997; 2002). As part of the Targeted Geoscience Initiative, a joint project between the Yukon Geological Survey (YGS; formerly the Yukon Geology Program) and the Geological Survey of Canada (GSC) was initiated in 2000 to further evaluate the mineral potential and to promote mineral exploration in the YTT. As part of this project, regional till geochemistry surveys were conducted over two regions: the Finlayson Lake map area (NTS 105G), and the Glenlyon (NTS 105L) and eastern Carmacks (NTS 115I) map areas (Fig. 1). In addition, detailed till sampling was completed at the Kudz Ze Kayah and the Clear Lake deposits to define glacial dispersal near known massive sulphide deposits in a mountainous region and a plateau. The regional till geochemistry was released as joint YGS and GSC open files (Bond et al., 2002; Colpron et al., 2003b; Plouffe and Bond, 2003). Interpretation of the geochemistry of the silt-and-clay-sized fraction of till (except for beryllium which was analysed after the publication of these reports) was provided by Bond and Plouffe (2002; 2003).



**Figure 1.** Location of Finlayson Lake, Carmacks and Glenlyon map areas in southern Yukon; CL – Clear Lake, KZK – Kudz Ze Kayah.

The objectives of this report are to present the interpretation of the geochemistry of the clay-sized fraction and beryllium analyses, and to compare the efficiency of the silt-and-clay- versus the clay-sized fractions of till as analytical media for drift exploration within the YTT.

## BEDROCK GEOLOGY

The YTT is composed of polydeformed Devonian to Permian metasedimentary and metaigneous (including metaplutonic and metavolcanic) rocks which were accreted to North America during late Paleozoic time (Murphy et al., 2003). In the Finlayson Lake region, YTT is composed of thrust-imblicated metasedimentary and metaigneous rocks juxtaposed with the North American miogeocline along the Inconnu thrust (Murphy et al., 2002). Post-thrusting intrusions include Jurassic granitic intrusions, Tertiary gabbro in the YTT, and Cretaceous granite in both the YTT and the North American craton. Undeformed Eocene basalt, rhyolite and gabbro overlie and cross-cut older rocks. The major volcanogenic massive sulphide deposits in the Finlayson Lake district are hosted in Upper Devonian to Lower Mississippian (Kudz Ze Kayah, GP4F, Fyre Lake, and Wolverine properties; Yukon MINFILE 2002, 105G 117, 105G 012, 105F 071, 105G 072, Deklerk, 2002) and Early Permian (Ice property; Yukon MINFILE 2002, 105F 073, Deklerk, 2002) metavolcanic rocks of the Wolverine Lake and Grass Lakes groups which are considered promising exploration targets for massive sulphide deposits (Murphy et al., 2002; Murphy, this volume; Fig. 2). In addition, the Grass Lakes group has potential to host other types of deposits, such as sedimentary exhalative (SEDEX; e.g., Argus (HOO), Yukon MINFILE 2002, 105G 013, Deklerk, 2002). In the southern sector of the Finlayson Lake map area, at Regal Ridge (Yukon MINFILE 2002, 105G 147, Deklerk, 2002), emerald crystals (a form of beryl) are found in association with quartz-tourmaline veins in mafic metavolcanic rocks of the Fire Lake formation unit (a subdivision of the Grass Lake group) near their contact with a mid-Cretaceous granite (Fig. 2; Groat et al., 2002; Murphy et al., 2002; Neufeld et al., this volume). Electron microprobe analyses of the emerald crystals (N=25) from Regal Ridge revealed that they contain high chromium (average: 3208 ppm) and high vanadium (average: 171 ppm) concentrations (Groat et al., 2002). The granite is interpreted to be the source of beryllium, and the mafic and ultramafic rocks the source of chromium and vanadium (Groat et al., 2002).

In eastern Carmacks and Glenlyon map areas, the YTT is in fault-contact to the northeast with sedimentary rocks of the North American miogeocline and to the southwest with the mafic metavolcanic rocks of the Semenof block (Fig. 3). Following restoration of 425 km of right lateral displacement along Tintina Fault, rocks of the YTT in Glenlyon map area are on trend with the massive sulphide district of the Finlayson Lake district (Colpron and Yukon-Tanana Working Group, 2000). In Glenlyon and eastern Carmacks map areas, the YTT is composed of northwest-trending metasedimentary, metavolcanic and metaplutonic rocks varying in age from Devonian (and possibly older) to Pennsylvanian (Colpron et al., 2003a). In the western sector, granitic rocks of probable Late Triassic to Early Jurassic age form two large plutons: the McGregor and Tatchun batholiths. Smaller Cretaceous granitic intrusions are present in the eastern sector, in both the YTT and the North American miogeocline. Known mineral occurrences within the region include volcanic-hosted massive sulphide, fault-related epithermal gold, and intrusion-related and sedimentary-exhalative types (Colpron et al., 2003a). Volcanic rocks of the Little Kalzas and Little Salmon formations, both part of the YTT, are considered good exploration targets for volcanogenic massive sulphide deposits (Colpron et al., 2003a). The Clear Lake sedimentary-exhalative deposit (Yukon MINFILE 2002, 105L 045, Deklerk, 2002) is located in the northern part of the Glenlyon map area within the Earn Group strata of the Cassiar Terrane which is part of the North American miogeocline (Figs. 1 and 3).

More details on the regional bedrock geology of the Finlayson Lake, Glenlyon and eastern Carmacks map areas are presented in Murphy et al. (2001 and this volume), Bond et al. (2002) and Colpron et al. (2002; 2003b; 2003a).

## PHYSIOGRAPHY AND GLACIAL HISTORY

Bond and Plouffe (2002; 2003) presented a detailed account of the physiography, Quaternary stratigraphy, and the glacial history of the Finlayson Lake, Glenlyon, and eastern Carmacks map areas which is only summarized here.

Most of the Finlayson Lake map area is part of the Yukon Plateau, an area of low relief with accordant uplands. The region was completely covered by ice during the Late Wisconsinan McConnell Glaciation (~20 000 years ago).

Glaciers were generally flowing to the northwest from an ice-divide located over the Wolverine Lake region (Prest et al., 1967; Dyke, 1990; Jackson, 1994; Fig. 4). Southeast of Wolverine Lake, ice flow was to the southeast.

The Glenlyon and eastern Carmacks map areas, which are dominantly part of the Yukon Plateau, straddle the limit of the McConnell Glaciation in central Yukon. During the last glacial event, the Selwyn and Cassiar ice lobes invaded the region but the highest summits and the westernmost sector remained unglaciated (Jackson, 2000; Ward and Jackson, 2000; Fig. 5). Since the glaciers were relatively thin, topography played an influential role on ice-flow patterns and ice-lobe configuration. Ice flow was dominantly to the northwest with local diversion to the west, southwest and north (Jackson, 2000; Ward and Jackson, 2000).

## METHODS

The details of the methodology of the regional till geochemistry surveys are given in Bond and Plouffe (2002; 2003) and Plouffe and Bond (2003). In summary, till samples were collected along foot traverses with a sample spacing averaging 1 km. At Kudz Ze Kayah and Clear Lake, where the orientation surveys were completed, sample spacing varied from 50 to 500 m. In total, 487 till samples were collected from the Finlayson Lake region (including the samples collected in 2000 as part of the Weasel Lake project; see Bond, 2001) and 285 from the Glenlyon and eastern Carmacks map areas. Till was collected at a depth > 50 cm below the surface to minimize the effect of soil weathering associated with the B-horizon. At each site, 50 pebbles were collected from the till. Pebble counts were completed at base camp for selected samples. Two size fractions were obtained from the till samples: 1) the silt-and-clay-sized fraction (<0.063 mm; -230 mesh) was separated by dry sieving in the commercial laboratory that conducted the geochemical analyses and 2) the clay-sized fraction (<0.002 mm) was obtained following the centrifuge method at the sedimentology laboratory of the Geological Survey of Canada in Ottawa (Lindsay and Shilts, 1995). Both size fractions were analysed for 40 elements in a commercial laboratory by inductively coupled plasma mass spectrometry (ICP-MS) following hydrochloric-nitric acid and demineralized water digestion (HCl:HNO<sub>3</sub>:H<sub>2</sub>O). Beryllium analyses, on the silt-and-clay-sized fraction only, were conducted by ICP-MS following a lithium metaborate (LiBO<sub>2</sub>) fusion. A fusion was

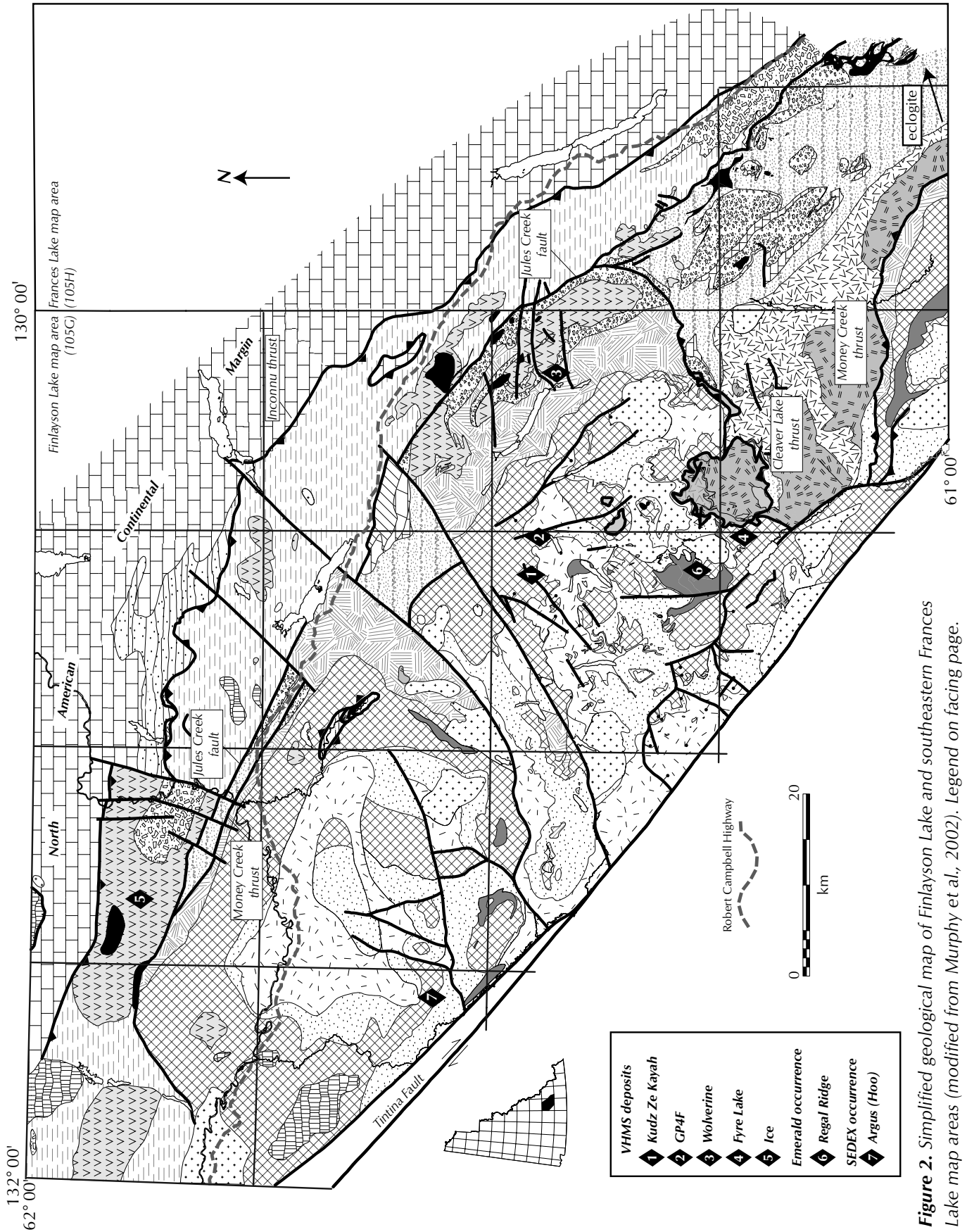
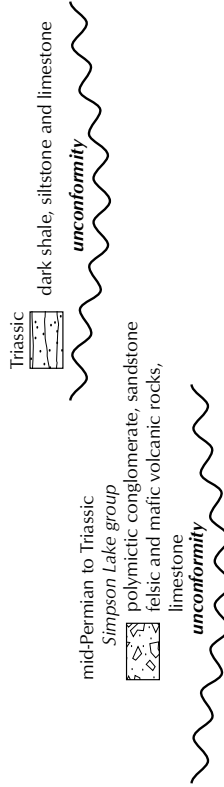


Figure 2. Simplified geological map of Finlayson Lake and southeastern Frances Lake map areas (modified from Murphy et al., 2002). Legend on facing page.

LEGEND

POST-ACCRETIONARY ROCKS

- Mesozoic and Cenozoic
- undifferentiated intrusive rocks
- undifferentiated volcanic rocks



Yukon-Tanana Terrane

Cleaver Lake thrust sheet

- Early Mississippian
- Simpson Range plutonic suite
- granite, quartz monzonite, granodiorite
- ultramafic and mafic intrusive rocks

Money Creek thrust sheet

- Early Mississippian
- Simpson Range plutonic suite
- granite, quartz monzonite, granodiorite

Footwall, Money Creek thrust

- Late Devonian to Early Mississippian
- Grass Lakes plutonic suite
- granite, quartz monzonite, augen granite
- ultramafic and mafic intrusive rocks

Slide Mountain Terrane

INTRUSIVE ROCKS

- Early Permian
- ultramafic and mafic intrusive rocks
- LAYERED ROCKS
- Lower Permian
- quartzite
- limestone
- unconformity
- Campbell Range formation
- basalt and varicoloured chert

North America

- Paleozoic
- undifferentiated formations of Selwyn Basin, Cassiar Platform, Earn Group and Mt. Christie Formation

LAYERED ROCKS

- Lower Permian
- Money Creek formation
- dark phyllite and sandstone, chert, chert-pebble conglomerate, diamictite
- unconformity
- massive bioclastic limestone
- unconformity

- Upper Mississippian to Lower Permian
- Whitefish limestone

- Lower Mississippian
- Tuchitua River formation
- intermediate, felsic and mafic volcanic rocks, sandstone, chert, limestone
- unconformity

- Upper Devonian to Lower Mississippian
- Waters Creek formation
- felsic to intermediate metavolcanic rocks and carbonaceous phyllite
- unconformity

- Pre-Upper Devonian
- North River formation
- quartzose metaclastic rocks, marble and non-carbonaceous pelitic schist

- Upper Devonian to Lower Mississippian
- Cleaver Lake formation
- calc-alkaline basalt, rhyolite, chert and volcanic-derived sandstone

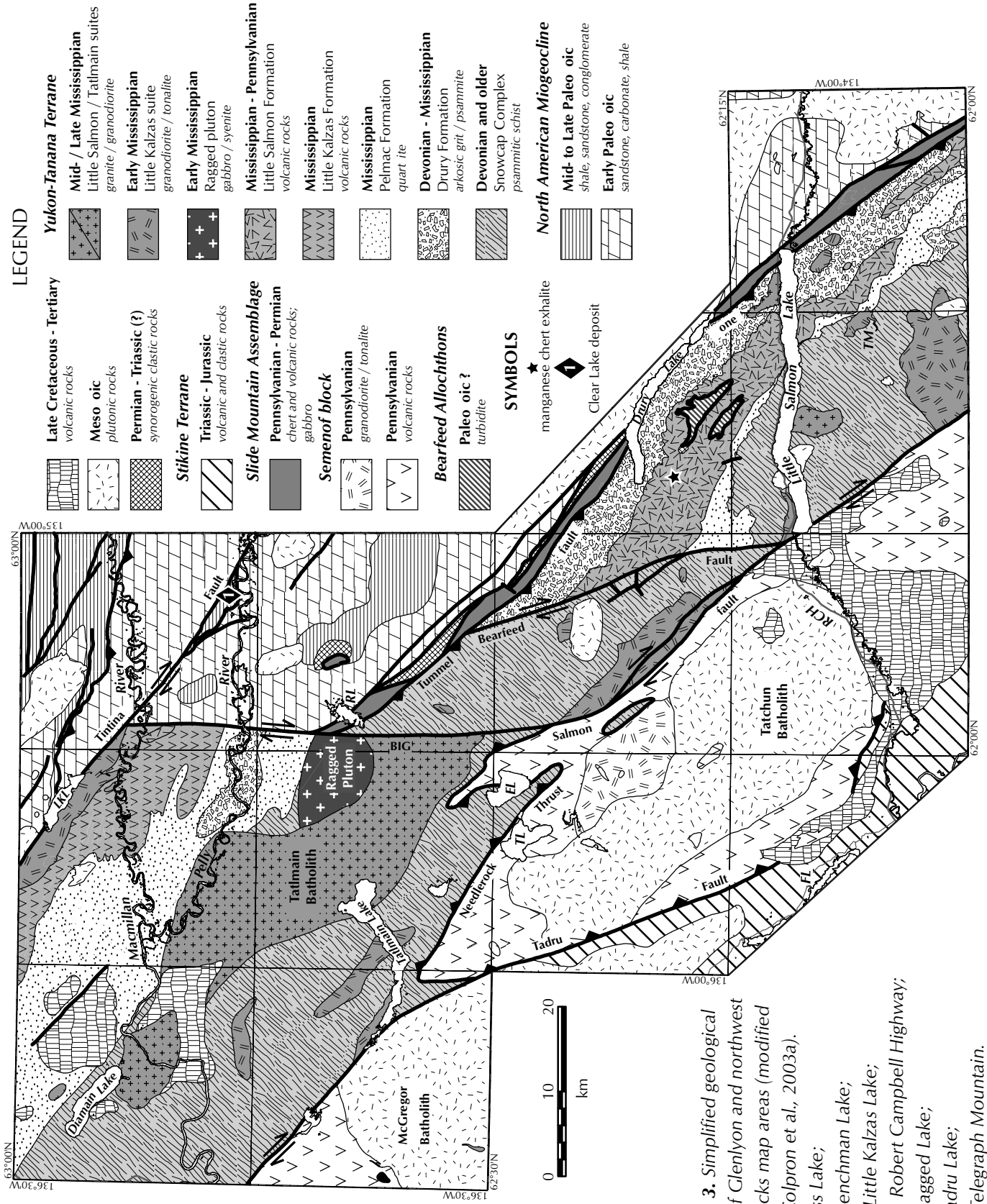
- Lower Mississippian
- Wolverine Lake group
- undifferentiated mafic and felsic volcanic rocks and dark clastic rocks

- Upper Devonian to Lower Mississippian
- Grass Lakes group
- undifferentiated mafic and felsic volcanic rocks and dark clastic rocks of the Fire Lake, Kudz Ze Kayah and Wind Lake formations

- Pre-Upper Devonian
- North River formation
- quartzose metaclastic rocks, marble and non-carbonaceous pelitic schist

- Carboniferous?
- Fortin Creek group
- dark phyllite and chert, varicoloured chert, chert-pebble conglomerate, sandstone, limestone

Figure 2. Legend for map on facing page.



**Figure 3.** Simplified geological map of Glenlyon and northwest Carmacks map areas (modified after Colpron et al., 2003a).  
 EL – Ess Lake;  
 FL – Frenchman Lake;  
 LKL – Little Kalzas Lake;  
 RCH – Robert Campbell Highway;  
 RL – Ragged Lake;  
 TL – Tadr Lake;  
 TM – Telegraph Mountain.

selected for the beryllium analyses because of its effectiveness in breaking down silicates such as beryl. A complete list of elements along with their detection limits is given in Plouffe and Bond (2003). Field and laboratory duplicates, and analytical standards were randomly inserted in the suite of samples to monitor analytical precision and accuracy. All quality assurance and quality control information is given in Plouffe and Bond (2003). Analytical precision is best, that is generally  $\leq \pm 15\%$ , for elements which occur well above their detection limit (copper, lead, zinc, mercury, silver, arsenic, barium, cobalt, chromium, tungsten) and is worst for elements occurring in low concentrations (beryllium  $\pm 94\%$ , palladium  $\pm 31\%$ , platinum  $\pm 29\%$ ) or heterogeneously distributed within the sediment (nugget effect; gold  $\pm 50\%$ ).

## RESULTS AND INTERPRETATION

### GEOCHEMICAL PARTITIONING

Numerous studies have demonstrated the enrichment of several elements in the clay-sized fraction of sediments compared to the silt-and-clay-sized fraction (for example Shilts, 1975; 1984; Nikkarinen et al., 1984; Klassen, 1999). Such elemental enrichment in the clay-sized fraction is attributed to a combination of the high adsorption capacity of clay and oxide minerals which can scavenge elements during weathering (Shilts, 1984), and to the high concentrations of metals in the structure of phyllosilicates in the primary bedrock source (Räisänen et al., 1992; Shilts, 1996; Klassen, 2001). Metal enrichment in

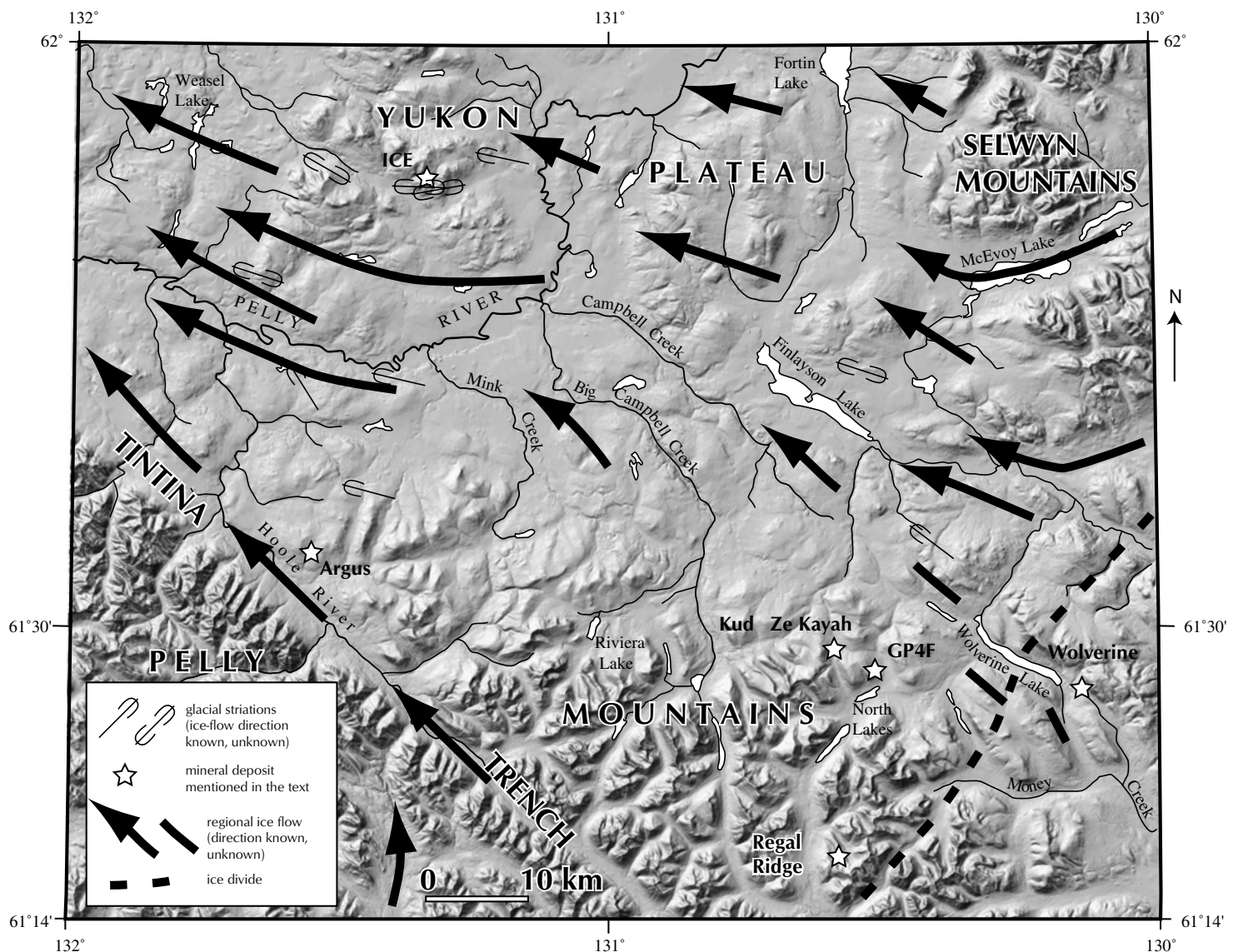


Figure 4. Physiography and regional ice flow of the Finlayson Lake map area (modified from Bond and Plouffe, 2003).

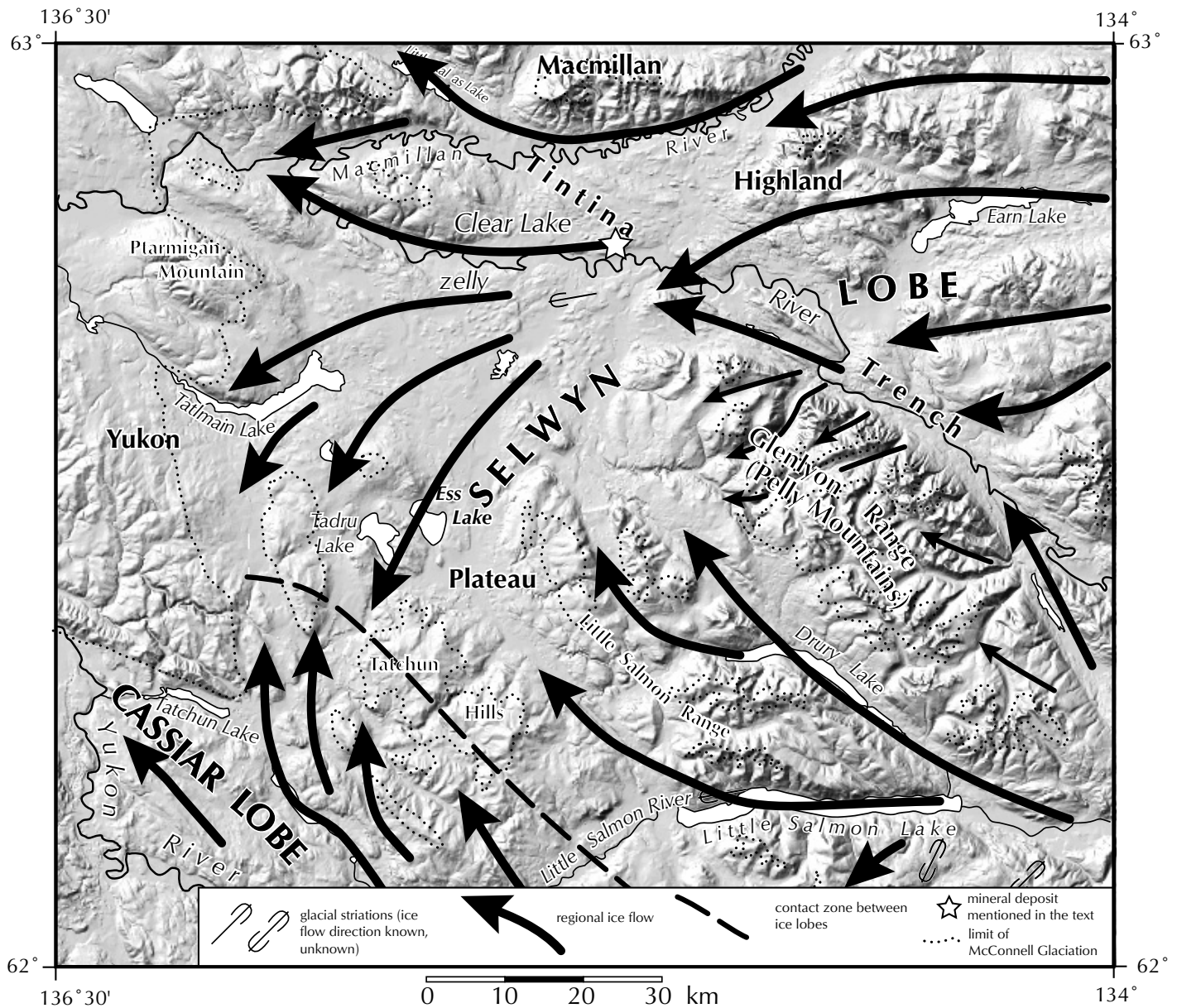
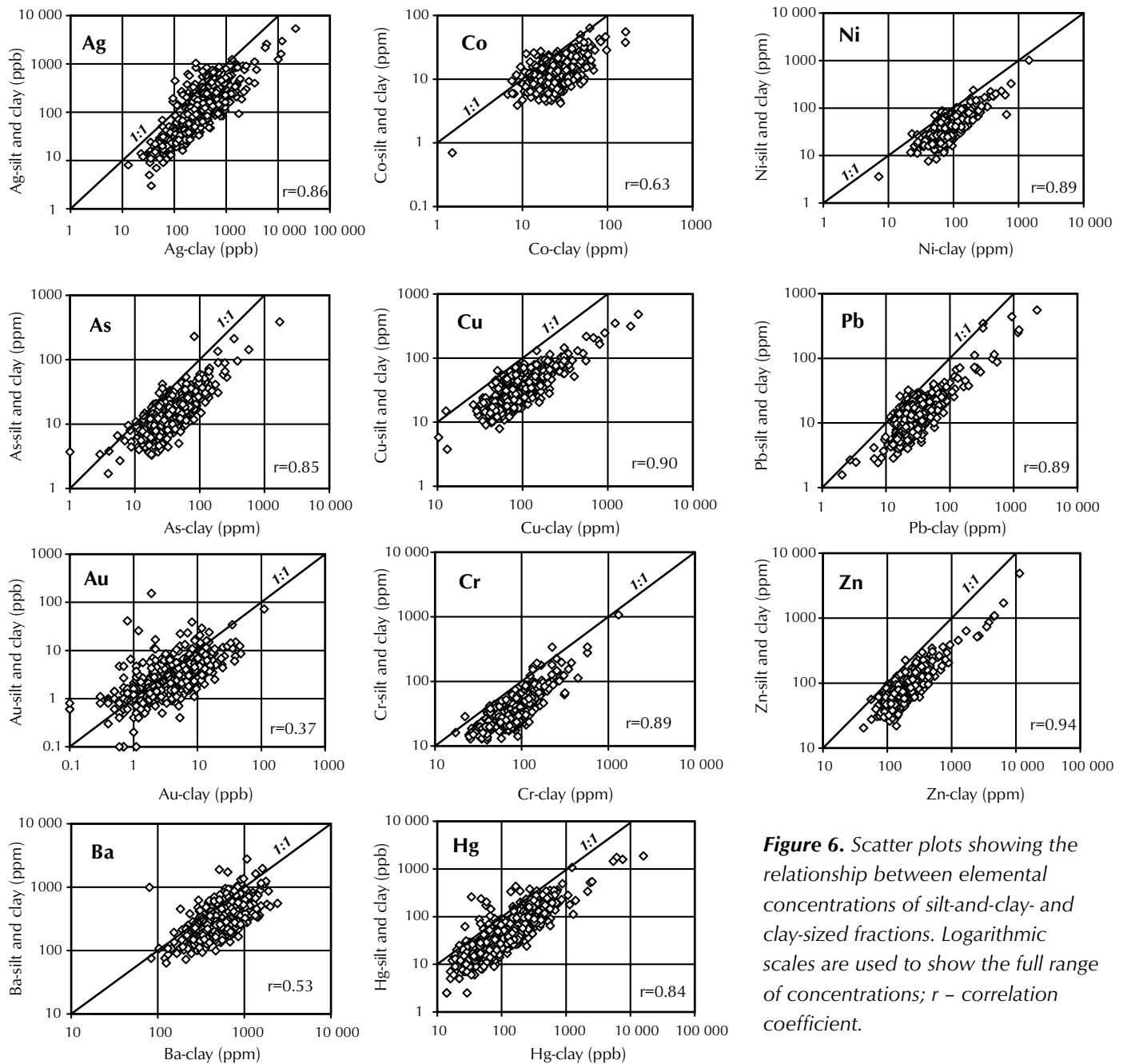


Figure 5. Physiography and regional ice flow of the Glenlyon and eastern Carmacks map areas.

phyllosilicate minerals in bedrock translates into high metal levels in the clay-sized fraction of till because phyllosilicates are easily comminuted to clay-sized particles during glacial erosion and transport. In addition, the lower metal concentrations in the silt-and-clay-compared to the clay-sized fraction is explained by the presence of metal-poor silicate minerals in the silt-sized fraction which act as dilutents (Shilts, 1984). Therefore, elemental partitioning between size fractions in till is controlled by mineralogy and glacial milling (DiLabio, 1982, 1988; Shilts, 1995; Plouffe, 1997). The analysis of the silt-and-clay-sized fraction of till has been used most

commonly for mineral exploration by industries and geological surveys, principally because it is easy and inexpensive to obtain (by dry-sieving) and it defines glacial dispersal trains at the local scale (Parent et al., 1996; Levson, 2001). On the other hand, geochemistry of the clay-sized fraction of till has been used dominantly for regional till composition surveys because it defines regional trends without being affected by textural variation in till (for example Shilts, 1971, 1996; Peuraniemi, 1982; Salminen and Hartikainen, 1985; Peuraniemi et al., 1997; Plouffe, 1998; Klassen, 2001).





**Figure 6.** Scatter plots showing the relationship between elemental concentrations of silt-and-clay- and clay-sized fractions. Logarithmic scales are used to show the full range of concentrations; *r* – correlation coefficient.

With the data combined from the Finlayson Lake and Glenlyon regions, it is clear that for most elements of interest there is a general enrichment in the clay-sized compared to the silt-and-clay-sized fraction with gold being an exception (Fig. 6). The linear correlation between both size fractions, expressed as the correlation coefficient, is strongest for silver ( $r=0.86$ ), arsenic ( $r=0.85$ ), chromium ( $r=0.89$ ), copper ( $r=0.90$ ), mercury ( $r=0.84$ ), nickel ( $r=0.89$ ), lead ( $r=0.89$ ) and zinc ( $r=0.94$ ), lesser in strength for barium ( $r=0.53$ ) and cobalt ( $r=0.63$ ),

and weak for gold ( $r=0.37$ ). The relationship could not be evaluated for palladium and platinum because only a few silt-and-clay samples yielded concentrations above detection limit. The relationships shown in Figure 6 do not take into consideration variation in underlying bedrock lithologies which can influence partitioning between both size fractions because of the difference in mineralogy (see for example, Klassen, 1999). From the mineral exploration point of view, the strong relationships signify that a high metal level is usually reflected in both size fractions.

However, there are important exceptions to this general rule with some samples yielding high concentrations in only one of the two size fractions. In such cases, the partitioning is most likely due to the elements being dominantly concentrated into a mineral form which preferentially occurs in only one size fraction. In the case of gold, the poor relationship between the silt-and-clay- and clay-sized fractions is attributed in part to the poor precision of the analyses which is related to the heterogeneous distribution of this metal in till (nugget effect). In addition, free gold can occur preferentially in only one of the two size fractions depending on its size in the source bedrock and the intensity of glacial comminution.

### FINLAYSON LAKE MAP AREA

#### *Kudz Ze Kayah orientation survey*

The Kudz Ze Kayah (KZK) deposit is located in the Pelly Mountains, approximately 20 km due south of Finlayson Lake, in an unnamed tributary valley of the Finlayson River. The mineralization at KZK consists of a volcanogenic massive sulphide body hosted in Devonian to Early Mississippian felsic metavolcanic rocks of the Grass Lakes group (Murphy et al., 2002; Murphy, this volume). It has an estimated open pit reserve of 11 million tonnes grading 5.9% Zn, 0.9% Cu, 1.5% Pb, 130 g/t Ag, and 1.3 g/t Au (Schultze, 1996). Sphalerite, chalcopyrite and galena are the main ore minerals (Yukon MINFILE 2002, 105G 117, Deklerk, 2002). The deposit lies under 2 to 20 m of ablation till, colluvium, and glaciofluvial sediments. The subcrop expression of the mineral deposit is lenticular in shape, being 2 to 39 m thick and 700 m long, and generally trending east-west, that is, transverse to the valley (Schultze, 1996). Based on the interpretation of the regional ice-flow patterns, ice in the KZK area was flowing to the north, parallel to the valley.

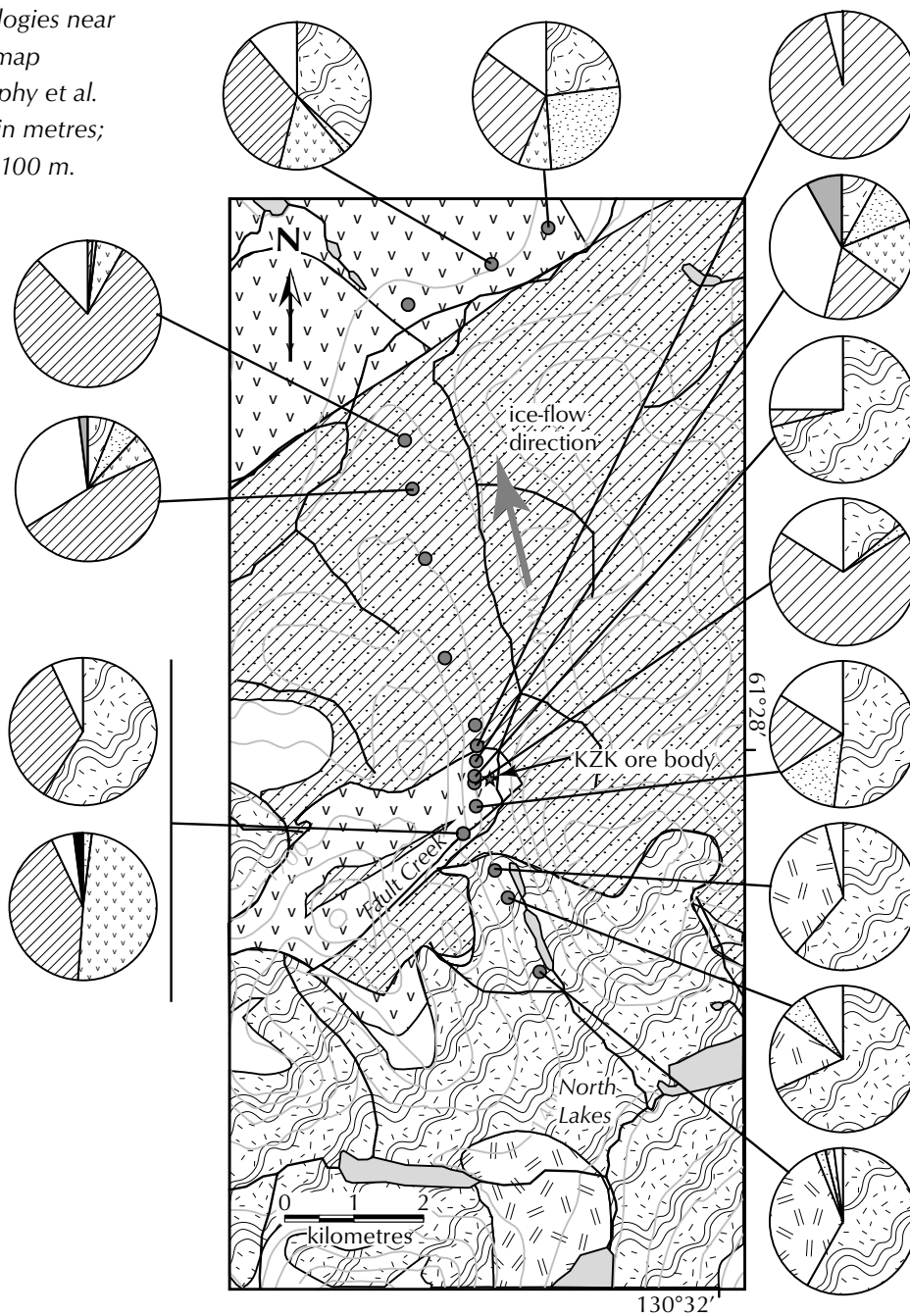
A till sampling transect was completed parallel to the KZK valley from approximately 3 km to the south (up-ice) to about 8 km north (down-ice) of the KZK mineral deposit (Fig. 7). Within 1 km of the mineralization, sample spacing averages 300 m, but beyond that distance it averages 1 km. Sampling of till within the valley was hampered by its scarcity; the till was either reworked as colluvium or covered by glaciofluvial sediments.

Till lithologies at KZK are thought to be related to bedrock provenance region, ice-flow direction, glacial process and till thickness. However, the interpretation of the till lithologies is limited by 1) the small clast size (pebbles)

collected in the field from which the source bedrock cannot always be identified, and 2) potential unmapped and concealed bedrock units. The granitic metaplutonic pebbles in till are thought to be derived from the Grass Lakes plutonic suite of Murphy et al. (2002; Fig. 7). Samples with the greatest concentration of granitic metaplutonic pebbles are found in the southern part of the transect near the Grass Lakes plutonic suite. The high percentage of granitic metaplutonic pebbles in the northernmost samples (37 and 23%) could be related to concealed granitic metaplutonic bedrock north of the KZK mineralization. Clasts of foliated diorite are only present in the southern samples and are most likely derived from the North Lakes metadiorite approximately 5 km south of the KZK mineralization (Murphy et al., 2002). In the Fault Creek valley, two till samples collected on a small creek bluff attest to the variability of till composition with depth. Lithologies in the lower sample are dominated by local felsic metavolcanic and phyllite clasts, whereas the upper sample contains mostly southerly derived granitic metaplutonic rocks. No mineralized clasts are observed in till down-ice of KZK except in the Fault Creek valley, where concealed mineralization is suspected (Bond and Plouffe, 2002). Even in the field, massive sulphide boulders and cobbles were found only close (<100 m) to the site of the KZK mineral deposit. This suggests that coarse massive sulphide debris was rapidly comminuted to smaller-sized particles during glacial erosion, transport and deposition. In addition, postglacial weathering has contributed to the destruction of sulphide-rich debris in the near surface.

Elevated concentrations of copper, lead, zinc, silver, arsenic, gold and mercury are found in till immediately down-ice of the KZK mineral deposit, and clearly define its presence (Fig. 8). High concentrations of these elements to the south (up-ice) of the main mineralized zone are most likely derived from mineralized bedrock near Fault Creek (Bond and Plouffe, 2002). In the clay-sized fraction of till, the length of glacial dispersal at KZK, estimated with a threshold equivalent to the 95th percentile of the regional data, is 3.3 km for zinc, 1.8 km for lead and gold, and 0.5 km for silver, arsenic, copper and mercury (Fig. 8). It is assumed that there is no concealed mineralization north of KZK when estimating the length of glacial transport. Glacial dispersal trains for arsenic, mercury, and zinc as defined by the clay-sized fraction are longer than the ones in the silt-and-clay-sized fraction. Increasing glacial comminution of mineralized debris with increasing distance of glacial transport is considered a probable cause for this difference. On the

**Figure 7.** Till lithologies near KZK; lithological map derived from Murphy et al. (2001). Contours in metres; contour interval =100 m.



**Pie Diagrams – Till Lithologies**

- |  |                             |  |                    |
|--|-----------------------------|--|--------------------|
|  | granitic metaplutonic rocks |  | phyllite           |
|  | foliated diorite            |  | mineralized clasts |
|  | quartzite                   |  | weathered clasts   |
|  | felsic metavolcanic rocks   |  | other              |

**Bedrock Lithologies**

- |  |   |  |  |
|--|---|--|--|
|  | granitic metaplutonic rocks (Grass Lakes plutonic suite)                      |  | felsic metavolcanic rocks (Fire Lake and Kudz Ze Kayah formations) |
|  | foliated diorite (North Lakes metadiorite)                                    |  | other  |
|  | phyllite and quartzite (Grass Lakes group with minor Kudz Ze Kayah formation) |  |  |

other hand, other elements (silver, gold, copper and lead) yielded similar dispersal distances in both the clay- and the silt-and-clay-sized fraction (Fig. 8).

The differences in the length of glacial transport amongst base metals at KZK are attributed to the elemental concentrations within the mineralization. For example, a direct relationship exists between base-metal concentrations in the mineralized zone and distance of glacial transport: zinc 5.9% and 3.3 km, lead 1.5% and 1.8 km, and copper 0.9% and 0.5 km. Such a relationship between metal concentrations in the ore zone and the distance of glacial transport is thought to be site-specific. The same relationship is not observed for precious metals: silver 130 g/t and 0.5 km, and gold 1.3 g/t and 1.8 km. This suggests that the length of glacial dispersal is not only influenced by the metal concentration in the ore zone but also by other factors such as the metal enrichment in the mineralized zone compared to the surrounding host rock and the physical and chemical properties of the host minerals.

As expected, copper, lead, zinc, silver, arsenic and mercury levels are generally higher in the clay- than in the silt-and-clay-sized fraction. In the case of gold, concentrations in both size fractions are similar, reflecting the fine-grained nature of the gold in the KZK mineral deposit. An obvious exception to this general rule is the sample located 3 km south of KZK which yielded gold concentrations of 153 ppb in the silt-and-clay- and only 2 ppb in the clay-sized fraction (Fig. 8). From this data, it could be speculated that the source of gold in this anomalous sample is coarser and derived from mineralization different in style from KZK. Bond and Plouffe (2002) suggested that the gold could be derived from intrusion-related mineralization associated with the nearby Grass Lake plutonic suite.

### *Regional survey*

As indicated above, regional geochemical maps and the interpretation of the geochemistry of the silt-and-clay-sized fraction were presented in Bond and Plouffe (2002). Therefore, only the clay-sized fraction geochemistry is depicted in Appendix 1.

*Base metals (copper, lead, zinc)* – Because of the good correlation between the base metal content of the silt-and-clay- and the clay-sized fractions, both media reflect similar, known mineralized rock and potential exploration targets. For example, the highest copper, lead and zinc concentrations are located near the KZK, Wolverine and

Argus mineralized zones (Appendix 1). On the other hand, a number of samples located 10 km northwest of Wolverine Lake contain high levels of lead and copper, and samples 17 km south of Wolverine Lake contain high lead concentrations. All of these are located above rocks of the Wolverine Lake group which host the Wolverine massive sulphide deposit and therefore are thought to reflect the presence of concealed mineralized rock. In the northern sector of the Finlayson Lake map area over the rocks of the North American miogeocline, zinc levels are slightly more elevated compared to the rest of the region (Bond and Plouffe, 2002). One of the highest zinc levels in both size fractions was obtained from this region.

The distribution of barium in till is discussed under the base metal heading because it can be used as a pathfinder element for massive sulphide deposits in the area. For instance, baritic iron formation is associated with the mineralization at Wolverine. However, barium results have to be interpreted with care because the leach used in this survey (similar to aqua regia) does not dissolve barite. Therefore, the reported barium concentrations relate to barium present in phases other than barite. As opposed to copper, lead and zinc, high barium concentrations in both size fractions are in several cases not located at the same sites. For instance, none of the high barium values in the silt-and-clay-sized fraction reported by Bond and Plouffe (2002) southwest of Finlayson Lake or southwest of Fortin Lake are present in the clay-sized fraction. On the other hand, the barium content of the silt-and-clay-sized fraction was generally low near both KZK and Wolverine and is more elevated in the clay-sized fraction. Two samples located 10 km northwest of Wolverine Lake, in a region with elevated lead and copper concentrations (see above) also yielded high barium levels.

*Precious metals (gold, silver, platinum group elements)* – As indicated above, there is a poor correlation between gold concentrations in the two size fractions. For example, at stations 24 and 45 km west of Finlayson Lake, two samples that yielded amongst the highest gold values in the silt-and-clay-sized fraction (01-PMA-075-01: 41 ppb and JB01-073: 39 ppb, see Bond and Plouffe, 2002) returned low gold levels in the clay-sized fraction (01-PMA-075-01 = 1 ppb and JB01-073 = 8 ppb). In contrast, 8 km northwest of Wolverine Lake, a series of samples collected at the northwestern extent of the Wolverine Lake group yielded high gold values (>11 ppb) in both the clay- and silt-and-clay-sized fraction indicating a range of gold particle sizes in till for that region. Some

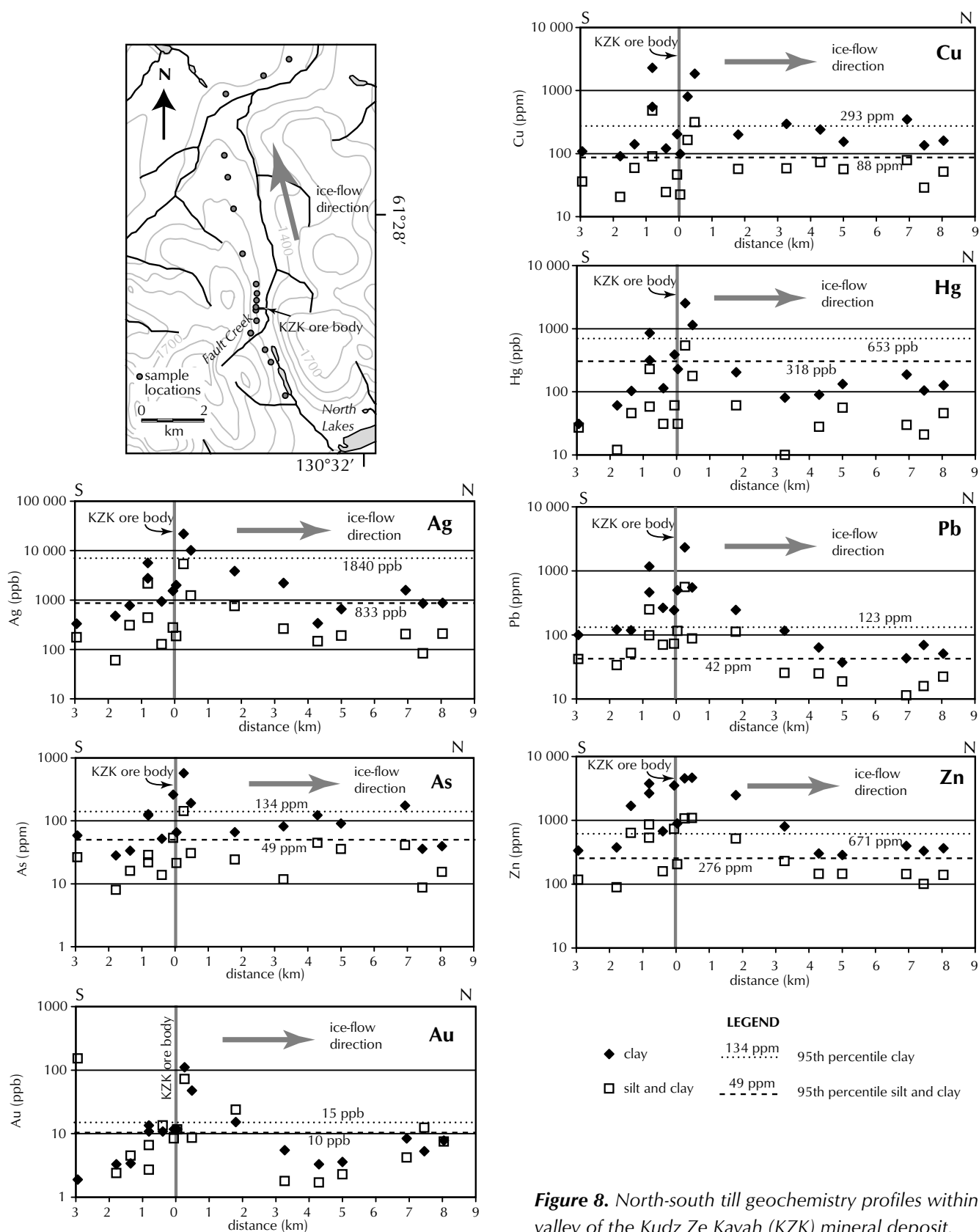


Figure 8. North-south till geochemistry profiles within the valley of the Kudz Ze Kayah (KZK) mineral deposit. Contours in metres; contour interval = 100 m.

of the samples from that area returned elevated levels of lead, zinc, copper, barium, mercury, silver and arsenic. This region represents a key exploration target given its multi-elemental signature and its proximity to the Robert Campbell Highway (ca. 6.5 km). Similarly, 17 km south of Wolverine Lake, a sample containing high gold concentrations (01-PMA-169: 17 ppb) also returned elevated levels of arsenic and lead (01-PMA-169: arsenic = 383 ppm and lead = 259 ppm) in the clay-sized fraction. These are also located above the Wolverine Lake group.

Most of the high silver concentrations in the clay-sized fraction are located above the Wolverine succession and are thought to be indicative of the high background silver concentration of that rock unit. Similarly, the arsenic levels in the clay-sized fraction of till are generally higher over the footwall rocks of the Money Creek thrust (see Murphy et al., 2002) within the Yukon-Tanana Terrane compared to the rest of the region (see data in Plouffe and Bond, 2003).

In the silt-and-clay-sized fraction, palladium concentrations are below detection limit in all samples, and platinum levels are above detection in only three of them. In contrast, in the clay-sized fraction, palladium and platinum concentrations are above detection limit for 12% and 38% of the samples, respectively. Consequently, the palladium and platinum levels in the clay-sized fraction are of better use at delineating exploration targets for platinum group elements than the silt-and-clay. Given the known association of platinum group elements with ultramafic rocks, high palladium and platinum concentrations found in association with elevated levels of nickel, chromium and cobalt represent the most attractive platinum group element targets. A sample collected 16 km southwest of Finlayson Lake, at the northern end of a Late Devonian to early Mississippian ultramafic intrusion (Murphy et al., 2002; Murphy, 2004), returned elevated palladium (40 ppb), platinum (10 ppb), chromium (252 ppm) and nickel (182 ppm) concentrations, reflecting its ultramafic source (see Ni and Cr data in Plouffe and Bond, 2003). High platinum (9 ppb) and palladium (26 ppb) levels and moderately elevated cobalt concentration (60 ppm) were measured in a sample located approximately 28 km southwest of Finlayson Lake, with a source region most likely located in the mafic volcanic rocks of the Fire Lake formation (Murphy et al., 2002; Murphy, 2004). Sample 01-PMA-004, collected only 4 km southwest of Finlayson Lake, yielded elevated palladium (12 ppb), platinum (7 ppb), cobalt (95 ppm),

and chromium (375 ppm) concentrations. The sample is located on top of a gossanous zone in the felsic volcanic rocks of the Grass Lakes group. Given the mafic to ultramafic signature of the sample (high cobalt and chromium) it could be derived from a concealed mafic or ultramafic bedrock source. Sample JB01-164, collected at the Wolverine deposit southeast of Wolverine Lake, and sample 01-PMA-122, located in the northwestern sector of the area yielded elevated palladium concentrations (29 and 32 ppb, respectively). In both cases, the source of the palladium is unknown.

*Emerald* – Beryllium in till is evaluated as a potential indicator of beryl occurrences in geological settings suitable for the formation of emerald. Beryllium concentrations in the silt-and-clay-sized fraction of till are low, with 27% of the samples returning concentrations below the detection limit of 1 ppm. The average concentration in the samples with measurable levels of beryllium is only 3 ppm. Given these low levels, analytical precision for beryllium is found to be low:  $\pm 90\%$  (Plouffe and Bond, 2003) which implies that analytical results have to be evaluated with caution.

Obvious exploration targets for emerald occurrences are Cretaceous granitic intrusions in proximity to the mafic volcanic rocks of the Fire Lake formation, a setting similar to the Regal Ridge emerald occurrence. This study did not find any high beryllium levels in till associated with such a setting in the Finlayson Lake region. However, concealed or unmapped small Cretaceous granitic intrusions could be present in the area of the Fire Lake formation and be a source of beryllium in till. For example, approximately 7.5 km south of the Hoole and Pelly River confluence, three samples located near the contact zone of the Fire Lake and North River formations contain elevated beryllium concentrations (7, 11 and 11 ppm). Several other samples located above the Fire Lake formation in the western sector of the area contain moderately elevated beryllium concentrations (6 to 10 ppm). In addition, the potential of older granitic intrusive rocks (e.g., Jurassic) to host emeralds has yet to be evaluated. Detailed mineralogical analyses of till, similar to that applied to diamond exploration, might be required to provide a more thorough evaluation of the potential for emerald occurrences in this region.

## GLENLYON AND EASTERN CARMACKS MAP AREAS

### *Clear Lake orientation survey*

The Clear Lake deposit is located in the north-central sector of the Glenlyon map area, approximately 30 km west of Earn Lake and less than 2 km north of Pelly River. It is a zinc-lead-silver sedimentary exhalative deposit hosted in Devonian-Mississippian sedimentary rocks of the Earn Group which is part of the North American strata (Deklerk, 2002, Yukon MINFILE 2002, 105L 045). It contains an estimated ore reserve of 6.1 million tonnes grading 11.34% Zn, 2.15% Pb, and 40.8 g/t Ag. The main ore minerals include sphalerite and galena with lesser pyrite (Deklerk, 2002). Except for a gossan exposed in the Pelly River valley, the deposit does not outcrop and is covered with a blanket of 10-25 m of till dating to the last (McConnell) glaciation during which it was glacially eroded (Bond and Plouffe, 2003). In subcrop, the ore body is sigmoidal in shape, approximately 1000 m long and up to 100 m wide with a general north-south orientation transverse to westward ice flow.

A detailed till sampling transect was completed parallel to ice flow extending from 200 m up-ice to 2.3 km down-ice of the mineralization (Bond and Plouffe, 2003). Sample spacing varied from 25 m over the deposit and up to 500 m down-ice from it. Till sampling was hampered by the presence of thick loess cover (on average >30 cm and exceeding 100 cm in places) and near-surface permafrost.

Till lithologies at Clear Lake are highly variable from one pebble sample to the next along the transect (Fig. 9). The dominant local bedrock lithologies (fine-grained sedimentary rocks: argillite, shale and sandstone) are not abundant as clasts in till, probably because they did not survive glacial comminution. On the other hand, the more indurated lithologies such as chert are commonly found as clasts in till. Given the high percentage of volcanic clasts in till, it is suspected that concealed volcanic units might be present in the local Earn Group rocks. In addition, till pebble lithologies seem to reflect bedrock composition only at some distance down-ice from the source. For example, the greatest percentage of oxidized and weathered clasts, potentially derived from the mineralized zone, only appear at surface at approximately 1 km down-ice from the ore body, probably because of the great till thickness in this region. Similarly, carbonate clasts are absent in till overlying carbonate bedrock and are only abundant (54%) in the westernmost sample. However, carbonate clasts may have been weathered

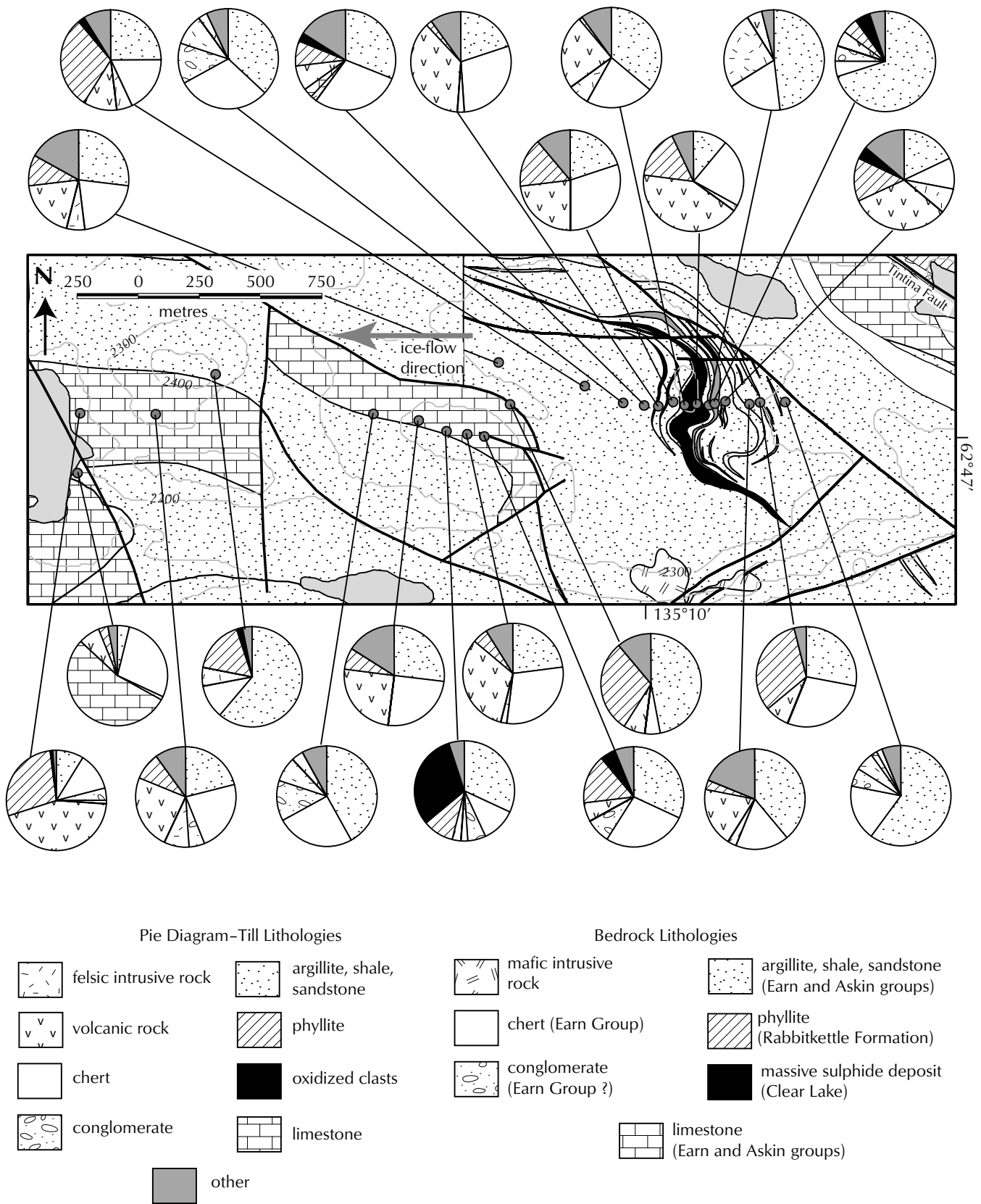
from the surface till during post-glacial time especially close to the mineralization where the weathering of sulphide minerals is acid-generating (see also Bond and Plouffe, 2003).

Bond and Plouffe (2003) presented the geochemical results of the silt-and-clay-sized fraction of till at the Clear Lake deposit. These results are compared here with the clay-sized geochemistry. As expected, lead and zinc concentrations are generally higher in the clay- than in the silt-and-clay-sized fraction (Fig. 10). However, the two metals show contrasting patterns. Using a threshold arbitrarily selected as the 95th percentile of the regional data, lead concentrations in both size fractions are anomalously low, as close as 100 m down-ice from mineralized rock (Fig. 10). Anomalous lead concentrations in the silt-and-clay-sized fraction extend 1.4 km down-ice from the deposit and in the clay-sized fraction they sporadically occur as far as 2.5 km down-ice. In contrast, zinc concentrations are anomalously high in both size fractions of till only 800 m down-ice of mineralized rock, and remain anomalously high sporadically for approximately 2.5 km. It is suspected that acid-generating sulphide minerals in till might have leached and removed sphalerite, hence zinc, from till which was remobilized into the nearby Clear Lake, with galena being less affected in this environment (Bond and Plouffe, 2003). This interpretation is supported by the high dissolved-zinc concentration (>1 ppm) and the low pH (<3) in the water of Clear Lake as well as the lower pH of the till above the mineralized zone (5.7) compared to the surrounding areas (>7.0; Fletcher et al., 2003). In addition to lead and zinc, high concentrations of mercury and silver were detected in both size fractions down-ice of mineralization, and therefore are thought to be good pathfinder elements for similar mineralization (Fig. 10). The source of the anomalous silver and zinc levels, dominantly present in the clay-sized fraction up-ice from Clear Lake is unknown.

### *Regional survey*

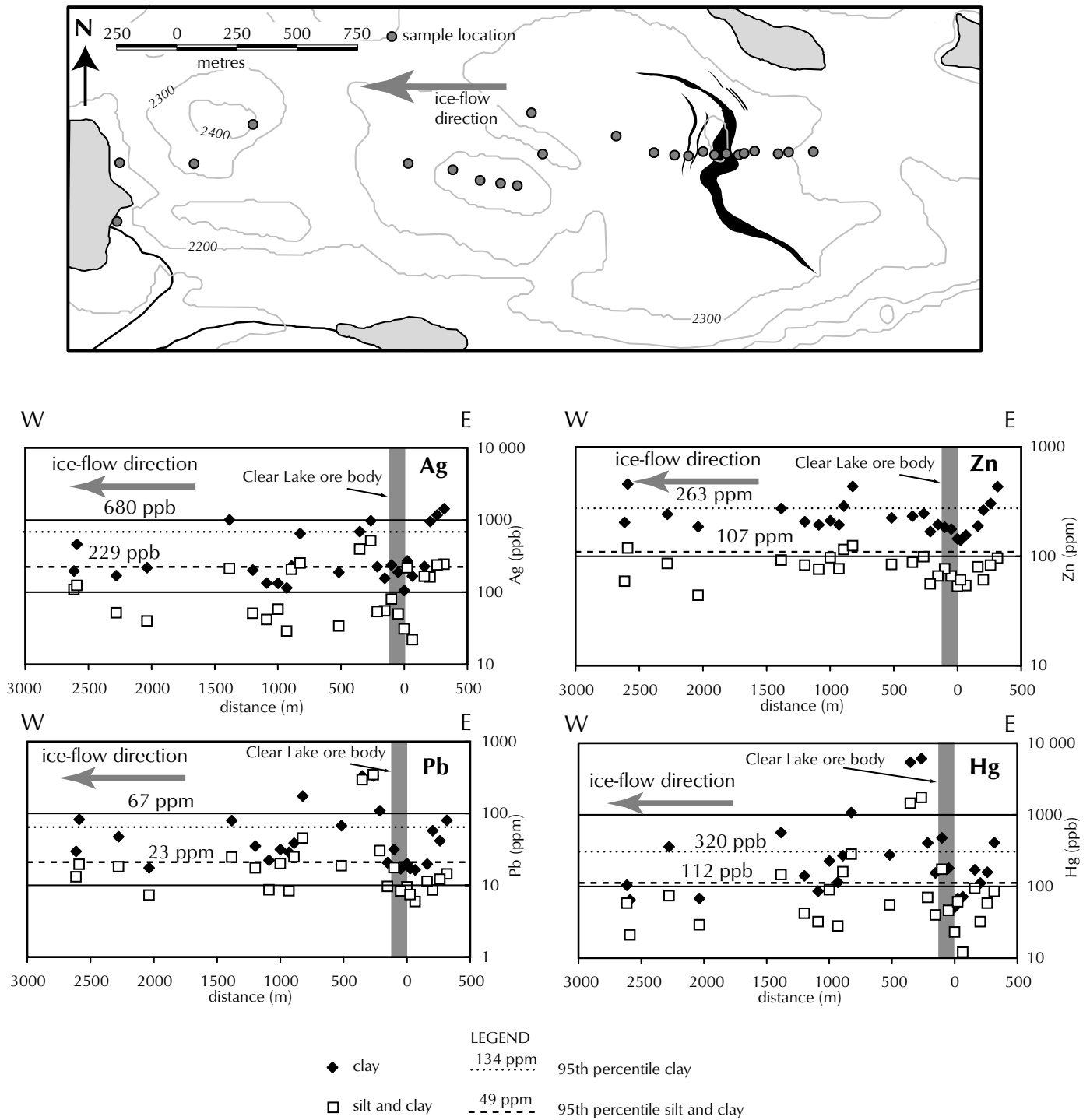
Results of the clay-sized fraction geochemistry for the Glenlyon and eastern Carmacks map areas are depicted in Appendix 2. Most of the exploration targets defined by the silt-and-clay-sized fraction geochemistry (Bond and Plouffe, 2003) are confirmed by the clay-sized geochemistry.

*Base metals (copper, lead, zinc)* – The Earn Group anomaly located near the contact zone of Earn Group and Askin Group rocks, i.e., in a stratigraphic setting



**Figure 9.** Till lithologies at the Clear Lake deposit; lithological map derived from Colpron et al. (2002), and Zuran and Basnett (1992). Contours in feet; contour interval =100 ft.





**Figure 10.** East-west till geochemistry profiles near the Clear Lake deposit. Corresponds in area to Figure 9. Contours in feet; contour interval = 100 ft.

similar to the Clear Lake deposit, and only 18 km south-southeast from it, was originally defined by Bond and Plouffe (2003) and is well reflected by the clay-sized fraction geochemistry of till with high zinc (up to 503 ppm – 100th percentile), silver (up to 814 ppb – 98th percentile) and molybdenum (up to 15 ppm – 100th percentile) concentrations. A winter road originating from the Klondike Highway to the west, passes 9 km north of the anomaly.

The Frenchman Lake zinc anomaly defined by Bond and Plouffe (2003) above conglomerate of the Lower Jurassic Laberge Group (Stikine Terrane) is also well outlined with the clay-sized fraction geochemistry. The sampling transect that starts less than 1 km east of Frenchman Lake contains at least one sample with high concentrations of silver (683 ppb – 95th percentile), cadmium (2.22 ppm – 99th percentile), mercury (708 ppb – 99th percentile), molybdenum (5 and 6 ppm – 97th percentile) and zinc (389 ppm – 99th percentile). The most attractive signature of the transect is the gold content of the clay-sized fraction which varies between 11 ppb and 20 ppb (87th and 98th percentiles, respectively). Such elemental association could be characteristic of concealed epithermal mineralization (C. Hart, pers. comm., 2002).

Two regions are characterized by high copper concentrations and are potential exploration targets for volcanogenic massive sulphide deposits. Eleven kilometres east of Frenchman Lake (Frenchman Ridge copper anomaly of Bond and Plouffe, 2003), elevated copper concentrations were detected in both size fractions of till above volcanic and volcanoclastic rocks of the Semenof block. The number of samples along Frenchman Ridge with high copper concentrations in the clay-sized fraction are greater than in the silt-and-clay fraction. In addition, moderately elevated concentrations of silver (493 ppb) and gold (a few samples with >10 ppb) were detected in samples along the same transect.

Southwest of Drury Lake in the Little Salmon Range, above intermediate to mafic metavolcanic rocks of the Little Salmon Formation and near a thin exhalite unit (light green and red manganese-bearing chert; see Colpron et al., 2002), high copper concentrations (up to 387 ppm – 99th percentile) are present in both size fractions of till. The region is also characterized by one or more samples with elevated concentrations of silver (up to 735 ppb – 96th percentile), cobalt (up to 59 ppm – 98th percentile), chromium (573 ppm – 99th percentile), nickel (222 ppm – 99th percentile) and vanadium (191 ppm – 99th percentile). The high cobalt, chromium and nickel content

of the till suggests an ultramafic bedrock source which might be more extensive than originally mapped by Colpron et al. (2002).

*Precious metals (gold and platinum group elements)* – Some of the gold exploration targets outlined in Bond and Plouffe (2003) based on the silt-and-clay-sized fraction geochemistry are also characterized by high gold and pathfinder element concentrations in the clay-sized fraction of till. For example, the east Detour gold anomaly (Bond and Plouffe, 2003) located northeast of Pelly River in Selwyn Basin is characterized by high gold (up to 35 ppb – 100th percentile), arsenic (up to 339 ppm – 100th percentile), bismuth (1.13 ppm – 97th percentile), lead (75 ppm – 96th percentile) and antimony (6.5 ppm – 99th percentile) concentrations in the clay-sized fraction of till. Similarly, 7 km southwest of the Clear Lake deposit, the Tummel River gold anomaly (Bond and Plouffe, 2003), likely related to the nearby Cretaceous granite, returned elevated gold (16 ppb – 96th percentile), arsenic (109 ppm – 99th percentile), silver (966 ppb – 98th percentile) and antimony (4.79 ppm – 98th percentile) levels in the clay-sized fraction. The Big Salmon Fault region northwest of Little Salmon Lake was identified as a potential target for fault-related hydrothermal mineralization by Bond and Plouffe (2003). Five out of the seven till samples collected in that region contain elevated concentrations of gold (12 to 25 ppb) and at least one sample from the same region contain elevated levels of arsenic (87 ppm – 97th percentile), silver (483 ppb – 91th percentile), mercury (609 ppb – 98th percentile), lead (78 ppm – 97th percentile), and antimony (7.3 ppm – 99th percentile) in the clay-sized fraction. In contrast, none of the sites with high gold concentrations in the silt-plus-clay-sized fraction in the vicinity of the McGregor Batholith (Bond and Plouffe, 2003) contain high gold values in the clay-sized fraction. This suggests that any gold mineralization associated with the McGregor Batholith is coarser than the clay fraction of the till.

A high gold concentration (33 ppb – 99th percentile) was measured in the clay-sized fraction of a sample south of Tatchun Lake above sedimentary and volcanic bedrock of the Whitehorse Trough. The same sample contains a moderately elevated gold level in the silt-plus-clay-sized fraction (14 ppb). No other element occurs in elevated concentration within that region.

Palladium and platinum concentrations in till are generally lower in the Glenlyon region compared to the Finlayson Lake area. The only potential exploration target outlined

from this survey for platinum group elements is located southwest of Drury Lake, near Paleozoic ultramafic rocks, where the clay-sized fraction of a till sample yielded the highest platinum concentration (4 ppb). As indicated above, the bedrock ridge southwest of Drury Lake in the Little Salmon Range is characterized by high nickel, cobalt and chromium concentrations in till.

*Emerald* – The highest beryllium concentrations (13 ppm in two samples) are found south of Drury Lake over the Late Devonian to Early Mississippian Drury Formation (grit) and in the north-central part of the area over slate bedrock of the Earn Group. None of these sites seem to be in a geological environment favourable for the occurrence of emerald. On the other hand, seven till samples northwest of Little Salmon Lake have moderately elevated beryllium concentrations (four samples with 4 to 8 ppm; 79th to 98th percentile, respectively). These are located less than 2 km down-ice from a small outcrop of the Early Jurassic granitic Tatchun Batholith which intruded the Carboniferous mafic volcanic rocks of the Semenof block. Although no high chromium concentrations are observed in till of that region, mafic volcanic rocks of the Semenof block do contain high chromium concentrations (800 to 1000 ppm) similar to the Fire Lake formation which hosts the emerald occurrences at Regal Ridge (M. Colpron, pers. comm., 2003). Furthermore, late-phase rare pegmatite dykes were observed in the northern sector of the Tatchun Batholith (M. Colpron, pers. comm. 2003). Consequently, this region represents a potential geological environment for the occurrence of emerald. On the other hand, the beryllium content of till of this region might be related to epithermal mineralization along the Big Salmon Fault.

## RECOMMENDATIONS FOR DRIFT PROSPECTING

In the region of the Yukon-Tanana Terrane of southern Yukon, till geochemistry is effective at delineating zones of mineralization as demonstrated here with examples from the Finlayson Lake (NTS 105G) and Glenlyon and eastern Carmacks (NTS 105L, 115I) map areas. The reported geochemical dispersal trains derived from known mineralization have different lengths which seems to be influenced by till thickness, elemental concentrations in the source rocks and enrichment compared to the country rocks, ore mineralogy, the nature of the ore subcrop, post-glacial weathering, and the size fraction analysed. Drift prospecting is efficient at

delineating mineralized rock over plateaus and within valleys where till can be sampled at surface and where it directly overlies bedrock. Good results are achieved both where till is thin (<3 m) and where it is thick (e.g., 25 m of till at Clear Lake), but in such cases, anomalies are not found immediately above mineralized rock but some distance down-ice from it due to glacial transport. Areas underlain by thick deposits of glacial lake and glaciofluvial sediments should be avoided for sampling because of the complex transport history of those sediments.

For base metal mineral exploration, geochemical analyses of the silt-and-clay- and clay-sized fractions generally give similar regional results. The low cost of silt-and-clay (dry sieving) compared to clay separation (centrifuge) makes the former more attractive considering that large sample sets need to be analysed. However, for more detailed follow-up surveys, analysis of the clay-sized fraction can provide additional information. For example, at KZK, glacial dispersal trains for arsenic, mercury and zinc as defined by the clay-sized fraction are longer than the ones in the silt-and-clay-sized fraction. This has obvious implications for mineral exploration because a longer dispersal train translates into a larger exploration target. The correlation between the high gold concentrations in both size fractions is not as good as for base metals, probably because certain types of gold occurrences are reflected in only one size fraction. For example, potential intrusion-related gold occurrences do not seem to be reflected in the clay-sized fraction of till, probably because most of the gold associated in those occurrences is coarser than clay. Consequently, both size fractions provide complementary information for drift prospecting for gold. In addition, it should be noted that the analytical precision for gold is generally better with the clay- compared to the silt-and-clay-sized fraction because of the reduced nugget effect in the clay-sized material (Plouffe and Bond, 2003).

The beryllium content of till might provide indication of the occurrence of beryl in bedrock but the low analytical precision of beryllium analyses (Plouffe and Bond, 2003) limits this approach. Nevertheless, more testing is required to establish a drift prospecting method that is useful at detecting emerald occurrences. Furthermore, a mineralogical study of surficial sediments near the known emerald occurrence at Regal Ridge should be undertaken to identify indicator minerals associated with emerald occurrences and to develop an exploration strategy similar to the methodology used for diamond exploration.

Because of the known low analytical precision of certain elements (e.g., beryllium, gold; see Plouffe and Bond, 2003 for details), any extensive follow-up surveys near some of the anomalies mentioned in this report should only be undertaken after reproducing these anomalies using the same sediment (till), size fraction, and analytical methods.

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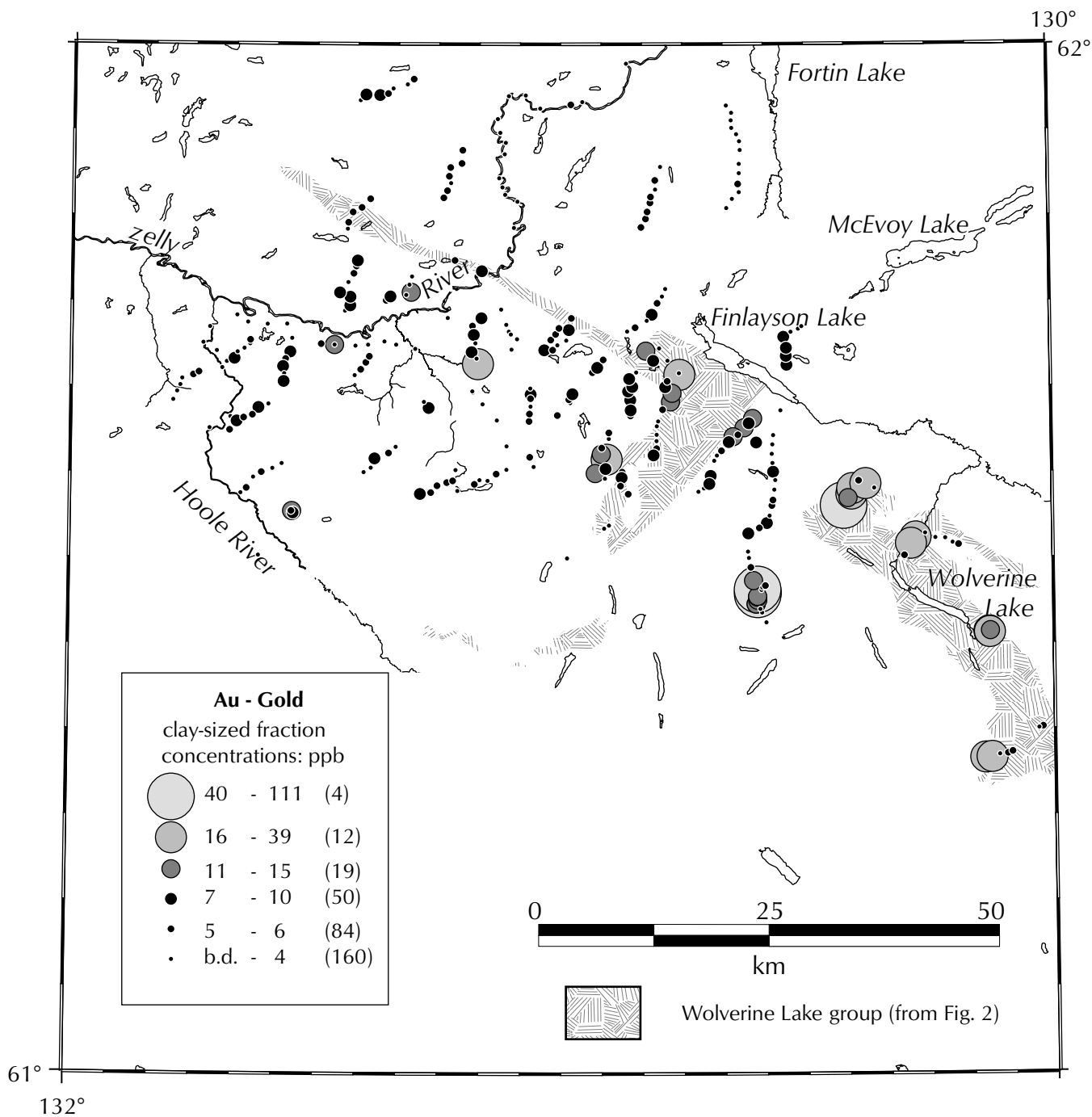
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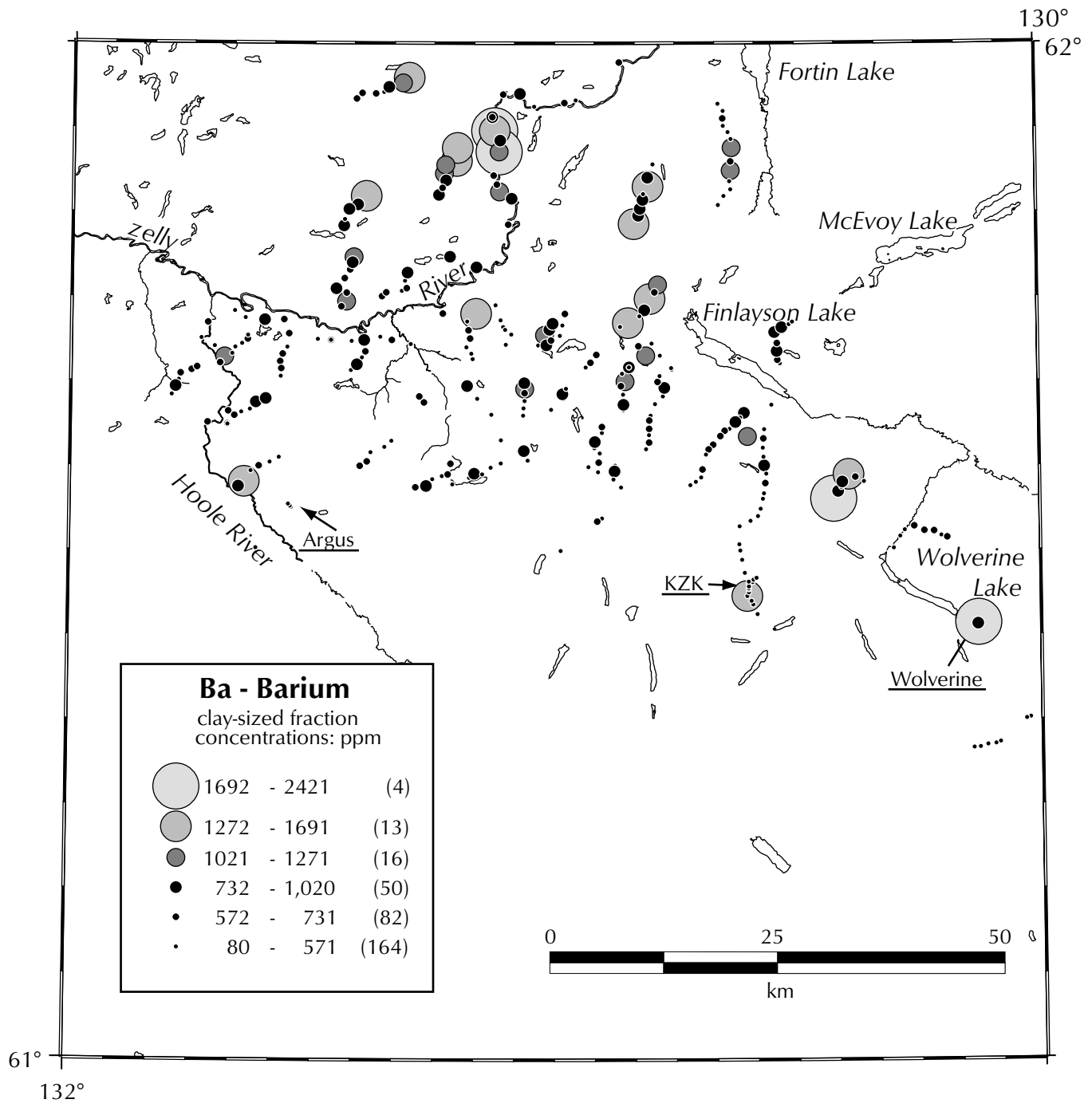
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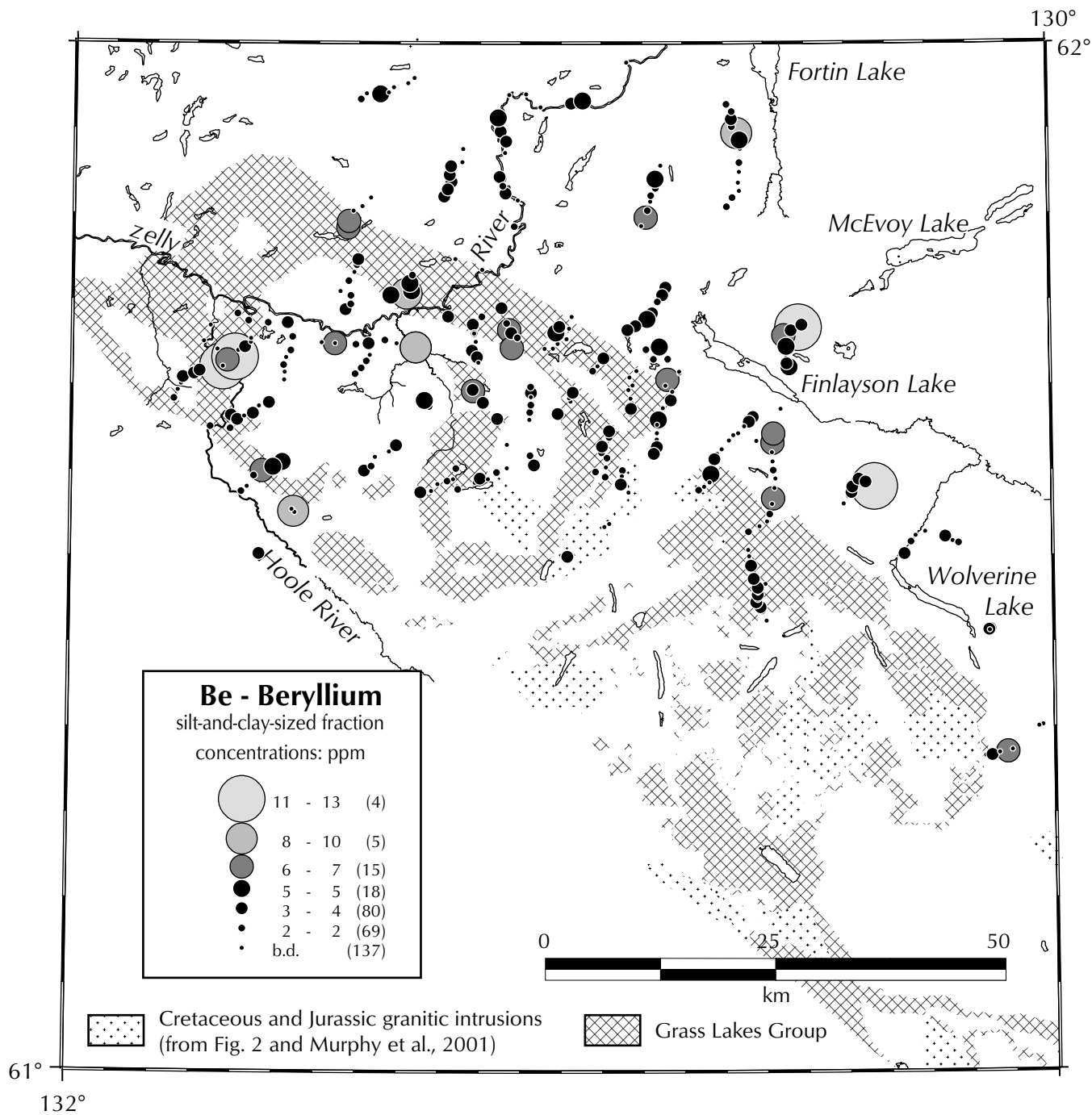
**APPENDIX 1**

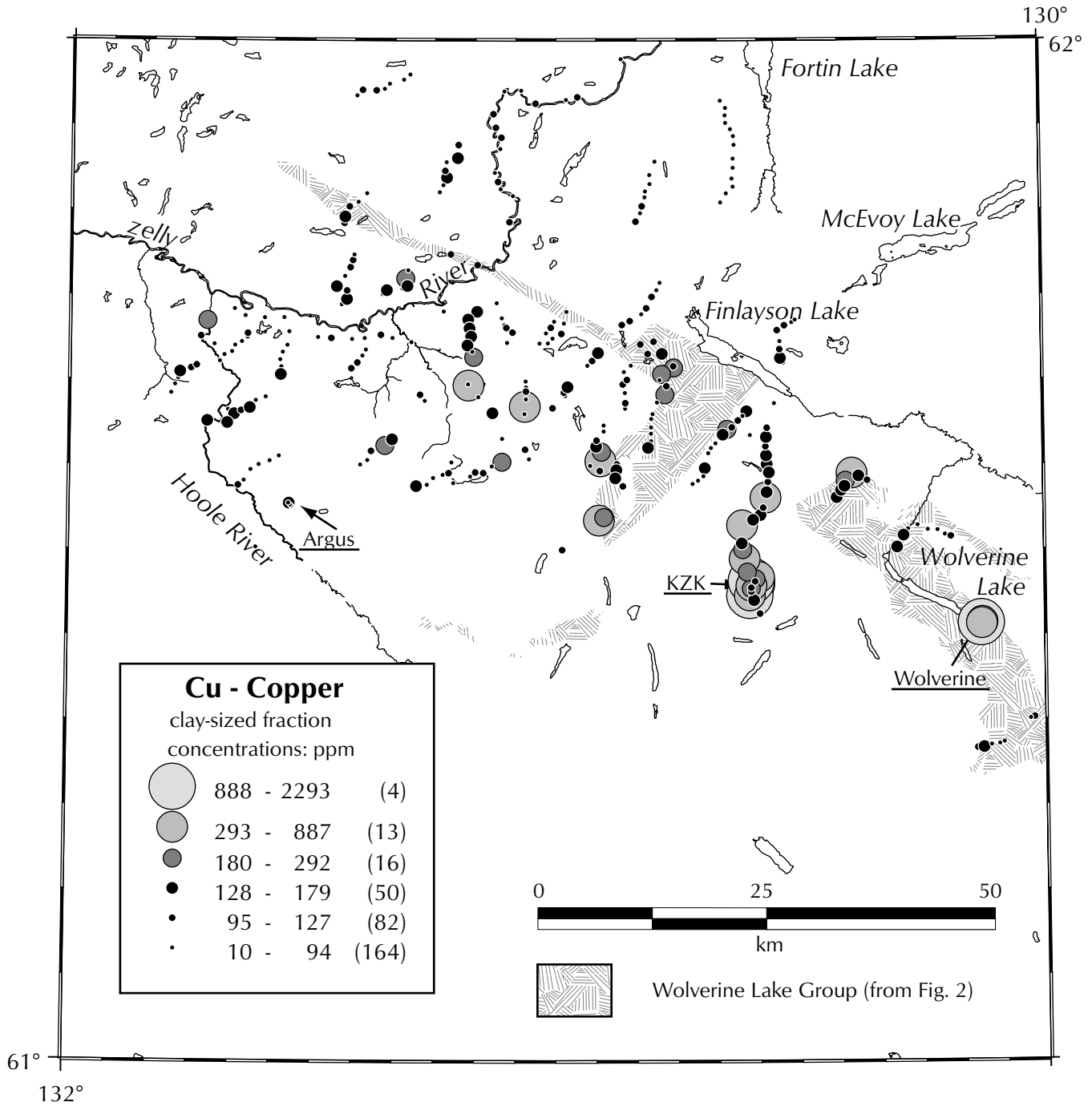
Geochemical maps of the clay-sized fraction for gold, barium, copper, lead, zinc, palladium, platinum and beryllium (silt-and-clay-sized fraction), Finlayson Lake map area. In the legend, numbers in parentheses define the number of samples within the concentration range; b.d. – below detection limit.

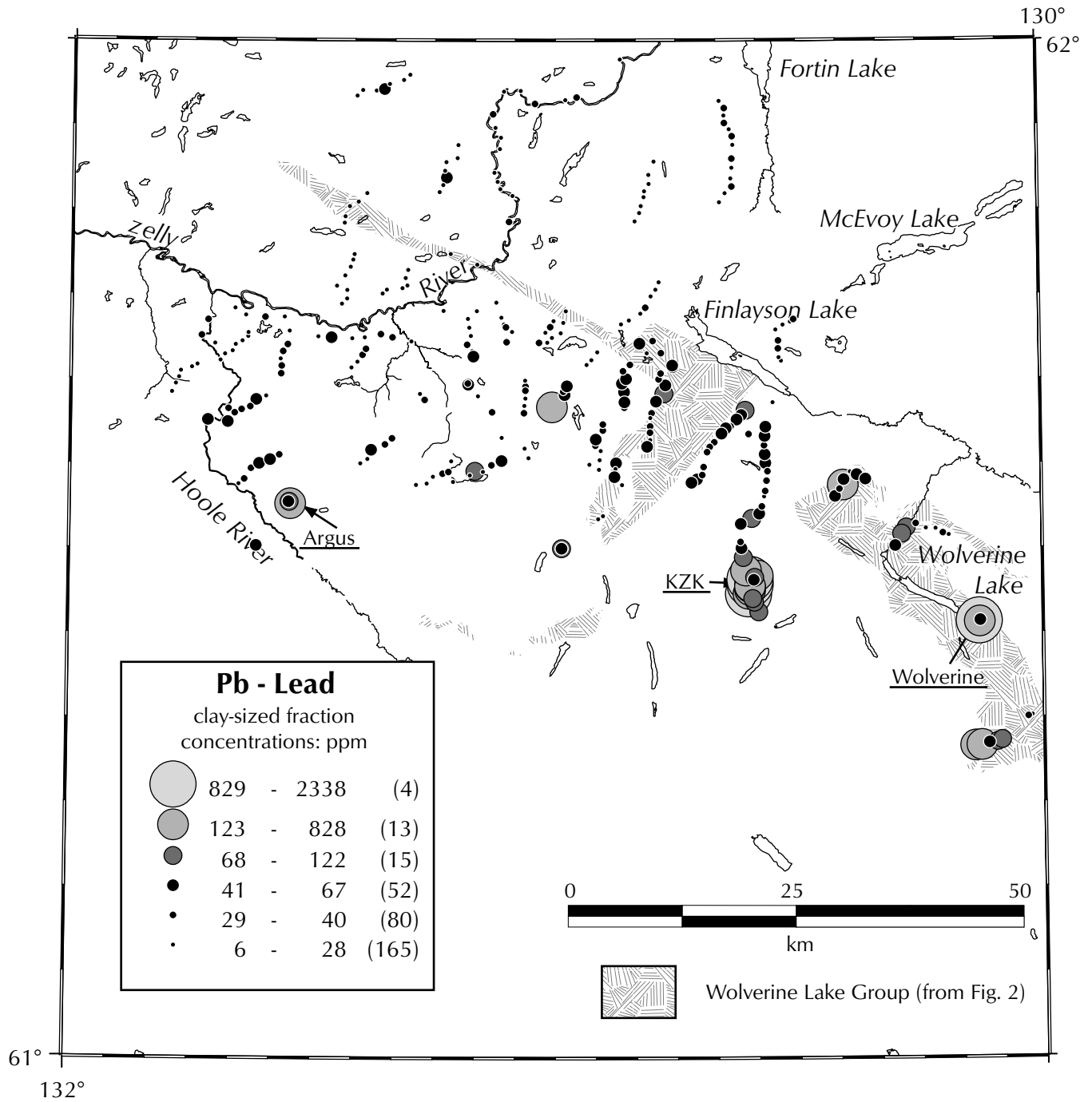


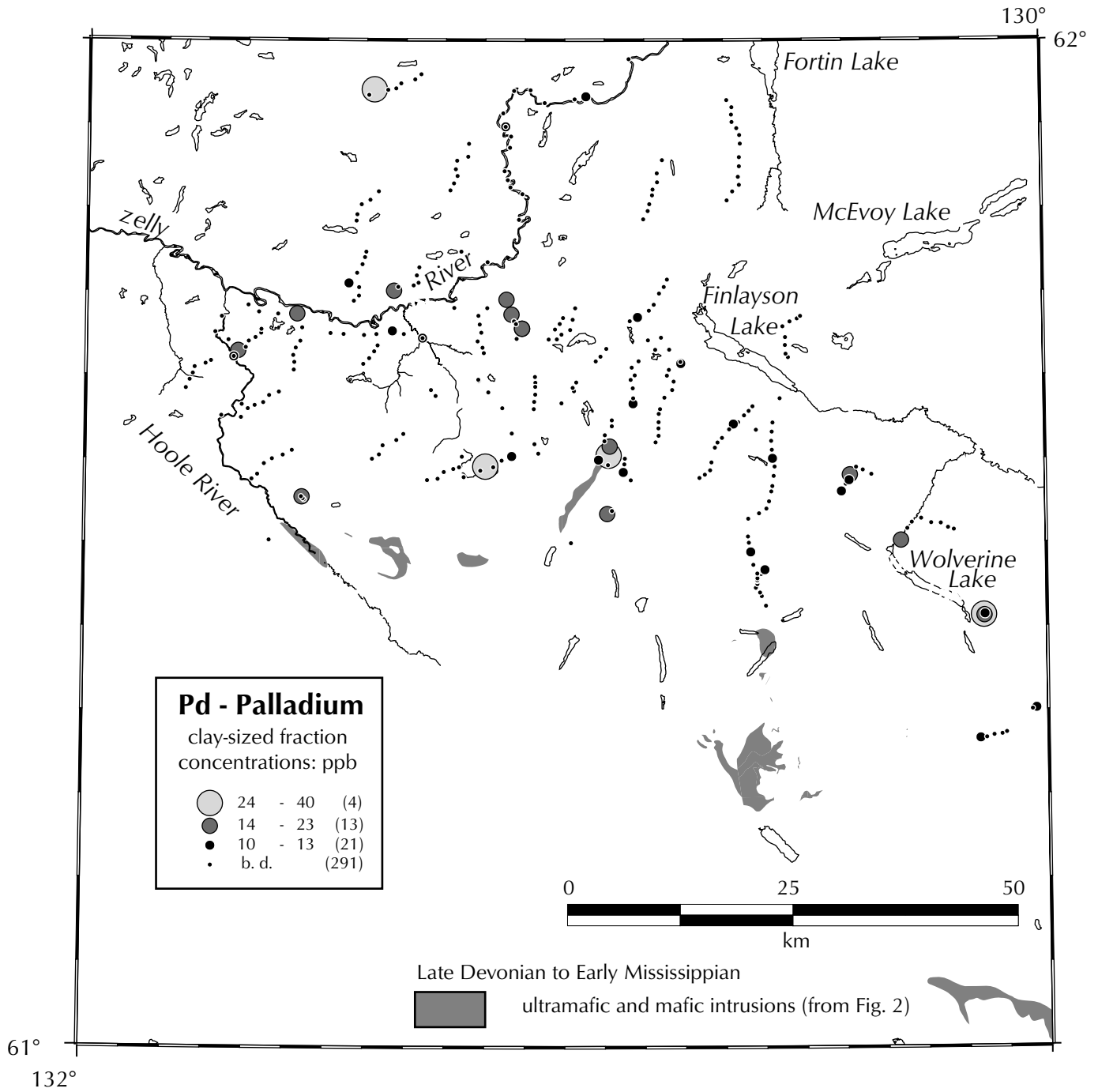


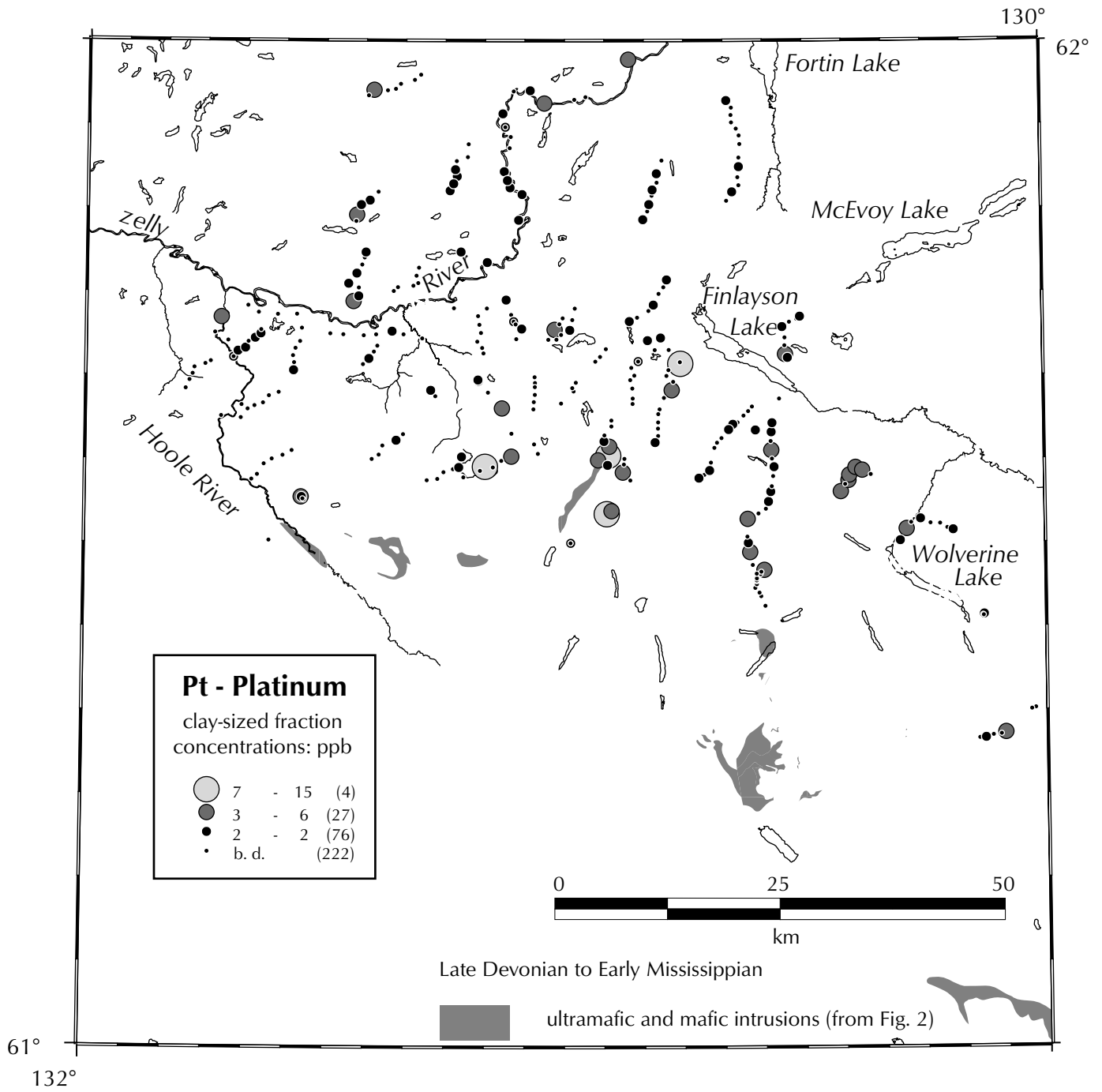


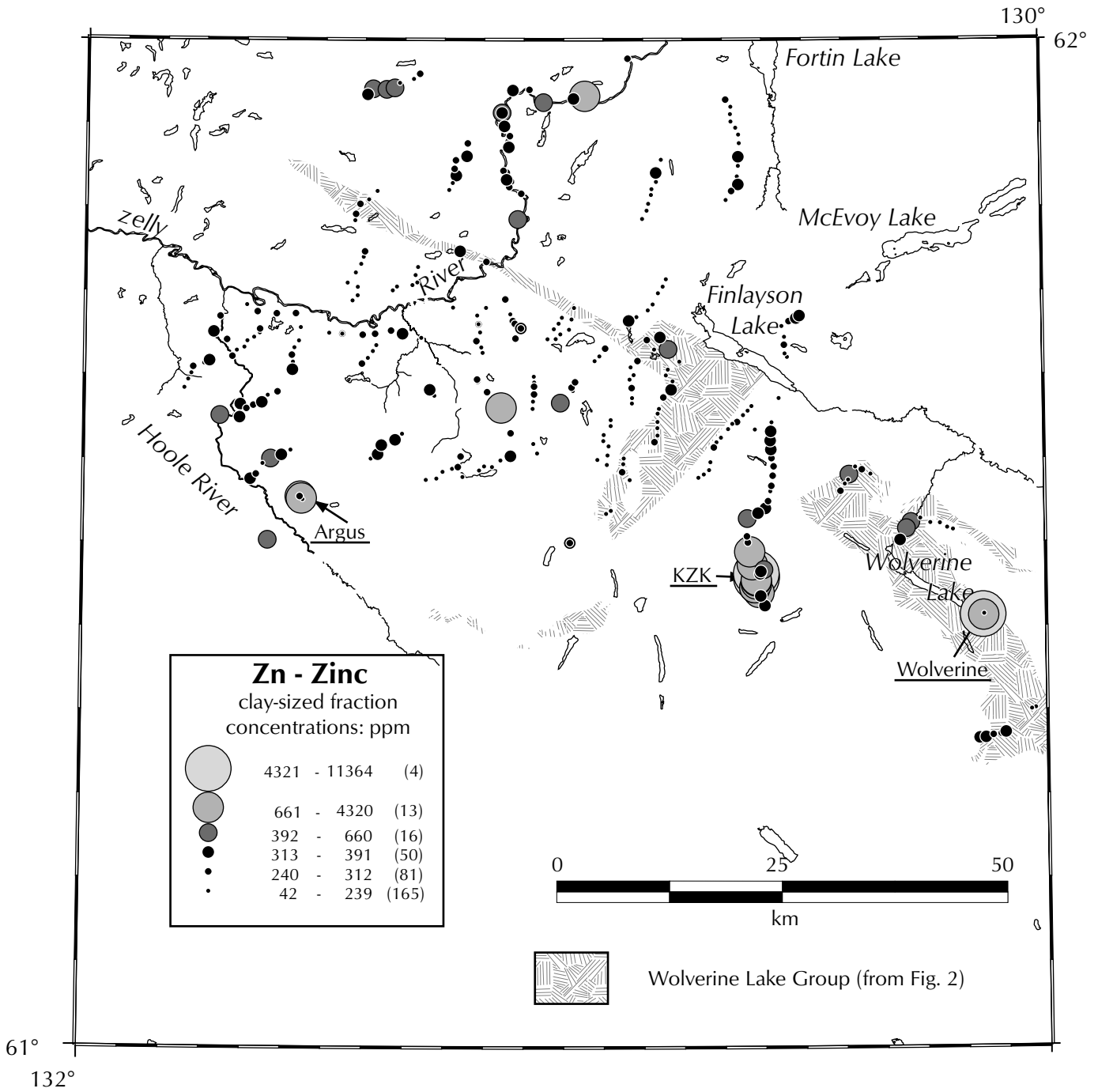












APPENDIX 2

Geochemical maps of the clay-sized fraction geochemistry for gold, copper, lead, zinc, palladium, platinum and beryllium (silt-and-clay-sized fraction), Glenlyon and Carmacks (east) map areas. In the legend, numbers in parentheses define the number of samples within the concentration range; b.d. – below detection limit.

