Geological Survey
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CURRENT RESEARCH
2002-C7

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2002

Natural Resources Canada
Ressources naturelles Canada

Canada

Catalogue No. M44-2002/C7E-IN
ISBN 0-662-31508-1

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An overview of gold grain distribution and geochemistry of till, Yellowknife Greenstone Belt, Northwest Territories

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Kerr, D.E. and Knight, R.D., 2002: An overview of gold grain distribution and geochemistry of till, Yellowknife Greenstone Belt, Northwest Territories; Geological Survey of Canada, Current Research 2002-C7, 8 p.

Abstract: Ongoing surficial geology studies and geochemical analyses of till and vegetation in the Yellowknife Greenstone Belt provide additional baseline data for mineral exploration and environmental studies. Soil profiles incorporating biogeochemical data may differentiate between elements from anthropogenic or natural sources. Newly recorded ice-flow indicators in areas of high mineral potential are consistent with regional southwestward ice movement of the last glaciation. Minor variations indicate property-scale local late-glacial flow from 230° to 255°. Gold-grain counts of the heavy-mineral fraction in till indicate background values over volcanic rocks of approximately 0 to 5 grains/10 kg of till. Significant concentrations of gold grains occur in till over some former mines, suggesting that visible gold-grain counts is a viable exploration method in the Yellowknife area. Anomalous concentrations of 20 to 30 gold grains/sample reflect potential exploration targets. Of particular interest are high gold-grain counts at locations underlain by metasedimentary terrain in the Banting and Walsh lakes areas.

Résumé : Les études de dépôts meubles et les analyses géochimiques du till et de la végétation dans la ceinture volcanique de Yellowknife fournissent des données de base additionnelles pour l'exploration minérale et les études environnementales. Les profils pédologiques incorporant des données biogéochimiques pourraient permettre de distinguer les éléments d'origine naturelle des éléments d'origine anthopique. Les formes d'écoulement glaciaire nouvellement reconnues dans les régions à potentiel minéral élevé sont compatibles avec la direction d'écoulement glaciaire régionale vers le sud-ouest de la dernière glaciation. Des variations mineures attestent de directions d'écoulement de 230° à 255° à l'échelle de la propriété. Le comptage des grains d'or dans la fraction des minéraux lourds du till donne des valeurs de fond d'environ 0 à 5 grains/échantillon de 10 kg dans les zones de roches volcaniques. Des concentrations importantes d'or se rencontrent dans du till au-dessus de certains anciennes mines, ce qui porte à croire que le comptage des grains d'or visibles serait une méthode d'exploration utile dans la région de Yellowknife. Des concentrations anomales de 20 à 30 grains d'or/échantillon reflètent des cibles d'exploration éventuels. Le nombre élevé de grains d'or dans des terrains métasédimentaires de la région des lacs Banting et Walsh présente un intérêt particulier.

INTRODUCTION

The Yellowknife EXTECH III program was initiated in order to enlarge and compile an integrated geoscience database to support exploration, in response to declining ore reserves at producing gold mines and reduced mineral exploration. Preliminary surficial geology studies (Kerr and Wilson, 2000) began in 1999 (NTS 85J/7, 8, 9, 10, 11, 16; 85-I/4, 5, 12, 13; 85-O/1 and 85P/4) to provide baseline data on surficial materials, ice-flow history, and soil geochemistry. In 2000, investigations were undertaken to improve the till geochemistry and biogeochemical databases over the Yellowknife Greenstone Belt (NTS 85J/8, 9, 16; 85-O/1 and 85P/4), as well as to further assess glacial provenance (Kerr et al., 2001). Final follow-up fieldwork in 2001 (NTS 85J/8, 9, 16) focused on collecting till for geochemical studies, gold-grain counts, and soil-profile sampling, to complement the existing till geochemistry database (Kerr, 2001). Contracts were issued for comparative biogeochemical studies in the Yellowknife area by C. Dunn, and biogeochemical research in the Drybones Bay area (Dunn et al., 2001)

METHODS

The area was surveyed using road access and helicopter-assisted traversing to complete the geology database in inaccessible areas, extending into regions underlain by sedimentary rocks with economic potential (Burwash, Jackson Lake, and Banting formations) (Henderson, 1985). This included the area west of Duncan Lake, as well as the area west and southwest of Prosperous Lake. Data from a total of 33 stations were collected in 2001 (Fig. 1, white dots), including 1) thirty-two 10 kg till samples collected to document the range and background concentrations of gold grains over the Yellowknife Greenstone Belt; 2) fourteen 1 kg till samples collected from hand-dug pits or excavated sections at depths of 0.1 to 0.7 m, to complete regional geochemical surveys; and 3) two soil profiles consisting of five leaf litter, six humus, and twenty soil samples, for comparison with sites closer to Yellowknife sampled in 2000.

Vegetation samples were ashed and analyzed using inductively coupled plasma mass spectrometry (ICP-MS) and instrumental neutron activation analysis (INAA). The silt+clay size fraction of till samples was analyzed by inductively coupled plasma-atomic emission spectroscopy (ICP-ES) and the clay fraction, by INAA. The soil-profile studies were undertaken to document postdepositional mobilization of selected elements in proximity to and more distal from the Con and Giant mine sites. Glacial striae were measured at 24 regional locations and rock type was noted, although surface weathering of outcrops prevented the preservation of striae at 8 other locations. An additional ten 20 kg till samples have been submitted for kimberlite indicator-mineral and gold-grain analyses as the final component of a detailed dispersal study in the Drybones Bay kimberlite area, southeast of Yellowknife (Fig. 1). Preliminary results of gold-grain and kimberlite indicator-mineral studies from the 1999 field season are given in Kerr et al. (2000, 2001).

REGIONAL SETTING AND SURFICIAL SEDIMENTS

The Yellowknife Greenstone Belt lies in the southwestern Slave structural province, and is characterized by abundant bedrock outcrops with till and glaciolacustrine sediments in topographic lows between outcrops. Till, a loosely compact,

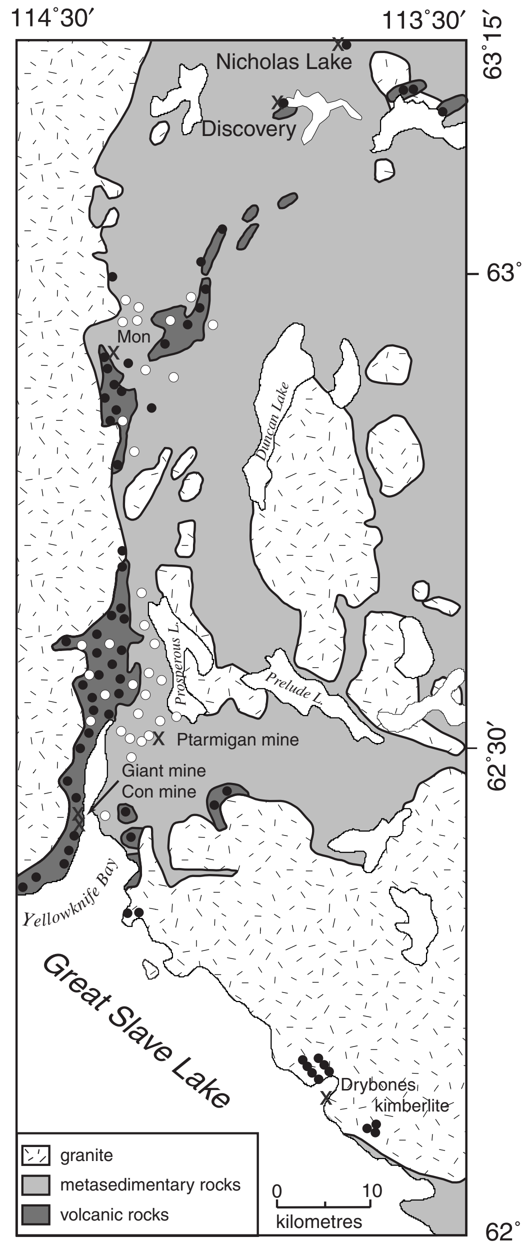

Figure 1. *Location of sample sites (black dots = collected in 2000; white dots = collected in 2001) and generalized bedrock geology with selected mineral deposits; modified from Jolliffe (1942), Henderson (1985), and Stubley (1997).*

stony, sandy diamicton, is the prevalent surficial sediment in the study area. It is generally <2 m thick and forms a discontinuous veneer over bedrock outcrops (Fig. 2a). Some till below 280 m a.s.l. has been reworked by glaciolacustrine and glaciofluvial processes. Glaciolacustrine deposits consist of poorly to moderately sorted coarse to fine sand, silt, and clay (Fig. 2b) estimated to be up to 20 m thick, with varied amounts of pebbles, cobbles, and boulders. These deposits are associated with Glacial Lake McConnell, which inundated the area during deglaciation (Craig, 1965), up to 100 m (275–280 m asl) above the present level of Great Slave Lake. As the lake level fell during deglaciation, the till was reworked and many large boulders (erratics) were exposed (Fig. 2c). Wave action during this period also created many boulder beaches perched on outcrops (Fig. 2d). Glaciofluvial sediments are relatively uncommon and consist of fine sand to cobbles in the form of eskers, kames, and subaqueous outwash. Important subaqueous outwash deposits occur in the Yellowknife airport area. Organic sediments consist of peat formed by the accumulation of fibrous, woody, and mossy vegetative matter. Peat is up to 1 m thick or more in bogs and other wetlands underlain by fine-grained glaciolacustrine sediments.

ICE-FLOW INDICATORS

Figure 3 is a summary ice-flow diagram based on striae measurements obtained from 1999 and 2000 fieldwork and on new data from 2001. A few regional observations made by Jolliffe (1942), Henderson (1985), Kerr (1990), and Boyce (1998) are also included. All glacial indicators are believed to

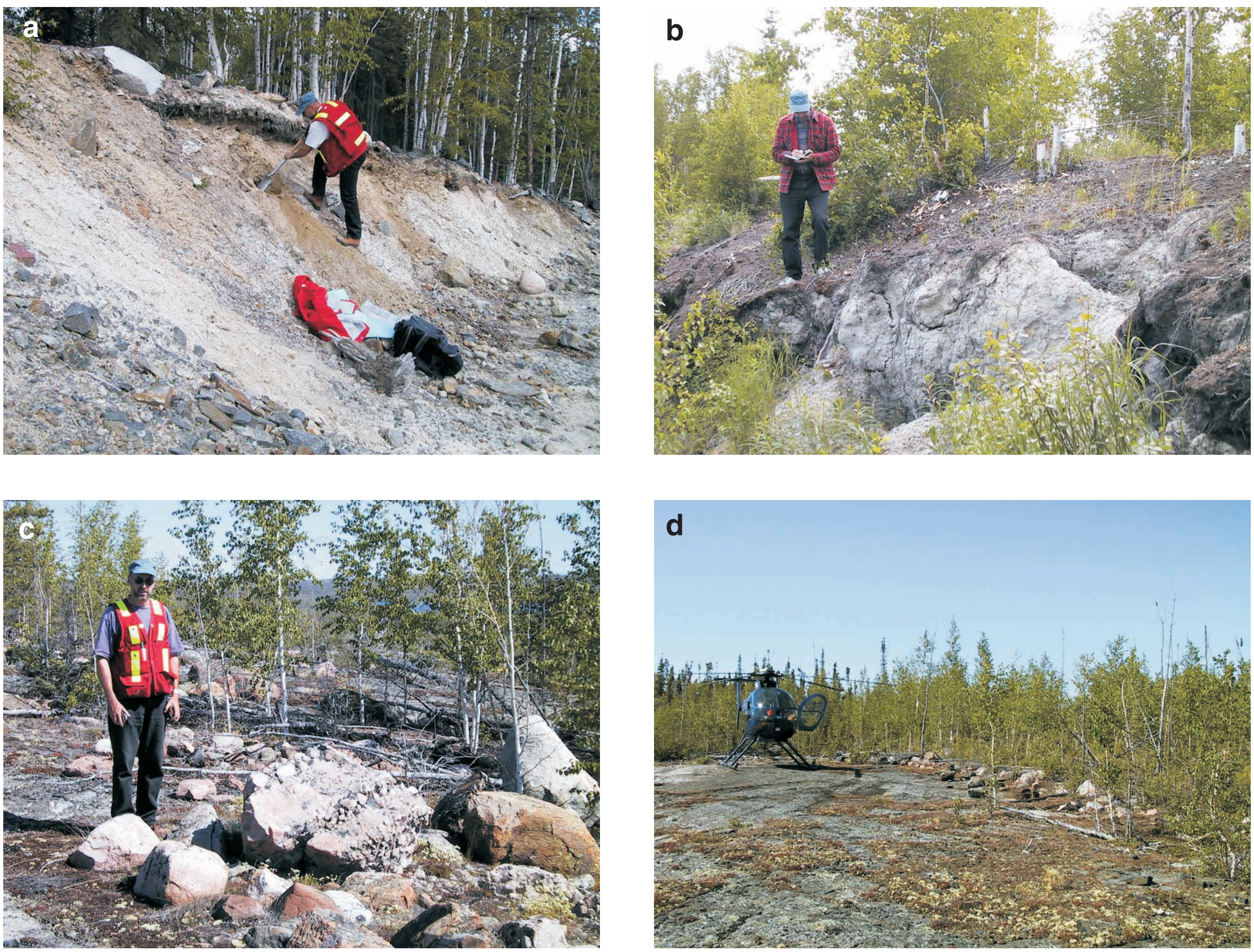

Figure 2. a.*) Sandy reworked till, 2 to 3 m thick, exposed in a trench near Cassidy Point, Prosperous Lake.* ***b****) Three-metre section of glaciolacustrine silt and clay along the banks of a small unnamed lake, near the turnoff to the road to Detah, Ingraham Trail.* ***c****) Boulder lag resulting from washed till with Clan Lake volcanic erratic (in centre), south of Clan Lake.* ***d****) Crescentic boulder beach developed on scoured bedrock at approximately 240 m elevation, south of Clan Lake.*

relate to the Late Wisconsin Glaciation (Dyke and Prest, 1987). As with till sampling, the 2001 mapping of ice-flow indicators throughout the study area focused primarily on sedimentary rocks (Burwash, Jackson Lake, and Banting formations) west of Duncan Lake, as well as west and southwest of Prosperous Lake. Data are generally consistent with the regional dominant southwestward flow, but provide more detailed information about ice movement on a local scale. As is common in the area, minor striae variations of less than 10° occur at most sites, depending in part on where striae are measured on bedrock outcrops. Wherever possible, readings were taken on the tops of outcrops. Larger scale ice-flow indicators such as fluted outcrops (roches moutonées) also typically reflect the dominant flow across the region. The 2001 striae data reflect a generally consistent southwest flow. Stations grouped west of Prosperous Lake exhibit little striae variation (230° to 250°), despite differences in topographic control. Striae recorded west of Duncan Lake also show limited variation in ice flow (230° to 255°). The apparent relatively simple ice-flow history may facilitate drift-prospecting investigations where sufficient and suitable till is present.

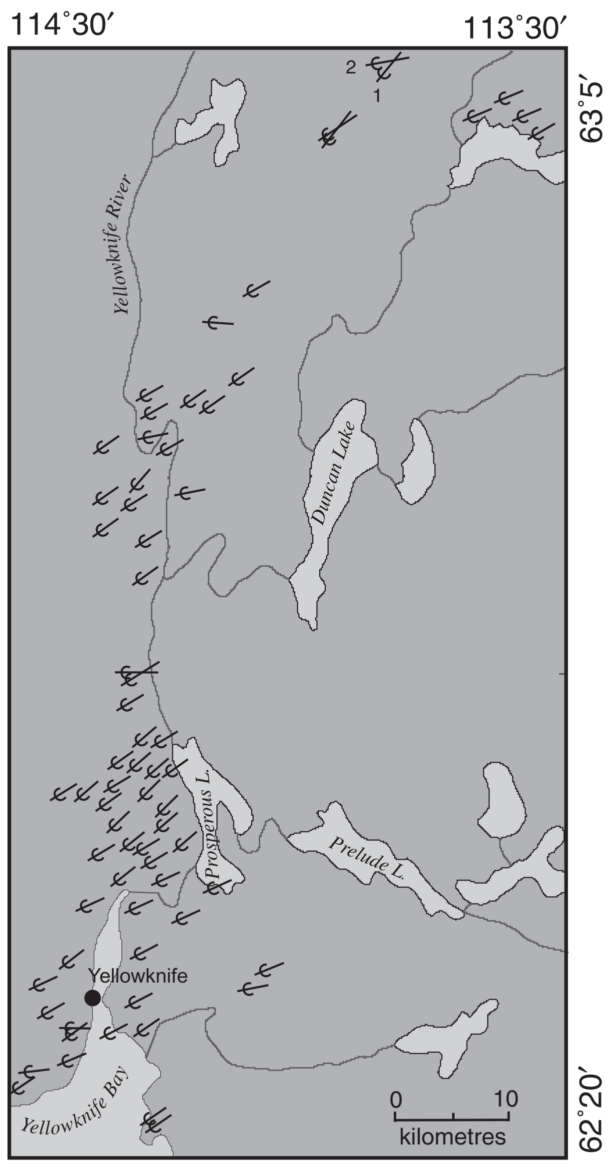

Figure 3. Detailed ice-flow summary diagram based on striae and fluted bedrock observed at sample locations; 1 = oldest, 2 = youngest.

GOLD GRAINS IN TILL

A preliminary analysis of heavy-mineral concentrates (<2 mm fraction) from 11 regional bulk till samples (*see* Kerr et al., 2000) in areas underlain by granite and metasedimentary rocks suggests that the background value for visible gold grains in till is approximately 0 to 1 in 10 kg of till. The 67 till samples collected in 2000, together with the 32 samples from 2001 (Fig. 1), provide a better indication of background gold-grain values in areas underlain predominantly by volcanic rocks and selected metasedimentary rocks near the volcanic belt. Sample sites were selected from a range of settings including areas with no recorded gold showings, down-ice of past-producing mines/deposits, and directly overlying mines and undeveloped properties such as Nicholas Lake. This range of geological settings provides important baseline data for mineral exploration. Sample processing, including preparation of heavy-mineral concentrates for gold-grain counting and optical determination of gold-grain morphology, was undertaken at Overburden Drilling Management Ltd. and is described in Kerr et al. (2000).

Table 1 summarizes some preliminary results for gold-grain studies based on these 99 till samples. Gold-grain abundances are significantly higher in areas underlain by volcanic rocks, where background values in till may reach approximately 0 to 5 grains/10 kg of till. Sites with more than 5 to 10 grains should be considered potentially anomalous, and those with >20 to 30 warrant further investigation. Sites with anomalous gold-grain counts that are underlain by the Jackson Lake Formation should be considered highly significant and a viable exploration target (J. Kerswill, pers. comm., 2001), as should the Banting Lake and Burwash formations, the latter being well known for its turbidite-hosted vein deposits (H. Falck, pers. comm., 2001).

Although reshaped gold grains, which generally reflect some degree of glacial transport, are most common, grains with a pristine morphology, generally associated with little or no glacial transport, are also found in significant numbers. Till samples collected near the Con, Giant, and Discovery mines are highly anomalous with respect to both total number of gold grains and number of pristine grains. Other till samples, however, such as those near Nicholas Lake and Mon Mine show no clear relationship to underlying mineralization. In such cases, more detailed studies of ice flow and the origin and composition of the local till are required. Ongoing studies are also addressing the relationship between gold-grain dimensions in till and visible gold occurring as inclusions within sulphides/sulphosalts vs quartz-rich veins (J. Kerswill, pers. comm., 2001).

Table 1. Gold-grain data in till samples, Yellowknife Greenstone Belt.

	Total number of gold grains / ~6 kg of <2 mm till fraction (n = 1446)							
	0	1 to 5	6 to 10	11 to 30	31 to 50	51 to 100	101 to 150	>150
Number of till samples (n = 99)	15	44	11	19	4	2	3	1

	Gold grain morphology (DiLabio, 1990)		
	Reshaped	Modified	Pristine
Number of gold grains (n = 1446)	624	265	557

		Number of gold grains by morphology (in one till sample at each location)			
		Reshaped	Modified	Pristine	Total
Mine/deposit	*Bedrock*				
Con	volcanic	34	53	54	141
Giant	volcanic	28	15	61	104
Discovery	volcanic	8	29	54	91
Cassidy Point	metasedimentary	12	1	4	17
Ptarmigan	metasedimentary	16	0	0	16
Crestaurum	volcanic	9	4	1	14
Nicholas Lake	metasedimentary	5	1	0	6
Mon	volcanic	2	0	1	3
Other showings/areas					
Jackson Lake	metasedimentary	13	13	201	227
Banting Lake-A	volcanic	54	30	43	127
Banting Lake-B	volcanic	17	7	7	31
Prosperous Lake	metasedimentary	26	2	3	31
Preg Lake	volcanic	13	5	9	27
Joe Lake	volcanic	3	6	17	26
Vee Lake	volcanic	15	3	4	22
Hook Lake	volcanic	0	6	14	20
Yellowknife Bay	metasedimentary	10	3	5	18
Clan Lake	metasedimentary	13	2	1	16

SOIL-PROFILE STUDIES

The soil profiles developed in till (cryosols) were studied for exploration and environmental purposes to document geochemical trends with depth of selected elements in three locations in proximity to and more distal from the Con and Giant mine sites. Preliminary results from two sites near the Con and Giant mines are presented in Figures 4a and 4b respectively. Data in each profile record geochemical values for black spruce bark and Labrador tea twigs growing within 1 to 2 m of each site (as indicated in the uppermost part of the profile in Figures 4a and 4b), and leaf litter (at 0 cm depth) overlying humus, which has been subdivided into two samples, upper humus (0–2.5 cm depth) and lower humus (2.5–5 cm) layers. Samples in the mineral soil record progressively deeper till samples in the profile, sampled at 5 cm intervals. Each element has its own geochemical profile except where some organic sample values are anomalously high (Au, Sb, Zn). In these cases, a second plot with a modified scale is included for mineral soil samples in order to show geochemical variation with depth. A list of elements and their corresponding method of analysis is presented in the legend.

An initial review of the data indicates high values for Au and As in the Labrador tea, spruce bark, leaf litter, and humus at both locations. Nickerson (1999) reported Au values up to approximately 6000 ppb and As values up to 2000 ppm in black spruce and Labrador tea near the Giant mine. The current study has also identified elevated concentrations of Au (>1300 ppb) and As (1000 ppm) in vegetation samples near the Giant mine. The highest reported values, however, were from the Con mine area where Labrador tea produced almost 12 000 ppb Au and humus, 3000 ppm As. Leaf litter produced 7300 ppb Au, spruce bark, 5880 ppb Au, and humus, up to 4220 ppb Au. The dramatic decrease in Au (<30 ppb) and As (<50–100 ppm) values in the mineral soil (underlying till) and the general decreasing concentrations with depth suggest an important airborne contamination, possibly from the roasting stacks at both mine locations. Similar signatures in profiles occur to varying degrees for other elements such as Zn and Sb. Other elements such as Co, Cr, Cu, and Ni show either little change or minor enrichment in the organic matter, followed by a slight depletion in the uppermost till, and a slight increase in concentration with depth toward mineralized bedrock. Background values of some elements in the Yellowknife area may be obtained by looking at organic and mineral

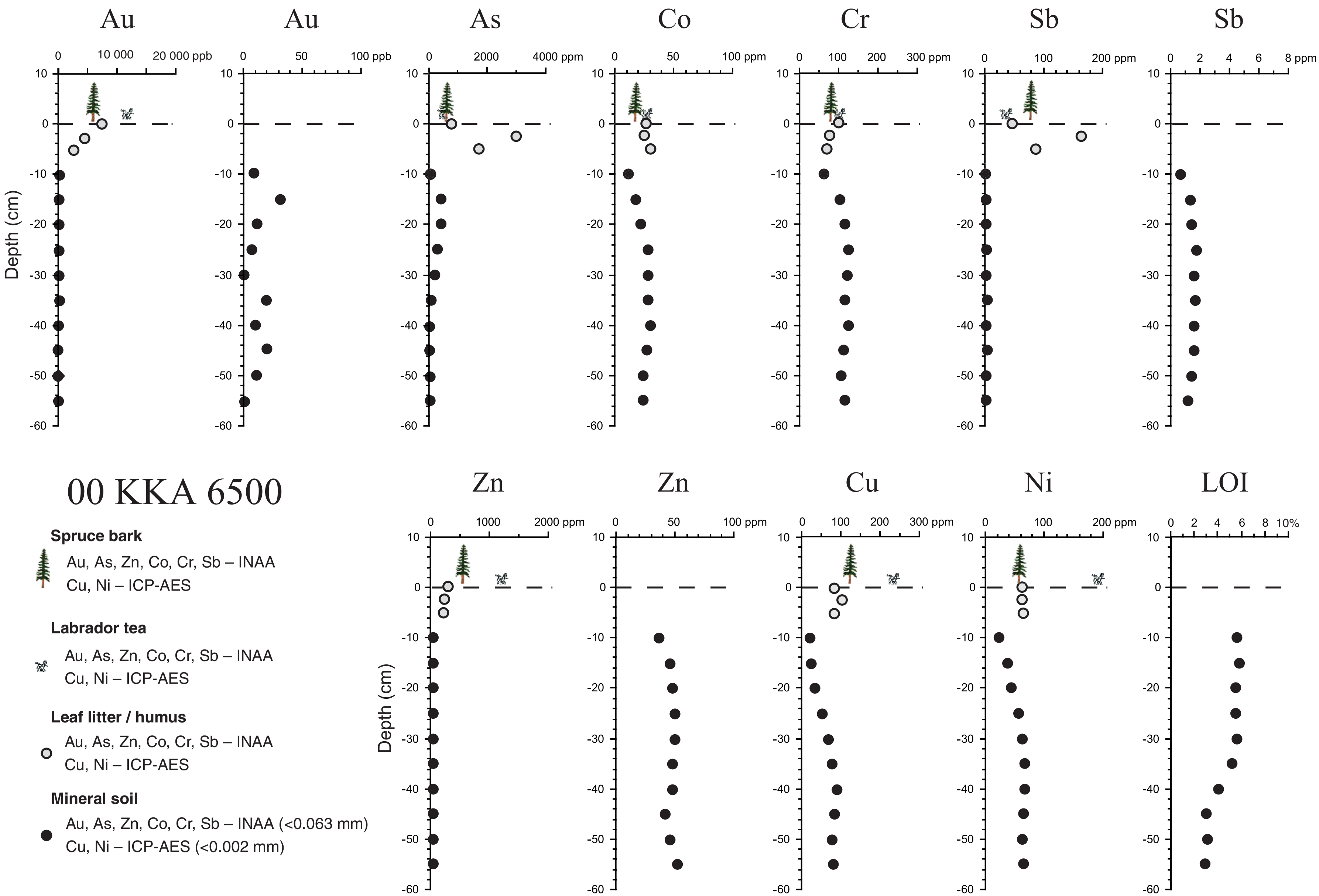

Figure 4. a) Soil profiles for selected elements at site 00 KKA 6500, in the centre of the Con mine complex.

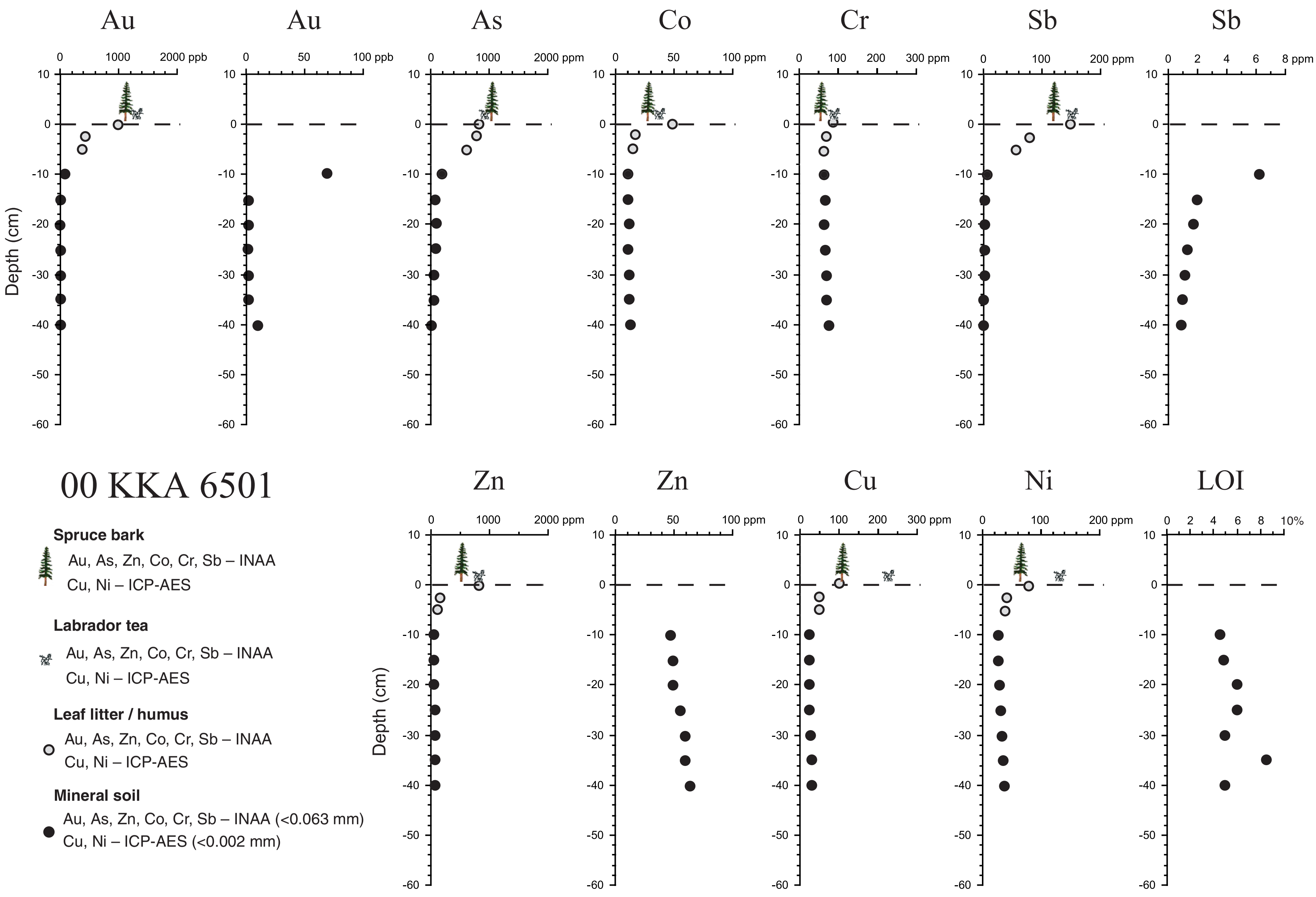

Figure 4. ***b****) Soil profiles for selected elements at site 00 KKA 6501, approximately 750 m north of the Giant mine roasters.*

soils at various distances from the Giant and Con mines. A comparison with leaf litter, humus, and mineral soil data observed in till profiles near the Horne Cu smelter, Rouyn-Noranda, shows some similarities with Co, Cr, Zn, Cu, and Ni (P.J. Henderson, R.D. Knight, and I. McMartin, pers. comm., 2001).

ACKNOWLEDGMENTS

The authors would like to thank Indian and Northern Affairs Canada and the C.S. Lord Centre for logistical support, as well as H. Falck and J. Kerswill for providing prospective sampling locations. The authors would also like to thank P. Henderson and C.D. Anglin for critical review.

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