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Enzyme leach[sm] geochemical profile over the Bil Group (Gods River) lithium pegmatite, Gods Lake area, east-central Manitoba (NTS 53L/16)

By
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Oxidized glaciolacustrine clay; note roots in oxidized b-horizon.

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Winnipeg, 2001

TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

CD-ROM

Accompanying CD-ROM has PDF and Word and Excel files for Appendix 1 and 2.

ABSTRACT

An enzyme leach^{sm} orientation program was carried out over the buried Bil Group lithium pegmatite in the Gods Lake area of east-central Manitoba. Sampling was conducted at 15 m spacings along a single transect 220 m in length and utilized both A- and B-horizon soils. A multi-element, moderate- to high-contrast geochemical anomaly was identified over 125 m of the sampling line. This anomaly was centred on the vertical surface projection of the dyke and has the form of an asymmetrical, doubly peaked response. The elements diagnostic of the dyke are Li, Ti, Cs, Ba, Zr, Nb, Hf, W, Rb, Pb, Ga and Ni. The presence of W, Cs, Ba and Nb suggest that a rare-element resource may be present in the pegmatite. The enzyme leach^{sm} selective-extraction technique is a useful method of 'seeing through' overburden of variable composition in the search for lithium and rare-element pegmatites.

INTRODUCTION

The Bil Group lithium pegmatite is situated in NTS area 53L/16 in the Gods Lake Domain of the northern Superior Province of east-central Manitoba (Fig. 1). A small outcrop of the pegmatite occurs approximately 100 m inland from the northeast shore of Johnson Bay, Gods Lake, approximately 6 km west-northwest of the town of Gods River.

A single transect of soil samples, utilizing available soil types, was collected over the vertical surface projection of the pegmatite dyke. These samples were intended to serve as an orientation survey for the enzyme leach^{sm} extraction technique over a rare-element pegmatite. A favourable survey response would indicate the potential for using this geochemical approach in a more extensive survey that could fully define the surficial geochemical signature of this dyke and hopefully provide a technique applicable to pegmatite exploration. This survey was undertaken as part of the assessment of selective- and partial-extraction techniques applied to a variety of mineral deposit types (Fedikow and Ziehlke, 1998; Fedikow, 1999a, b) and as an adjunct to ongoing multimedia geochemical surveys (Fedikow et al., 1998, 1999).

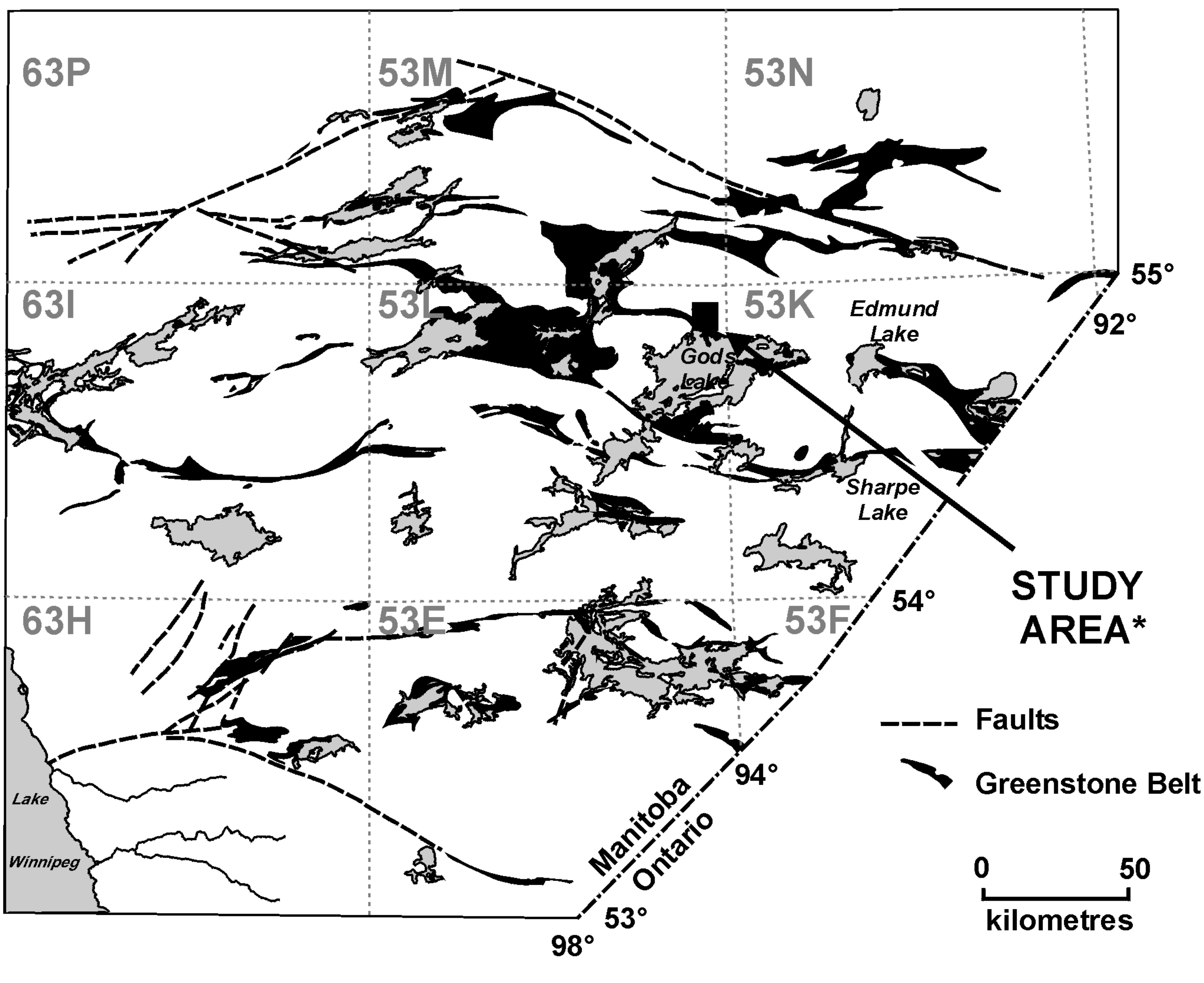

Figure 1: Location map for the Bil Group lithium pegmatite enzyme leach^{sm} orientation survey.

ENZYME LEACH^{sm}

Enzyme leach^{sm} is a phase-specific leach that preferentially attacks and liberates trace metals from amorphous manganese dioxide coatings on mineral grains. Amorphous manganese dioxide is an efficient chemical sieve or trap for cations, anions and polar molecules because of its large surface area and the random distribution of positive and negative charges on this surface. Mineral grains within the B-horizon soil tend to be coated with a film of amorphous manganese dioxide and, as such, represent the target for dissolution with the enzyme leach^{sm}.

Metals that are trapped/sieved or complexed with the amorphous manganese dioxide are interpreted to represent the chemical signatures of oxidizing bedrock-hosted mineralization at depth. Metal-enriched volatiles (Hg-vapour, halides, halogens) move upward through fracture systems or induced zones of permeability in bedrock and overburden under the influence of electrochemical cells, groundwater flow, capillary flow, evapotranspiration pumping, or, as in the case of Hg-vapour, the partial pressure of the gaseous compounds generated by oxidation. Buried mineralized boulders resident in a dispersion train may also contribute trace metals to the B-horizon.

Of some concern is the potential for the subtle additions of the oxidized minerals to the B-horizon to be concealed or swamped by the downward movement of metal-enriched compounds from the A-horizon soil. These compounds are derived from the weathering of till and/or organometallic humate or fulvate compounds. Despite these concerns, the anomalies delineated by the enzyme leach^{sm} generally occur directly over the mineralized target in the form of high-contrast 'oxidation' or low-contrast 'apical' anomalies, each with their own unique element associations. The high-contrast oxidation anomalies, which are developed for elements such as Cl, Br, I, As, Sb, Mo, W, Re, Se, Te, V, U and Th, typically form doubly peaked or 'rabbit-ear' anomalies with low concentrations of metals directly over the deposit and peak concentrations on either side of the mineralization. The low-contrast apical anomalies result from the diffusion of commodity elements along an electrochemical gradient or by vapour phase transport moving from an area of high concentration to one of lower concentration, and are characterized by a series of high concentrations directly over the target zone. In this type of anomaly, the metals present are representative of the mineralized source. Variability in the morphology of the anomalies can be attributed to depth of burial of the source. Combination anomalies, representing combined apical and oxidation anomalies, can also be present.

The leachate from the B-horizon soil is analyzed by inductively coupled plasma mass spectrometry (ICP-MS) for multiple elements at detection limits in the parts per billion (ppb) and sub-ppb range. The enzyme leach^{sm} will not detect elemental Au or Hg in the B-horizon. Details of the enzyme leach^{sm} are provided in Clark et al. (1993).

GEOLOGICAL SETTING OF THE BIL GROUP (GODS RIVER) PEGMATITE

The Bil Group pegmatite is a spodumene-rich dyke (Chackowsky, 1987) that is classified as an albite-spodumene pegmatite by Cerny (1987). The dyke contains 20 to 25% spodumene, is 3 to 10 m thick, and extends for greater than 2 km along strike to a depth of at least 250 m (Southard, 1977). Based on available diamond-drilling results, the deposit is estimated to contain "4.8 million tons grading 1.27% Li_2O" (B. Dunlop, pers.comm., 2001).

The north-dipping dyke intrudes strongly foliated and sheared metabasalts and is discordant to the southeast-trending, 60° northeast dip of the schistosity in the metabasalts. Most of the pegmatite dyke is covered by glacial sediment and organic deposits. Previous exploration on the dyke by Inco Limited indicated a range in Li_2O content of 1.08% over 5.2 feet (1.58 m) to 1.79% over 38.6 feet (11.76 m) (Assessment File 92618, Manitoba Industry, Trade and Mines, Winnipeg; Fig. 2). The dyke is open at depth. Exploration undertaken by Inco Limited also indicated a dyke-parallel fault that separates the main pegmatite dyke on the north from a thinner pegmatite dyke to the south (Fig. 3).

Available chemical data for individual mineral phases in the pegmatite are presented in Table 1 and the ranges in concentration for 15 elements in four representative whole-rock analyses are given in Table 2.

MINERALOGY, INTERNAL STRUCTURE AND MINERAL CHEMISTRY

The Bil Group pegmatite has a relatively simple mineralogy comprising spodumene, quartz, white muscovite and subordinate potassium feldspar and plagioclase. Accessory deep purple muscovite occurs in late, crosscutting veins.

Mineralogically and texturally, the pegmatite is described as homogeneous. Bladed spodumene crystals (2-10 mm long) are aligned at 150 to 160°, which approximates the schistosity of the host metabasalts. The aligned spodumene and interstitial white muscovite impart a pervasive 'foliation' to the dyke. Potassium feldspar crystals, up to 1 m in length, are also parallel to the 'foliation' of the pegmatite. This 'foliation' is occasionally offset by narrow mylonite zones.

SAMPLE COLLECTION, PREPARATION AND ANALYSIS

Soil samples were collected from hand-dug pits at 15 m intervals along a single 220 m long transect oriented at 225° (Fig. 2). Humus samples were collected at six sites. The humus at 25 and 40 m was frozen and inorganic material was not obtainable. Duplicate sample pairs were collected at 25 m and 160 m on the transect and, for comparative purposes, both A- and B-horizon samples were collected at 220 m on the transect. All samples were stored in large Ziploc® bags, air dried on

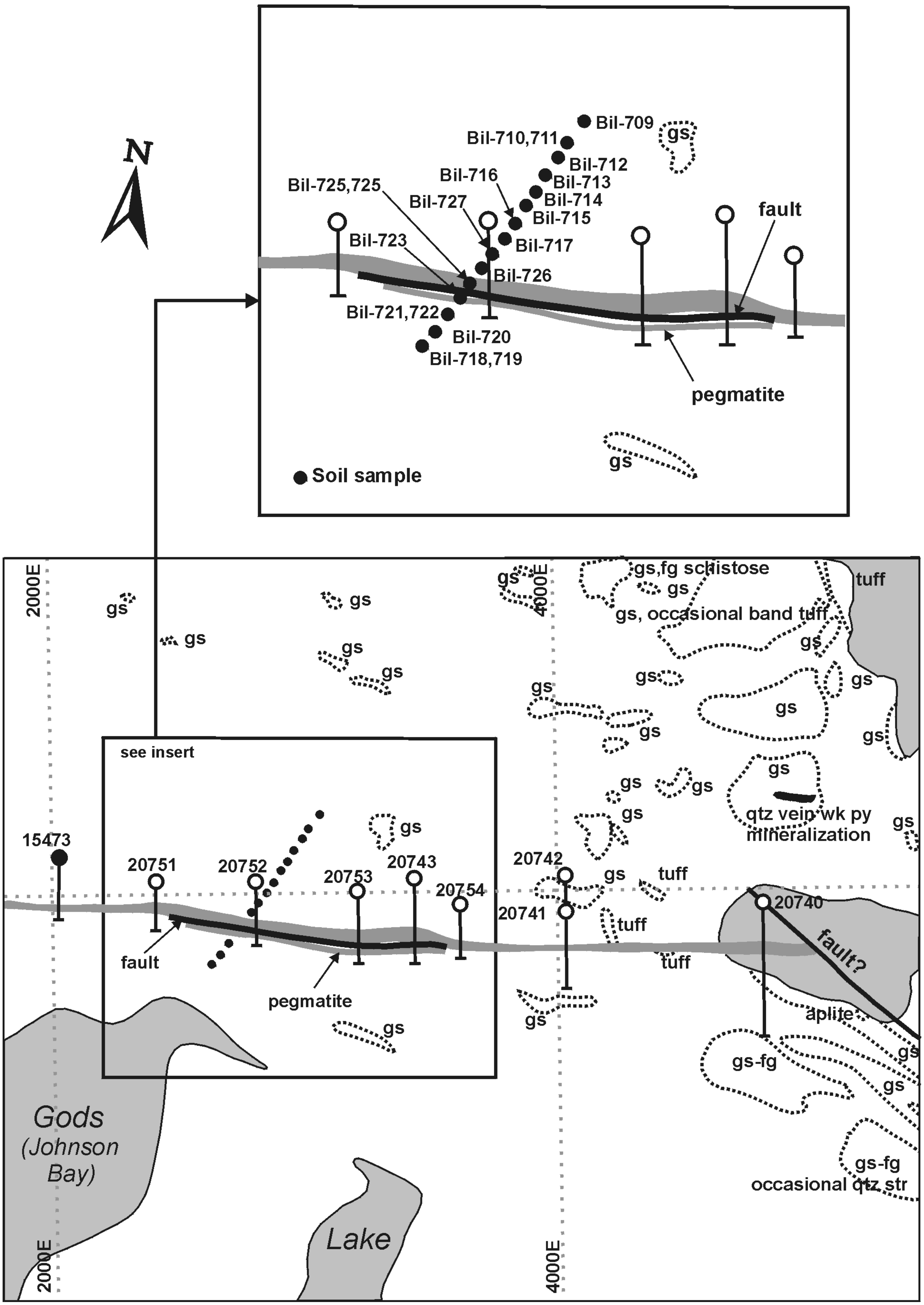

*Figure 2: Geological setting of the Bil Group lithium pegmatite (*after *Assessment File 92618, Manitoba Industry, Trade and Mines, Winnipeg) and the location of the soil sampling transect.*

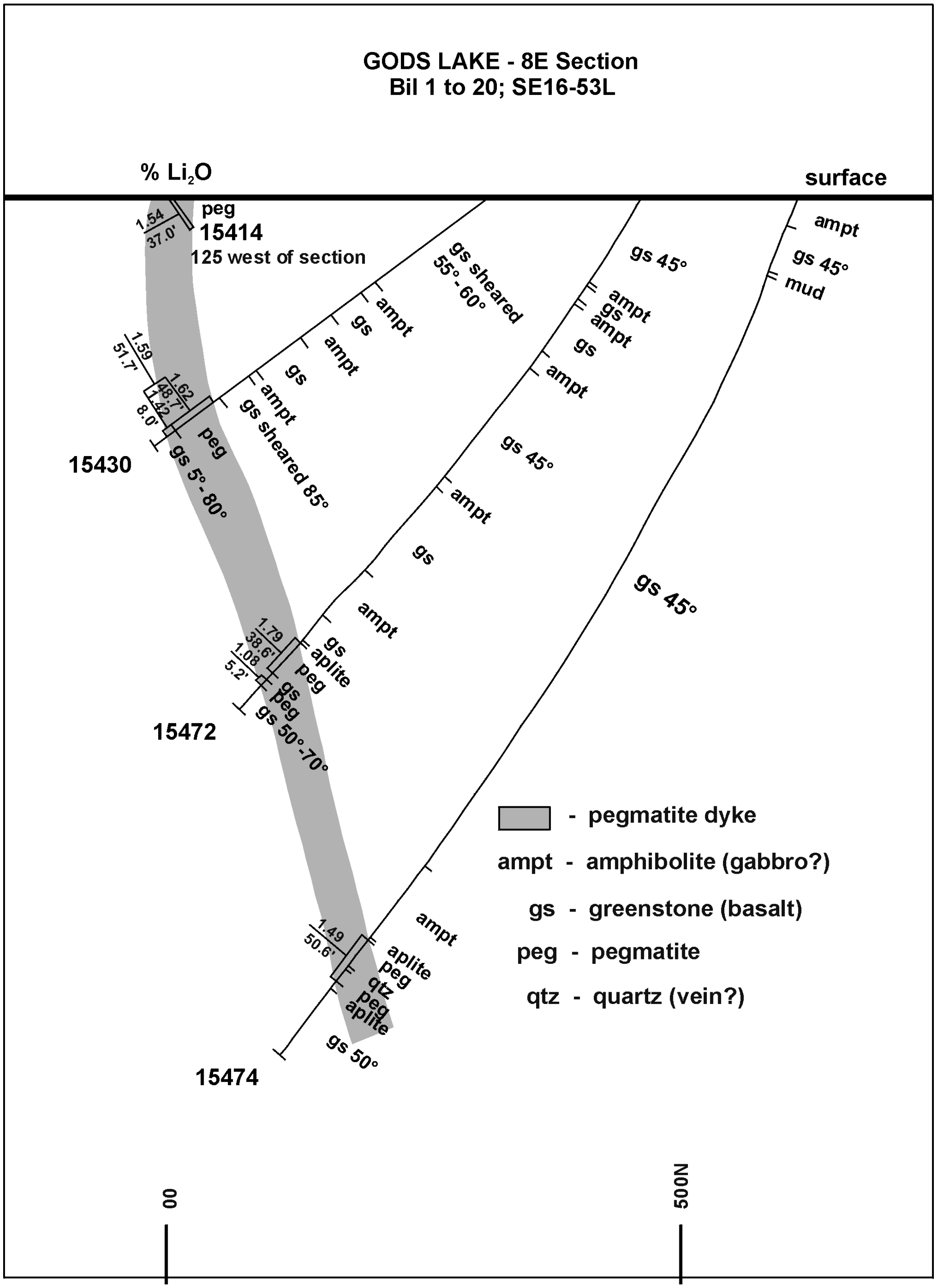

Figure 3: Diamond-drill intersections with assays, Bil Group lithium pegmatite.

*Table 1: Summary of the concentrations of selected elements from potassium feldspar, muscovite and spodumene in the Bil Group lithium pegmatite (*from *Chackowsky, 1987). All data in ppm unless otherwise stated.*

Element	Potassium Feldspar	Muscovite	Spodumene
Li_2O	32-155		1.08-1.79 wt%
Rb	11800-18700	15600	
Cs	522-1350	4980	
Sr	106-151		
Ba	11-31		
Pb	84-160		
Be		290	
MnO (wt%)		0.6	
K_2O (wt%)	5.07-6.80		

disposable plates and sieved to obtain the –60 mesh size fraction. Drying and sieving were done in the laboratories of the Manitoba Geological Survey in Winnipeg. Samples were shipped to Activation Laboratories Ltd. in Ancaster, Ontario, for analysis using enzyme leach^{SM} technology. Sample descriptions are given in Appendix 1 (*see* accompanying CD-ROM). Analytical data are presented in Appendix 2 (*see* accompanying CD-ROM).

Table 2: Whole-rock trace-element concentrations in the Bil Group lithium pegmatite (after Assessment File 92618, Manitoba Industry, Trade and Mines, Winnipeg).

Element	Range (ppm)
Rb	2843-5131
Cs	250-793
Be	61-127
Sr	29-51
Ba	457-725
Ga	177-240
Zn	227-332
U	<2-4
Th	1-2
Zr	<10
Hf	<1
Sn	11-20
Nb	31-53
Ta	42-78
Y	94-140
Li_20	1.08-1.79 wt%

Duplicate Sample Pairs

The duplicate pairs collected at sites 25 m and 160 m have good reproducibility for the majority of elements determined by ICP-MS (Appendix 2; *see* accompanying CD-ROM). Vanadium reproducibility at site 25 m is suspect, with values of 241 and 520 ppm. It is possible some organic material may have been inadvertently included with one of the duplicate samples. The organic samples on the transect contain more V than the inorganic samples. Manganese concentrations in samples from both sites are erratic (852 and 1460 ppm at site 25 m; 294 and 452 ppm at site 160 m). The reproducibility of critical elements enriched in the deposit (Table 2), and likely to be important in defining geochemical anomalies associated with the dyke, is acceptable.

Organic and Inorganic Samples – Site 220 m

The variability introduced into the data by samples of different character was briefly assessed in this survey. A black, fine-grained, well-decomposed humus sample (718A) and a dark brown, oxidized, silty clay sample (719B) were collected from 220 m on the sampling transect. The organic sample contained higher V, Sr, Mo and I, whereas the silty clay sample contained elevated concentrations of almost all other elements (Appendix 2; *see* accompanying CD-ROM). This observation indicates that, for selected elements, samples of different character may have to be interpreted as a separate geochemical/sample population. In this study, plotting enzyme leach^{sm} data from organic and inorganic samples together does not appear to affect the overall geochemical signature of the lithium pegmatite.

RESULTS

A multi-element enzyme leach^{sm} geochemical signature is particularly well developed over the Bil Group pegmatite. The general character of each response is described below.

Semiquantitative ('SQ') Li (Figure 4)

A doubly peaked, asymmetric response for Li is defined along the transect with maximum responses at 115 m (65 ppb) and 190 m (187 ppb). These two peaks are separated by a two-sample low at 130 m and 145 m. The major response of 187 ppb is adjacent to the vertical surface projection of the dyke. Samples collected directly over the dyke have a range in concentration from 30 to 78 ppb.

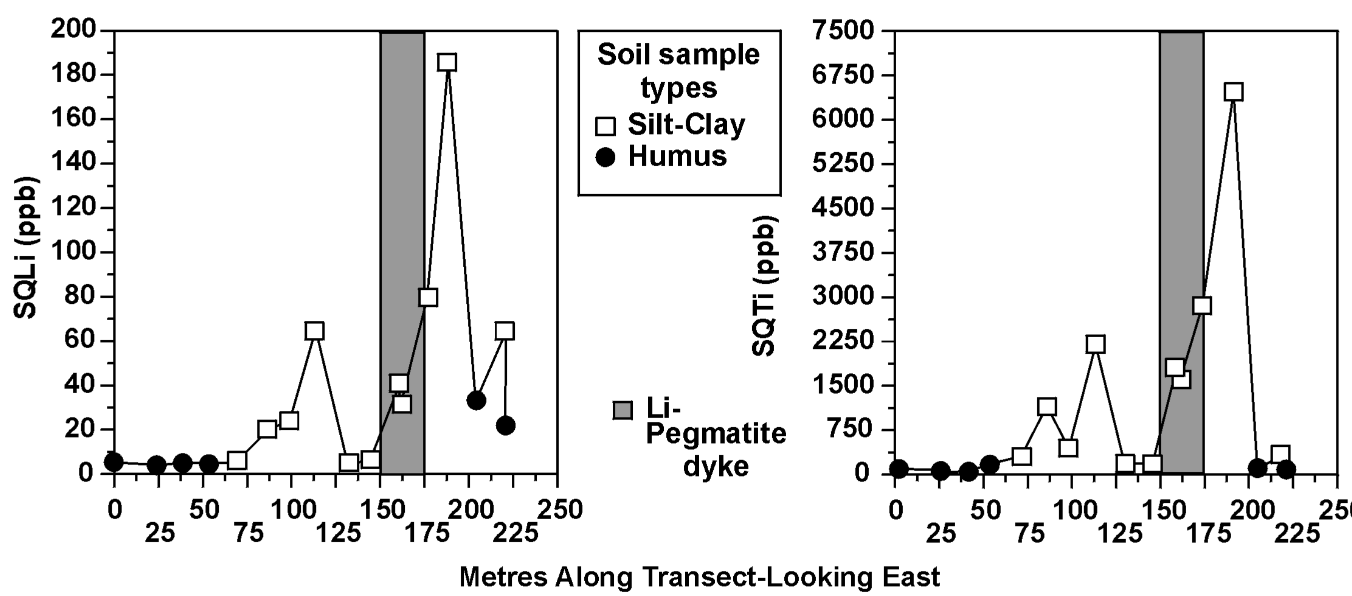

Figure 4: Semi-quantitative ('SQ') Li and Ti enzyme leach^{sm} profiles over the Bil Group lithium pegmatite. Samples collected along a transect oriented 225°.

SQTi (Figure 4)

The results for Ti are coincident with those for Li with peaks of 2239 ppb at 115 m and 6552 ppb at 190 m. These peaks are separated by a two-sample low at 130 m and 145 m. Samples collected over the dyke contain 1662 to 2851 ppb.

Cs (Figure 5)

A low-contrast Cs response occurs at 115 m (3 ppb) and again at 190 m (10 ppb). The form of this response is identical to the Li and Ti anomalies. Soils sampled over the dyke contain 3 to 5 ppb Cs.

Ba (Figure 5)

Ba responses are characterized by a well-defined, four-sample response of 350 to 1154 ppb directly over the dyke and a somewhat less diagnostic response of 305 to 423 ppb between 70 and 115 m on the transect.

Zr (Figure 6)

An asymmetric, doubly peaked Zr response is documented over the dyke. A lower contrast response of 51 to 104 ppb occurs between 70 and 115 m with a two-sample higher contrast response of 233 and 253 ppb at 175 m and190 m.

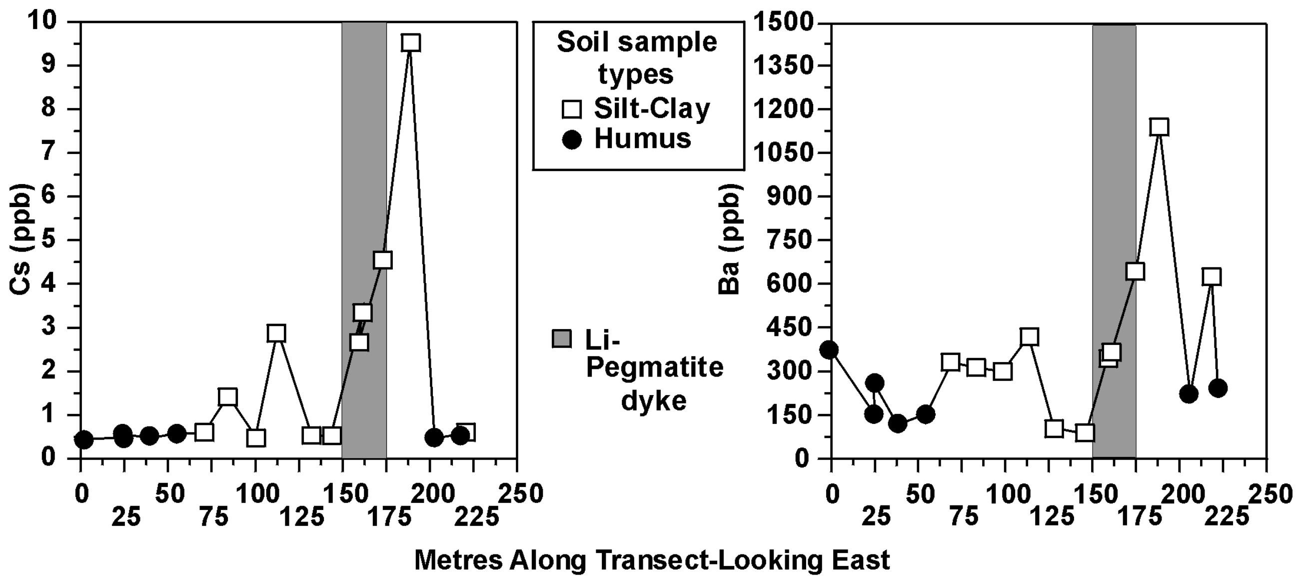

Figure 5: Profiles of enzyme leach^sm Cs and Ba over the Bil Group lithium pegmatite. Samples collected along a transect oriented 225°.

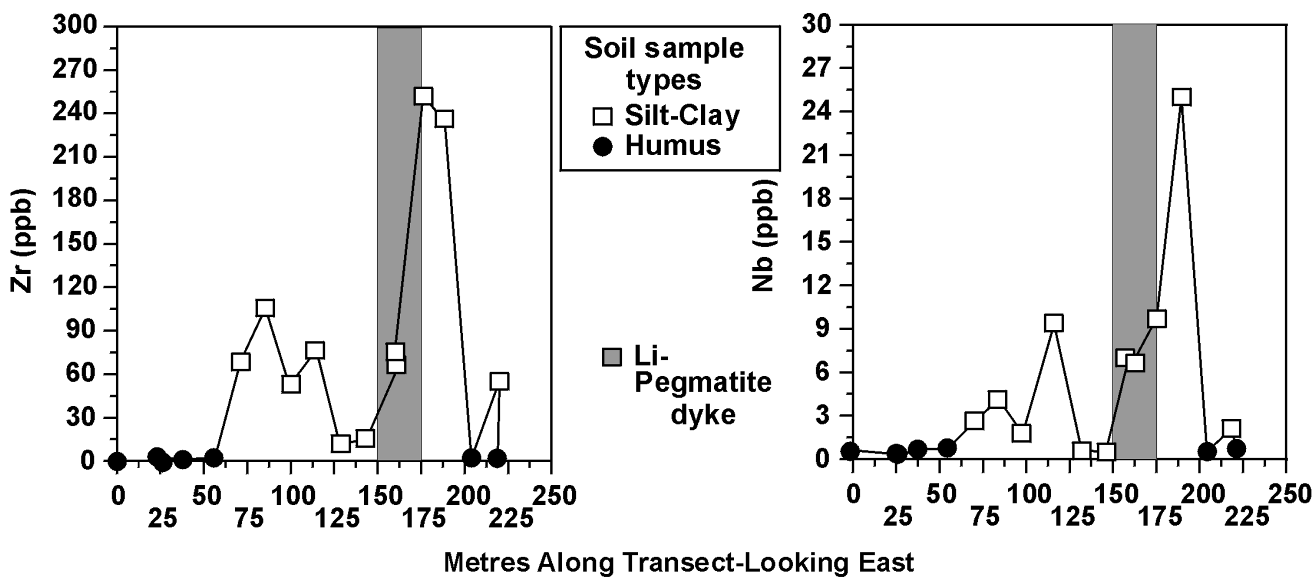

Figure 6: Profiles of enzyme leach^sm Zr and Nb over the Bil Group lithium pegmatite. Samples collected along a transect oriented 225°.

Nb (Figure 6)

The Nb response is very similar to those identified for each of the previously discussed elements. Nb forms a moderate- to low-contrast response of 9 ppb at 115 m and a range from 7 to 25 ppb between 160 and 190 m.

Hf (Figure 7)

A low-contrast, weakly developed response is documented between 60 and 190 m on the transect. This signature consists of a single-sample response (2 ppb) at 85 m and a two-sample response of 2 and 5 ppb at 175 m and 190 m. The highest Hf response on the transect is located 15 m south of the vertical surface projection of the dyke.

W (Figure 7)

The W responses along the sampling transect are at or near the lower limits of determination (LLD) except at 115 m (1 ppb) and close to the dyke at 160 to 190 m (1-3 ppb). Despite the low-contrast, the responses appear to be diagnostic of the dyke and these responses are coincident with many other anomalous enzyme leach^{sm} responses on the transect.

Ga (Figure 8)

A single-sample response of 11 ppb occurs at 115 m on the transect. With proximity to the surface projection of the dyke there is a four-sample response of 8 to 37 ppb with the highest response occurring 15 m south of the dyke.

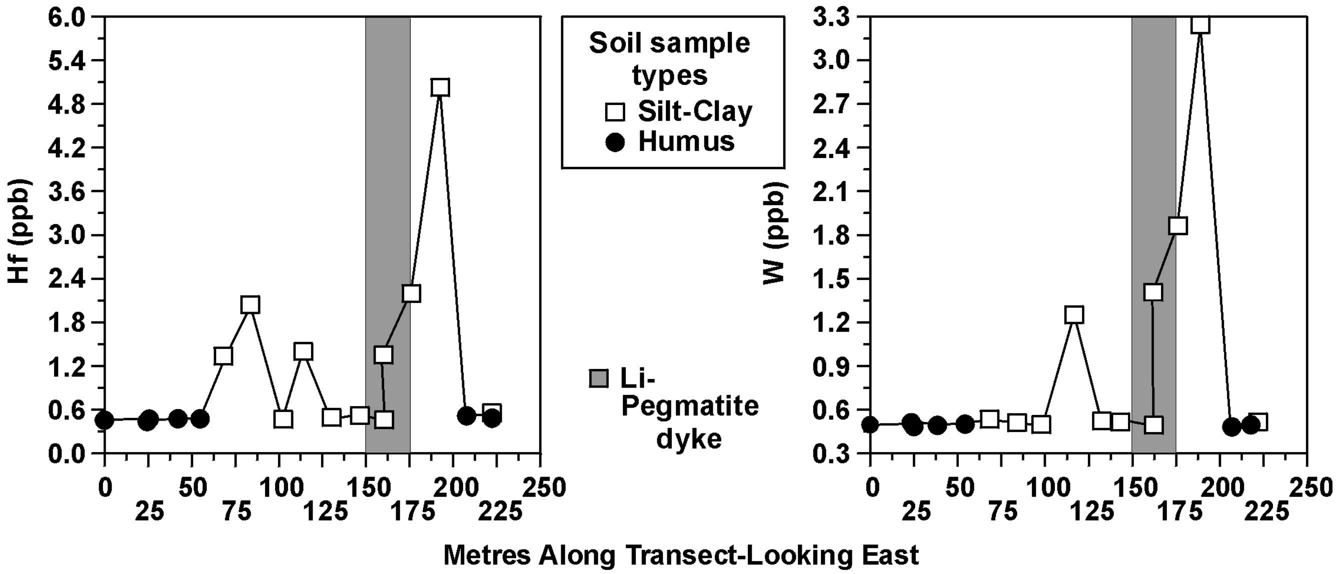

Figure 7: Profiles of enzyme leach^{sm} Hf and W over the Bil Group lithium pegmatite. Samples collected along a transect oriented 225°.

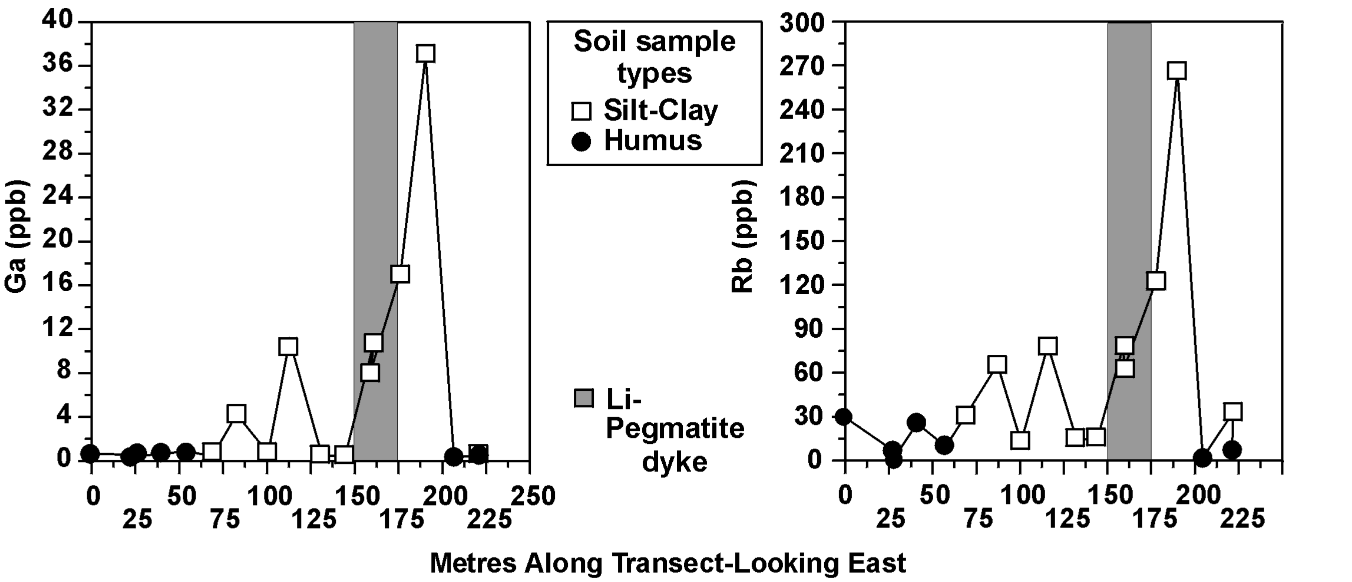

Figure 8: Profiles of enzyme leach^{sm} Ga and Rb over the Bil Group lithium pegmatite. Samples collected along a transect oriented 225°.

Rb (Figure 8)

Rubidium forms a two-sample apical response directly over the dyke at 175 m (123 ppb) and adjacent to the dyke at 190 m (269 ppb). There is a two-sample, low-contrast, non-diagnostic response at 85 m (66 ppb) and 115 m (79 ppb).

Cu (Figure 9)

The enzyme leach^{sm} Cu profile is difficult to relate to the pegmatite dyke. A single-sample response of 79 ppb occurs at 190 m on the transect and this coincides with a high Ga response.

Ni (Figure 9)

Nickel response along the sampling transect is characterized by a single, high response of 125 ppb at 190 m. In the absence of this response, the Ni results would be non-diagnostic of the dyke.

Pb (Figure 10)

A doubly peaked, asymmetric anomaly is documented for Pb. A single-sample response of 12 ppb at 115 m and a four-sample anomaly (9-32 ppb) with proximity to the dyke define the pattern to this response. This apical response is similar to the responses for other elements.

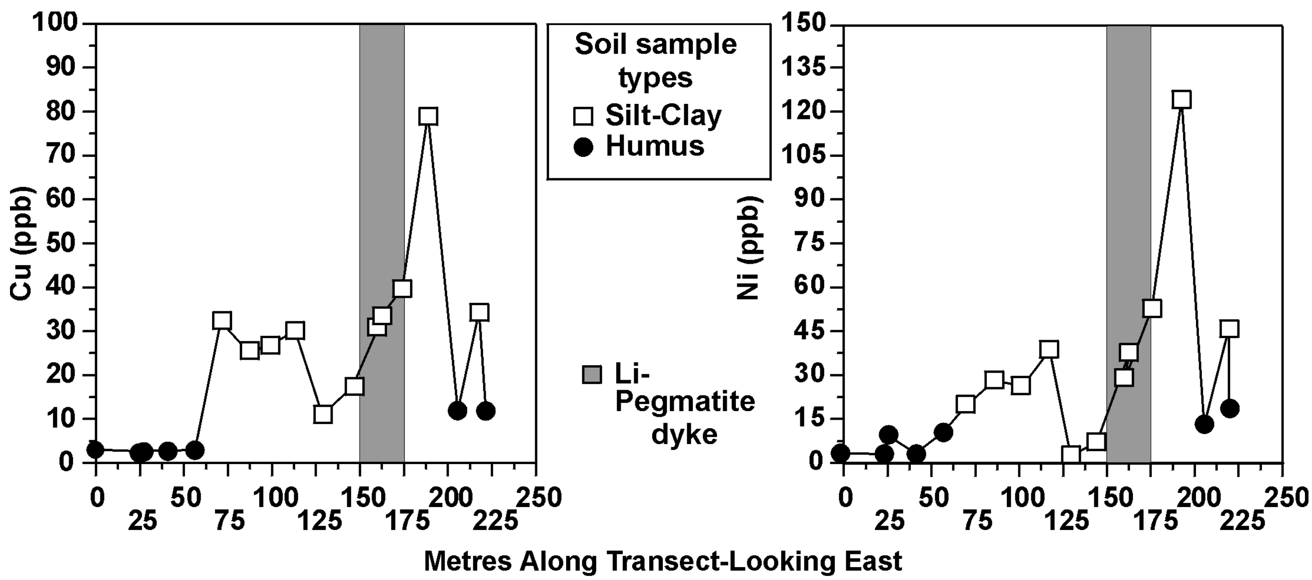

Figure 9: Profiles of enzyme leach^{sm} Cu and Ni over the Bil Group lithium pegmatite. Samples collected along a transect oriented 225°.

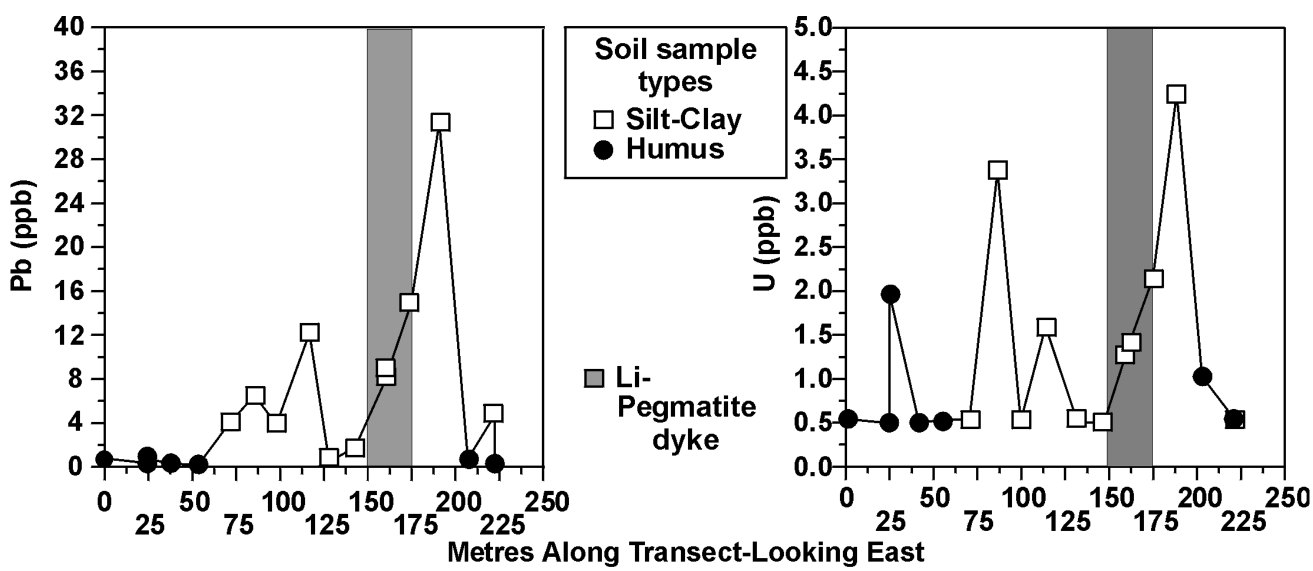

Figure 10: Profiles of enzyme leach^{sm} Pb and U over the Bil Group lithium pegmatite. Samples collected along a transect oriented 225°.

U (Figure 10)

Uranium responses along the sampling transect are erratic and of low contrast with single-sample highs at 25 m (humus; 2 ppb), 85 m (3.5 ppb) and at 190 m (4 ppb). A four-sample response of 1 to 4 ppb with proximity to the dyke produces the same pattern of variation in concentration as Pb.

DISCUSSION

Geochemical responses related to the presence of the pegmatite dyke in enzyme leach^{sm} analytical data are observed approximately 100 m north of the pegmatite dyke and 75 m to the south along the orientation-survey transect. This is true for all of the indicator or anomaly-forming elements. The overall pattern of response is one of an asymmetric, doubly peaked, 'rabbit ear' anomaly for elements depicted in figures 4 through 10. The lesser or lower contrast peak occurs approximately 50 to 75 m north of the dyke, whereas the high-contrast response is developed directly over and/or adjacent to the vertical surface projection of the dyke. Interestingly, many of the anomaly-forming elements have been previously identified as enriched elements in the dyke (Table 2).

It is possible that the doubly peaked pattern reflects the geological setting of the Bil Group pegmatite dyke as indicated by diamond-drilling results (Fig. 2). The pegmatite is divided into two portions by a fault. The thicker portion of the pegmatite may be reflected by the higher contrast geochemical response between 150 and 175 m on the transect, with the lesser response at 100 and 110 m attributable to the thinner pegmatite slice. This speculative interpretation is not supported, however, by rare-element or high field-strength element apical responses over the fault. The elements Zr, Nb, La and others are typically elevated over buried structures. The Zr and Nb response in Figure 6 may indeed be related to the fault intersected during diamond-drilling and, if so, the interpreted location of the vertical surface projection of the pegmatite dyke may be in error.

Geochemical background conditions are present for most elements outside of the area of the anomaly regardless of sample type. It should be noted that during sample collection some of the organic samples were frozen but this appears to have had little effect on the samples' enzyme leach^{sm} geochemical signature.

Of considerable interest in this study are the elements other than Li that define the position of the geochemical signature of the pegmatite along the sampling transect. Elements such as Cs, Ba, W and Nb suggest that the pegmatite may, in fact, be a resource for rare elements in addition to Li. This hypothesis can only be proven by analysis of core from a diamond-drill program.

CONCLUSIONS

The following conclusions flow from this very brief enzyme leach^{sm} orientation transect over the Bil Group pegmatite:

1. The Bil Group lithium pegmatite has an enzyme leach^{sm} geochemical signature consisting of Li, Ti, Cs, Ba, Zr, Nb, Hf, W, Rb, Pb, Ga and Ni. These anomalies take the form of doubly peaked responses that are formed over 125 m of the transect.
2. The responses are moderate to high contrast in character and well above the lower limit of determination for ICP-MS.
3. The presence of the elements W, Cs, Ba and Nb as geochemical anomalies over this deposit indicate potential may exist for rare-element mineralization in the dyke.
4. The enzyme leach^{sm} analysis of A- and B-horizon soils provides a useful method of 'seeing through' glaciolacustrine and organic overburden in this area. As such, a grid soil sampling program would help to define the extent of the pegmatite and possible 'hot spots' that might indicate higher grade material along the length of the dyke, thereby focusing diamond-drill testing.

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