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## Renseignements :



Ontario Geological Survey MAP 80 797 **GEOCHEMICAL SERIES** 

## Humus Geochemistry near Barbara and Hanes Lakes Algoma District

NTS References: 41 N/8, 41 0/4 ODM-GSC Aeromagnetic Maps: 2203G, 2215G OGS Geological Compilation Map: 2419

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"During chemical weathering primary minerals, which have been formed at high temperatures and pressures mostly in the absence of air and/or water, and changed into phases that are stable under surface conditions characterized b lower temperatures and pressures and the presence of air and water. The redis tribution of elements involves interactions between bedrock and water containing dissolved gases with replacement of bedrock by particulate and colloidal products having physical properties which are intermediate between bedrock and water together with fragments of minerals and rocks which are resistant to weathering and solutions" and Robert Raiswell. Principles of Environmental Geochemistry. Applied Environmental Geochemistry, edited by lain Thornton, Academic Press

INTRODUCTION

collected from the Williams Property at Hemio (Fortescue 1985). The aim of the study was to examine the geochemical behaviour of elements i humus and to provide information on the use of humus as a medium for geochemical exploration in the vicinity of the Hemlo deposit. The Williams Property area was chosen for study partly because the landscape conditions in the area were near ideal for an investigation of this type and partly because the area was about to be disturbed by mining activity. It was thought that a permanent record of geochemical conditions at this unique site should be prepared for use as a basis for comparisons with future, similar. studies completed by the Ontario Geological Survey. The Hemio humus study introduced three new concepts in order to standardize the study of humus during geochemical surveys at the local scale. . to divide the landscape into a series of

small scale study of the geochemistry of humus

New York, 1983, p.9.

humus samples in order to facilitate the interpretation of multielement geochemical patterns within the humus determined later on to base the study on three different size fractions derived from each humus sample in order to verify the data obtained from chemical analysis of the humus and to detect subtle changes in the abundance of chemical elements in each size fraction to convert the data obtained from chemical analysis of the humus fractions to geochemical

"Geochemical Domains" during the collection of

data using the Clarke Index-I transform which is based on the estimate for the abundance of each element in the Earth's crust as a whole In practice these innovations are found to work well. For example the use of "Geochemical Do mains" facilitates the interpretation of the individual element geochemical patterns along each of the cut lines studied; the use of three size fractions of humus samples verifies in detail the complexity of the geochemical patterns for individual elements and the use of the Clarke Index-I transform simplifies the display of the element data sets and also facilitates the interpretation of the geochemical pat-The success of the Hemio experimental study also raises a number of questions. One is, to what extent is geochemical data for elements homogeneous within a particular "Landscape Domain"? Another is, to what extent does a Landscape Domain underlain by two or more "geochemical domains"

smooth out the differences between the geochemical response of different bedrock types? The purpose of the study described here is to answer these questions and to further develop the standardized approach to the multielement geochemical study of humus in the conditions which are found on the Canadian Shield in Ontario. In order to achieve this purpose, two 200 m long lines were selected for study where the overburden, soil, and vegetation, together with the slope and made with the spade all around the board. The aspect, were practically identical. One of the lines is resulting sod was overturned on to the board and located over typical granitic rocks of the Canadian any mineral matter on its undersurface removed with Shield and the other over metavolcanic terrain in- a trowel and stiff brush. The intact sod was then cluding a small area of zinc and base metal min-eralization. The fieldwork for the study is part of a larger investigation completed in September, 1985, designed to investigate environmental decline geochemistry of lakes and forested areas. The line sampled over metavolcanic terrain is near Hanes Lake (Latitude 47°07'N, Longitude 83°54'W) and the granitic terrain sampled is at Barbara Lake (Latitude 7°17'N. Longitude 84°20'W) both located to the east of Lake Superior south of Montreal River (Figure 1). The scope of the environmental study which

## OBJECTIVES The objectives of this study are:

Fortescue and Webb (1985).

to use the conceptual model developed a Hemio to carry out two small scale humus studies along two 200 m cut lines, one at Barbara Lake located over granitic terrain, and the other at Hanes Lake over metavolcanic terrain which includes a small base metal mineralized zone on the basis of the Barbara Lake and Hanes Lake studies, to discover variations in the abun-

includes the study described here is outlined by

dance of elements in humus derived from bedrock within the same "Landscape Domain" to draw conclusions regarding the interpretation of multielement geochemical data patterns in humus in the two landscapes at the Global (i.e. province-wide), Regional, and Local levels of geochemical survey.





METHODOLOGY In 1983 the Ontario Geological Survey completed a The methodology described below for the Barbara and Hanes Lakes humus lines was standardized previously at Hemio (Fortescue 1985).

CHOICE OF LANDSCAPE

The Hemio conceptual model calls for a 200 m cut line oriented in a north-south direction, at right anburden should be less than 5 m with few actual outcrops. The soil cover should be uniform zonal and podzolic although patches of organic rich soil are expected in hollows. In order that the

"Landscape Domains" should be considered identical, the ground, understory, and overstory vegeta tion should be very similar along both of the lines The locations of the sampled lines at Barbara

Lake (Line B) and Hanes Lake (Line C) is indicated on Figures 2a and 2b. Both sites had been logged some tens of years ago and the line at Hanes Lake is crossed by a minor road which has not visibly disturbed the landscape. At Hanes Lake an area of bedrock had been cleaned off previously to expose the base metal showing some 30 m along strike from the line. A pit had been due in bedrock at this location in order to obtain samples of bedrock for hemical analysis (Grunsky 1980). As far as can be ascertained, the depth of the soil and overburden is less than 5 m along both humus lines. Outcrops occur on, and beside, both lines in both areas. The amplitude of the relief along the lines is about 10 m, with the surface being more uneven at Barbara Lake than at Hanes Lake.

SAMPLING PLAN AND SAMPLING The line at Barbara Lake was designated Line B with station BA at its northern end Similarly the line at Hanes Lake was designated Line C with station CA at its northern end (Figures 2b and 3). On each line, humus samples were collected at 10 m intervals and the samples designated by letters of the alphabet (i.e. BA, BB, BC etc.). These code letters are also used on the graphical displays of the geochemical data (see Figure 5). Prior to sampling, each line was surveyed for relief and wooden pegs placed along it to mark sample points. Generalized descriptions of the soil and vegetation were later made at each sample point together with a tape recording of details of the vegetation cover. Samples of the common plants along each line were collected, pressed, and taken to Toronto where they were identified at the Roval Ontario Museum. Humus samples were collected using a 25 by 30 cm board and a sharpened spade. The board was first placed on the surface to be sampled, which was usually within 1 m of the sample point. A cut through the humus layer to the mineral soil was then

placed in a 25 kg (50 pound) multiwalled paper sack and sealed. The sealed bads were transported to Toronto and allowed to become air dry prior to subsampling UBSAMPLING AND CHEMICAL ANALYSIS When the bacaded humus samples were completely dry, the sacks were opened, the sample crushed ently in a plastic tub, and passed through a 50 mesh (i.e. 300 micron) stainless steel sieve. The -50 abundance for each element (in Clarke (K) units) mesh material was divided into two parts, one part being further sieved to -80 mesh (i.e. 180 micron). The resulting three fractions (-50 mesh, -50/+80 mesh, and -80 mesh) were placed in 57 ml (2 ounce) vials for chemical analysis. The vials were then sequenced for chemical analysis by inserting at random replicate samples of three standard mixtures of humus in order to provide quality control on the performance of the methods of chemical analysis. Two identical batches of subsamples were then sent to contractors for chemical analysis by multielement instrumental methods. One batch was sent to Barringer Research Limited of Toronto, who determined Al, Fe, Ca, Mg, Na, K, , Mn, Sr, Zr, Cr, Ni, Zn, Cu, Pb, Be. Mo, and Ag by Inductively Coupled Plasma (ICP) methodology plus loss on ignition on the samples. The other batch was

analyzed by X-Ray Assay Limited of Toronto for Ba. in, La. Co, Sc, Th, Hf, Br, U, As, Lu, Sb, and Au of variation obtained for each element in each size zone fraction of the standard replicates.







Table 2. Data for the Loss on Ignition of the reference standard replicates included in the quality control experiment Humus Number of Mean Standard Coefficient of Fraction Samples Deviation Variation

63.7% 0.77 73.5% 2.45 59.5% 1.35 DISPLAY OF GEOCHEMICAL DATA

From the viewpoint of the geochemical map of Ontario (Fortescue 1983) the multielement humus data sets obtained from the three size fractions of humus can be studied at each of three levels of detail. These are: the Global Level designed to present the entire data set in a standardized format which can be compared directly with other, similar data sets obtained elsewhere in the province; the Regional Level which is designed to relate data for selected elements to other humus deochemical data sets obtained within the same Region of Ontario; and the Local Level which relates the humus geochemical tata patterns for selected elements directly to the geology of the area using an approach common in mineral exploration.

The Global Level

Global Level humus data is displayed in each of two ways, both of which use the Clarke Index-I transform to obtain normalized geochemical data sets which are applicable province-wide. Transformation of geochemical data, in order to facilitate the interpretation of abundance patterns, is not new in geochemistry; for example it has long been used in the study of Rare Earth abundances which are normalized to abundances in chondritic meteorites Henderson 1984). The transform used for humus data is called the Clarke Index-I (Fortescue 1985) and is based on estimates for the abundance of elements in the Earth's crust (i.e. Clarkes) listed by Ronov and Yaroshevski (1972) and Bowen (1979) Table 3). The importance of the Clarke Index-I ticularly common. transform in Global Level geochemical data is that it enables a single legend to be used for geochemical maps for the province as a whole instead of a separate legend for each geochemical study based on element abundances from that area. It should be line. In general, this site is considered typical of noted that the Clarke index-I normalization procedure does not automatically indicate "geochemical anomalies" which are due to mineralization. For ex- rocks. The forest cover along Line B is also consid- Group A Elements gles to the strike of the bedrock, with humus sam- ample, humus is known to accumulate certain ele- ered typical of a large area of the Shield where pling points at 10 m intervals along it. The relief of ments (e.g. bromine) independently of the presence second growth of balsam fir and cedar have rethe daylight surface along the line should not ex- of mineral deposits so that high bromine values as placed a first growth of white pine which was the viewpoint of mineral exploration. Let us summaceed 10 m and the thickness of the cover of over- measured by the Clarke Index-I do not always signify the presence of mineralization. Otherwise the Clarke Index-I simplifies considerably the plotting of

> Table 3. Clarke Index-I values for all elements. lements included in this study are shown in bold

multielement data sets and their interpretation for

comparative purposes.



\*Based on crustal abundance data for rocks from Bowen (1979). \*\*Note that 1% = 10 000 ppm.

The Global Level geochemical data are displayed in two ways; a table of mean values for each element is prepared for purposes of general overview and a scan sheet is prepared showing the plotted on a trace of the daylight surface of a traverse line, drawn to scale (see Figures 5 and 6) Note that the scale used on the scan sheets is arithmetic with one range for elements of relatively low abundance (i.e. 0.1 to 2.0 K) and another for elements of high abundance (i.e. 1.0 to 20.0 K). The low abundance range is indicated by grey shading on the scan sheets whereas the high abundance range is in black.

The humus lines sampled at Barbara and Hanes

**Regional Level** 

Lakes are considered to be located within the same Landscape Domain but, because of differing bedrock types underlying them, are considered to be in different Geochemical Domains. They belong to the same landscape domain because the lines have similar aspect, slope, relief, overburden cover, soil using a neutron activation methodology. The meth- cover, and plant cover. The Barbara Lake line is odology performance of the two analytical methods underlain by granitic rocks, and that at Hanes Lake is summarized on Table 1 which lists the coefficient by metavolcanics including a small mineralized The aim of Regional Level data processing is to produce generalized information on the abundance level and variability of elements of interest within each geochemical domain in a study. An advantage of the Barbara Lake/Hanes Lake study is that the landscapes sampled are considered to belong to the same landscape domain which is often not true in other areas. For example at Hemlo (Line L) five landscape domains were identified along a single ine traverse (Fortescue 1985). In order to produce a Resultant Plot for humus data for an element along a traverse line, the abun-

An exploration geologist using the results of a humus survey requires the most accurate spatial in formation regarding variations in abundance of ele ments within an area surveyed. At this level of detail he "parts per million" unit is used in the display o element data to fall in line with current practice in mineral exploration. Because of the heterogeneity of he humus material sampled and the intimate mixture of organic and mineral matter which constitutes numus it is not practical to divide the material int n organic and a mineral fraction for chemical ana sis. However, at the Local Level, enhancement o he data patterns may be achieved by normalizin he humus element values by the data for Loss o nition. Consequently the display of an element o nterest at the Local Level involves a graph showing peochemical values plotted against the distance beeen sample sites with, and without, the normalization for Loss on Ignition. In this case each data point is plotted separately with no rolling mean calculation of the type used for the Regional Level data. In this study an attempt has been made to standardize the display of multielement geochemical data sets obtained from humus for use at each of three levels of detail. The Global Level is designed to be used for all elements for comparisons and interretations on a province-wide basis; the Regional evel display is designed to highlight different abundance levels between geochemical domains and to ndicate the abundance variations within each domain and the Local Level is designed to provide

values (Figure 7).

he Local Lev

element in all the humus samples (ratio value of 1.0)

Resultant Plots are useful for making compari-

omains within the same general study area. A stan-

larly useful as an aid to the interpretation of humus

to a cover of Quaternary materials.

eochemical data patterns in new areas where the

detailed information on geochemical patterns within a given domain in a form suitable for comparison th results from other, parallel, exploration surveys. e experimental approach developed has the goal of proving data display methods which can be used ater on for image processing and interpretation of nultielement geochemical data in real time. ESCRIPTION OF FIELD AREAS The landscape traverses at Barbara and Hanes Lakes are summarized on Figures 3 and 4 and

cated as shown on Figures 2a and 2b.

HE BARBARA LAKE AREA The Barbara Lake line is underlain by felsic intrusive and metamorphic rocks of Archean age which are not subdivided into granitic and migmatic rocks. The rocks outcrop around the margins of Barbara Lake and on the shores of the Island upon which Line B s located. Outcrops of bedrock occur on and beside the traverse line. The overburden along Line B is shallow and believed to be less than 5 m deep. The soils are nodzolic except at the bottom of hollows where th aver of organic material thickens. Four strata regetation are recognized at the site. The topmost is "superstory" of a few mature individuals of white nine (Pinus strobus) which tower above the rest of the vegetation. The overstory is largely an open canopy of cedar (Thuia occidentalis) but includes some individuals of balsam fir (Abies balsamae) naple (Acer spicatum) and birch (Betula lutea) The understory vegetation is variable and includes both shrubs and bushes of cedar, balsam fir, maple, and some mountain ash (Sorbus americana) together with snowberry bush (Symphoricarpos albus). The ground is covered with a variety of small plants. In well lit areas raspberry (Rubus idaeus var. strigosus), dogwood (Cornus canadiensis), golder thread (Contis trifolia), and lilv (Clintonia borealis are found. In shaded areas bracken fern (Pteridium aquilinum), maiden-hair moss, (Polvtrichun juniperinum), club mosses (Lycopodium clavatum and L. dendroideum), and mosses (Atrichum undilatum, Brachythecium sp.) are found. In the damp hollows underlain by organic soil, mosses are par-The main features of the landscape section at

Line B are illustrated on Figure 3 which also in cludes information on the relief of the daylight sur face and the location of sampling points along the much of the Canadian Shield of Ontario where a thin cover of glacial material lies directly on granitic logged off several decades ago. THE HANES LAKE AREA he geological substrate at Hanes Lake is more complex than at Barbara Lake. According to Grunsky

1980, p.9) "the most common mafic to intermediate netavolcanics encountered in the field [i.e. to the west of Hanes Lake, Figure 2b ]are fine-grained submassive to schistose hornblende-chlorite schists that represent volcanic flows... In this section these oeks are composed of fine-grained plagioclase, inolite, carbonate, opaque minerals, and a fine- er on Line C than on Line B. grained indiscernible groundmass." Grunsky (1980, 5.57) also describes the "Hanes Lake West Occurence" which underlies Line C as follows: This occurrence consists of a mineralized area about 1.0 km west of Hanes Lake and is accessible via the Domtar Road. The occurrence contains minor copper and silver values with traces of lead, nickel, and gold. Unreported trenching has been carried out on the occurrence. The mineralization is not restricted to any one zone, but rather a number of interflow metasedimentary units in which sulphide iron formation and magnetite iron formation are common. These units strike N50°W and dip 80°to the north. The mineralization occurs in a rusty gossan-like weathered sequence of graphite. argillite, chert, siltstone, and chlorite schist interbedded with mafic to intermediate pillowed flows. Visible mineralization consists of pyrite and pyrrhotite occurring in massive and disseminated forms within black and white chert, parallel to the bedding. The cherty units were observed to contain thin laminae of argillite similar to the nearby iron formations. Calcite rhombs up to 2.0 cm in diameter were found in one trench which displayed intense shearing in the wall rocks. The width of the mineralized zone is approximately 100 m. Grunsky also reported the chemical analysis of for arsenic, antimony, and hafnium in humus is less rom the geochemical data (described below). sample site on Line C (CA) is beyond the hanging-No mineralization or staining was observed in rock lying Line C is indicated on Figure 4. The overburden cover along Line C is thin but present along most of the line with few outcrops. It considered to be less than 5 m deep except at the ample station CU at the extreme south end of the line. The soil is podzolic with a well developed humus layer overlying a grey A2horizon. In general the relief along the line is similar to that at Barbara Lake (Figure 3) except that at Hanes Lake the hollows are less well marked and the general slope is owards the south. The roadbuilding caused minimal

The overstory on Line C includes cedar with minor balsam fir. At the south end of the line there are signs of logging of first growth large trees some decades ago. Along the line there are large birch (B.Lutea) and maple (A.saccharum) individuals vithin the overstory. In the vicinity of CG and CH a 15 m high birch clone was conspicuous. The underand choke cherry (Prunus pennsylvanica). The stringosus), current bush (R. lacustre), and snowberry bush (S. albus) in the better drained areas, and grass (Calamagrostic canadiensis). mined by the nature of the understory and overstory canopy and the moistness of the soil.

sturbance to the landscape on either side.

erburden, relief, aspect, soil cover, and plant cov-"Hemio Model" described above. Consequently used for the initial selection of elements of interest dance levels for the element (in K units) in all three Lines B and C are considered to belong to the same within a data set. size fractions at one sample point are averaged and Landscape Domain.

ement	(K.DOM)	-50	)	-50/	+80	-80	
		Mean(pom)	C/V8	Mean(pom)	C/V%	Mean(ppm)	C/V%
21	92 600	21 200	2.2	16 464	12.1	22 610	4.0
AI Eo	83 600	21 200	3.2	10 404	13.1	23 518	4.9
Ca	46 600	10 800	3.4	10 162	3.2	11 019	3.7
Ma	27 640	2 048	7.5	1 635	8 9	2 213	4.0
Na	22 700	5 635	10.3	3 709	19.3	6 544	6.2
K	18 400	5 097	14.0	3 757	15.3	5 635	14.4
Ti	6 320	1 131	7.8	838	9.3	1 391	5.4
P	1 120	887	5.6	984	3.2	844	3.9
Min Ba	1 060 390	1 645 394	5.6	339	10.1	386	6.3
Sr	384	96	2.7	74	11.1	108	3.1
2r	162	50	14.2	29	15.4	60	6.8
v	132	26.0	5.7	18.6	12.2	28.3	6.9
Cr	122	20.0	5.4	15.9	18.0	22.4	6.0
Ni	99	10.9	9.6	10.4	7.8	10.8	8.1
$2n_2^1$	76	415.9	4.8	458.4	10.2	419.8	7.0
Zn	76	390.0	7.2	406.0	24.6	385.0	25.4
Cu	68	19.1	5.2	18.1	3.3	19.0	3./
La	35	11.8	5.3	9.7	4.0	7 25	3.1
0	29	/.24	0.0	1.22	0.9	/.35	4.1
Sc	25	4.08	5.1	3.10	8.7	4.45	3.1
Pb	13	71.3	19.8	84.5	2.7	73.20	2.1
Th	8.1	2.54	14.7	1.81	8.0	10.85	10.6
Br	2.8	3.84	9.7	12.70	10.5	4.53	6.9
U	2.3	0.77	14.3	1.81	8.0	2.85	17.6
Be	2.0	0.34	7.9	0.30	16.7	0.38	8.7
As	1.8	6.64	5.9	7.45	6.1	6.58	5.0
Mo	1.2	-	-	-	-	-	-
Lu	0.54	0.16	8.8	0.12	9.3	0.17	7.1
Sb	0.20	1.05	7.2	1.26	5.5	1.00	4.3
Ag	0.08	-	-	-	-	-	-
Au	0.004	-	-	-	-	-	-

### then a rolling mean of three averaged values is The bedrock geology which underlies the two alculated. The Resultant Plot includes a horizontal lines is quite different mineralogically and ine on a graph denoting the average level of the geochemically. Consequently Line B and Line C are said to belong to different Geochemical Domains. A olus plots of the rolling mean values divided by the further complicating factor is that within the bedrock verage level (plotted as ratio values). In this way underlying Line C there is a significant mineralized zone which, as we shall see, gives rise to a signifimean values for an element in different geochemical domains can be identified together with the sample cant geochemical anomaly in the humus. From the theoretical viewpoint, Lines B and C site to sample site variation within the rolling mean provide an interesting experiment in geochemistry. The Line B geochemical data can be considered to sons between background levels of elements in huindicate how elements behave in areas where the mus within different landscape and/or geochemical overburden is thin and forests are growing on granitic terrain. This state of affairs provides backdardized system of reporting of this type is particuground geochemical data for humus geochemical behaviour in vast areas of the Canadian Shield where the vegetation cover is similar to that at Barbara Lake. Similarly, the geochemical data from extent of geochemical domains is not known owing Line C provides detailed information on the behaviour of elements in areas underlain by metavolcanic rocks in general and small mineralized zones in particular. The use of Global Level, Regional Level, and Local Level methodologies for processing the geochemical data derived from humus at the two sites rovides readers with bases for comparison of the Barbara and Hanes Lakes data sets with other, similar data sets obtained at other locations within the Canadian Shield where the landscape conditions are

## DESCRIPTION AND DISCUSSION OF RESULTS **GLOBAL LEVEL ABUNDANCE PATTERNS** The processing of the geochemical data at the Glo-

bal Level resulted in a lookup table (Table 4) and two multielement scan sheets, one for Barbara Lake (Line B, Figure 5) and the other for Hanes Lake ine C, Figure 6). Global values based on the Clarke Index-I relate directly to estimates for the level of individual elements in the Earth's crust (Table 3). These estimates are then used as datum levels for the calculation of values listed in Table 4. It should be stressed that high Clarke Index-I values may not be always associated with "geochemical anomalies" due to mineral deposits. Consequently, the description of Global Level data in this Section should be interpreted with caution by scientists involved in mineral exploration. The lookup table (Table 4) provides readers with an overview of element abundance relationships for three humus fractions in samples collected from Lines B and C. Bearing in mind the constraint described above, the use of the Clarke Index-I transform smooths the data considerably and facilitates a general discussion of abundance relationships within the different geochemical domains. A glance at Table 4 indicates a grouping of the elements according to Clarke Index-I numbers as follows: A-Elements with relatively high K values (Mn, Ba, Zn, Pb, Br, As, Sb, and Hf) B-Elements with relatively low K values (Fe, Mg, Cr, Ni, and Co) C-Elements with intermediate abundance levels (AI. Ca, Na, K, Ti, P, Sr, Zr, V, Cu, La, Sc, Th, U, Be, and

Table 4. Global Level lookup table for humus data from Lines B and C. Data listed in Clarke Index-I

Element	-50		-50/+80		-80	
	B	с	В	с	в	с
Al	0.160	0.242	0.133	0.029	0.171	0.255
Fe	0.081	0.145	0.072	0.137	0.083	0.150
Ca	0.108	0.293	0.099	0.278	0.110	0.301
Mg	0.038	0.076	0.033	0.069	0.040	0.079
Na	0.131	0.230	0.102	0.179	0.154	0.246
K	0.161	0.251	0.134	0.226	0.187	0.257
Ti	0.112	0.180	0.081	0.146	0.125	0.19
P	0.724	0.906	0.714	0.991	0.697	0.873
Mn	0.189	1.182	0.184	2.080	0.193	1.690
Ba	0.560	1.030	0.530	0.930	0.600	1.030
Sr	0.148	0.245	0.122	0.207	0.157	0.26
Zr	0.213	0.279	0.123	0.190	0.254	0.32
v	0.117	0.187	0.095	0.169	0.123	0.19
Cr	0.082	0.174	0.064	0.153	0.090	0.18
Ni	0.066	0.089	0.080	0.080	0.087	0.119
Zn	1.010	5.530	1.080	6.820	1.010	5.400
Cu	0.173	0.343	0.220	0.345	0.192	0.34
La	0.219	0.328	0.195	0.289	0.243	0.34
Co	0.075	0.224	0.073	0.242	0.076	0.17:
Sc	0.090	0.163	0.079	0.140	0.101	0.17
Pb	4.040	6.510	5.320	6.850	4.840	6.140
Th	0.190	0.290	0.160	0.250	0.210	0.03
H£	0.790	1.280	0.440	0.810	1.050	1.470
Br	6.340	4.390	6.350	4.690	6.160	4.380
U	0.270	0.356	0.220	0.306	0.310	0.348
Be	0.107	0.158	0.084	0.152	0.110	0.163
As	4.140	3.470	4.220	3.640	4.050	3.380
Sb	5.780	5.520	5.950	6.260	5.480	5.120
Lu	0.186	0.274	0.157	0.228	0.214	0.29

# These elements are perhaps the most important from

rize the behaviour of each element in turn. Manganese The manganese levels from Line B are consistently low compared with those from Line C (Table 4). When the pattern for Line C is examined In detail (Figure 6) it is seen that a single high value occurs in all three humus size fractions at sample point CL which is located at the foot of a rise. This suggests the possibility of a seepage as a source of manganese and that the humus sample from that point is not typical of the line as a whole. chlorite. hornblende. saussurite. sericite. uralite. ac- Barium The values for barium are consistently high-Zinc As expected, high zinc values in humus are found to be associated with the mineralized zone (Figures 4 and 6) on Line C. On Line B zinc values are relatively uniform with a range from 0.36 to 2.6 K with a mean of 1.04 K. The standard deviation is 0.46. On Line C the data for the same size fraction (-50 mesh) of the humus has a range from 1.53 to 19.21 K, a mean of 5.52 K, and a standard deviation of 4.92. This indicates that the high zinc values on Line C are indeed a true "geochemical anomaly". Lead and Bromine These elements are both known

to be concentrated in organic matter by "biogeochemical cycling". On Line B, lead values in the -50 mesh fraction range from 2.3 to 7.3 K with a mean of 4.4 K and a standard deviation of 2.36. The lead values for Line C range from 4.08 to 9.85 K with a mean of 6.52 K and a standard deviation of 1.55. This may indicate a more subtle response for lead in humus compared with zinc over a mineralized zone. The bromine values are found to be more variable than for lead. For example on Line B (-50 mesh fraction) the range is from 0.68 to 12.00 K with a mean of 6.34 K and a standard deviation of 2.40. Comparable data for Line C range from 0.84 to 7.20 K with a mean of 4.39 K and a standard deviation of Arsenic, Antimony, and Hafnium The abundance

sample of sulphides in banded chert/siltstone col- well known. Similar Clarke levels for arsenic are ected from the mineral showing. It was found to found at both sites. For example, on Line B (-50 contain 23 ounces Ag per ton, 0.01 ounce Au per mesh fraction), arsenic values range from 2.5 to 6.1 ton, 60 ppm Cr. 1200 ppm Cu. 10 ppm Pb, 820 ppm K with a mean of 4.14 K and a standard deviation of 200 ppm Ni, and 42% Fe (Grunsky 1980, p.44). 0.87. These values compare with a range of 1.11 to Data from Line C indicates that this estimate of the 3.89 K and a mean of 2.45 K (10 samples) in width of the mineralized zone is consistent with that Domain I at the Williams Property at Hemlo (Fortescue 1985). Line C is oriented in a north-south direction at Similarly, antimony values on Line B range from right angles to the slope of the hillside and the 4.0 to 8.5 K with a mean of 5.7 K and a standard strike of the bedrock. The line is located 30 m east deviation of 1.15, and those on Line C range from of the trench described above. The most northerly 3.5 to 7.5 K with a mean of 5.52 K and a standard deviation of 1.03, all in the -50 mesh fraction. Com wall of the mineralized zone A bush road crosses parable data for antimony in Domain I at Hemlo the Line C between stations CJ and CK (Figure 4). range from 3.0 to 6.0 K with a mean of 4.15 K (Fortescue 1985). This suggests from levels for aroutcrops on, or near the line along strike from the senic and antimony that the Clarke Index-I values deposit. The geological section in bedrock under- are relatively high for use in humus in parts of the Canadian Shield although further work is required to verify this statement. No data for hafnium was obtained from the Hemlo study.

> Other Elements So far we have been concerned with the elements which are grouped together because they are found to have relatively high Clarke index-I values. Three other elements, silver, gold, and molybdenum, also are found to have high values in the humus. They are not included in this discussion because the performance of the analytical methods by which they were determined in humus was not as reliable as that for the elements discussed above (Table 2). Discussion of the abundance patterns for elements in Groups B and C is postponed to the next section where the Global scan sheets are discussed.

Summary The Global lookup table provides an story in the area is largely maple bushes with some effective way of looking at multielement geochemihazel (Corvius cornata), dogwood (C. canadiensis), cal data from humus in order to discover which elements have relatively high values according to plants covering the ground include michaelmas dai- the Clarke Index-I scale. This procedure demonsy (Aster macrophyllus), raspberry (R. idaeus var. strates how two groups of elements with relatively high levels in humus can be distinguished. One group which includes Zn. Mn. and Ba and, possibly, As and Sb. includes elements likely to be associated sedge (Carex sp.), ferns (P. aquilinium), club mos- with mineralization, and the other group including ses (Lycopodium dendroidem, L. clavatum), and Pb, Br, and perhaps Hf are found to have high mosses (A. undilatum, Brachythecium sp.) in damp values which could be related to biogeochemical areas. The mix of plants at any one spot is deter- cycling of normal levels in mineral substrate. The Global lookup table as described here has other uses. For example it can be used as a hard copy introduction to a multielement geochemical data set of the type described in this broadsheet for use in the interpretation of geochemical patterns in humus in real time using image processing and It is evident from the above descriptions that the computer graphics as described by Fortescue (1986). Such a procedure does away with the need er on Lines B and C are very similar to that of the for a broadsheet but not the lookup table which is



-50 mest (300 µm) ECa ⊧Bα I IN NOPERS



Barbara Lake - Line B Figure 5. Scan sheet of the 32 elements of interest and Loss on Ignition in the three fractions of humus, Line B, Barbara Lake area.



ead Relatively high values on both lines (5 to 10 as that for the other elements discussed above.

higher values were found over the mineralized zone and several stations south of the road. Lead patterns repeat well from humus fraction to humus fraction.

Elements with Clarke Index-I Values from 1.0 to 10 ppm (Th, Hf, Br, U, Be, As, and Mo) These elements are usually found in trace quantities in rocks except in the vicinity of mineral showings. In spite of the low Clarke values for these elements the geochemical data for all, with the exception of molybdenum, are considered to be reliable enough for a Global Level discussion (see Table 1 for performance data). Let us consider the elements in this group one at a time.

Thorium Relatively low values are found on both Lines B and C. The thorium pattern on Line B resembles that for zirconium. Slightly higher than normal eralized zone. The -50/+80 mesh fraction has less thorium than the other two fractions on both lines. Hafnium As expected from its general geochemical behaviour the pattern for hafnium resembles that for zirconium on Line B with lower values in the 50/+80 mesh fraction than in the other two fractions. On Line C the hafnium patterns are also similar to those for zirconium. Bromine Bromine appears to be accumulated in organic matter by biogeochemical cycling in a manner similar to lead. However, the repeatability of the humus fraction patterns for bromine is not as good as for lead.

Uranium On Line B the uranium pattern mimics that for zirconium except that the two peaks at the south end of the line are higher for uranium. In general uranium values on Line C are higher than on Line B with a small peak at CM suggesting a seepage at Bervilium Low values are found along both lines. Good reproducibility from size fraction to size fraction in humus. Arsenic Like lead and bromine, arsenic is enriched

along both lines in relation to its Clarke Index-I value. However, the biogeochemical accumulation of arsenic has yet to be proven in humus from the Canadian Shield. The arsenic values reproduce well from humus fraction to humus fraction along both lines. The relationship between arsenic level and topography is evident on Line B. Molybdenum The quality control data for molybdenum (see Table 1) indicates that the sampling/analytical methodologies for this element are unsuited for use on humus. This is apparent from the nature of the patterns for all three humus fractions on both lines. The association of high molybdenum values with the mineralized zone of

Line C is not established on Figure 6.

Elements with Clarke Index-I Values of Less Than 1.0 ppm (Lu, Sb, Ag, and Au) Like the values for uranium, the lutecium values in humus are more variable along Line B compared with Line C. On Line B the lutecium values have a pattern which resembles that for zirconium and other elements. Like arsenic, the antimony values are relalively high compared with the Clarke Index-I value. As is the case at Hemlo (Fortescue 1985) arsenic similar levels, with the data for antimony being more noisy. Like molybdenum cited above, the data for silver and gold along Lines B and C is variable from size fraction to size fraction, suggesting that the analytical methodology employed is not as effective Lutecium On Line B the lutecium pattern resembles that for zirconium and hafnium. This element is more variable in humus from Line B than from Line C.

Antimony The patterns for this element in humus fractions are similar to those for arsenic. Silver As expected, the values for silver on Line E are lower than on Line C. The mineralized zone on Line C is accompanied by a clear silver anomaly (Figure 6). This is in accord with the data for chemial analysis of a sample of the sulphide rock described above.

Gold The data for gold, like that for silver and nolybdenum, is not considered as reliable as that for other elements. In general, gold values on Line B are higher than on Line C and no clear geochemica anomaly for gold is seen associated with the min eralized zone on Line C. Global Level General Summary

The Global lookup table and scan sheets have been used to provide a commentary on the behaviour o 2 elements in humus fractions derived from lines a Barbara Lake and Hanes Lake. This procedure vields information which is significant in relation to the Barbara and Hanes Lake areas and, more importantly, in relation to the general use of humus as a medium for geochemical surveys in forested areas The detailed discussions of the behaviour of th 2 elements focus attention on the reliability of ampling and analytical methodologies in relation to the sampling of humus. The data for gold, silver, and molybdenum provides information of value or

the apparent behaviour of elements when the analytical methodologies used are not quite reliable enough to do the job required. n general the uniformity of the landscapes, of nore correctly, the landscape domain on Lines I and C. enables the geochemical effects associated ith different bedrock types to overprint the humus lata from mesh fraction to mesh fraction. This suggests that, provided that the proper elements are hosen (e.g. zirconium, uranium, etc.) and the Quaternary cover is not too thick, it should be possible to indicate lithological boundaries using humus mapping, provided that the area is within a single land cape domain. Further research is required to test is hypothesis and to discover the significance of landscape domains of various kinds as modifiers of eochemical patterns in humus.

- More specifically the Global Level study at Barpara and Hanes Lakes has shown that: Zinc is the best indicator of the mineralized zone at Hanes Lake because almost identical geochemical anomalies for this element are ound in all three size fractions of humus. Of the other elements studied, copper, silver cobait, manganese, and to a lesser extent scandium and gold, mimic the zinc pattern, but none, with the possible exception of silver, is as good an indicator of the mineralized zone as
- At Barbara and Hanes Lakes, lead, bromine and to a lesser extent phosphorous, arsenic and antimony all appear to be accumulated in humus fractions by biogeochemical cycling. The relatively uniform patterns for these ele ments in the humus suggest that the uniformity
- of the landscape domain conditions along the two lines may contribute to this behaviour. In the granitic terrain at Barbara Lake, several elements show a consistent local variation of pattern which is repeated from fraction to fraction of humus. The type element pattern here is Irconium although other elements (i.e. Na, K i, Sr. V. La, Th. U. and Lu) also behave in a similar manner (Figure 5). Other elements provide general information on evels and behaviour in humus fractions in geo-
- chemical domains located on granitic and metavolcanic terrain. For example, the data for hafnium indicate that this element is always concentrated in the -80 mesh tractic compared with the other two humus fractions.
- 6. In the case of silver there is a marked difference in contrast between values from Line B compared with Line C (i.e. mean values of 1.54 K and 6.63 K respectively). Because of the relatively poor precision of the silver method (see Table 1) the variation in the values for Line B shows very clearly compared with that for Line C where the higher than normal values anomaly due to the mineralized zone (I).
- The plots for scandium are intermediate between those for gold and silver with less confor gold. The coincident scandium highs with zinc is not considered significant in this case. Manganese is the element with the greatest contrast in mean values on Figure 7. The mananese mean for Line B is 0.189 K and for Line 1.86 K. On Line B there is a manganese high associated with H, I, and J which are on a outh-facing slope (J). This sequence of highs is coincident with the high for zinc (K). This suggests that humus on the south-facing slope s relatively high in zinc and manganese which is similar to results for these elements at Hemio (Fortescue 1985). The absence of highs on sta-
- tions L, M, N, and O on Line B for zinc and manganese may be due to different forest canopy conditions at these locations. The cobalt data is found to have a contrast similar to that for scandium with random variations along Line B. On Line C a cobalt anomaly is found (L) which coincides with highs fo manganese (M). This suggests influence from the mineralized zone. The copper patterns on Figure 7 indicate that this element has relatively low contrast between the two lines with minimal variation on Line B On Line C a significant copper high is found (N) just to the north of the high for zinc (H). This
- suggests that the mineralized zone is copperich to the north of the zinc zone and, from Point 9, that cobalt is high to the south of the zinc zone. . The patterns for zinc are, as expected from Figure 6, the most clear cut of all the elements ncluded on Figure 7. The difference in mean values between the two lines is 4.86 K and the variations giving rise to positive values on both lines ((K) on Line B, (H) on Line C) are clear cut. The zinc anomaly on Line C is considered to be a classic pattern particularly when com-

## pared with the data from Line B where the element is found at normal levels. It should be noted that the Resultant Plot (Figure 7) provides explorationists with data regarding the geochemical behaviour of elements in a succinc and comparable format which may be reproduced easily when image processing is applied to geochemical data later on. Figure 7 provides data for are seen to coincide with the geochemical element abundance both in Clarke Index-I values (K units) and on a weight percent (i.e. parts per million) bases. The advantage of the Resultant Plot over the Global Level plots on Figure 5 and 6 is that it uses trast than for silver and similar patterns to those all the geochemical data to synthesize patterns and levels related to the region from which the samples e location of the geochemical anomaly for were collected. Future application of this approach will provide sets of element levels and contrast plots which can be used for purposes of comparison and interpretation of humus data where the landscape conditions are more complex than at Hemlo (Fortescue 1985) or Barbara and Hanes Lakes.

## patterns for these elements might cause confu-1979: Environmental Chemistry of the Elements; sion during geochemical prospecting surveys. As in the study at Hemio (Fortescue 1985), Zn and Mn tend to be accumulated in humus col- 1985: A Standardized Approach to the Study of the lected from south-facing slopes. This effect is

important information because, otherwise the

- masked by the elements derived from the mineralized zone on Line C. The data for Mo, and to a lesser extent Au and Ag, provide information on the problem of interpreting humus data when the analytical methods are unsuitable even though the field and
- subsampling procedures worked well. This information may be of considerable practical importance in the interpretation of humus patterns in new areas. The patterns for major elements (AI, Fe, Ca, Mr Na, K, and Ti) in humus provide general information on the homogeneity of humus along the lines. It is interesting that the behaviour c elements which are not readily accumulated by plants or are not plant nutrients tend to be

relatively low in the organic-rich -50/+80 mesh The mineralized zone underlying Line C produces clear geochemical anomalies in the humus fractions for Zn, Co, Cu, Ag, Au, and Mn. This suggests that the multielement approach to humus surveying in areas of thin glacial cover is effective in pinpointing the presence of mineralization. The effectiveness of humus in areas where the glacial cover is thick and/or complex is not currently known.

- In areas where there is thin (1.0 to 5.0 m thick) overburden and uniform slope, geochemical surveys based on the -50 mesh fraction of humus detects anomalies due to Zn, Cu, Ag, Co, and possibly Au mineralization. In areas with the same landscape domain (i.e. cedar overstory, shrub maple understory, with ground cover of bushes, grasses, or mosses) it s poossible to distinguish granitic from metavolcanic terrain by the level of Zn and other elements in all three fractions of humus. At Barbara and Hanes Lakes, Ca. Mn. and Ba
- were found to be indicator elements for the different rock types underlying these areas. The results of this study suggest that the interpretation of humus patterns for Pb and Br as well as P. As. and Sb may require caution because these elements appear to be accumulated naturally in humus.
- It is concluded that the methodology used here for processing and displaying multielement data sets is effective for purposes of mineral resource appraisal baseline data collection. These humus methods can be used anywhere where suitable landscape conditions occur in the province, particularly where the overburden is 0 to 5 m in depth and relatively coarse in texture.
- The display of multielement data used here is suitable for adaption to image processing in real time along the lines described by Fortescue (1986) although this step has not yet been taken with humus data.

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- issued 198 Information from this publication may be quoted if credit is given. It is recommended that reference to this map be made in the following form;
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Geochemical data listings for individual elements		ELEMENT:  Strontium  LINE: B  ELEMENT:  Strontium  LINE: C    -50  -50/+80  -80  -50  -50/+80  -50/+80  -80    Site  ppm  K  ppm  K  Site  ppm  K
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T 5 300 0.06 4 900 0.06 5 620 0.07 T 9 920 0.12 9 860 0.12 9 650 0.12 Mean 13 347 0.16 11 110 0.13 14 272 0.17 S.D. 8 500 0.10 6 945 0.08 9 058 0.11 Mean 20 230 0.24 17 439 0.21 21 318 0.26 S.D. 11 861 0.14 9 358 0.11 12 837 0.15	S  1270  0.07  1420  0.08  S  3280  0.18  3010  0.16  3320  0.18    T  1360  0.08  1160  0.06  1440  0.08  T  3020  0.16  3000  0.16  3080  0.17    Wean  2954  0.16  2468  0.13  3445  0.19  U  2040  0.11  2060  0.11  1920  0.10    Mean  2954  0.16  2468  0.13  3445  0.19  U  2040  0.11  2060  0.11  1920  0.10    S.D.  1521  0.08  1394  0.08  2125  0.12  Mean  4626  0.25  4163  0.23  4725  0.26    S.D.  2290  0.12  1655  0.09  2368  0.13	ELEMENT:  Zirconium -50  LINE:  B  ELEMENT:  Zirconium -50  LINE:  C    Site  ppm  K  ppm  K  ppm  K  Site  ppm  K  ppm  LINE:  C  16.0  11  15.0
ELEMENT:    Iron -50    LINE: B -50/+80    LINE: B -80    -50/+80    LINE: C -80      Site    ppm    K    ppm    K    Site    ppm    K	$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$
P  2  410  0.04  2  520  0.04  P  3  920  0.06  3  800  0.06  3  410  0.05    Q  2  860  0.05  2  880  0.05  3  240  0.05  Q  4  470  0.07  5  680  0.09  4  560  0.06    R  2  850  0.05  2  500  0.04  2  620  0.04  R  5  790  0.09  6  050  0.10  5  540  0.09    S  2  730  0.04  2  800  0.05  3  090  0.05  S  5  420  0.09  4  800  0.08  5  420  0.09    T  2  810  0.05  2  630  0.04  2  940  0.05  T  4  130  0.07  4  480  0.07  4  490  0.07    T  2  803  0.08  4  489  0.07  <	P  164  0.03  171  0.03  210  0.03  P  366  0.06  424  0.07  368  0.06    Q  370  0.06  404  0.06  464  0.07  Q  526  0.08  648  0.10  554  0.09    R  310  0.05  272  0.04  298  0.05  R  742  0.12  680  0.11  712  0.11    S  304  0.05  242  0.05  330  0.05  S  636  0.10  564  0.09  646  0.10    T  300  0.05  242  0.04  326  0.05  T  550  0.09  512  0.08  566  0.09    U  280  0.04  290  0.05  254  0.04    Mean  710.7  0.11  509.9  0.08  789.5  0.13  0.12  Mean  1141  0.18  923.7  0.15  1230  0.20    S.D.  591.1  0.09  406.1  0.06  66	ELEMENT:  Vanadium -50  -50/+80  LINE: B -80  ELEMENT:  Vanadium -50  -50/+80  LINE: C -80    Site ppm  K  ppm  K  ppm  K  Site ppm  K  ppm  LINE: C  1.1  1.1  1.1
ELEMENT:  Calcium -50  LINE: B -50/+80  LINE: B -80  ELEMENT:  Calcium -50  -50/+80  LINE: C -80    Site  ppm  K  ppm  Sido  0.14  Sido	ELEMENT:    Phosphorus -50    LINE: B -50    ELEMENT:    Phosphorus -50    LINE: C -50    LINE: C -50      Site    ppm    K    pp <td< td=""><td>J 10.8 0.08 7.0 0.05 12.5 0.09 J 43.1 0.32 34.7 0.26 49.4 0.36 K 30.4 0.22 28.1 0.21 35.0 0.26 K 35.7 0.26 25.0 0.18 36.9 0.27 L 11.8 0.09 12.0 0.09 12.4 0.09 L 34.8 0.26 33.7 0.25 38.7 0.28 M 8.4 0.06 8.6 0.06 8.5 0.06 M 35.4 0.26 32.6 0.24 38.4 0.28 N 45.8 0.34 35.6 0.26 47.2 0.35 N 37.8 0.28 29.1 0.21 39.6 0.29 O 17.4 0.13 12.9 0.09 18.4 0.14 O 9.0 0.07 10.4 0.08 9.4 0.07 P 6.4 0.05 6.3 0.05 7.1 0.05 P 10.1 0.07 10.9 0.08 9.8 0.07 Q 8.7 0.06 8.4 0.06 10.1 0.08 O 12.5 0.09 14.8 0.11 13.1 0.10 R 8.4 0.06 7.4 0.05 8.1 0.06 R 15.6 0.11 15.5 0.11 13.1 0.10 R 8.4 0.06 7.4 0.05 9.1 0.07 S 15.1 0.11 13.2 0.10 14.8 0.11 T 8.5 0.06 7.4 0.05 9.1 0.07 T 11.4 0.08 11.3 0.08 11.4 0.08 Mean 15.89 0.12 12.96 0.10 16.75 0.12 S.D. 10.87 0.08 8.03 0.06 11.11 0.08 Mean 25.48 0.19 22.92 0.17 27.04 0.20 S.D. 12.20 0.09 10.15 0.08 14.30 0.11</td></td<>	J 10.8 0.08 7.0 0.05 12.5 0.09 J 43.1 0.32 34.7 0.26 49.4 0.36 K 30.4 0.22 28.1 0.21 35.0 0.26 K 35.7 0.26 25.0 0.18 36.9 0.27 L 11.8 0.09 12.0 0.09 12.4 0.09 L 34.8 0.26 33.7 0.25 38.7 0.28 M 8.4 0.06 8.6 0.06 8.5 0.06 M 35.4 0.26 32.6 0.24 38.4 0.28 N 45.8 0.34 35.6 0.26 47.2 0.35 N 37.8 0.28 29.1 0.21 39.6 0.29 O 17.4 0.13 12.9 0.09 18.4 0.14 O 9.0 0.07 10.4 0.08 9.4 0.07 P 6.4 0.05 6.3 0.05 7.1 0.05 P 10.1 0.07 10.9 0.08 9.8 0.07 Q 8.7 0.06 8.4 0.06 10.1 0.08 O 12.5 0.09 14.8 0.11 13.1 0.10 R 8.4 0.06 7.4 0.05 8.1 0.06 R 15.6 0.11 15.5 0.11 13.1 0.10 R 8.4 0.06 7.4 0.05 9.1 0.07 S 15.1 0.11 13.2 0.10 14.8 0.11 T 8.5 0.06 7.4 0.05 9.1 0.07 T 11.4 0.08 11.3 0.08 11.4 0.08 Mean 15.89 0.12 12.96 0.10 16.75 0.12 S.D. 10.87 0.08 8.03 0.06 11.11 0.08 Mean 25.48 0.19 22.92 0.17 27.04 0.20 S.D. 12.20 0.09 10.15 0.08 14.30 0.11
K  5500  0.12  6420  0.14  5600  0.12  K  13 300  0.29  12 100  0.26  13 500  0.29    L  3790  0.08  4000  0.09  3680  0.08  L  10 800  0.23  10 600  0.23  11 600  0.25    M  4880  0.10  4760  0.10  M  7 660  0.16  7 080  0.15  8 420  0.18    N  8620  0.18  7460  0.16  9820  0.21  N  14 600  0.31  14 300  0.31  15 300  0.33    O  2260  0.05  2360  0.06  3230  0.07  P  22 600  0.48  23 000  0.49  24 000  0.52    P  3130  0.07  3000  0.16  6520  0.14  Q  18 100  0.39  17 500  0.38  18 600  0.49  23 300  0.50    Q  7020  0.15  6800  0.16  7 900  0.38  18 600  0.49  28 300  0.61	K  840  0.75  820  0.73  710  0.63  K  880  0.79  900  0.80  900  0.80    L  850  0.76  790  0.71  870  0.78  L  1270  1.13  1450  1.29  1160  1.04    M  740  0.66  710  0.63  720  0.64  M  1050  0.94  1300  1.16  1.04  1.04    M  740  0.63  850  0.76  460  0.41  N  570  0.51  840  0.75  580  0.52    O  1200  1.07  1110  0.99  1160  1.04  0  1290  1.15  1370  1.22  1330  1.19    P  560  0.50  550  0.49  590  0.53  P  950  0.85  960  0.86  930  0.83    Q  570  0.51  610  0.54  S  850  0.76  870  0.78  800  0.71    S  580  <	$ \begin{array}{c c c c c c c c c c c c c c c c c c c $
ELEMENT:  Magnesium -50  LINE: B -50  ELEMENT:  Magnesium -50  LINE: C -50    Site  ppm  K  ppm  K  Site  ppm  K  ppm  K    A  680  0.025  722  0.026  748  0.027  A  2460  0.089  2240  0.081  2480  0.090    B  500  0.018  499  0.018  576  0.021  B  1330  0.048  1410  0.051  1240  0.045    C  720  0.026  818  0.030  1020  0.037  C  1620  0.055  1520  0.055  1750  0.063    D  1280  0.046  462  0.017  1340  0.048  D  1370  0.050  1050  0.038  1290  0.047	ELEMENT:  Manganese -50  LINE: B -50/+80  ELEMENT:  Manganese -50  -50/+80  LINE: C -80    Site  ppm  K  ppm  K  Site  ppm  K  ppm </td <td><math display="block"> \begin{array}{cccccccccccccccccccccccccccccccccccc</math></td>	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$
E 850 0.031 764 0.028 804 0.029 E 3000 0.109 2720 0.098 3600 0.130 F 2720 0.098 1990 0.072 2660 0.096 F 1390 0.050 1400 0.051 1430 0.052 G 1060 0.038 886 0.032 1150 0.042 G 2120 0.077 1890 0.068 2320 0.084 H 1050 0.038 848 0.031 1180 0.043 H 2620 0.095 2320 0.084 2480 0.090 I 1440 0.052 1370 0.050 1400 0.051 I 2320 0.084 2180 0.079 2340 0.085 J 762 0.028 592 0.021 814 0.029 J 3720 0.135 3300 0.119 4040 0.146 K 1150 0.042 1130 0.041 1148 0.023 H 2480 0.030 2760 0.100 3740 0.135 L 648 0.023 640 0.023 672 0.024 L 3080 0.111 2780 0.101 3340 0.121 M 658 0.024 676 0.024 644 0.023 M 2480 0.090 2120 0.077 2700 0.098 N 2220 0.080 1780 0.066 1700 0.062 0 1160 0.042 1290 0.047 1200 0.043 P 806 0.029 808 0.029 834 0.030 P 1170 0.042 1290 0.047 1200 0.043 C 1090 0.039 832 0.030 860 0.031 C 1380 0.050 1490 0.054 1400 0.051 R 510 0.018 438 0.016 467 0.017 R 1640 0.059 1660 0.066 1640 0.059 S 944 0.033 919.1 0.033 1111 0.040 K 1151 0.038 919.1 0.033 1111 0.040 Mean 1051 0.038 919.1 0.033 1111 0.040 S.D. 560 0.020 434.0 0.016 602 0.022 Mean 2096 0.076 1907 0.069 2194 0.079 S.D. 822 0.030 610 0.022 939 0.034	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$	ELEMENT: Nickel -50  LINE: B -50/+80  LINE: B -80  ELEMENT: Nickel -50  -50/+80  LINE: C -80    Site ppm  K  ppm
ELEMENT:  Sodium -50  LINE: B -50/+80  LINE: B -80  ELEMENT:  Sodium -50  -50/+80  LINE: C -80    Site  ppm  K  ppm  K  ppm  K  ppm  K  ppm  K    A  1  100  0.05  1  1010  0.04  A  7  720  0.34  6  040  0.27  9  420  0.41    B  830  0.04  770  0.03  780  0.03  B  1  480  0.07  1  620  0.07  1  370  0.06    C  1  200  0.05  1  480  0.07  1  620  0.07  1  370  0.06    C  1  200  0.05  1  410  0.06  2  290  0.13  C  7  500  0.33  4  350  0.19  8  200  0.36  0.15    D  5  740  0.25  1  300  0.06  6  620  0.29  D  3  860	$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	S.D.  1.9  0.02  4.1  0.04  4.9  0.05  Mean  8.9  0.09  8.0  0.08  11.8  0.12    S.D.  1.9  0.02  4.1  0.04  4.9  0.05  Mean  8.9  0.09  8.0  0.08  11.8  0.12    ELEMENT:  Zinc  5.9  0.06  6.4  0.06  5.4  0.06    ELEMENT:  Zinc  -50  -50/+80  LINE: C  -50  -50/+80  LINE: C    Site  ppm  K  ppm  K  Site  ppm  K  ppm  K    A  70  0.92  71  0.93  72  0.95  A  256  3.37  306  4.03  234  3.08    B  70  0.92  65  0.86  66  0.87  B  132  1.74  126  1.66  126  1.66
1  2  580  0.11  1  1  8  700  0.33  6  240  0.27  9  260  0.41    J  1  820  0.08  710  0.03  2  100  0.09  J  13  100  0.52  13  100  0.58    K  6  640  0.28  7  840  0.35  7  520  0.33  K  9  140  0.40  8  200  0.36  9  600  0.42    L  3  110  0.14  3  920  0.17  3  160  0.05  M  8  400  0.37  5  800  0.26  9  520  0.42    N  8  640  0.38  6  260  0.28  11  500  0.51  N  11  800  0.52  8  440  0.37  12  600  0.56    0  3  890  0.11  1  100  0.05  P  890  0.04  980  0.04  860	J 310 0.79 270 0.69 310 0.79 1 070 1.44 470 1.54 730 1.87 J 170 0.44 150 0.38 200 0.51 J 560 1.44 470 1.21 540 1.38 K 360 0.92 330 0.85 350 0.90 K 420 1.08 360 0.92 540 1.38 L 210 0.54 200 0.51 230 0.59 L 620 1.59 470 1.21 220 0.56 M 190 0.49 200 0.51 190 0.49 M 630 1.61 430 1.10 650 1.67 N 320 0.82 290 0.74 390 1.00 N 530 1.36 420 1.08 540 1.38 O 180 0.46 120 0.31 190 0.49 O 210 0.54 220 0.56 210 0.54 P 150 0.38 140 0.36 P 150 0.38 170 0.44 160 0.41 Q 130 0.33 150 0.38 170 0.44 R 260 0.67 260 0.67 310 0.79 S 110 0.28 130 0.33 120 0.31 S 260 0.67 260 0.67 290 0.74 T 130 0.33 130 0.33 130 0.33 T 270 0.69 250 0.64 290 0.74 Mean 217.5 0.56 206.5 0.53 235.0 0.60 S.D. 85.0 0.22 79.2 0.20 95.0 0.24 Mean 402 1.03 364 0.93 405 1.04 S.D. 177 0.45 144 0.37 188 0.48	C  70  0.92  77  1.01  05  0.86  C  116  1.33  135  1.76  103  1.35    E  70  0.92  72  0.95  74  0.97  E  244  3.21  264  3.47  225  2.96    F  70  0.92  85  1.12  69  0.91  F  804  10.58  792  10.42  794  10.45    G  55  0.72  51  0.67  G  404  5.32  486  6.39  344  4.53    H  64  0.84  62  0.82  61  0.80  H  720  9.47  896  11.79  670  8.82    I  198  2.61  213  2.80  203  2.67  I  1290  16.97  2420  31.84  1380  18.16    J  96  1.26  106  1.39  97  1.28  J  704  9.26  884  11.63  735  9.67    K  72  0.95
Quality control data listings		ELEMENT: Copper -50  -50/+80  LINE: B -80  ELEMENT: Copper -50  -50/+80  LINE: C -80    Site <ppm< td="">  K<ppm< td="">  K<ppm< td="">  K  ppm  K  site<ppm< td="">  K<ppm< td="">  K  ppm  K    A  11.6  0.17  10.1  0.15  15.1  0.22  A  12.7  0.19  14.4  0.21  10.9  0.16    B  13.0  0.19  12.8  0.19  14.4  0.21  B  19.4  0.29  20.1  0.30  23.0  0.34    C  17.7  0.26  17.1  0.25  22.4  0.33  C  13.1  0.19  15.5  0.23  12.2  0.19    D  9.2  0.14  4.0  0.06  9.1  0.13  D  17.4  0.26  18.1  0.27  16.8  0.25    E  10.6  0.16  10.3  0.15  11.3  0.17  E  73.7  1.08  74.9  1.10  74.4  1.09    F  9.1  0.13  10.4  0.15  10.5</ppm<></ppm<></ppm<></ppm<></ppm<>
$ \begin{array}{c c c c c c c c c c c c c c c c c c c $	La  Co  Sc  Pb  Th  Hf  Br  U  Be  As  Mo  Lu  Sb  Ag  Au  LOI    12.2  8.0  4.23  30  3.2  3.7  15.0  0.7  0.38  6.6  <0.5	H10.20.1510.20.1511.80.17H17.30.2521.90.3218.40.27I16.10.2414.70.2217.10.25I24.20.3623.60.3519.80.29J17.60.2611.20.1614.10.21J19.00.2817.70.2621.90.32K9.20.149.10.139.10.13K29.60.4424.10.3530.10.44L12.30.1811.60.1713.40.20L29.10.4331.20.4629.40.43M8.10.128.70.1310.30.15M21.20.3122.30.3322.30.33N9.70.1411.40.1710.30.15N11.30.1714.90.2211.00.16O12.60.1912.00.1813.20.19O24.80.3626.50.3928.60.42P9.10.138.50.139.90.15P18.00.2618.10.2718.10.27Q8.70.138.40.129.50.14Q16.30.2416.90.2516.80.25R11.30.1710.90.1613.80.20R18.60.2719.60.2918.20.27S
$\begin{array}{c} \textbf{s.d.} & \textbf{6.76} & \textbf{2.82} & \textbf{3.11} & \textbf{1.34} & \textbf{7.5} & \textbf{10.3} & \textbf{14.0} & \textbf{7.8} & \textbf{5.6} & \textbf{5.6} & \textbf{5.6} & \textbf{3.2} & \textbf{2.77} & \textbf{14.2} & \textbf{5.7} & \textbf{5.4} & \textbf{9.6} & \textbf{4.8} & \textbf{5.2} \\ \textbf{c.v.} & \textbf{3.2} & \textbf{3.1} & \textbf{3.4} & \textbf{7.5} & \textbf{10.3} & \textbf{14.0} & \textbf{7.8} & \textbf{5.6} & \textbf{5.6} & \textbf{8.2} & \textbf{2.7} & \textbf{14.2} & \textbf{5.7} & \textbf{5.4} & \textbf{9.6} & \textbf{4.8} & \textbf{5.2} \\ \textbf{509} & \textbf{22} & \textbf{300} & \textbf{9} & \textbf{800} & \textbf{10} & \textbf{800} & \textbf{1980} & \textbf{5640} & \textbf{5090} & \textbf{1010} & \textbf{930} & \textbf{2090} & \textbf{310} & \textbf{96.9} & \textbf{34} & \textbf{23.7} & \textbf{19.7} & \textbf{11} & \textbf{496} & \textbf{18.3} \\ \textbf{520} & \textbf{14} & \textbf{700} & \textbf{7} & \textbf{210} & \textbf{10} & \textbf{000} & \textbf{1460} & \textbf{3150} & \textbf{3400} & \textbf{748} & \textbf{1000} & \textbf{1780} & \textbf{-} & \textbf{68.1} & \textbf{25} & \textbf{16.7} & \textbf{12.2} & \textbf{10} & \textbf{457} & \textbf{18.2} \\ \textbf{533} & \textbf{16} & \textbf{400} & \textbf{8} & \textbf{670} & \textbf{10} & \textbf{500} & \textbf{1670} & \textbf{3530} & \textbf{3820} & \textbf{798} & \textbf{1050} & \textbf{1980} & \textbf{350} & \textbf{73.7} & \textbf{40} & \textbf{19.6} & \textbf{15.8} & \textbf{11} & \textbf{441} & \textbf{18.7} \\ \textbf{549} & \textbf{16} & \textbf{400} & \textbf{8} & \textbf{490} & \textbf{10} & \textbf{500} & \textbf{1700} & \textbf{3690} & \textbf{3510} & \textbf{900} & \textbf{980} & \textbf{1890} & \textbf{360} & \textbf{75.7} & \textbf{25} & \textbf{21.0} & \textbf{16.5} & \textbf{11} & \textbf{477} & \textbf{18.0} \\ \textbf{563} & \textbf{14} & \textbf{500} & \textbf{7} & \textbf{750} & \textbf{10} & \textbf{200} & \textbf{1600} & \textbf{3310} & \textbf{3890} & \textbf{898} & \textbf{970} & \textbf{2180} & \textbf{360} & \textbf{72.9} & \textbf{28} & \textbf{18.6} & \textbf{16.7} & \textbf{11} & \textbf{431} & \textbf{18.7} \\ \textbf{590} & \textbf{15} & \textbf{700} & \textbf{7} & \textbf{590} & \textbf{9} & \textbf{970} & \textbf{1550} & \textbf{3500} & \textbf{3800} & \textbf{860} & \textbf{360} & \textbf{68.9} & \textbf{28} & \textbf{17.9} & \textbf{17.0} & \textbf{11} & \textbf{410} & \textbf{17.6} \\ \textbf{607} & \textbf{17} & \textbf{700} & \textbf{8} & \textbf{900} & \textbf{10} & \textbf{200} & \textbf{1700} & \textbf{4210} & \textbf{4260} & \textbf{854} & \textbf{950} & \textbf{1830} & \textbf{320} & \textbf{79.5} & \textbf{28} & \textbf{18.8} & \textbf{17.8} & \textbf{11} & \textbf{573} & \textbf{17.4} \\ \textbf{621} & \textbf{16} & \textbf{100} & \textbf{7} & \textbf{790} & \textbf{9} & \textbf{860} & \textbf{1590} & \textbf{370} & \textbf{75.3} & \textbf{30} & \textbf{18.4} & \textbf{18.1} & \textbf{10} & \textbf{445} & \textbf{19.3} \\ \textbf{638} & \textbf{16} & \textbf{300} & \textbf{8} & \textbf{01} & \textbf{10} & \textbf{10} & \textbf{170} & \textbf{3520} & \textbf{3520} & \textbf{3520} & \textbf{3520} & \textbf{350} & \textbf{75.3} & \textbf{30} & \textbf{18.4} & \textbf{18.1} & \textbf{10} & \textbf{445} & \textbf{17.8} & \textbf{11} \\ \textbf{638} & \textbf{16} & \textbf{300} & \textbf{8} & 0$	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	ELEMENT: Lanthanum  LINE: B  ELEMENT: Lanthanum  LINE: C    -50  -50/+80  -80  ELEMENT: Lanthanum  -50/+80  ELINE: C    Site ppm  K  ppm  K  Site ppm  K  ppm
s.d.  2 163  756  325  146  717  575  78.3  31.4  131  34.1  8.27  4.5  2.27  2.88  0.8  46.7  0.66    c.v.  13.1  9.5  3.2  146  717  575  78.3  31.4  131  34.1  18.27  4.5  2.27  2.88  0.8  46.7  0.66    c.v.  13.1  9.5  3.22  160  10.0  11.1  15.4  12.2  18.0  7.8  10.2  3.3    -80  505  25  000  10  600  11  300  2280  7260  6450  1310  870  1630  390  113.0  68  31.2  23.9  12  466  19.0    512  23  400  950  11  200  2600  6405  5760  1310  840  1610  370  110.0  54  26.1  21.6  11  396  19.9    538  24  900  10  100  1200  5760  1320	$\begin{array}{cccccccccccccccccccccccccccccccccccc$	$ \begin{array}{cccccccccccccccccccccccccccccccccccc$

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$\begin{array}{c c c c c c c c c c c c c c c c c c c $	ELEMENT: Gold -50    -50/+80    LINE: B -80    ELEMENT: Gold -50    -50/+80    LINE: C -80      Site ppb    K    ppb    K    ppb    K    Site ppb    K    ppb
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$	ELEMENT: Loss on Ignition $-50$ LINE: BELEMENT: Loss on Ignition $-50$ LINE: CSite%%Site%%A88.690.089.0A48.859.539.9B91.491.890.8B78.076.477.1C87.987.582.7CC52.266.143.3D49.571.745.1D75.081.874.2F54.867.349.4F77.482.275.8G83.787.278.6G56.9680.044.6H75.381.171.0H46.558.046.5I80.483.378.5I42.256.637.1J83.291.381.6J22.528.826.9K53.659.143.0K48.655.846.9L81.582.382.1L54.661.450.8M89.590.288.2M43.153.037.4O74.381.972.7O084.983.285.4P92.592.891.9P85.685.386.3O83.086.5O81.972.187.6S92.292.691.3S78.181.379.9T91.993.191.2T <t< td=""></t<>
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