A Provisional Geochemical Exploration Model (GEM) for the Sappho Property, B.C. (82E/2E)

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INTRODUCTION

This paper describes an orientation survey on the Sappho mineral property, Greenwood, (MINFILE 82ESE 147) to study the geochemical response of platinum group elements (PGE) and associated metals from massive sulphide mineralization in soil, stream sediment and vegetation (Figure 1). The survey is a contribution to a multi-disciplinary initiative to better understand the occurrence and means of discovering PGE mineralization in B.C. (Nixon, 2002). Results of stream sediment, B and C-horizon soil, basal till and vegetation sampling have been integrated with data from assessment reports and other sources to develop a geochemical exploration model (GEM).

GEM's are designed to simplify data interpretation by visually demonstrating the relationship between bedrock and surficial geochemistry. They are based on a series of conceptual, three-dimensional models first proposed by Bradshaw (1974) for the Canadian Cordillera and later modified by Kauranne (1976), Lovering and McCarthy (1978) and Butt and Smith (1980). The models are formulated from existing geochemical data rather than being based on purely conceptual considerations and can therefore be used with more confidence when designing future surveys.

Several diagrams were used by Bradshaw (1975) to construct the conceptual models. Broad, spatial, element variations were summarized on three-dimensional block diagrams whereas more detailed horizontal and vertical geochemical changes were shown on cross sections and prisms. The diagrams have no scale because geochemical anomaly size is variable and the models were intended primarily to show geochemical relationships and to identify dispersion processes in the near-surface environment. However, anomaly dimensions can be predicted by linking the conceptual models to the supporting data gathered from geochemical case studies and orientation surveys. These predictions can be used when planning geochemical surveys to help, for example, in selecting the appropriate sample type and sampling density.

In this paper a GEM has been developed to summarize important features of the geochemical expression associated with PGE-copper-nickel sulphide mineralization found on the Sappho property. Bedrock geology and sulphide mineralization, surficial deposits (soil, till, etc.) and surface drainage are displayed three-dimensionally by a series of stacked, block diagrams. These diagrams are linked to series of geochemical landscape layers showing the observed geochemical expression of mineralization from the bedrock interface into the surficial deposits and vegetation. Ice-flow direction and the projected expression of mineralization at the bedrock surface onto the surficial layers are also shown on the diagrams.

SAMPLING AND ANALYTICAL METHODS

B and C-horizon soil samples were collected from pits dug at eight stations approximately 100 m apart along a traverse extending north from the international boundary to the Main showing on the Sappho property. Duplicate soil samples were taken at one site to measure sampling variability. Douglas-fir (*Pseudotsuga menziesii*) bark samples were also taken at each station by one of the authors (CD). Basal

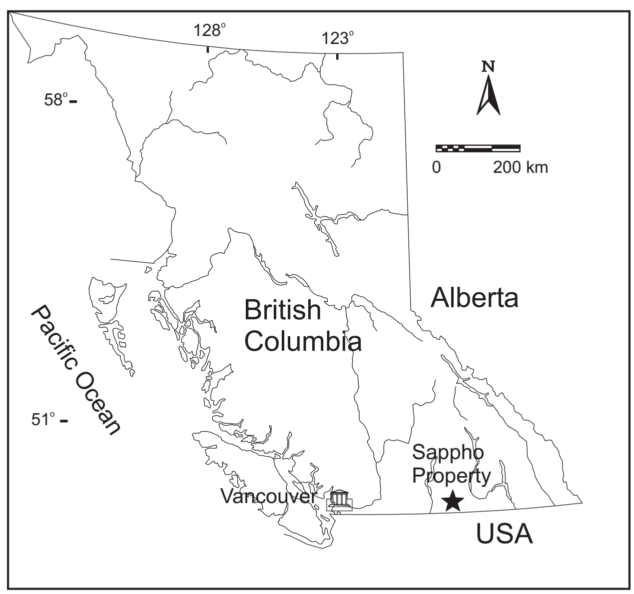

Figure 1. Location of the Sappho Property.

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till samples were collected at three sites where thick tills were exposed in trenches (Figure 2). Stream sediment and moss mat sediment samples were collected from the north-flowing Norwegian Creek (Figure 2).

Up to 5 kg of fine-textured sediment, typical of material collected during a regional survey, was taken from the sandy part of a bar in Norwegian Creek, and stored in high wet strength Kraft paper bags. Live moss (1-2 kg) containing trapped sediment, collected from the surface of boulders and logs in the active stream above the water level, was also stored in Kraft bags. Sampling was carried out on June 27 and 28, 2001. Locations of soil, tree bark, stream and moss mat sampling stations are shown in Figure 2. Rock samples were taken from the main showing during geological mapping (Nixon, 2002).

Soil, drainage sediment, moss mat sediment, till and rock samples were prepared in the B.C. Geological Survey Branch Laboratory, Victoria, B.C. The samples were air dried and the - 18 mesh (< 1 mm) recovered by gently disagregating the sediment or by pounding moss mats before dry sieving through a 1 mm stainless steel screen. One part of the 1 mm fraction was then screened to - 80 ASTM mesh (<0.177 mm) and a second part screened to - 230 mesh (<0.063mm). Control reference material and analytical duplicates were inserted into the batch of samples sent for analysis.

The – 80 and –230 mesh of stream sediment and moss mat sediment, tree bark ash, till and soil samples, and the – 150 mesh of milled rock samples were analysed for 37 trace and minor elements by inductively coupled plasma mass spectroscopy (ICP-MS) and inductively coupled plasma emission spectroscopy (ICP-ES) following aqua regia digestion. Platinum, palladium, gold and rhodium in the two fractions of the field survey samples and in the milled rock samples were also determined by ICP-MS following lead fire assay. The samples were analysed by Acme Analytical Laboratories Ltd. (Vancouver).

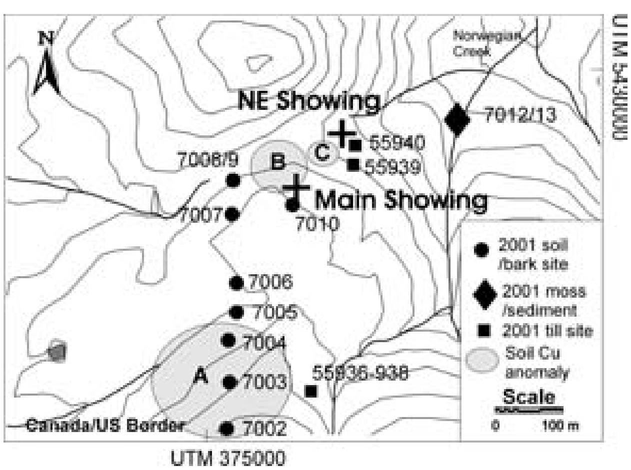

Figure 2. Soil and sediment sample sites and outline of copper anomalies (>90 ppm) from assessment report data (Keating and Fyles, 1984).

COMPILATION OF DATA FOR GEM DEVELOPMENT

Geological and geochemical data from assessment files (Keating and Fyles, 1984) and from results of the orientation survey have been used to formulate a GEM for the Sappho property. This information is briefly summarized:

GEOLOGY

The central part of the property where the orientation survey was carried out is underlain by Jurrassic age greenstone that has been intruded by Tertiary age microdiorite and younger cross-cutting syenomonzonite-shonkinite bodies. These intrusions are the principal hosts for the sulphide mineralization (Keating and Fyles, 1984; Nixon, 2002).

MINERALIZATION

The principal sulphide mineral occurrences on the Sappho property are the Main and Northeast showings where the microdiorite has massive lenses and disseminations of pyrite and chalcopyrite. Grades up to 3.2 per cent copper and 0.9 grams per tonne platinum in grab samples of the suphides have been reported (Keating and Fyles, 1984; Nixon, 2002).

DESCRIPTION OF THE AREA

The Main and Northeast sulphide showings are located on a northeast-facing, moderately steep (20^{o}) hill side that extends for 700 m from the Canada/USA boundary. The property has a maximum elevation of 1125 m and is drained by Norwegian Creek and several smaller creeks. The climate is semi-arid. Bedrock exposure is roughly 10 percent. Surficial sediments are basal till deposited over most of the property, colluvium and colluviated till on steeper hill slopes. Loess and organic accumulations occur in flatter part of the property and in depressions. The regional ice flow direction is southerly. The surficial sediments have been disturbed by road construction and by trenching in some areas. Brunisolic, luvisolic and organic soils have formed on these sediments and support second growth ponderosa pine, Douglas-fir (*Pseudotsuga menziesii*) and birch between patches of open grassland.

SOIL GEOCHEMISTRY

B-soil horizon survey results from assessment reports (Keating and Fyles, 1984) outlined three copper (determined by atomic absorption spectroscopy following nitric-perchloric acid digestion) anomalies (> 90 ppm) on the property (Figure 2). The first anomaly (A) 200 x 300 m size is 500 m south of the main showings and extends to the Canada/USA boundary. The anomaly trends northerly and soils contain up to 270 ppm copper. A second anomaly (B) 150 m by 200 m is centred over the Main showing and a third anomaly (C) 200 m northeast of the main showing is 100 m x 100 m size with up to 280 ppm copper in the soil. Zinc (> 80 ppm) and lead (> 13 ppm) anomalies are smaller than copper and there is a weak spatial correlation between the copper, lead and zinc. Gold values in the B-horizon soil are below 10 ppb.

Results of the 2001 orientation survey reveal an association of platinum, palladium, nickel, gold and copper in B and C-horizon soils. The variation of elements in the B-soil horizon from south to north towards the Main showing (Figure 3) indicates that platinum, palladium, gold, copper and nickel gradually decrease from higher values close to the Canada/USA boundary and then increase over the Main zone sulphide mineralization. Platinum, platinum and gold are generally (but not consistently) higher in the -230 mesh (<0.063 mm) size fraction compared to the - 80 (<0.18 mm) fraction of the soil (Figure 4). Element values for the two size fractions of soil samples from station 10, close to the Main showing, are shown in Table 1. These data demonstrate an association of elevated copper, chromium, manganese, nickel, vanadium, zinc, platinum, palladium and gold in the B and C soil horizons. Values for all elements increase with depth in the soil profile and are similar in the two size fractions. However, anomaly thresholds for elements in the soil cannot be determined because of the small number of samples.

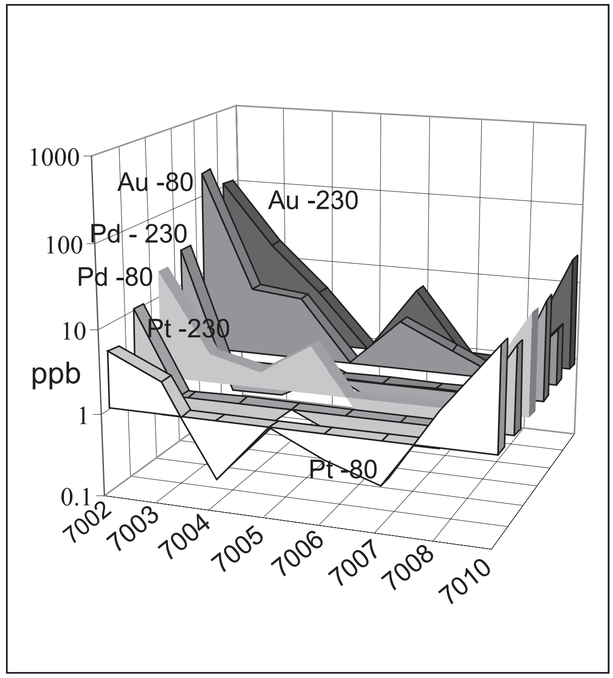

Figure 4. Gold, silver and platinum in -80 and -230 mesh fraction of the B-C soil horizons across the Sappho property.

STREAM SEDIMENT GEOCHEMISTRY

Samples from a previous regional geochemical survey (Matysek *et al.*, 1991) covering the Sappho property have not been analysed for platinum and palladium. In Table 2, the 95th percentile values are shown for elements commonly found associated with platinum and palladium (Au, As, Cu, Co, Cr, Ni, Zn), calculated from RGS data for 1500 samples from NTS 82E. The geochemistry of the Norwegian Creek RGS sample (82E765134), shown for comparison, indicates that nickel is the only element above the 95th percentile. Element data for the -80 (<0.180 mm) and -230 (<0.063 mm) mesh size fractions of moss sediment (M) and stream sediment (S) 2001 orientation survey samples from

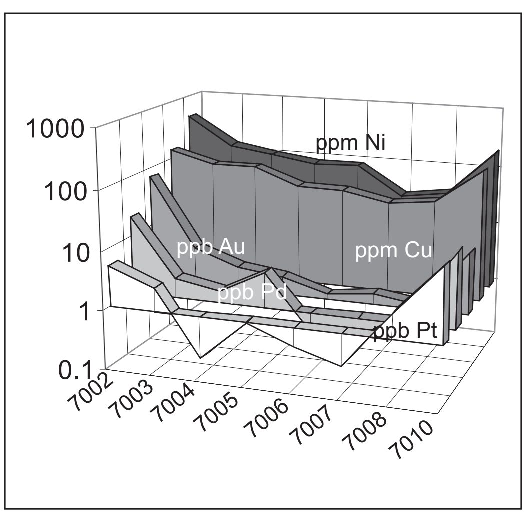

Figure 3. Elements in B-horizon soil (- 80 mesh fraction) across the Sappho property.

TABLE 1
GEOCHEMISTRY OF SOIL CLOSE TO THE MAIN SHOWING AT 25 AND 35 CM DEPTH AND IN THE -80 AND -230 MESH FRACTIONS

Sample		55925	55926	55927	55928
Depth		25 cm	25 cm	35 cm	35 cm
Fraction		-80 mesh	-230 mesh	-80 mesh	-230 mesh
Ag-MS	ppb	200	218	255	376
As-MS	ppm	3.5	3.6	4.3	5.3
Au-MS	ppb	4.9	7	10.6	15.3
Au-FA	ppb	5	8	5	25
Co-MS	ppm	27.1	22.1	48.7	41.9
Cr-MS	ppm	162.5	135.1	294.2	269.6
Cu-MS	ppm	163.7	168.0	210.6	247.2
Fe-MS	%	4.19	3.36	7.36	6.13
Hg-MS	ppb	23	22	22	44
La-MS	ppm	19.4	20.6	22.7	26.9
Mg-MS	%	1.87	1.45	3.59	3.03
Mn-MS	ppm	3305	3154	4524	5525
Ni-MS	ppm	101.0	90.1	152.8	133.9
Pd-FA	ppb	9.9	7.2	17.8	16.9
Pt-FA	ppb	6.6	6.4	17.6	11.2
S-MS	%	0.04	0.05	0.04	0.06
Se-MS	ppm	< .1	0.2	< .1	0.1
V-MS	ppm	155	121	299	265
Zn-MS	ppm	172.6	134.7	384.0	316.2

TABLE 2
95 PERCENTILE VALUES FOR ELEMENTS COMMONLY FOUND ASSOCIATED WITH PLATINUM AND PALLADIUM CALCULATED FROM 1500 RGS SAMPLES FROM NTS 82E COMPARED TO DATA FROM ONE RGS SITE (82E765184) ON THE SAPPHO PROPERTY

Element	Au	As	Cu	Co	Cr	Fe	Ni	Pb	Zn
Units	ppb	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm
Method	INAA	INAA	AAS	INAA	INAA	INAA	AAS	AAS	AAS
95^{th} Percentile	31	13.0	58	25	260	6.4	21	21	103
82E765134	11	7.1	24	14	220	3.9	25	2	40

Norwegian Creek are shown in Table 3. Results show that whereas arsenic, copper, cobalt, chromium, iron, nickel, lead and zinc are highest in the -230 mesh size fraction of moss sediment, gold is highest in the -80 mesh fraction of stream sediment. Platinum and palladium are highest in the -80 mesh of moss sediment although concentrations for both elements are below 3 ppb. Higher arsenic, cobalt, chromium and iron in the RGS sample (82E765134), compared to levels found in the orientation moss and stream sediment may be the result of higher concentrations determined in the sample by instrumental neutron activation (INAA) compared to levels released by aqua regia with an ICP-MS finish.

BIOGEOCHEMISTRY

The distribution of elements in bark samples from Douglas-fir close to the soil sites along the orientation traverse are shown in Figure 5. Results are listed in Table 4. Copper and zinc are elevated in the bark at the southern end of the traverse (01-07-002). Elevated palladium (5 ppb) was also detected in the bark at this site. Elevated silver, arsenic, gold and platinum at site 01-07-006 can be explained by higher accumulation of these elements in bark from an older Douglas-fir compared to the bark from younger trees sampled at the other sites. It is noteworthy that the highest platinum (26 ppb) and copper (876) occurs in bark (01-07-010b) from a tree close to the Main showing.

TILL GEOCHEMISTRY

Results of geochemical analysis of tills sampled in the Sappho area are provided in Table 5. Samples 55936 to 38 are from a vertical profile in a pit (old collapsed adit?) in the area of soil anomaly ‘A’ (Figure 2). Soil development at the site includes about 2-3 cm of an LFH layer, a 0.5 cm Ah horizon, a 30-70 cm thick Bm horizon and a Cca horizon extending to over one m depth. The site is well drained, with an open Douglas-fir forest and a surface slope of about 10°.

Sample 55936 is from a depth of 2.5 m in a moderately dense, massive, matrix-supported diamicton interpreted as a basal till. The matrix is an unoxidized silty-sand to sandy-silt and shows a strong, slope-parallel fissility, highlighted by calcium carbonate precipitate. Clasts are of varied lithologies (*e.g.* pyroxenite, syenite, gabbro, greenstone, rhyolite and schist), and some are striated indicating glacial transport. The till contains about 20-30% clasts and most are subangular to subrounded. Several clasts with sulphide mineralization (mainly pyrite) were observed. Sample 55937 is from 70 cm depth in diamicton that gradationally overlies and is similar to the underlying unit except that it shows weaker fissility, some oxidation and a higher percentage of angular clasts. The diamicton is inferred to be a colluviated till. Sample 55938 is from 25 cm depth in pebbly, fine sand with minor silt. The sand is loose, massive, oxidized, light reddish brown, and contains about 5-10% clasts many of which are quite angular. The lower contact of this unit is gradational and occurs at about 50 cm depth. The unit is interpreted to be of colluvial origin, as indicated by the angular clasts, possibly with an aeolian component. Wind, water and/or gravity sorting of the material are indicated by the loose, fine sandy texture and by the low proportion of fines.

For almost all elements, concentrations increase significantly, with depth (Table 5). Most notably, gold and palladium concentrations are more than 10 times higher in the underlying till and about 5 times higher at 70 cm depth than they are in the B-horizon at 25 cm depth. Gold decreases from 38 ppb in the basal till to 2 ppb in the B horizon, platinum decreases from 3.5 ppb in the till to 1.6 ppb in the B-horizon and palladium decreases from 6.5 ppb in till to below detection (<0.5) in the B-horizon. The analytical duplicate of sample 55936 shows even higher platinum (4.5 ppb) and palladium (13.2 ppb) in the till. Copper, cobalt, chromium, iron and nickel also show progressively increasing concentrations with depth. Other elements show little

TABLE 3
ELEMENT DATA FOR THE -80 (<0.180 mm) AND -230 (<0.063 mm) SIZE FRACTIONS OF MOSS SEDIMENT (M) AND STREAM SEDIMENT (S) FROM 2001 ORIENTATION SURVEY SAMPLES FROM NORWEGIAN CREEK

Element	Au	As	Cu	Co	Cr	Fe	Ni	Pb	Zn	Pt	Pd
Units	ppb	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppb	ppb
Method	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	ICP-MS	FA-MS	FA-MS
5931-80S	2.3	2.7	49.9	9.6	64.5	2.03	66	5.8	52.4	0.8	2.0
5932-230S	10.3	3.0	59.9	10.5	69.8	2.05	79	6.3	57.6	0.9	1.1
5933-80M	1.6	3.7	54.0	13.8	85.8	2.46	96	7.0	61.3	2.6	2.1
5934-230M	1.6	4.0	59.8	13.8	91.3	2.56	112	7.8	66.5	0.9	1.6

TABLE 4
GEOCHEMISTRY OF DOUGLAS-FIR BARK SAMPLES FROM THE SAPPHO PROPERTY

Sample	Ag	As	Ash	Au	Cu	Ni	Pd	Pt	Se	Zn
	ppb	ppm	%	ppb	ppm	ppm	ppb	ppb	ppm	ppm
01-07-002	185	24	2.35	2.4	344	10	5	-2	2.3	1024
01-07-003	162	21	2.08	1.6	352	14	-2	-2	2.1	1511
01-07-004	188	15	2.38	2.5	265	14	6	-2	1.4	697
01-07-005	143	37	2.85	3.4	258	11	-2	-2	2	830
01-07-006	257	119	1.99	12.2	335	13	-2	-2	2.4	476
01-07-007	181	40	3.06	2.2	272	14	9	-2	1.6	906
01-07-008	190	25	3.36	2.4	245	6	-2	-2	1.3	640
01-07-010a	392	33	2.93	3.7	683	10	7	3	1.6	797
01-07-010b	370	33	2.24	4	876	15	-10	26	2.6	936
Median	188	33	2.38	2.5	335	13	2	-2	2	830

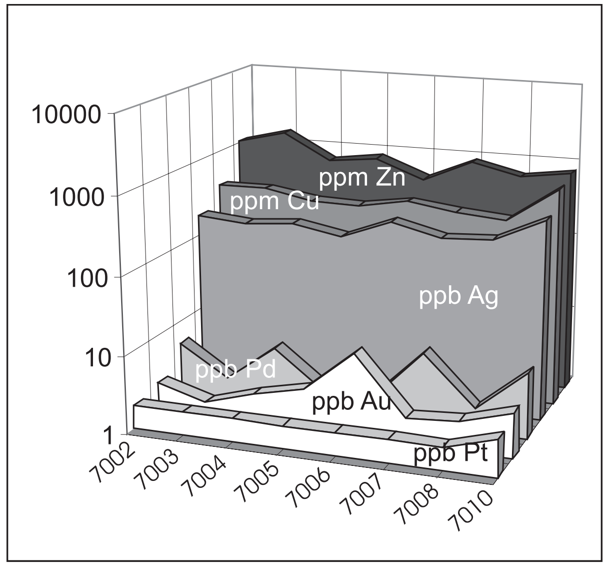

Figure 5. Geochemistry of tree bark samples from the Sappho property.

variation with depth. Only arsenic is higher in the B-horizon than in the underlying till but the difference is minimal (7.5 vs. 7.2 ppm). Lead and zinc are slightly more concentrated at intermediate depths (sample 55737, Table 5).

Decreasing element concentrations with depth have been observed in several other parts of the Cordillera and probably reflect modifying processes that are most active at the surface (Levson, 2001a, b). The downward migration of metals is probably due to post-depositional, gravity sorting and water washing of the near surface layers. The greater effect on heavy elements, such as gold and palladium, than on lighter elements is consistent with mechanisms of gravity and water sorting. In this area, the addition of windblown fine sands and silty loess may also contribute to lower metal concentrations at the surface. These observations suggest that B-horizon soil sampling in this region would be less effective for exploration than would till sampling. Although concentrations clearly increase with depth, for practical sampling purposes it is probably sufficient to sample near the top of the C-horizon.

Gold concentrations in till at the south end of the property are higher than in soils over the main showing area and other metals such as platinum, palladium and nickel show comparable levels to shallow soils at the showing (compare Tables 1 and 5). Other elements such as copper also are elevated in till at the south end of the property. This suggests that there is potential for discovery of a new mineralized zone in that area, although dispersal from the main showing has not been ruled out.

Samples 55939 and 55940 (Table 5) are from the area around the NE showing area. Sample 55939 is from till in a trench about 30 m south (down-ice and upslope) of the showing whereas sample 55940 is from colluvium about 10 m downhill of the showing. The till is similar to the lowest diamicton unit in the trench described above. It was sampled at a depth of 1.5 m below surface and is overlain by up to 50 cm of pebbly sand. The colluvium is a silty, loose to moderately dense, matrix-supported diamicton with gravelly lenses. Clasts are mostly subangular to angular, medium to large pebbles and cobbles. The diamicton shows crude, slope-parallel stratification and locally contains up to 50% clasts. It was sampled at a depth of 2 m from surface and is overlain by up to 1 m of anthropogenic fill.

Interestingly, concentrations of most elements, including copper, nickel, platinum and palladium (341 ppm, 267 ppm, 15 ppb and 27 ppb, respectively) are much higher in the till down-ice (and up-slope) of the showing than in the colluvium directly down-slope of the showing (189 ppm, 138 ppm, 10 ppb and 10 ppb, respectively). Concentrations

TABLE 5
TILL SAMPLE DATA FOR THE -230 MESH FRACTION OF SAMPLES FROM THE SAPPHO PROPERTY (SAMPLES 55936-38 FROM SOUTH END OF PROPERTY; SAMPLES 55939-40 FROM NE SHOWING AREA

Element	Depth	Au	As	Cu	Co	Cr	Fe	Ni	Pb	Zn	Pt	Pd
Units	m	ppb	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppb	ppb
55936	2.50	37.8	7.2	136.6	20.6	149.6	3.4	93.1	9.6	51.3	3.5	6.5
55937	0.70	11.6	6.6	76.2	19.9	138.5	3.3	89.3	10.5	58.5	3.1	2.1
55938	0.25	2.0	7.5	54.1	15.5	87.2	2.5	65.4	9.0	54.9	1.6	-0.5
55939	1.50	13.1	11.2	341.4	35.1	236.4	5.5	267.2	18.3	80.7	15.4	27.1
55940	2.00	52.7	14.9	189.0	27.8	189.5	4.9	138.4	26.6	68.0	10.5	10.3

of iron, zinc, cobalt and chromium are also higher in the till whereas gold, arsenic and lead are lower in the till. In addition, all element concentrations except zinc are higher in the till than they are in shallow soil samples directly over the main showing (compare Tables 1 and 5). A higher concentration of metals in till than in colluvium is unusual as tills typically reflect a much larger source area and therefore tend to have diluted metal concentrations. Relatively low levels of elements in the colluvium suggests that either the sampled material was not derived from the area of the showing or colluvial processes such as those discussed above have resulted in a significant decrease in metal concentrations in the colluvium in comparison to the original source rocks. The latter interpretation is preferred as the sample site is located directly down-slope from the mineralized zone and almost certainly is derived from it. This interpretation may also explain why elements such as gold and lead are not affected in the same way as most other elements, as variability in the colluvial processes would be expected. Although these results are limited, they suggest that tills in this area may yield higher anomaly contrasts than colluvial materials. The data also support the above conclusion that C-horizon sampling is a better approach for exploration on the property than B-horizon soil sampling.

ROCK GEOCHEMISTRY

The chemistry of sulphide-rich rock samples from the Sappho property is shown in Table 6. Elevated cadmium, cobalt, mercury, lanthanum, antimony and selenium are associated with the high copper, gold, platinum and palladium in the sulphides and can be considered as pathfinders for PGE-rich sulphides.

DEVELOPMENT OF A PROVISIONAL GEM FOR PGE MINERALIZATION IN SOUTHERN B.C.

Because exploration for PGE mineralization is currently important, and because there is very little published data for the application of geochemistry for PGE's, a provisional GEM has been developed on limited data. Regional geochemical survey (RGS), assessment file data and the results of an orientation geochemical survey are integrated to illustrate the development of a GEM for massive sulphide bearing platinum-palladium mineralization (Figure 2) in southern B.C. To date data are only available for one PGE occurrence, the Sappho property, and so the GEM must be regarded as provisional. When data are available for other occurrences this GEM can be updated. In Figure 6 three dimensional stacked block diagrams show the relationship between bedrock geology, surficial geology, soils and topography on a GEM for the Sappho property. Mineral deposits can have a distinct multi-element signature that may, to a varying degree, be reflected in the geochemistry of the overlying glacial sediments, soil, vegetation, and water and stream sediment. A copper-silver- gold-nickel-arsenic- platinum-palladium-selenium-lanthanum signature is shown on the bedrock geochemistry layer in Figure 6 because these elements are enhanced in the sulphides at the Main showing.

TABLE 6
GEOCHEMISTRY OF ROCK SAMPLES FROM THE SAPPHO PROPERTY

Sample	Units	56333	56334	56335	56336	Median
Ag-MS	ppm	56	>100	>100	>100	>100
As-MS	ppm	33.2	38.5	10.7	9.3	21.9
Au-FA	ppb	189	609	2263	1876	1243
Au-MS	ppb	156	612	1881	1609	1110
Bi-MS	ppm	1.3	2.4	1.2	1.2	1.3
Cd-MS	ppm	24.6	12.7	26.2	25.4	25
Co-MS	ppm	412	337	102	99	220
Cu-MS	ppm	69175	86734	>100000	>100000	93367
Fe-MS	%	14.56	19.72	25.35	27.09	22.54
Hg-MS	ppb	102	252	326	360	289
La-MS	ppm	140.4	193.7	57.8	49.9	99.1
Mn-MS	ppm	1967	1347	402	299	875
Ni-MS	ppm	162	255	121	102	142
Pd-FA	ppb	729	1226	934	454	834
Pd-MS	ppb	273	1455	986	528	757
Pt-FA	ppb	567	981	2018	3099	1499
Pt-MS	ppb	409	624	424	526	475
Re-MS	ppb	2	<1	2	1	2
Rh-FA	ppb	1.2	1.9	2.9	2.1	2
Sb-MS	ppm	2.4	3	4.5	5.3	3.8
Se-MS	ppm	60.1	85.1	142.8	162.4	114
S-MS	%	6.74	8.78	4.53	5.02	5.88
Zn-MS	ppm	1628	1089	1802	1729	1678

Glacial dispersal trains (DiLabio, 1990) in till are displayed on the surficial geochemistry layer in Figure 6. In the Cordillera, dispersal trains are typically a few to several km long and elongated parallel to ice-flow (Levson, 2001a). In some parts of southern British Columbia the Quaternary stratigraphy is complex and includes glacial and non-glacial deposits (Fulton and Smith, 1978; Ryder *et al.*, 1991). For this reason the GEM applies to regions where the surficial geology comprises sediments from the last glacial event. The relative magnitude and size of platinum-palladium-copper-nickel C- horizon soil anomalies are represented by shaded vertical patterns on the surficial geochemistry layer. One anomaly reflects a short dispersal down-ice (south) of the Main zone. The second anomaly, partly in colluviated till, may be a part of this dispersal train that has been displaced a greater distance down-ice and incorporated in colluvium on the north-facing hill slope. This anomaly could also be a completely separate dispersal train from a different bedrock source. Additional sampling is needed to determine which interpretation is correct. B-horizon anomalies shown on the sediment-soil layer are of similar strength but generally lower than those in the C soil horizon. A nickel-copper stream-moss sediment anomaly is also shown on the sediment soil layer although values only just exceed regional thresholds (Table 2). Low platinum, palladium and gold values in the sediment could re-

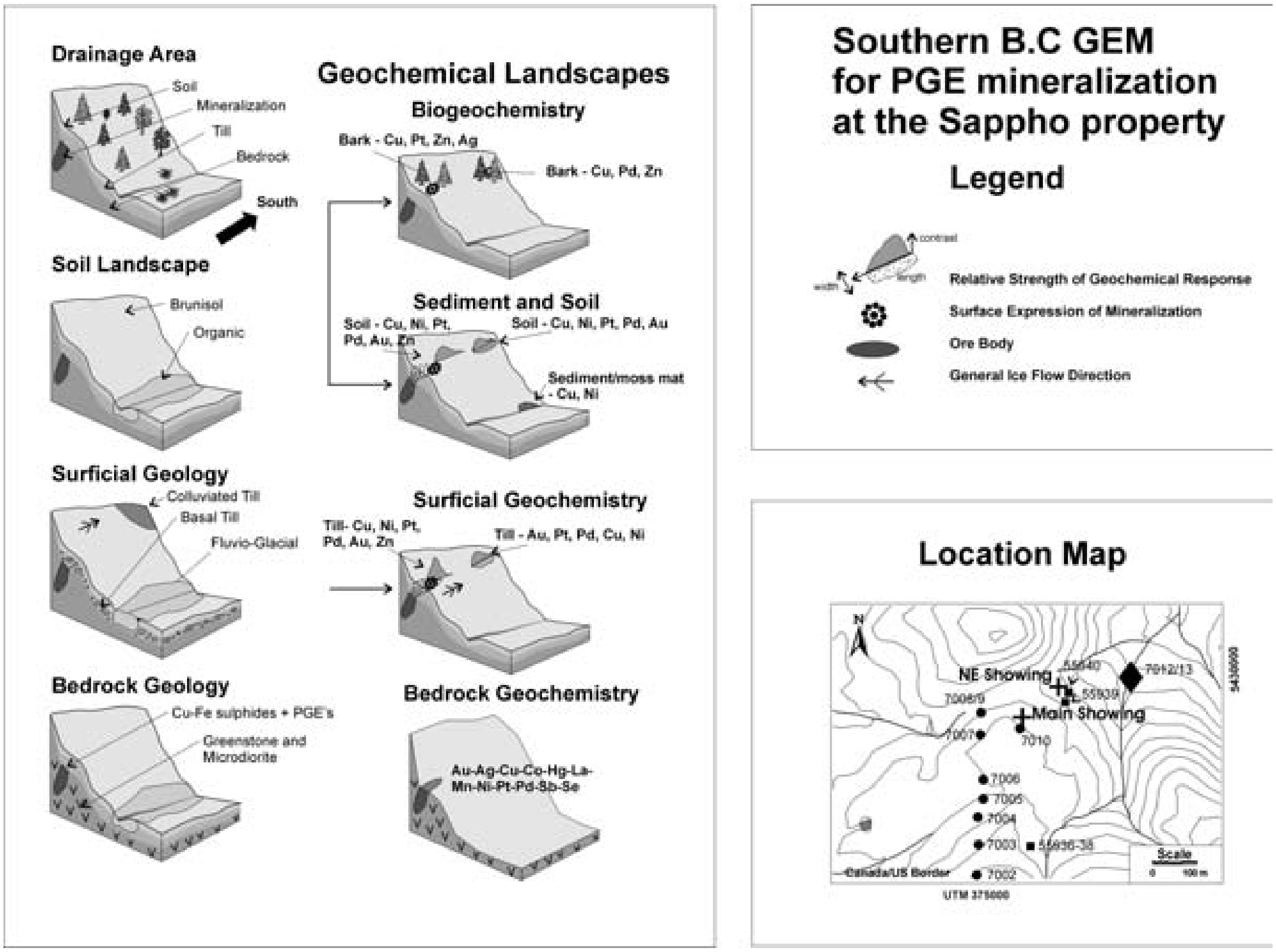

Figure 6. Provisional GEM for PGE mineralization in southern B.C.

flect the limited occurrence of mineralised bedrock or till in the drainage basin. Two patterns are shown on the biogeochemical layer. A strong platinum-copper-silver bark anomaly with additional pathfinders is associated with the Main showing whereas a weaker copper-zinc-palladium signature is associated with the B and C soil anomaly to the south.

CONCLUSIONS

A geochemical exploration model (GEM) for the Sappho property shows that:

- Elevated platinum, palladium, gold, nickel and copper levels in bedrock sulphide mineralization can be detected by B and C-soil horizon sampling but higher values typically occur in the C-horizon.
- Elevated platinum, palladium, copper, silver and zinc levels can be detected by Douglas-fir bark sampling.
- Concentrations of gold, platinum and palladium and most other metals in till increase with depth due to gravity sorting and water washing of the near surface layers and the probable addition of aeolian sediment.
- Basal till down-ice of sulphide mineralization locally yields higher metal values than does down-slope colluvium.
- Soil, till and tree bark anomalies in the southern part of the Sappho property could reflect a second source of bedrock mineralization that has not been discovered.
- Low platinum, palladium, gold, nickel and copper in stream and moss mat sediments can be explained by limited erosion of mineralised bedrock or till into the stream.

Table 7. is a summary of element associations and anomaly characteristics for the Sappho property based on survey results and the relationships summarized by the GEM. While these geochemical associations and anomaly dimensions can be extended to exploration for sulphide-bearing PGE deposits in other areas, any new GEM must be supported by additional field data.

TABLE 7
SUMMARY OF ELEMENT ASSOCIATIONS AND ANOMALY CHARACTERISTICS FOR THE SAPPHO PROPERTY

Mineralization	Media	Pathfinders	Anomaly Size	Remarks
Pyrite-chalcopyrite with high levels of Au, Cd, Co, Cu, Hg, La, Sb, Se, Pt, Pd.	B and C-soil horizon	Cu, Ni, Pt, Pd, Au, (La)	B-horizon soil anomaly (>90 ppm) is 150 m x 200 m over sulphide mineralization. Anomalies are stronger in the C-soil horizon.	Little advantage of using -230 mesh fraction compared to -80 mesh fraction. Colluvial and aeolian effects present at surface.
	Basal till	Au, Pd, Pt, Cu, Ni	No indication on length of dispersal train, but probably >1 km.	Ice flow from north to south. Anomalies stronger with depth.
	Stream sediment		Weak expression in sediment and moss mat may reflect limited occurrence of mineralized source	No advantage to using moss mat compared to stream sediment
	Vegetation	Ag, Pt, Pd, Cu, Zn	Tree bark anomalies are associated with B and C soil anomalies	Extreme differences in tree maturity can introduce spurious variations in element patterns.

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