



**PRELIMINARY REPORT ON THE DISTRIBUTION AND DISPERSION OF
PLATINUM IN THE SOILS OF THE TULAMEEN ULTRAMAFIC COMPLEX,
SOUTHERN BRITISH COLUMBIA***

(92H/10)

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KEYWORDS: Applied geochemistry, Tulameen complex, platinum, chromite, dunite, soil, till, colluvium.

Grasshopper Mountain connect with the Lawless Creek forestry road and provide access from both the village of Tulameen and the Coquihalla Highway.

INTRODUCTION

Exploration for platinum in British Columbia is hampered by a lack of data on its distribution and behavior in the surficial environment. To obtain some of the information required and suggest practical guidelines for exploration, this study, involving systematic sampling and analysis of soils and other media in the vicinity of a platinum deposit in the Tulameen district of southwestern British Columbia, was initiated in 1988 (Fletcher, 1989). Preliminary results of work in progress are described.

BEDROCK GEOLOGY

Grasshopper Mountain is the northern segment of the dissected dunite core of the Tulameen ultramafic complex, a Late Triassic zoned Alaskan-type ultramafic-gabbroic intrusion within metasedimentary and metavolcanic rocks of the Upper Triassic Nicola Group. Geology of the complex, described by Findlay (1969) and Nixon and Rublee (1988), comprises a dunite core surrounded by crudely concentric shells of olivine clinopyroxenite, hornblende clinopyroxenite and gabbroic rocks (Figure 6-2-1).

DESCRIPTION OF THE STUDY AREA

LOCATION AND ACCESS

The field area, on Grasshopper Mountain north of the Tulameen River, approximately 25 kilometres west of Princeton, is divided into the main study area, on the southern slope of the mountain, and a second, smaller area near the summit (Figure 6-2-1). The lower part is accessible by pack trail from the Tulameen River road. Several kilometres of recently constructed drill road on the north and west sides of

The focus of the current study is within the dunite core. The dunite is typically fine grained, extensively serpentinized, and weathers buff-brown on exposed surfaces. Platinum mineralization is restricted to chromite-rich dunite (Nixon *et al.*, 1989; St. Louis *et al.*, 1986). Platinic chromite is best exposed in the summit region and in the subvertical Cliff Zone area (Bohme, 1987) of Grasshopper Mountain, as randomly distributed massive to discontinuous pods, segregations, schlieren and disseminated grains. Schlieren are randomly distributed throughout the dunite and are thought to represent foliation-concordant remnants of former cumulate layers (Nixon and Rublee, 1988). Several zones of mineralization have been defined within the well-exposed central region of the core (Bohme, 1987), but till-covered areas are largely untested.

Platinum-group minerals (PGMs) include several platinum-iron alloys and platinum antimonides occurring as euhedral to subhedral inclusions within chromite grains, as anhedral platinum arsenide (sperrylite) interstitial to chromite grains, and platinum as a solid solution in native copper (St. Louis *et al.*, 1986; Nixon *et al.*, 1989). Nickel sulphides include pentlandite, violarite, and possibly millerite. PGMs are typically less than 30 microns in size, although grains up to 120 microns have been observed.

PHYSIOGRAPHY AND SURFICIAL GEOLOGY

Grasshopper Mountain lies on the western margin of the Thompson Plateau in its transitional zone with the Cascade Mountains. The flatter topography of the summit region, with a maximum elevation of 1500 metres, is deeply dissected by the steep, forested slopes of the Tulameen River and its tributaries. Prominent cliffs and sparsely forested scree

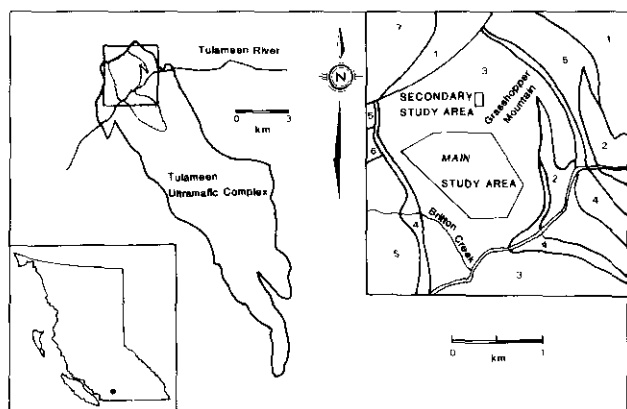


Figure 6-2-1. Location of the study areas and generalized geology, Tulameen ultramafic complex, B.C. (1) Nicola Group, (2) syenogabbro, (3) dunite, (4) olivine clinopyroxenite, (5) hornblende clinopyroxenite, (6) mylonitic rocks, (7) Eagle granodiorite (modified after Nixon and Rublee, 1988).

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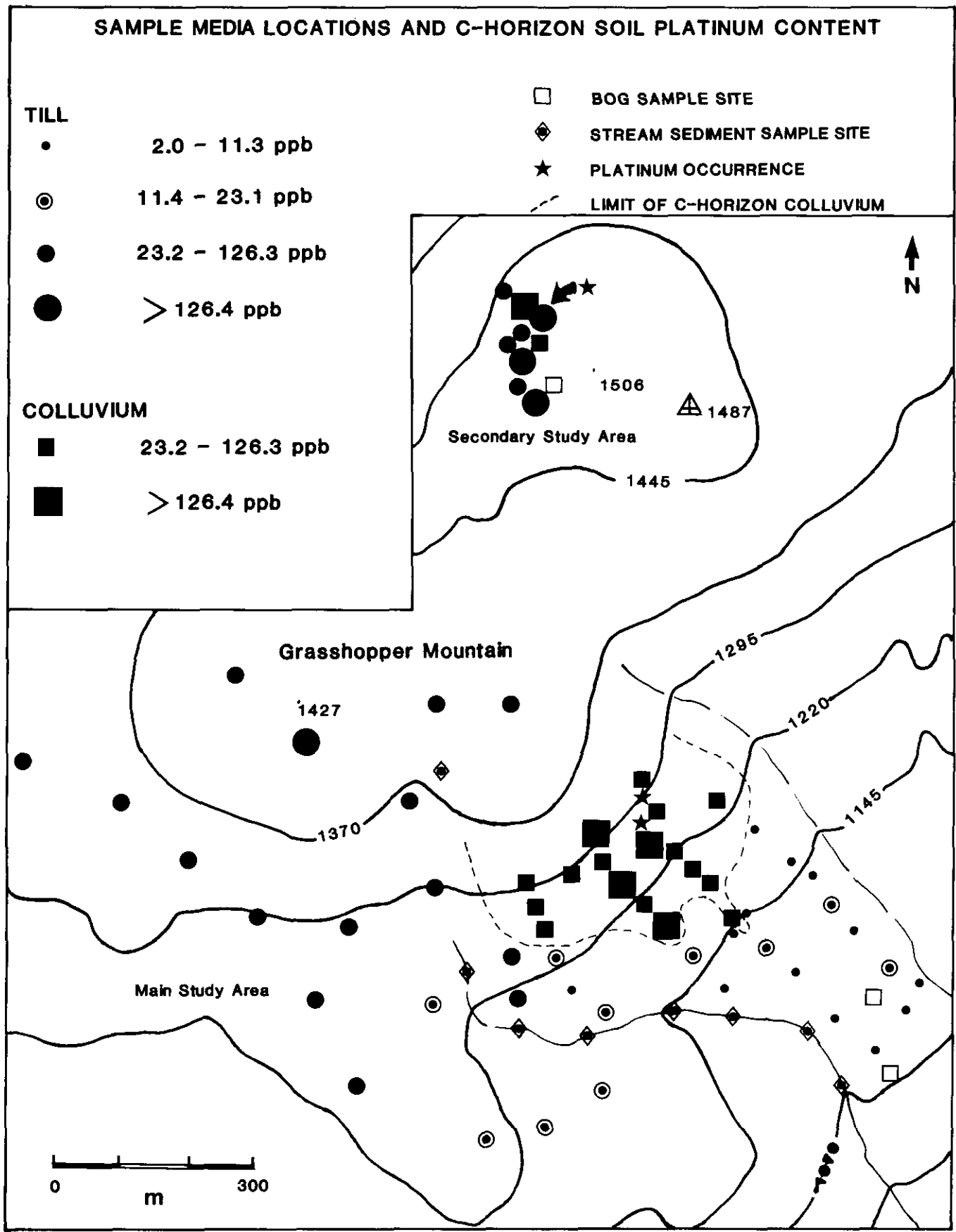


Figure 6-2-2. Sample locations and -70 mesh C-horizon-soil platinum content. Grasshopper Mountain, Tulameen, B.C.

slopes occur on the southeast and southwest faces of the mountain above the Tulameen River and Britton Creek. The mountain, with stands of mature Douglas fir, is largely unlogged near the study areas.

The region was ice-covered during the Pleistocene glaciation (Rice, 1947) and the forested slopes of Grasshopper Mountain are now mantled with glacial till. Near the summit this is thin and discontinuous, and disintegrating bedrock locally forms near residual soils. In this vicinity glacial striae indicate a south-southwesterly direction of ice movement. There is a thick postglacial apron of active scree below the cliffs (Cliff Zone) on the southeast face of the mountain and on the western slopes till is buried by stabilized dunitic colluvium. Fluvial channel deposits are exposed in roadcuts at two localities. At one site three soil parent materials – till, fluvio-glacial outwash and colluvium – were observed. At lower elevations, fluvio-glacial sediments are exposed in the valleys of the Tulameen River and its tributaries.

Small seepage-zone bogs occur in the lower part of the main study area and there are perched bogs on the summit. A small intermittent stream, Grasshopper Creek, flows through the area into the Tulameen River.

SOILS

Soil development, limited by high relief and active colluvial processes, is generally juvenile. The thickness of surficial LFH horizons seldom exceeds a few centimetres.

The main study area has three principal physiographic units (unstable colluvium, steep forested slopes, and base-of-slope areas) each with distinctive soil types. Unstable colluvium is characterized by orthic regosols. Genetic horizons are absent, although at some sites downslope of serpentinite outcrops the fines content increases with depth and there is an orange-brown surface coloration. Steep forested slopes exhibit a range of soil types with humo-ferric podzols and minor orthic regosols predominating in the east and eutric brunisols in the west. Development of near-residual brunisolic soils is most pronounced on gentler slopes and ridges and on the summit area where colluvial activity is minor. Relatively flat base-of-slope areas are characterized by seepage zones, small bogs and gleysolic soils.

SAMPLE COLLECTION, PREPARATION, AND ANALYSIS

SAMPLE COLLECTION

Soils, stream sediments and associated banks, bogs and waters were sampled (Tables 6-2-1 and 2). Soils were profiled and sampled in 76 pits dug in the two separate study areas during 1988 and 1989 (Figure 6-2-2). Duplicate samples of 10 to 15 kilograms each were typically collected from mineral horizons. Soil pedons were classified according to the Canadian System of Soil Classification (Agriculture Canada Expert Committee on Soil Survey, 1987).

Stream sediments were collected at approximately 100-metre intervals from seven sites along Grasshopper Creek. Moss-mat samples were also collected, if present, and bank

TABLE 6-2-1
DISTRIBUTION OF SOIL PROFILES
ACCORDING TO STUDY AREA AND PARENT MATERIAL,
GRASSHOPPER MOUNTAIN, B.C.

	Main Study Area	Secondary Study Area	Total
Till	38	11	49
Colluvium	25	2	27
Total Soil Profiles	63	13	76

TABLE 6-2-2
DISTRIBUTION OF SAMPLE MEDIA
ACCORDING TO STUDY AREA,
GRASSHOPPER MOUNTAIN, B.C.

	Main Study Area	Secondary Study Area	Total
Mineral horizons	149	31	180
LFH horizons	40	7	47
Stream sediments	8	—	8
Mossmats	5	—	5
Bank samples	10	—	10
Bog samples	4	2	6
Water samples	17	—	17

samples were taken at five of the sites. Bog-centre and marginal samples were taken from three bogs. Following the spring snowmelt in 1989, waters were sampled and pH measured at stream sediment sites, bogs and some soil pits. Waters were filtered to <0.45 micron and acidified with hydrochloric acid in the field.

SAMPLE PREPARATION

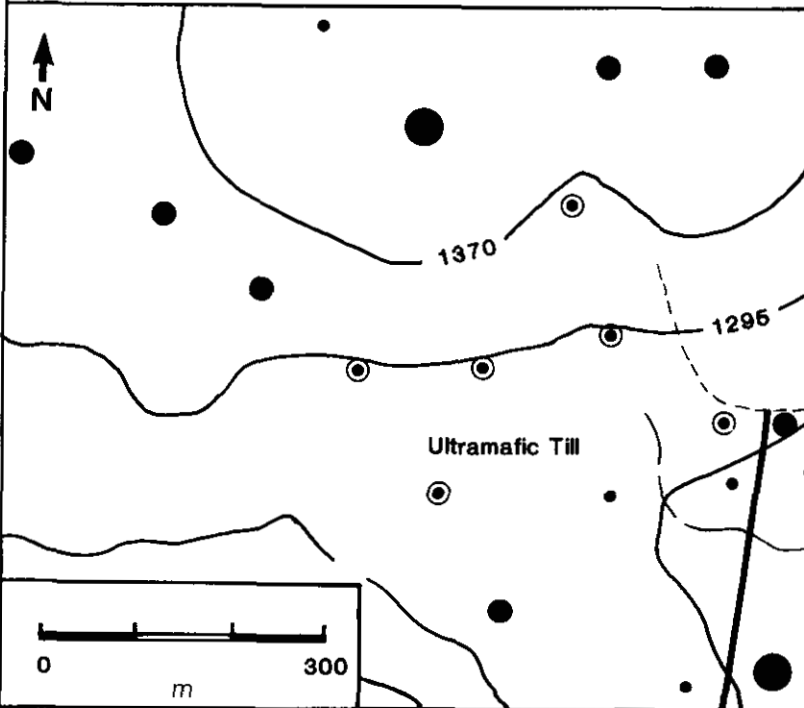
Preparation of samples involved wet sieving a representative split of all C-horizon soil, stream sediment, moss-mat and bank samples to obtain a – 70 mesh (<212 microns) fraction. Two-hundred-gram splits were then taken with a Jones riffle and ground to approximately – 200 mesh in a tungsten carbide ring mill. Ground LFH and dried bog samples were ashed in a muffle furnace at 700°C.

ANALYTICAL TECHNIQUES

Samples were analyzed for three groups of elements and major element oxides at a commercial laboratory.

- (1) Pt-Pd-Au-Rh by lead-fire assay on 10.0 gram subsamples using an ICP-MS finish in 1988 and ICP-AES in 1989. For platinum concentrations greater than 10 ppb analytical precision, based on duplicate analyses, is better than ± 20 per cent at the 95 per cent confidence level.
- (2) As-Sb-Bi-Ge-Se-Te by hydride generation. A 0.5 gram sample was digested with 3 millilitres 3:1:2 HCl-HNO₃-H₂O at 95°C for one hour and diluted to 10 millilitres with water. Hydrides are then determined by ICP-AES.
- (3) Whole-rock analysis. A 0.2 gram sample was fused with LiBO₂, dissolved in 100 millilitres nitric acid, and analyzed for Si, Al, Fe, Mg, Ca, Na, K, Mn, Ti, P, Cr, and Ba by ICP-AES. Loss on ignition was also determined.

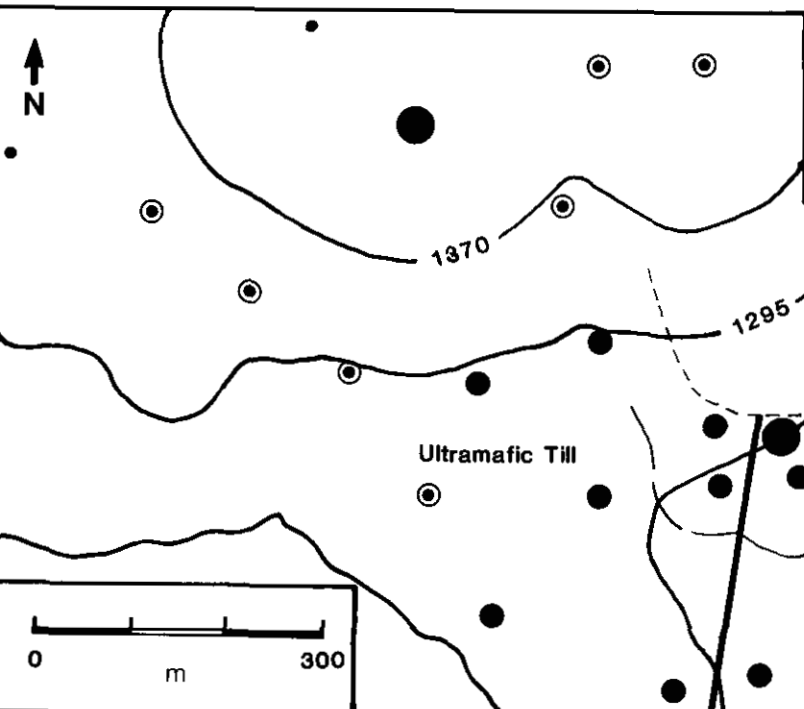
**PLATINUM DISTRIBUTION
IN ULTRAMAFIC AND NON-ULTRAMAFIC TILL**



- ULTRAMAFIC TILL**
- 16 - 30 ppb
 - ⊙ 31 - 40 ppb
 - 41 - 55 ppb
 - > 55 ppb
- NON-ULTRAMAFIC TILL**
- 2 - 9 ppb
 - 10 - 15 ppb
 - 16 - 20 ppb

A

**Cr₂O₃ DISTRIBUTION
IN ULTRAMAFIC AND NON-ULTRAMAFIC TILL**



- ULTRAMAFIC TILL**
- 0.12 - 0.13 %
 - ⊙ 0.14 - 0.20 %
 - 0.21 - 0.26 %
 - > 0.26 %
- NON-ULTRAMAFIC TILL**
- 0.03 - 0.05 %
 - 0.06 - 0.10 %
 - 0.11 - 0.16 %

B

Figure 6-2-3. Distribution of Platinum (A) and Cr₂O₃ (B) in ultramafic and non-ultramafic till, main study area, Grasshopper Mountain, Tulameen, B.C.

Ashed LFH and organic samples were analyzed for Pt-Pd-Au-Rh as above. Platinum content of waters was determined at the Geological Survey of Canada, Ottawa, Ontario.

RESULTS

C HORIZON SOILS

Preliminary analytical results of the platinum content of soils on till and colluvium parent materials are shown in Figure 6-2-2. Mean and median concentrations of platinum and selected elements are given in Table 6-2-3.

TILL COMPOSITION

Two distinct non-overlapping till populations of MgO concentrations occur in the main study area below and adjacent to the colluvium. The south-southwest-trending boundary between the two is shown in Figure 6-2-3. The population in the western half of the area has a mean MgO content of 16.51 per cent and is associated with generally higher values of platinum and chromium. The second population, in the eastern half of the area, has a mean MgO content of 5.60 per cent. These are considered to be predominantly ultramafic and a non-ultramafic exotic till, respectively.

PLATINUM

Contour values for platinum were determined using log probability plots to separate lower (2.0-11.3 ppb) and upper (23.2-126.3 ppb) platinum populations in soils on tills (Figures 6-2-2 and 3). These populations generally correspond to soils derived from the ultramafic and non-ultramafic tills, which average 52 and 9 ppb platinum, respectively, in the main study area (Table 6-2-3). The mean platinum content of

colluvium (120 ppb) is considerably greater. Median values, unaffected by outliers, give a better approximation of typical concentrations of platinum – 7.5 ppb in non-ultramafic till, 36 ppb in ultramafic till, and 88 ppb in colluvium. The maximum concentration (885 ppb) is in colluvium below one of the Cliff Zone platinum occurrences (Figure 6-2-4).

CHROMIUM

Distribution of chromium is generally similar to that of platinum. Thus, colluvium has the greatest mean Cr₂O₃ content (0.33 per cent) whereas soils on ultramafic and exotic tills have mean contents of 0.20 per cent and 0.07 per cent, respectively (Figures 6-2-3 and 4; Table 6-2-3). However, on a more detailed scale, there are differences. For example, within the area of ultramafic till a zone of higher chromium values lies downslope and to the southeast of an area of relatively high platinum values. Similarly, although an anomalous chromium value coincides with the maximum platinum concentration of 885 ppb in colluvium below the Cliff Zone (Figure 6-2-4), the chromium anomaly extends considerably farther, following a general trend for chromium content of colluvium to increase downslope.

OTHER ELEMENTS

Concentrations of palladium, gold, arsenic and antimony are summarized in Table 6-2-3. The most notable features are: (1) concentrations of palladium are generally less than 5 ppb except in soils derived from ultramafic till; (2) similar average arsenic concentrations in soils on all parent materials with 90 per cent of the values being greater than 10 ppm. High arsenic values, up to 43.5 ppm, are found downslope of the showings in the Cliff Zone; (3) the three to four times greater gold content of colluvial parent material from the

TABLE 6-2-3
MEAN, MEDIAN, AND RANGE OF PLATINUM AND OTHER SELECTED CONSTITUENTS OF C-HORIZON SOILS
ACCORDING TO PARENT MATERIAL, GRASSHOPPER MOUNTAIN, B.C.

		Pt (ppb)	Pd (ppb)	Au (ppb)	As (ppm)	Sb (ppm)	MgO (%)	Cr ₂ O ₃ (%)	CaO (%)	Na ₂ O (%)	K ₂ O (%)
NON-ULTRAMAFIC TILL	x	9.1	4.0	7.9	15.2	1.0	5.60	0.07	4.66	2.64	1.34
Main Study Area	M	7.5	3.0	6.0	14.3	0.9	5.44	0.05	4.75	2.58	1.34
(n = 21)	Min	2	2	2	8.1	0.5	3.86	0.03	3.13	2.34	1.09
	Max	20	15	34	23.2	1.8	8.23	0.16	5.51	3.20	1.64
ULTRAMAFIC TILL	x	52.8	8.9	8.4	15.8	0.3	16.51	0.20	3.71	1.27	0.83
Main Study Area	M	36.0	6.5	8.0	13.1	0.2	16.25	0.19	3.61	1.13	0.83
(n = 17)	Min	16	2	2	5.3	0.1	10.45	0.12	1.88	0.85	0.57
	Max	311	48	21	52.5	0.8	28.73	0.29	5.58	2.08	1.07
ULTRAMAFIC TILL	x	158.1	7.0	5.1	18.5	0.4	13.84	0.28	3.28	1.72	0.66
Secondary Study	M	89.0	2.5	4.0	15.6	0.4	13.21	0.26	3.46	1.83	0.73
Area (n = 8)	Min	42	2	1	7.4	0.1	10.64	0.12	1.24	1.06	0.35
	Max	455	36	10	30.5	0.8	19.06	0.51	4.48	2.29	0.75
COLLUVIUM	x	120.0	2.6	21.0	21.3	0.6	24.16	0.33	1.73	0.83	0.30
Main Study Area	M	88.0	2.0	18.5	15.8	0.5	23.29	0.32	1.90	0.85	0.22
(n = 25)	Min	24	2	2	7.5	0.2	14.29	0.20	0.35	0.08	0.05
	Max	885	5	56	56.3	1.2	32.78	0.50	3.29	1.44	0.82

x = mean

M = median

Min = minimum value

Max = maximum value

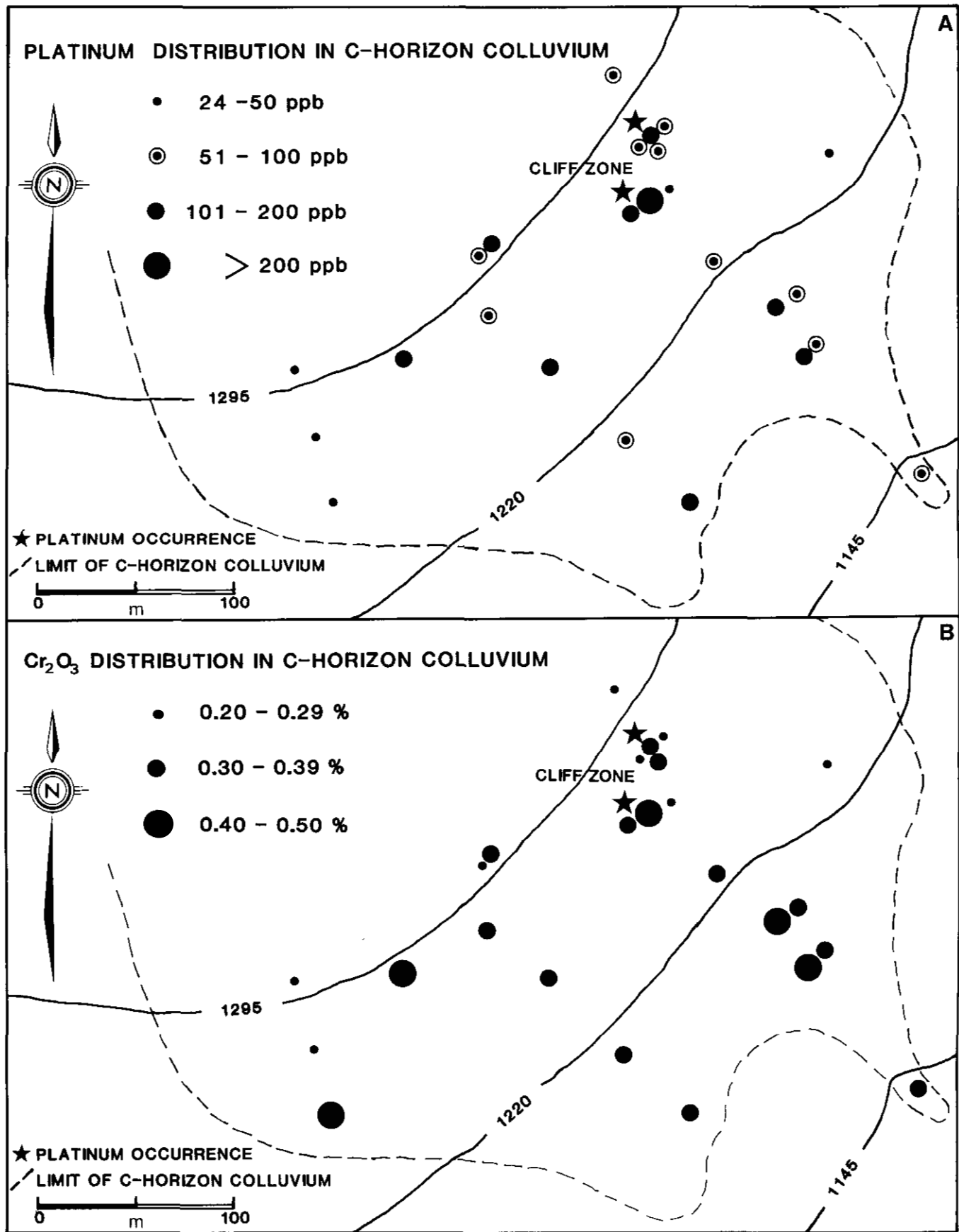


Figure 6-2-4. Distribution of Platinum (A) and Cr₂O₃ (B) in C-horizon colluvium, main study area, Grasshopper Mountain, Tulameen, B.C.

Cliff Zone (average 21.0 ppb with up to 54 ppb in serpentinized material) compared to soils on tills; and (4) antimony values (1.2 – 1.8 ppm) in the seepage zone at the base of the main study area that are three to six times greater than those upslope.

LFH HORIZON SOILS

Up to 167 ppb platinum has been obtained in LFH horizons from the secondary study area where a zone of high LFH platinum values appears to be indicative of the underlying mineralization. The few LFH horizons sampled from active colluvium contain up to 141 ppb platinum. Elsewhere platinum content of LFH horizons is low (typically less than 10 ppb) and erratic. The data have not yet been evaluated for contamination by mineral matter.

STREAM SEDIMENTS AND WATERS

Platinum concentrations in stream sediments from Grasshopper Creek range from 8 to 91 ppb (Table 6-2-4). Associated moss-mats contain 8 to 47 ppb platinum. Most stream water and seep samples at lower elevations contain less than 1 part per trillion platinum. However, samples from the summit area contain 1.3 – 3.5 parts per trillion platinum.

TABLE 6-2-4
DISTRIBUTION OF PLATINUM IN STREAM SEDIMENTS
AND MOSS-MATS, GRASSHOPPER CREEK,
GRASSHOPPER MOUNTAIN, B.C.

Site	Pt in Sediment (ppb)	Pt in Moss-mat (ppb)	-70# Sediment (%)	-70# Moss-mat (%)	Stream Topography
1	18	17	10.7	40.7	L
2	78	8 (17)	9.5	36.3	B
3	11 (12)	—	25.2	—	M
4	8	11	20.2	25.5	M
5	53	47	18.1	41.8	G
6	20	—	26.7	—	G
7	91	—	33.6	—	B
8	32	23	51.6	75.6	B

L = Level to gentle
B = Break of slope
G = Gentle slope
M = Moderate slope

Site 8 is farthest upstream

-70#(mesh) as Wt.% of -10 mesh

BOGS

Two bogs in the lower till-covered part of the main study area contain up to 9 ppb platinum and a bog in the summit area contains up to 21 ppb. On the basis of very limited data, greater concentrations of platinum appear to be associated with bog-margin than bog-centre sites. Concentrations of antimony (0.8 to 4.1 ppm) in bogs are similar or slightly higher than those in base-of-slope soil samples.

DISCUSSION

The high chromium and MgO content of colluvium below the Cliff Zone clearly reflects its origin in mechanical weathering and mass wasting of the dunite cliffs. However,

MgO concentrations (average 24.16 per cent) in the -70 mesh colluvium are appreciably lower than an average of 42.85 per cent for the dunite, based on analyses by St.Louis *et al.* (1986). It is not clear to what extent this is a result of weathering. In this context, platinum concentrations (average 120 ppb) in active colluvium are very similar to estimates of 48 to 180 ppb platinum in dunite, serpentinized dunite and serpentinite (St. Louis *et al.*, 1986). Chromitic dunite, with an average platinum content of 3410 ppb (St. Louis *et al.*, 1986) is the most likely source of the highest platinum value (885 ppb) in colluvium.

Based on a south-southwesterly direction for ice movement and composition of the dunite, the relatively high concentrations of MgO and chromium in tills from both the summit area and the western part of the main study area indicate that they contain relatively high proportions of dunitic material. Conversely, lower concentrations of both elements in tills in the eastern part of the area are probably indicative of their lower dunite content and greater compositional influence of rock units to the north or northeast. Determination of MgO and chromium content in soils may thus provide a useful method of delineating glacial dispersion, and mixing and dilution of material derived from the dunite core. In this case platinum concentrations in soils could be evaluated against soil chromium or MgO values (Figures 6-2-5 and 6). The presence of complex, composite soil profiles where shallow colluvium (upslope source) overlies till (up-ice source) suggests that without adequate care, routine soil sampling may result in erroneous interpretations of anomaly contrast and probable source.

The relationships between the remaining elements and platinum are not clear. However, arsenic and antimony concentrations might, in part, be related to the platinum arsenides and antimonides in the dunite and their redistribution during weathering. Relatively high values of antimony in base-of-slope and bog samples may indicate some hydro-morphic dispersion for this element. Above average concentrations of gold in serpentinized colluvium are consistent with lithochemical results obtained by St.Louis *et al.* (1986).

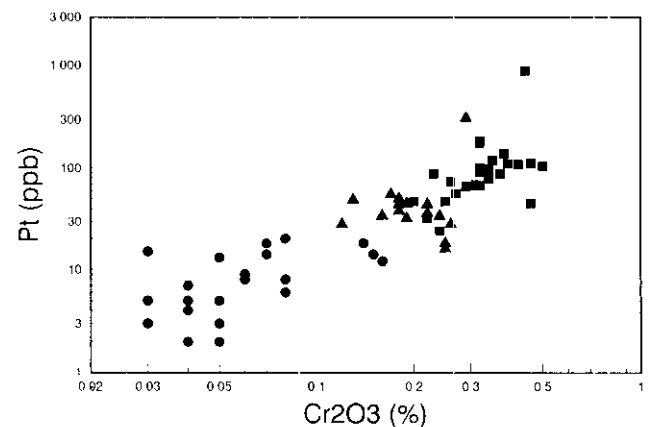


Figure 6-2-5. Pt (ppb) versus Cr₂O₃ (%) in colluvium (squares), ultramafic till (triangles) and non-ultramafic till (circles).

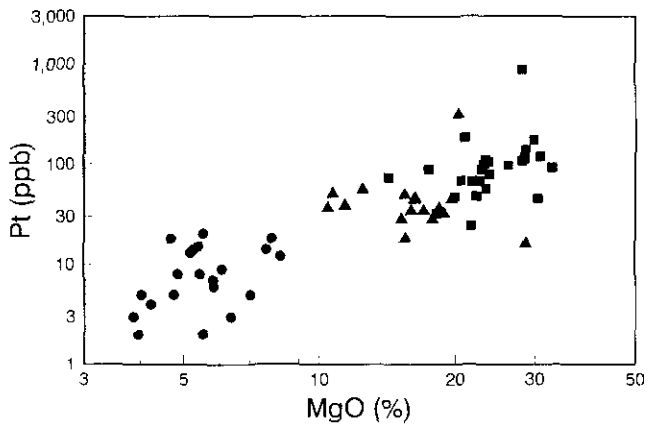


Figure 6-2-6. Pt (ppb) versus MgO (%) in colluvium (squares), ultramafic till (triangles) and non-ultramafic till (circles).

CONCLUSIONS

Glacial dispersion and post-glacial mass wasting are the dominant processes influencing distribution of platinum in the vicinity of platinum occurrences on Grasshopper Mountain. Platinum content of soils, ranging from 2 to 885 ppb, is strongly dependent on the amount of dunite in the soil parent material. This can be estimated roughly from soil MgO and chromium contents. The presence of composite till-colluvium soil profiles necessitates careful sampling for correct interpretation of geochemical patterns.

ACKNOWLEDGMENTS

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