ALASKAN-TYPE MAFIC-ULTRAMAFIC ROCKS IN BRITISH COLUMBIA: THE GNAT LAKES, HICKMAN, AND MENARD CREEK COMPLEXES*

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INTRODUCTION

A project designed to investigate the economic potential of mafic and ultramafic rocks in British Columbia was begun in 1987. The initial phase of the project attempts to provide a geological database for Alaskan-type ultramafic complexes in British Columbia as well as preliminary geochemical and mineralogical data with which to evaluate their potential for precious metals, especially platinum-group elements, and other commodities. The 1987 field season focused on the Tulameen complex, an Alaskan-type mafic-ultramafic intrusion in southern British Columbia (Nixon and Rublee, 1988; Nixon, 1988; Findlay, 1963, 1969). The field program continued in July and August 1988 with an investigation of Alaskan-type ultramafic rocks in central and northern British Columbia.

The lithologies that comprise Alaskan-type complexes may include dunite and minor chromitite, olivine clinopyroxenite, magnetite clinopyroxenite, hornblende clinopyroxenite, hornblendite, and various gabbroic rocks. Not all of these lithologies are exposed, or perhaps even present, in each intrusion. Some complexes exhibit a crude zonation of rock types from an inner dunite core through clinopyroxenites to an outer hornblendite and/or gabbroic margin. However, this is not a universal trait and their designation as "Alaskan-type" complexes is preferable to "zoned" complexes (Irvine, 1974a; Taylor, 1967). At the type locality of Duke Island in southeastern Alaska, layering and sedimentary features in cumulate sequences are exceptionally well developed (Irvine, 1974a). However, primary layering in many Alaskan-type complexes is only locally developed, or may be absent altogether, or obscured and modified by post-cumulus processes. The cumulate mineralogy usually includes forsteritic olivine, diopsidic clinopyroxene, and spinel (chromite-magnetite), and may also include phlogopitic mica and hornblende, in addition to plagioclase in the more differentiated rocks. Orthopyroxene is characteristically lacking, which is indicative of an alkalic magmatic affinity. The Tulameen complex serves as a well-documented example with which to compare other Alaskan-type intrusions in British Columbia. The term "ultramafic complex" (or simply "ultramafite") as used below, carries no connotation as to the relative abundance of associated gabbroic rocks; their proportions in outcrop may vary from practically nil (for example, the Turnagain complex) to substantial (for example, the Tulameen complex).

This report describes the geology and geochemistry of three mafic-ultramafic intrusions that have been categorized as Alaskan-type (Evenchick *et al.*, 1986): the Hickman (Telegraph Creek map sheet, 104G), Gnat Lakes (Cry Lake map sheet, 104I), and Menard Creek (McConnell Creek map sheet, 94D) complexes. In addition the Turnagain River complex (Cry Lake map sheet, 104I), an unusually sulphide-rich Alaskan-type body, and the Polaris complex (Mesilinka River map sheet, 94C), one of the largest in British Columbia, are the subjects of Open File releases by the Ministry of Energy, Mines, and Petroleum Resources.

The Regional Geochemical Survey for 104G, released in 1988, revealed anomalous nickel and cobalt over ultramafic complexes but no samples were analyzed for platinum-group

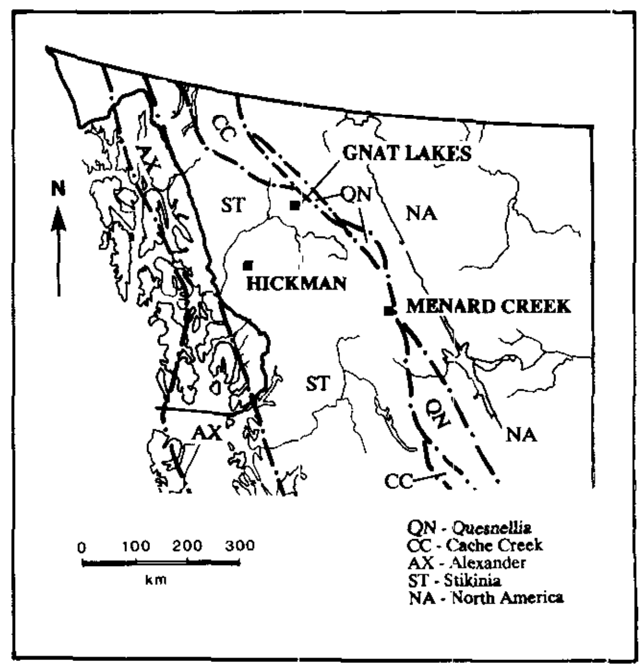

Figure 2-10-1. Location map of the Gnat Lakes. Hickman, and Menard Creek mafic-ultramafic complexes in relation to major tectonostratigraphic terranes in northern British Columbia.

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British Columbia Ministry of Energy, Mines and Petroleum Resources, Geological Fieldwork, 1988, Paper 1989-1.

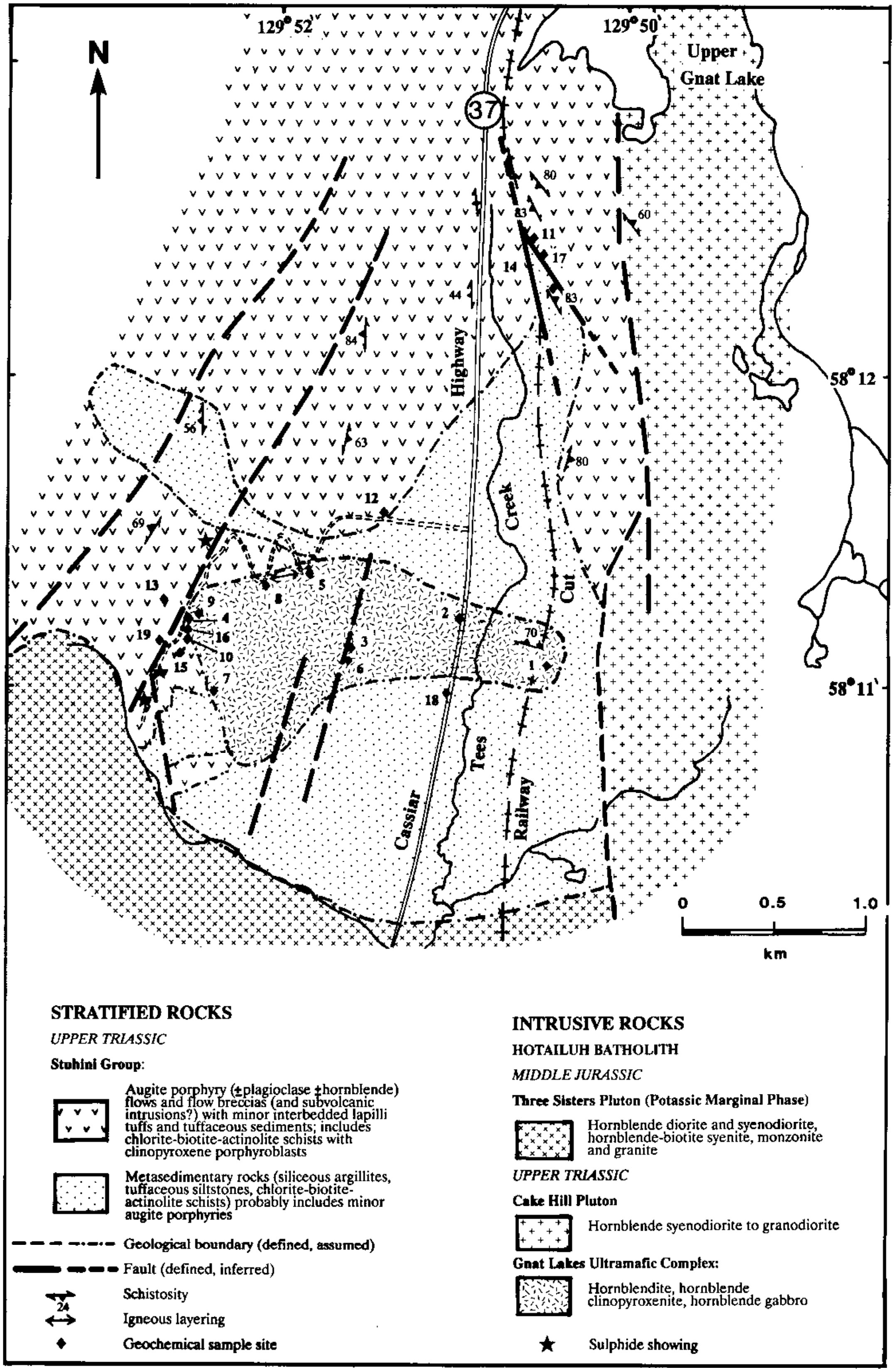

Figure 2-10-2. Geologic map of the Gnat Lakes mafic-ultramafic complex showing distribution of geochemical sample sites and sulphide showings.

elements (PGEs). Analytical data for platinum, palladium, rhodium, and gold in mafic, ultramafic and associated rocks are reported in this paper.

The locations of the Gnat Lakes, Hickman, and Menard Creek complexes and their tectonic setting are shown in Figure 2-10-1. All lie within Stikinia, a tectonostratigraphic terrane comprising Middle Paleozoic to Mesozoic sedimentary, volcanic and plutonic rocks.

THE GNAT LAKES MAFIC-ULTRAMAFIC COMPLEX

LOCATION AND ACCESS

The Gnat Lakes complex (50°11.5′ north, 129°51′ west) is located some 30 kilometres south of Dease Lake on Highway 37, the Stewart-Cassiar Highway (Figure 2-10-2). The complex is named for Lower and Upper Gnat Lakes, and lies approximately 3 kilometres south of Upper Gnat Lake. A four-wheel-drive access road climbs west from the highway to treeline near the western margin of the complex. On the whole, the complex is poorly exposed and probably has a maximum extent of about 2 square kilometres.

GENERAL GEOLOGY AND GEOCHRONOMETRY

The Gnat Lakes complex has traditionally been included as part of the composite Hotailuh batholith (Hanson and McNaughton, 1936) which has been studied in detail by Anderson (1983). The batholith is composed of at least four distinct granitoid plutons, two of which, the Three Sisters and Cake Hill plutons, occur within the map area (Figure 2-10-2). The main outcrops of ultramafic rocks are completely enclosed by metavolcanic and metasedimentary rocks of the Stuhini Group which lie within an embayment at the northwestern margin of the batholith. In addition, small isolated exposures of ultramafic rocks form pendants within the Three Sisters pluton about 2.5 kilometres to the south, and occur in the Cake Hill pluton 14 kilometres south-southeast and 18 kilometres east-northeast of the Gnat Lakes ultramafite (Anderson, 1983). The ultramafic complex bears no unique signature on the regional aeromagnetic map (Geological Survey of Canada, 1978) due to the overwhelming aeromagnetic response associated with a northwest-trending apophysis of the Three Sisters pluton (Anderson, 1983).

Potassium-argon dating of hornblende in hornblendite and hornblende clinopyroxenite of the Gnat Lakes complex yields isotopic ages of $230 \pm 10(2\sigma)$ and 227 ± 14 Ma respectively, or earliest Late Triassic (Carnian) (Anderson, 1983; Stevens *et al.*, 1982). These dates are identical (within analytical error) to potassium-argon isotopic ages for hornblende in the Cake Hill pluton (220 ± 11, 218 ± 11 and 227 ± 14 Ma; Stevens *et al.*, 1982) which according to Anderson (1983) is intruded by the Gnat Lakes ultramafite. A quartz monzonite of the potassic marginal phase of the Three Sisters pluton has been dated by potassium-argon and uranium-lead geochronometry at a locality approximately 3 kilometres west of the Gnat Lakes ultramafite. Zircon fractions lying essentially on concordia yield a preferred uranium-lead isotopic age of 170 ± 1 Ma (Anderson *et al.*, 1982) which is concordant with a potassium-argon date of 169 ± 11 Ma for hornblende in the same sample (Stevens *et al.*, 1982). The age of the Stuhini Group is established as Late Triassic on the basis of ammonite faunas recovered from epiclastic sequences at the northern margin of the Hotailuh batholith (Anderson, 1980).

COUNTRY ROCKS

STUHINI GROUP

The Stuhini Group is composed of volcanic flows and breccias, subvolcanic intrusive rocks, and tuffaceous sandstones, siltstones and shales that appear variably metamorphosed to upper greenschist mineral assemblages. The volcanic rocks are relatively well exposed above treeline immediately west of the ultramafic body. The predominant rock-type is a dark greenish grey porphyry characterized by euhedral phenocrysts (less than 1 centimetre) of augite ± plagioclase ± amphibole set in a finer grained matrix. These augite porphyries form flows and massive shallow intrusions and are incorporated as angular fragments in volcanic breccias and thinly bedded tuffs and epiclastic rocks. Similar lithologies appear in stratigraphic sections measured by Anderson (1980) about 3 kilometres farther west and along the northern margin of the Hotailuh batholith. In thin section, clinopyroxene and hornblende phenocrysts are commonly rimmed and replaced along fractures by actinolitic amphibole, and plagioclase is extensively saussuritized. Locally, secondary amphibole and biotite form rounded radiating crystal aggregates. Rare glomeroporphyritic clots contain intergrowths of augite, hornblende, plagioclase, iron-titanium oxides and apatite, with or without sphene.

In road and railway cuts north of the ultramafic complex augite porphyries are strongly schistose and mylonitic. Under the microscope, relict augite phenocrysts exhibit flaser textures with pressure shadows and are altered extensively to tremolite-actinolite. The fine-grained matrix is recrystallized to actinolite, biotite, chlorite and sericite, which define the foliation, and carbonate, iron-titanium oxides and minor sulphides.

Metasedimentary rocks within the Stuhini Group include grey-green to rusty brown or buff-weathering tuffaceous sandstones, siltstones and black argillites, variably silicified and locally epidotized and pyritic. Near the southwestern margin of the Gnat Lakes complex these rocks have been recrystallized to fine-grained chlorite-biotite-actinolite-feldspar schists.

INTRUSIVE ROCKS

CAKE HILL PLUTON

Outcrops of the Cake Hill pluton were examined south of Upper Gnat Lake in the eastern part of the map area. The rock is a pink to buff-weathering, medium-grained equigranular hornblende syenite to monzonite and monzodiorite with accessory magnetite and sphene. The predominant lithology in the central part of the pluton is hypidiomorphic granodiorite (Anderson, 1983). A penetrative foliation is defined locally by alignment of partially chloritized mafic minerals.

Three Sisters Pluton

The potassic marginal phase of the Three Sisters pluton crops out along the highway and in railway cuts to the south of the Gnat Lakes complex. It is composed of pale pink to white-weathering, medium-grained hornblende monzonite to hornblende-biotite syenite or quartz syenite cut by aplite and diabase dykes. The rocks are generally massive and well jointed. In thin section, plagioclase is seen to be partially altered to sericite and epidote, and hornblende (25 volume per cent) is chloritized. Accessory phases include biotite (less than 1 per cent), iron-titanium oxides (less than 3 per cent) and sphene.

Mafic-ultramafic Rocks

The Gnat Lakes ultramafic complex comprises medium-grained grey-green hornblende clinopyroxenite, black hornblendite, and dark to medium grey feldspathic hornblendite, hornblende gabbro, and rare pyroxene gabbro. The predominant lithologies appear to be feldspathic hornblendite and hornblende gabbro. These rocks are locally pegmatitic with prismatic amphibole crystals reaching 3 centimetres in length.

Ultramafic rocks are well exposed in a railway cut at the eastern edge of the complex (Figure 2-10-2). Here, a continuous gradation is observed from variably carbonatized hornblende clinopyroxenite in the north to saussuritized hornblende gabbro in the south. However, the crude zonation from pyroxenitic core to hornblendite/hornblende gabbro margin, as inferred by Anderson (1983), could not be confirmed. Crude igneous layering involving hornblende clinopyroxenite and feldspathic hornblendite grading into hornblende gabbro was observed in glacially polished outcrops along the access road. The rocks exhibit no tectonic foliation yet in places the layering is contorted and appears to have been remobilized prior to complete solidification. Layered horizons are commonly transected by irregular, locally derived leucocratic veins that appear to have been generated by coalescence of residual gabbroic liquids. Veins of similar style and origin have been documented in the Tulameen complex (Nixon and Rublee, 1988).

Petrography and Mineral Chemistry

As seen in thin section, hornblende clinopyroxenite contains cumulus clinopyroxene with intercumulus hornblende (20 volume per cent), iron-titanium oxides (5 to 10 per cent) and minor sphene (1 per cent). Cumulus clinopyroxene is also present in pyroxene gabbro but is replaced by cumulus amphibole in hornblendite, feldspathic hornblendite and hornblende gabbro. Plagioclase is a cumulus and intercumulus phase in the gabbroic rocks which also contain interstitial iron-titanium oxides (2 to 5 volume per cent), apatite (less than 1 per cent), and sphene (less than 1 per cent). Secondary minerals include epidote, carbonate, chlorite, sericite, and sulphides, largely pyrite.

Anderson (1983) provided electron microprobe data for clinopyroxene and amphibole phenocrysts in Gnat Lakes ultramafic rocks, augite-plagioclase porphyry dykes, and augite $\pm$ hornblende $\pm$ plagioclase porphyries of the Stuhini Group. Overall, phenocryst compositions are similar. Clinopyroxenes (diopsidic augite to magnesium-rich salite) exhibit little zoning and have low titania (less than 1 weight per cent) and moderate alumina (generally 2.5 to 5 weight per cent) and consequently relatively low octahedral alumina, indicative of crystallization within the crust. However, clinopyroxene compositions alone provide tentative evidence for their magmatic subalkaline affinity and tectonic environment (*see* Anderson, 1983).

Primary amphibole compositions are predominantly ferroan pargasite (Leake, 1978) with low TiO_2 and uniformly high K_2O (1 to 1.6 weight per cent). Amphiboles in Gnat Lakes hornblendite are zoned outwards towards actinolitic hornblende. Their levels of potash enrichment and potassium:sodium ratios are similar to those detected in amphiboles from hornblende clinopyroxenites and gabbroic rocks of the Tulameen complex (G.T. Nixon, unpublished data). Evidently, the liquids with which these crystals last equilibrated were relatively potassic. In general, these data support Anderson's contention that Gnat Lakes mafic and ultramafic rocks are likely comagmatic with Stuhini Group volcanism.

INTRUSIVE RELATIONSHIPS

Despite poor outcrop, intrusive relationships in the map area are well known. A sharp intrusive contact between metasedimentary schists of the Stuhini Group and Gnat Lakes ultramafite is exposed at the southwestern margin of the complex. Hornblende gabbro and hornblendite exhibit a decrease in grain size as the contact is approached, indicating the presence of a marginal chill zone. These observations, together with the Carnian isotopic age (227 $\pm$ 14 Ma) for the ultramafic rocks, suggest that the Gnat Lakes complex represents a high-level intrusion coeval with Stuhini Group volcanism. The augite-plagioclase porphyry dykes, presumably the hypabyssal equivalents of Stuhini lavas, must be of various ages since they cut all of the Upper Triassic lithologies including Gnat Lakes ultramafite.

Relationships between ultramafic and granitic rocks are well exposed in railway cuts at the eastern extremity of the complex. Irregular dykes of pink aplite and fine to medium-grained syenite have invaded hornblende clinopyroxenite and hornblende gabbro to produce localized agmatites. Irregular bodies of medium-grained hornblende-biotite syenite to monzonite also intrude the western part of the Gnat Lakes complex. Anderson (1983) considered these intrusions to be apophyses of the potassic marginal phase of the Three Sisters pluton, and therefore Middle Jurassic in age. Other minor intrusions into the Gnat Lakes ultramafite include dykes of pale buff dacite containing phenocrysts of hornblende, plagioclase and quartz, and diabase dykes with abundant plagioclase microphenocrysts and iron-titanium oxides (4 volume per cent).

STRUCTURE

The structure of the map area is poorly understood due to the lack of marker horizons. Major northerly to northeasterly trending lineaments observed on aerial photographs are interpreted as faults. Outcrops located near such lineaments may display a subparallel foliation or localized mylonitic fabric. The western margin of the Cake Hill pluton appears to be a fault.

A steeply dipping regional foliation, defined by amphiboles and micas, has been detected in all lithologies but is poorly developed or absent in the more massive augite porphyries and intrusive rocks. In the northeastern part of the map area, this foliation trends northwesterly, consistent with fabrics further east that characterize the northwestern part of the Hotailuh batholith (Anderson, 1979). Further west, foliations swing north to northeasterly, possibly influenced by faulting. In general, the mineral foliation reflects inhomogeneous regional deformation accompanied by variably developed metamorphic assemblages attaining upper greenschist grade. The timing of this deformation is currently uncertain; it may be synchronous with Late Triassic plutonism or associated with southwesterly verging folds and associated thrust faults of Middle Jurassic (post-Toarcian) to Cretaceous age (Monger *et al.*, 1978; R. G. Anderson, personal communication, 1988).

MINERALIZATION

Minor amounts of disseminated sulphides are distributed throughout the map area but mineralization is preferentially developed near faults.

Sulphides in the mafic and ultramafic rocks generally form no more than 5 volume per cent of the rock and comprise finely disseminated pyrite and rare chalcopyrite. Most of the mineralized outcrops occur near the western margin of the complex. No net-sulphide textures were observed.

Granitoid rocks commonly contain disseminated sulphides (less than 3 volume per cent) and thin (0.5 millimetre) discontinuous stringers of sulphide and chlorite along joint planes. Disseminated pyrite is also found in diabase dykes cutting the granitic rocks.

Control of mineralization by faults is seen at several localities. A fault contact between black argillites and schistose augite porphyry is well exposed in a railway cut in the northern part of the map area. Here, the abundance of disseminated sulphide in the argillite, intensity of carbonate veining, and degree of silicification increase towards the fault.

The most important mineralization occurs along a major north-northeasterly trending fault in the Stuhini Group near the western limit of the ultramafite (Figure 2-10-2). In the mid-1960s, a program of geologic mapping, prospecting and trenching, and an induced polarization survey, were carried out on a number of known mineral showings distributed along the fault (Roed, 1966a, b; Malinsky, 1966; Reynolds, 1967). Mineralized zones comprise massive pyrite, chalcopyrite, and minor pyrrhotite and arsenopyrite in a gangue of siderite, limonite, hematite and smoky quartz.

The age of the mineralization is not well constrained. On the whole, the association of mineralization with brittle phenomena such as faults and joints suggests that the mineralizing event(s) occurred late in the history of regional deformation (presumably post-Toarcian).

GEOCHEMISTRY

Whole-rock analyses of Gnat Lakes ultramafic rocks taken from Anderson (1983), and preliminary assay results for platinum, palladium, rhodium, and gold, are given in Tables 2-10-1 and 2-10-2 respectively. The occurrence of cumulate textures in the ultramafic rocks, and thus accumulative origin, precludes the use of whole-rock compositions as a means of classification (for example, Irvine and Baragar, 1971). The hornblende clinopyroxenites and hornblendites have high total iron and titania, reflecting in part the abundance of intercumulus iron-titanium oxides, and high alkalies and iron:magnesium ratios. These compositions compare rather closely with those of similar rocks in the Tulameen complex (Table 2-10-1). Their relatively high potassium:sodium ratio is a trait shared by the majority of Stuhini Group volcanic rocks and porphyry dykes (Anderson, 1983). However, the latter rocks are altered (2 to 4 weight per cent H_2O and up to 5 weight per cent CO_2) and have clearly suffered some degree of alkali mobility

TABLE 2-10-1
MAJOR AND TRACE ELEMENT COMPOSITION OF GNAT LAKES ULTRAMAFIC ROCKS

	Gnat Lakes				Tulameen	
Rock Type	**1 Hb**	**2 Hb**	**3 Hb Cpx**	**4 Hb Cpx**	**5 Hb Cpx**	**(Range)**
Weight %						
SiO_2	45.00	41.60	39.80	39.60	40.74	(3.34)
TiO_2	1.24	1.58	1.97	2.06	1.48	(1.23)
Al_2O_3	5.80	6.70	11.10	6.50	5.06	(3.29)
Fe_2O_3	6.40	9.60	6.00	13.30	11.59	(6.92)
FeO	8.60	9.90	10.00	9.90	8.84	(2.57)
MnO	0.26	0.20	0.23	0.20	0.22	(0.04)
MgO	11.70	11.07	8.70	10.54	12.58	(2.13)
CaO	17.80	15.48	13.57	15.74	16.86	(1.92)
Na_2O	0.68	0.81	1.60	0.74	0.61	(0.34)
K_2O	0.48	0.55	0.72	0.42	0.53	(1.31)
P_2O_5	0.33	0.35	1.53	0.10	0.05	(0.10)
H_2O_T	1.80	1.30	2.20	0.70	1.03	(0.48)
CO_2	BD	0.70	0.50	0.10	0.16	(0.38)
S	BD	0.21	0.80	BD	0.03	(0.04)
Cl	0.05	0.11	0.10	0.06	NA	
F	0.04	0.05	0.14	0.04	NA	
Total	100.18	100.16	98.76	100.00	99.77	
ppm						
Rb	0	70	100	30		
Sr	270	240	400	140		
Ba	200	650	200	150		
U	0.4	NA	NA	NA		
Zr	21	58	53	39		
Y	BD	44	41	50		
Cr	110	120	27	160		
Co	64	57	53	76		
Ni	63	91	33	150		
V	450	560	530	750		
Cu	13	210	250	17		
Zn	50	80	130	140		

Hb = Hornblendite; Hb Cpx = Hornblende clinopyroxenite; H_2O_T = total water; NA = not analyzed; BD = below detection limit.

Columns 1-4 are analyses from Anderson (1983, Table 2-4-2).

Column 5 is the arithmetic mean (and range) for 4 hornblende clinopyroxenites from the Tulameen complex (Findlay, 1969, Table 4).

TABLE 2-10-2
NOBLE METAL ABUNDANCES OF THE GNAT LAKES
MAFIC-ULTRAMAFIC COMPLEX AND ASSOCIATED ROCKS

Sample Location*	Sample No.	Rock Type	Sulphide (volume %)	ppb[1] Pt	Pd	Au
GNAT LAKES MAFIC-ULTRAMAFIC COMPLEX						
1	GN-88-0005	Hb clinopyroxenite	—	1	20	1
1	GN-88-0006	Hb clinopyroxenite	—	1	17	6
2	GN-88-0001	Hornblendite	—	2	35	3
3	CA-88-0006	Hornblendite	<5	4	2	1
4	GN-88-1029	Hornblendite	Tr	1	11	2
5	GN-88-0009	Feldspathic hornblendite	Tr	2	19	6
6	CA-88-0005	Feldspathic hornblendite	Tr	6	2	1
7	GN-88-4018C	Feldspathic hornblendite	<5	11	17	2
1	GN-88-0007	Hb gabbro	<5	1	2	2
8	GN-88-1022	Hb gabbro	—	2	19	8
9	GN-88-1030	Hb gabbro	5–10	1	2	1
10	GN-88-4006	Hb gabbro	<5	1	2	1
STUHINI GROUP — Metavolcanic Rocks						
11	GN-88-0003	Cpx porphyry schist	—	2	25	1
12	GN-88-0008	Cpx-Plag porphyry schist	—	3	22	1
13	GN-88-1025A	Cpx porphyry (silicified)	Tr	2	29	25
14	GN-88-2025B	Cpx porphyry schist	<5	5	22	1
15	GN-88-4004	Cpx porphyry schist	Tr	3	26	1
16	GN-88-4007	Cpx-Plag porphyry	—	1	13	4
STUHINI GROUP — Metasedimentary Rocks and Veins						
17	GN-88-0004	Argillite	5	1	5	3
18	CA-88-0003	Metasediment (silicified)	<5	26	20	1
14	GN-88-2025A	Quartz vein in argillite	15–20	7	18	1
14	[2]GN-88-2025A			7	15	1
19	GN-88-1026	Pyrite-chalcopyrite	ore	1	4	824

Detection limits: Pt and Au, 1 ppb; Pd and Rh, 2 ppb.
* *See* Figure 2-10-2.
[1] Rh is at or below detection limit in all samples.
[2] Duplicate analysis.
Plag = plagioclase; Hb = hornblende; Cpx = clinopyroxene; Tr = trace sulphides; – sulphides not detected.
Samples designated schist contain abundant tremolite-actinolite, biotite, chlorite, and sericite ± carbonate.

(Na_2O:K_2O greater than 12 in extreme cases), which renders rigorous geochemical comparisons uncertain.

The noble metals were preconcentrated by fire assay from 30 gram splits of 200 grams of rock powder (−200 mesh) and analyzed by inductively-coupled plasma mass spectroscopy by Acme Analytical Laboratories, Vancouver. Accuracy was checked by in-house standard FA-5X (supplied by Acme) which contains 100, 100, 20, and 100 ppb platinum, palladium, rhodium and gold respectively, and during analysis gave 98, 101, 20 and 100 ppb of each element respectively. Analytical precision (and any nugget effect) was monitored by hidden duplicates and internal standards.

The tenor of noble metals in Gnat Lakes ultramafite, Stuhini Group volcanic and metasedimentary rocks, and sulphide-bearing quartz veins is relatively low (Table 2-10-2). Typical economic PGE deposits have an average platinum grade of 5 to 10 grams per tonne (Macdonald, 1986). One anomalously high gold value (824 ppb) occurs in a sulphide sample collected from a showing located on the fault near the western edge of the ultramafic complex. However, there is no evidence to suggest remobilization of platinum-group elements within the fault zone. It is interesting to note that Stuhini Group augite porphyries are as enriched in palladium as rocks of the Gnat Lakes complex. In general, there is no correlation between the amount of pyritic sulphides in a rock and the abundance of noble metals.

In the Gnat Lakes suite, the abundance of platinum-group elements is slightly lower, on average, in gabbros than in ultramafic rocks, which in turn are distinctly impoverished relative to their counterparts in the Tulameen complex (Table 2-10-3). From a mineral exploration viewpoint, the best prospects in the vicinity of the Gnat Lakes complex would appear to be structurally-controlled gold-bearing sulphide deposits.

THE HICKMAN MAFIC-ULTRAMAFIC COMPLEX

LOCATION AND ACCESS

The Hickman mafic-ultramafic complex (57°16′ north, 131°05′ west) is located approximately 150 kilometres south-southwest of Dease Lake and 55 kilometres south of Tele-

TABLE 2-10-3
MEAN CONCENTRATIONS OF PLATINUM-GROUP ELEMENTS IN ALASKAN-TYPE COMPLEXES

	ppb			
	Pt	**Pd**	**Rh**	**Au**
Alaskan overall (range of values)	43 10–105	32 8–45	19 0.7–29	
Tulameen Complex[1]				
Ol clinopyroxenite and clinopyroxenite	30 (10)	—	0.8 (0.3)	0.4 (0.2)
Hb clinopyroxenite and hornblendite	50 (20)	140 (80)	0.2 (0.1)	3.4 (2.9)
Syenogabbro and syenodiorite	20 (10)	25 (15)	0.2 (0.1)	40 (40)
Sulphide-rich[2]	50 (20)	120 (60)	0.2 (0.1)	30 (30)
Magnetite-rich[2]	40 (10)	40 (20)	0.5 (0.2)	0.5 (0.3)
Tulameen overall[3]	80 (20)	100 (50)	1.2 (0.2)	7.8 (6.2)
Tulameen (weighted)[4]	12 (3)	30 (10)	0.4 (0.1)	1.5 (1.2)

Data from Crocket (1981) and St. Louis *et al.* (1986).
— below detection limit.
[1] Mean values and standard error of the mean (in brackets).
[2] Opaque minerals >10 volume per cent.
[3] Arithmetic mean includes PGE-rich chromitites.
[4] Weighted on the volume percentages of all rock types.

graph Creek (Figure 2-10-3). The project area is covered by 1:50 000 topographic maps 104G/6 and 104G/3. Access to the region is by air from Dease Lake to an airstrip at the confluence of the Scud and Stikine rivers. The airstrip provided a staging area to a helicopter-supported base camp established by members of the Stikine and Telegraph projects (Brown and Gunning, Logan and Koyanagi, 1989, this volume) located 25 kilometres to the east on the Scud River floodplain. The base camp lay 16 kilometres west of Mount Hickman for which the ultramafic complex is named. The region has excellent, though rugged, rock exposures that skirt receding mountain glaciers at altitudes between 1200 and 2800 metres.

GENERAL GEOLOGY AND GEOCHRONOMETRY

The Hickman ultramafic complex lies near the eastern edge of the Coast Mountains in the Intermontane Belt. The project area is underlain by Late Triassic granitoid rocks of the Hickman batholith and volcanic sequences that appear to belong to the Late Triassic Stuhini Group. Brief descriptions of the regional geology are given below based on work by Souther (1972), Holbeck (1988), and Brown and Gunning (1989, this volume).

The Hickman batholith (1200 square kilometres) is a composite body incorporating the Late Triassic (Carnian-Norian) Nightout and Hickman plutons and Middle Jurassic (Bajocian-Bathonian) Yehiniko pluton which intrudes the other two (Holbeck, 1988). Potassium-argon and rubidium-strontium geochronometry on mineral separates and whole rocks yields essentially concordant dates of 228 ± 16 (2σ; potassium-argon on hornblende), 221 ± 16 (potassium-argon on hornblende), and 178 ± 22 Ma (rubidium-strontium whole rock) for the Nightout, Hickman, and Yehiniko plutons respectively (Holbeck, 1988). The Hickman pluton underlies some 300 square kilometres at the southern limit of the Hickman batholith. Two phases are recognized within the map area: a main granodioritic to monzonitic phase and a mafic, more gabbroic phase.

The ultramafic rocks were originally considered to form an integral part of the Hickman pluton (Souther, 1972). However, more recent mapping by Holbeck (1988) and Brown and Gunning (1989, this volume), and our work, indicates that Mount Hickman itself is underlain by an assemblage of volcanic and volcaniclastic rocks that extends northeastward along the western margin of the ultramafic complex. We have therefore decided to treat the Hickman ultramafic complex as a separate entity rather than assume genetic links with the Hickman pluton for which there is currently no strong evidence.

The Stuhini Group east of Mount Hickman generally forms elongate outcrops that are bounded by north-trending normal faults or intruded by batholithic rocks. Regionally, the Stuhini Group is characterized by mafic to intermediate augite-phyric flows, sills and volcaniclastic rocks with sub-greenschist metamorphic assemblages. The upper part of the succession contains hornblende-plagioclase-phyric andesitic flows, heterolithic volcanic breccias and conglomerates, and rare felsic tuffs capped by fossiliferous limestones of Norian to Carnian age. These rocks appear to be correlative with similar lithologies that occur 100 kilometres to the northeast around the margin of the Hotailuh batholith (Anderson, 1983, 1988).

The structural and metamorphic history of the region is complex (summarized by Brown and Gunning, this volume). At least two phases of pre-Permian folding are recognized, and deformation also occurred in post-Early Jurassic time with southwesterly directed folding and thrusting. The latter phase of compression involved the margins of the Hickman pluton and the Stuhini Group. Faulting in the region appears to have continued into the Late Tertiary.

COUNTRY ROCKS

STUHINI GROUP

Volcanic assemblages of uncertain age (Holbeck, 1988) almost completely surround the ultramafic complex. In the north, the contact with ultramafic rocks is faulted, but to the east a sharp intrusive contact has been recognized between weakly hornfelsed volcanic rocks and marginal gabbros of the Hickman complex (M. Gunning, personal communication, 1988). The exact position and nature of the western contact just east of Mount Hickman is not known.

The volcanic stratigraphy comprises predominantly mafic aphyric flows with subordinate porphyritic andesites and minor intercalated volcaniclastic material. The rocks are generally dark greenish to medium grey or maroon, and are locally bleached pale green to buff. Andesitic flows contain phenocrysts of plagioclase (20 per cent by volume) up to 3 millimetres in length, and pyroxene and/or amphibole (less than 5 per cent). These lithologies are tentatively included within the Stuhini Group, although doubt remains as to their exact stratigraphic position.

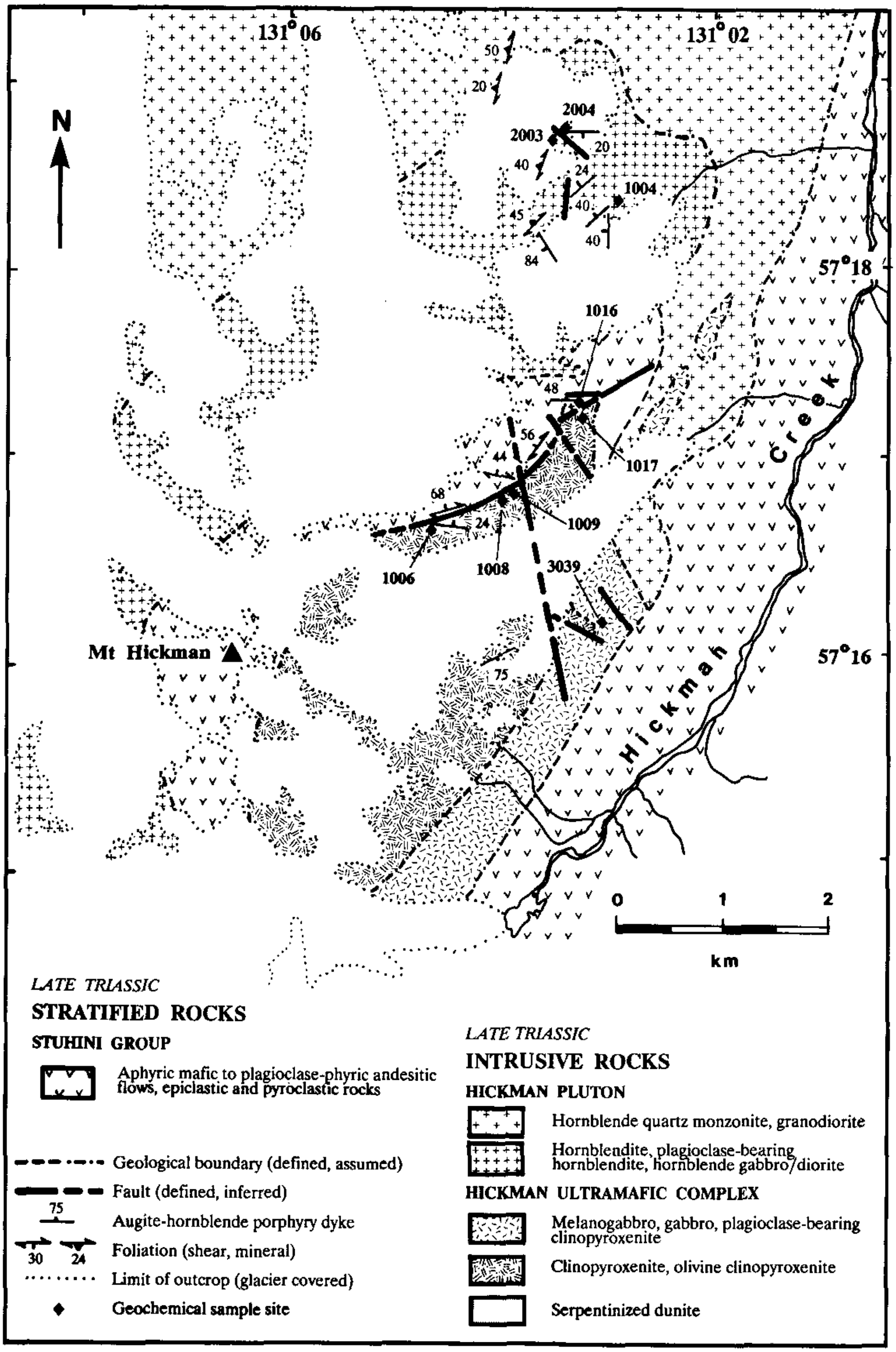

Figure 2-10-3. Geologic map of the Hickman mafic-ultramafic complex (in part after Brown and Gunning, this volume) showing distribution of geochemical sample sites.

INTRUSIVE ROCKS

HICKMAN PLUTON

Main Phase

The main phase of the Hickman pluton delineates the northeastern margin of the ultramafic complex. It comprises a pale grey to pinkish grey-weathering, medium-grained hornblende-biotite monzonite to granodiorite which grades into a more melanocratic phase towards the core of the pluton. The granitoid rocks become finer grained and enriched in biotite towards their contacts and irregular apophyses of fine-grained biotite monzonite locally cut the volcanic assemblages.

Mafic Phase

The mafic phase of the pluton is largely composed of medium to coarse-grained black hornblendite, plagioclase-bearing hornblendite, and dark to light grey hornblende gabbro to diorite with minor biotite. Prismatic hornblende crystals (less than 4 centimetres in length) in the more melanocratic rocks locally define an igneous lamination, probably a flow foliation, that wraps around inclusions. The xenolith suite comprises angular to rounded blocks of hornblendite, hornblende gabbro and grey-green pyritic diorite that appear to be cogenetic, and large rafts of hornfelsed sedimentary(?) rocks.

MAFIC-ULTRAMAFIC ROCKS

The main outcrops of mafic and ultramafic rocks that comprise the Hickman ultramafic complex are found immediately east of Mount Hickman, which itself is underlain by volcanic rocks of uncertain age (Holbeck, 1988), possibly correlative with the Stuhini Group. The ultramafic complex covers 11 square kilometres and forms an elongate body trending northeast with maximum dimensions of about 6 by 3 kilometres. The ultramafic rocks are spatially associated with the Hickman pluton.

Dunite

A small wedge of altered dunite occurs at the northern end of the complex in fault contact with volcanic rocks and intruded by the main phase of the Hickman pluton. The rock is dark to pale grey-weathering, moderately magnetic, and cut by numerous white calcite veins (less than 6 centimetres in width) especially near contacts. Two samples collected within 10 metres of the contact are thoroughly serpentinized. In thin section, olivine is seen to be completely replaced by serpentine and grain boundaries are coated with secondary magnetite dust. Tiny euhedral chromite crystals (1 per cent by volume) are dispersed throughout the rock.

Olivine Clinopyroxenite and Clinopyroxenite

The central part of the Hickman ultramafic complex is predominantly composed of dark grey-green to brownish weathering, coarse to medium-grained clinopyroxenite containing minor olivine (up to 20 per cent by volume) and interstitial magnetite (5 to 10 volume per cent), accessory biotite (less than 1 per cent), and rare hornblende. The rock is generally massive and uniform except in proximity to faults where anastomizing veins of carbonate, serpentine, talc and clay minerals are found. Some fault zones are commonly silicified and contain disseminated sulphides. In northern outcrops, the modal proportion of olivine appears to decrease to the east away from the dunite. Locally, the clinopyroxenite is enriched in biotite which forms crystals up to 1 centimetre across. Clinopyroxenites gradually become feldspathic towards the contact with marginal gabbros. Generally, olivine and clinopyroxene occur as cumulus minerals that locally exhibit adcumulus growth. Iron-titanium oxides and biotite with or without hornblende form an intercumulus framework.

Gabbroic Rocks

Gabbroic rocks crop out in a narrow belt 500 metres wide along the eastern margin of the complex. These marginal gabbros are dark to medium grey, equigranular rocks containing subequal proportions of plagioclase and clinopyroxene, and minor hornblende (5 volume per cent), biotite (usually less than 5 per cent) and magnetite. The gabbros are cut locally by leucocratic plagioclase-rich dykes several centimetres in width.

DYKES

Dykes of variable mineralogy and texture intrude the ultramafic and granitoid rocks. The dominant orientation is east-west with moderate dips to the north. Dark grey mafic dykes (less than 1 metre in width) are weakly vesicular and either aphyric or contain sparse plagioclase microphenocrysts (less than 1 millimetre). Medium to pale grey porphyritic dykes (2 to 4 metres in width), with large (less than 3 centimetres) phenocrysts of hornblende and augite (10 to 20 per cent by volume) and sparse plagioclase, commonly exhibit chilled margins and multiple injection. These dykes mineralogically resemble typical Stuhini Group volcanic rocks although they postdate emplacement of the Hickman pluton and presumed Stuhini Group equivalents that form the immediate country rock of the ultramafic complex.

INTRUSIVE RELATIONSHIPS

The age of emplacement of the Hickman ultramafic complex is tightly constrained by intrusive relationships, stratigraphic correlations and isotopic dating. The complex is truncated on the north by the main phase of the Hickman pluton dated at approximately 221 ± 16 Ma or Late Triassic (Holbeck, 1988), and intrudes volcanic rocks that are Upper Triassic equivalents of the Stuhini Group or older. Thus, the age of the Hickman ultramafic complex is probably Late Triassic.

Internally, the ultramafic complex comprises several distinct lithologies that include dunite, olivine clinopyroxenite to clinopyroxenite, and gabbroic rocks. The contact between dunite and olivine clinopyroxenite appears to be sharply transitional, and that between clinopyroxenite and the gabbroic rocks is sharp to gradational over several metres. The latter transition is marked by a gradual increase in the modal

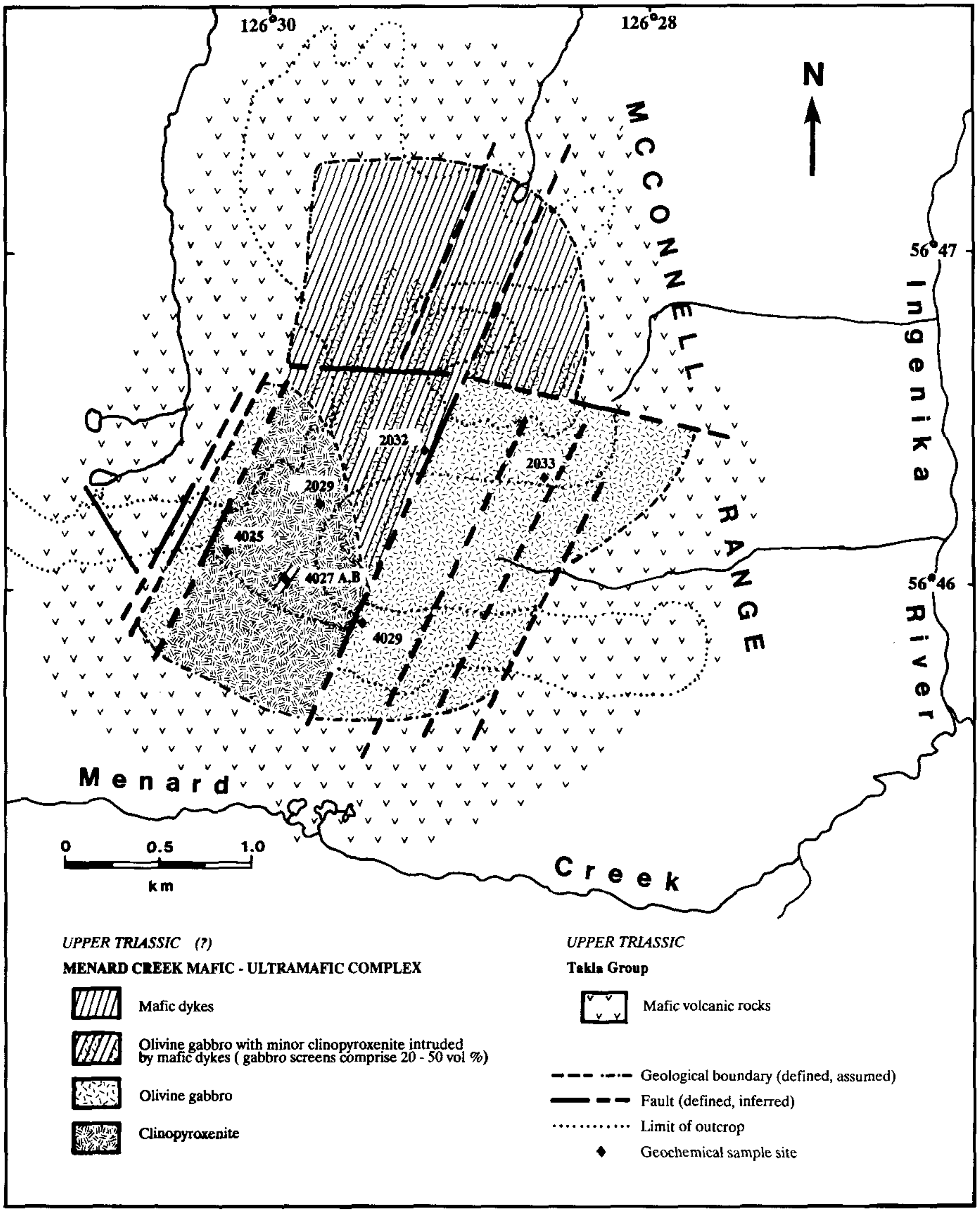

Figure 2-10-4. Geologic map of the Menard Creek mafic-ultramafic complex (in part after Irvine, 1976) showing distribution of geochemical sample sites.

proportion of plagioclase (less than 15 per cent). The youngest intrusives in the map area are mafic to intermediate dykes of Late Triassic age or younger.

STRUCTURE

Faults trending west-southwest and north to northwest are the prominant structural features in the map area. A moderately dipping (60°), west-southwest-trending fault separates the northern margin of the Hickman ultramafic complex from the volcanic rocks. The fault zone is about 30 metres wide, strongly foliated, and mineralized. This fault may belong to a regional set of west-striking normal faults with north-side-down displacement (Brown and Gunning, 1989, this volume). North-trending faults have much narrower foliated zones and may be related to east-west brittle extension in the Tertiary. One such structure offsets the west-southwest-trending fault with an east-side-down sense of displacement.

MINERALIZATION

The Hickman ultramafic complex lies within a metallogenic belt that encompasses the eastern margin of the Coast Mountains and hosts precious metal and base metal deposits, notably copper-molybdenum and copper-gold porphyries, and structurally controlled epigenetic gold deposits. The regional metallogeny is reviewed by Brown and Gunning (1989, this volume).

Mineralization within the map area appears to be dominantly controlled by faulting. The west-southwest-trending fault zone is silicified and locally carbonatized, and weathers a deep orange-brown at its western end due to the presence of disseminated sulphides, mostly pyrite (less than 5 volume per cent). Northerly trending faults appear to be unmineralized though fault zones are locally silicified. The age of the mineralization may be Early to Middle Jurassic (Brown and Gunning, 1989, this volume).

GEOCHEMISTRY

Analytical results for noble metals in the Hickman mafic-ultramafic complex, porphyritic dykes, and mafic phase of the Hickman pluton are given in Table 2-10-4. The abundance of platinum-group elements in the mafic-ultramafic complex is relatively low compared to Alaskan-type intrusions in general, and olivine clinopyroxenites and clinopyroxenites of the Tulameen complex in particular (Table 2-10-3). Platinum abundunces are highest in olivine clinopyroxenite whereas gold has an affinity for sulphide-bearing and carbonatized rocks. Proximity to faults may account for the anomalously high gold (87 ppb) content of sample GN-88-1009.

TABLE 2-10-4
NOBLE METAL ABUNDANCES OF THE HICKMAN MAFIC-ULTRAMAFIC COMPLEX AND ASSOCIATED ROCKS

Sample No.	Rock Type	Sulphides (volume %)	ppb[1] Pt	Pd	Au
HICKMAN MAFIC-ULTRAMAFIC COMPLEX					
GN-88-1008	Ol clinopyroxenite	—	18	2	3
GN-88-1009	Ol clinopyroxenite	<5	9	2	87
GN-88-1017	Ol clinopyroxenite	—	2	2	1
GN-88-1006	Clinopyroxenite	—	2	2	3
GN-88-3039	Gabbro (carbonatized)	—	5	28	13
HICKMAN PLUTON — Mafic Phase					
GN-88-2003	Hb gabbro	—	1	2	1
GN-88-1004	Diorite	<5	1	17	8
DYKES					
GN-88-1016	Cpx-Hb porphyry	—	1	2	2
GN-88-2004	Cpx-Hb porphyry	—	1	2	1

[1] Rh is at or below detection limit (2 ppb) in all samples.
Ol = olivine; other abbreviations as in Table 2-10-2.

THE MENARD CREEK MAFIC-ULTRAMAFIC COMPLEX

LOCATION AND ACCESS

The Menard Creek mafic-ultramafic complex (56°45.5′ north, 126°29′ west) is located in the Intermontane Belt of north-central British Columbia. It underlies part of the McConnell Range of the Omineca Mountains (94D/16), and lies just north of Menard Creek for which the complex is named (Figure 2-10-4). Access to the area is by four-wheel-drive vehicle along a seemingly endless gravel road that leads north from Fort St. James to the Toodoggone River. A narrow spur road branches north towards the Menard complex just before Kilometre 423 on the main Cheni mine road. Alternatively, the area may be reached by helicopter from the Sturdee airstrip in the Toodoggone River area. The best exposures of the complex occur along serrated, locally precipitous ridges at altitudes between 1900 and 2200 metres. Lichen cover on the crest of these ridges is fairly extensive.

GENERAL GEOLOGY

Ultramafic rocks of the Menard Creek complex were initially included by Lord (1948) with the Early Cretaceous Omineca intrusions, a granitoid mass of batholithic proportions composed of mainly granodiorite to quartz diorite. Meyer and Overstall (1973) first identified the ultramafic nature of the complex during an exploration program to investigate an intense magnetic high over the body. Later, Irvine (1974b, 1976) identified the clinopyroxenites of the complex as an Alaskan-type association, produced the first detailed geologic map, and formally named the body the Menard Creek complex.

The Menard Creek complex (Figure 2-10-4) is a clinopyroxenite-gabbro body of probable Late Triassic age. It is surrounded by Late Triassic mafic volcanic rocks of the Takla Group. A possibly coeval high-level intrusive phase is represented by an augite and plagioclase-porphyritic dyke swarm which intrudes the northern margin of the complex. Similar rock types occur within the Savage Mountain Formation which is part of the "western assemblage" of Takla Group rocks that crop out to the immediate west of the complex (Richards, 1975).

The structure of the Takla Group is dominated by northerly to northwesterly trending folds and faults and at least two phases of deformation have been recognized (Bellefontaine and Minehan, 1988). The metamorphic grade of the Takla Group is greenschist to subgreenschist (Monger, 1977).

COUNTRY ROCKS

TAKLA GROUP

The Takla Group was initially described by Lord (1948) as an essentially Late Triassic to Jurassic conformable assemblage of more than 10 000 metres of mafic volcanic and sedimentary rocks. Subsequent work by Richards (1976), Monger, (1976, 1977), and Monger and Church (1977) refined this definition to include only rocks of Late Triassic age (Late Carnian to Middle Norian). The group was subdivided into two distinct facies, representing eastern and western assemblages, separated by a north-trending lineament, the Ingenika fault, which runs along the Ingenika River (Figure 2-10-4). In the vicinity of the Menard Creek complex, Takla Group rocks have been included as part of the eastern assemblage (Richards 1975), which includes mafic to intermediate lava flows, volcanic and epiclastic breccias, tuffaceous rocks and green phyllite, phyllitic schists and minor metasedimentary rocks.

INTRUSIVE ROCKS

ULTRAMAFIC-MAFIC ROCKS

The Menard Creek mafic-ultramafic complex (less than 4 square kilometres) is a roughly circular body with its outcrop pattern modified by faulting. The complex contains a mass of clinopyroxenite in its southwestern corner and a high proportion of gabbro. Igneous layering appears to be absent.

Clinopyroxenites

At the present level of exposure, clinopyroxenites, olivine-bearing clinopyroxenites, and olivine clinopyroxenites form 25 to 30 per cent of the complex. They comprise grey to green-weathering, medium to coarse-grained (5 to 10 millimetres) or locally pegmatitic (less than 2 centimetres) rocks that are generally massive and isotropic. Varieties that contain olivine carry about 5 to 15 volume per cent and contacts between olivine-bearing and olivine-free clinopyroxenites appear gradational. Olivine grains are usually highly altered and weather rusty brown.

In thin section, olivine and clinopyroxene exhibit cumulate textures and clinopyroxene has locally undergone adcumulate growth. Olivine is completely altered to a fine-grained assemblage of magnetite, serpentine and carbonate. Thin (0.5 to 1 millimetre) carbonate veinlets (2 to 3 volume per cent of the rock) are also common.

Gabbro

Pyroxene gabbro variably enriched in magnetite is the dominant lithology in the complex. The principal outcrops occur along east-trending ridges in the eastern part of the body. The gabbro is a dark to pale grey, massive, medium-grained rock that is texturally rather uniform and strongly magnetic. It contains subequal proportions of clinopyroxene and plagioclase, and locally grades into more leucocratic or melanocratic variants.

A fault-bounded sliver of extensively epidotized and sericitized gabbro occurs on the western margin of the clinopyroxenite unit. Melanocratic xenoliths of fine-grained mafic rocks are found within sheared and saussuritized gabbro, and may represent stoped blocks of Takla Group wallrocks. Locally these xenoliths are very abundant.

In thin section, clinopyroxenes are fresh whereas cumulus plagioclase is weakly to highly altered to sericite (10 to 90 volume per cent). Magnetite (5 to 15 modal per cent) forms anhedral intercumulate grains, and subhedral crystals of serpentinized olivine (1 to 2 millimetres) occur in trace amounts together with intercumulus biotite (less than 1 volume per cent).

MAFIC DYKES

At the northern margin of the complex, medium-grained equigranular gabbros, and a variety of gabbro with augite phenocrysts set in a fine-grained feldspathic matrix, are intruded by augite-phyric dykes that comprise up to 50 per cent of the outcrop. Further north, gabbro screens disappear and the dykes are sheeted.

Two texturally distinct varieties of dyke rock can be identified. One contains conspicuously bladed subhedral crystals of plagioclase with subtrachytic texture that reach over a centimetre in length; the other carries subhedral to euhedral, roughly equidimensional phenocrysts of augite. However, both types of dyke contain phenocrysts of plagioclase (less than 30 volume per cent), clinopyroxene (3 to 10 per cent) and olivine (1 per cent). In thin section, oscillatory-zoned plagioclase phenocrysts are partially resorbed, augite is partly altered to chlorite and olivine is replaced by serpentine and chlorite. The groundmass is composed of finely crystalline clinopyroxene, feldspar, and iron-titanium oxides (less than 20 per cent).

CONTACT RELATIONSHIPS

Intrusive contacts between the Menard Creek complex and the Takla Group have not been identified, although it is likely that such relationships originally existed. Most contacts are represented by faults. However, the contact between clinopyroxenite and gabbro is well exposed and identified as transitional.

The mafic dykes clearly intrude the gabbros. The contact between the units is represented by an intrusive zone with up to 50 per cent gabbro screens. Chilled margins provide good evidence for the chronology of dyke intrusion. In all cases, augite porphyry dykes are chilled against dykes with bladed plagioclase textures, indicating that the latter dykes are earlier. The timing of dyke intrusion is uncertain, but they may represent feeders for Takla Group volcanism.

STRUCTURE

A system of northeasterly trending faults appears as well-defined lineaments on aerial photographs. The faults are recognized in the field by localized zones of highly fractured rock and clayey gouge. In the vicinity of faults, alteration of the surrounding rock is locally severe, but no mineralization has been identified. Epidote and carbonate veining also becomes more intense within these fault zones.

GEOCHEMISTRY

Noble metal abundances for mafic and ultramafic rocks of the Menard Creek complex and mafic dykes are presented in

Table 2-10-5. Platinum-group element abundances are generally low with weak enrichment of platinum in clinopyroxenites relative to gabbros. Anomalously high palladium (41 ppb) in gabbro sample GN-88-4029 does not appear to coincide with the presence of sulphides and may be related to magnetite enrichment.

SUMMARY AND DISCUSSION

Some remarkable similarities exist among the Gnat Lakes, Hickman and Menard Creek mafic-ultramafic complexes. All occur within the Stikine tectonostratigraphic terrane and are closely associated with Upper Triassic volcanic and epiclastic assemblages of the Stikine and Takla Groups. Isotopic dating and geological relationships indicate that the Gnat Lakes and Hickman bodies are also Late Triassic in age, and this is likely true for the Menard Creek complex although the evidence is not as conclusive. Both the Hickman and Gnat Lakes complexes are spatially associated with large granitoid intrusions (Hickman and Hotailuh batholiths respectively). However, the Alaskan-type bodies are demonstrably separate entities on the geologic maps. Their emplacement within the volcanic pile preceded granitic intrusion, and they appear to have closer genetic ties with their immediate volcanic hosts than with the batholithic rocks.

Some differences among the ultramafic complexes are also apparent. In the Gnat Lakes complex only the more differentiated phases of the Alaskan-type association are present, namely hornblende clinopyroxenite, hornblendite and gabbro. Fortunately, this body has been well studied, and whole-rock and mineral chemistry support an Alaskan-type affiliation. Although gabbroic rocks are a volumetrically dominant phase of the Menard Creek complex, olivine clinopyroxenites and clinopyroxenites are also present. In view of the lack of detailed study, perhaps its most distinctive Alaskan-type trait is the absence of cumulus orthopyroxene, abundance of magnetite, and occurrence of biotite in the gabbroic rocks. The Hickman complex, on the other hand, comprises a more complete suite of Alaskan-type lithologies, including dunite, olivine-bearing clinopyroxenites, and gabbros. A distinctive feature is the presence of phlogopitic mica in olivine clinopyroxenites. In the Tulameen Complex, for example, this mineral first appears in early cumulates (Nixon and Rublee, 1988).

Intrusive relationships with their host rocks have been documented in the case of the Hickman and Gnat Lakes complexes. However, such relationships are rarely observed and external contacts are commonly affected by ductile and brittle faults. In all three cases, internal contacts between the various lithologies are gradational.

Sulphide mineralization in the vicinity of these mafic-ultramafic complexes is predominantly associated with fault zones. Preliminary assay results for the precious metals suggest that these epithermal sulphides carry interesting gold values (up to 0.85 gram per tonne). However, there is no evidence within the mineralized zones for remobilization of platinum-group elements whose concentrations in the mafic and ultramafic rocks appear to be low in comparison to their abundances in the Tulameen complex.

TABLE 2-10-5
NOBLE METAL ABUNDANCES OF THE MENARD CREEK MAFIC-ULTRAMAFIC COMPLEX AND ASSOCIATED ROCKS

Sample No.	Rock Type	Sulphides (volume %)	ppb[1] Pt	Pd	Au
MENARD CREEK MAFIC-ULTRAMAFIC COMPLEX					
GN-88-4025	Ol clinopyroxenite	—	7	2	1
GN-88-2029	Clinopyroxenite	—	6	4	1
GN-88-2033	Gabbro	Tr	1	6	1
[2]GN-88-2033	Gabbro	Tr	1	6	1
GN-88-4029	Gabbro	—	1	41	2
MAFIC DYKES					
GN-88-4027A	Cpx porphyry	—	1	2	1
GN-88-4027B	Cpx porphyry	—	1	2	2
GN-88-2032	Cpx porphyry	—	1	8	1

[1] Rh is at or below detection limit (2 ppb) in all samples.
[2] Duplicate analysis.
All abbreviations as in Tables 2-10-2 and 2-10-4.

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