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THE GEOLOGY AND GEOCHEMISTRY OF THE MINERAL HILL - WORMY LAKE WOLLASTONITE SKARNS, SOUTHERN BRITISH COLUMBIA (92G/12W)

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INTRODUCTION

The Mineral Hill - Wormy Lake area is located on the Sechelt Peninsula approximately 60 kilometres west-northwest of Vancouver and 5 kilometres north of Sechelt (Figure 1). It lies at the southern end of the Coast Plutonic Belt and the wollastonite-bearing skarns are hosted by elongate and deformed roof pendants of calcareous rocks that possibly form part of the Upper Triassic Quatsino Formation. These pendants are surrounded by a variety of Jurassic plutonic rocks that range in composition from gabbro to granodiorite.

Publications relevant to the regional geology include those by Roddick (1970, 1979, 1983), Price *et al.* (1985) and Friedman *et al.* (1990). In 1987 and 1988, Tri-Sil Minerals Inc. conducted an exploration program on the property which is described by Goldsmith and Logan (1987) and Goldsmith and Kallock (1988). Later, brief examinations of the property were conducted by staff of the British Columbia Geological Survey; these observations are described by White (1989) and Fischl (1991).

This paper presents the results of a four-week mapping and sampling program conducted in the summer of 1995. An 18 square kilometre area between Wormy Lake and Mineral Hill was geologically mapped (Ray and Kilby, 1995). Major and trace element geochemical data from the intrusive rocks, and assay data from mineralized occurrences, are reported here. The results of microprobe analysis of skarn minerals such as wollastonite, garnet and pyroxene are also presented.

METASEDIMENTARY ROCKS

Skarn-altered and deformed remnants of calcareous sedimentary rocks form narrow, discontinuous units that lie close to, and are partially controlled by the Wormy Lake fault zone, a linear zone of ductile and brittle deformation (Figure 2). Both the metasedimentary units and the fault zone extend from Snake Creek, northwestwards to Wormy Lake. Beyond Wormy Lake, the metasediments and the fault are believed to extend northwards beyond the mapped area. However, south of Snake Creek, the metasediments and the fault zone terminate against gabbroic rocks of the Crowston Lake pluton along the easterly striking Snake Creek fault (Figure 2).

In the Wormy Lake area, and northeast of the Wormy Lake fault, the metasedimentary package reaches its maximum outcrop width of approximately 400 metres. Less than 800 metres southeast of the lake, it quickly thins or disappears and is only seen as very narrow units (some less than 20 m thick) that form discontinuous fault-bound slices within the Crowston Lake pluton. Further south, however, and southwest of the Wormy Lake fault, the skarn-altered package again thickens until, at its southern extremity southeast of Mineral Hill, it reaches 250 metres in outcrop width.

Figure 1: Location of the Mineral Hill - Wormy Lake area, southern British Columbia.

The calcareous units have been intruded by swarms of gabbroic sills and dikes from the adjoining Crowston Lake pluton. The metasediments have been deformed and overprinted by varying degrees of exoskarn alteration so that, in many instances, the character of the protolith is uncertain. Originally, however, they are believed to have mainly comprised relatively pure, massive to bedded limestone and calcareous siltstone. Some of the original limestones now form discontinuous but extensive marble units which are marked by karst topography. The marbles are coarse-grained, white to grey rocks that vary from massive to well foliated and layered. The layering probably represents transposed bedding; many marbles

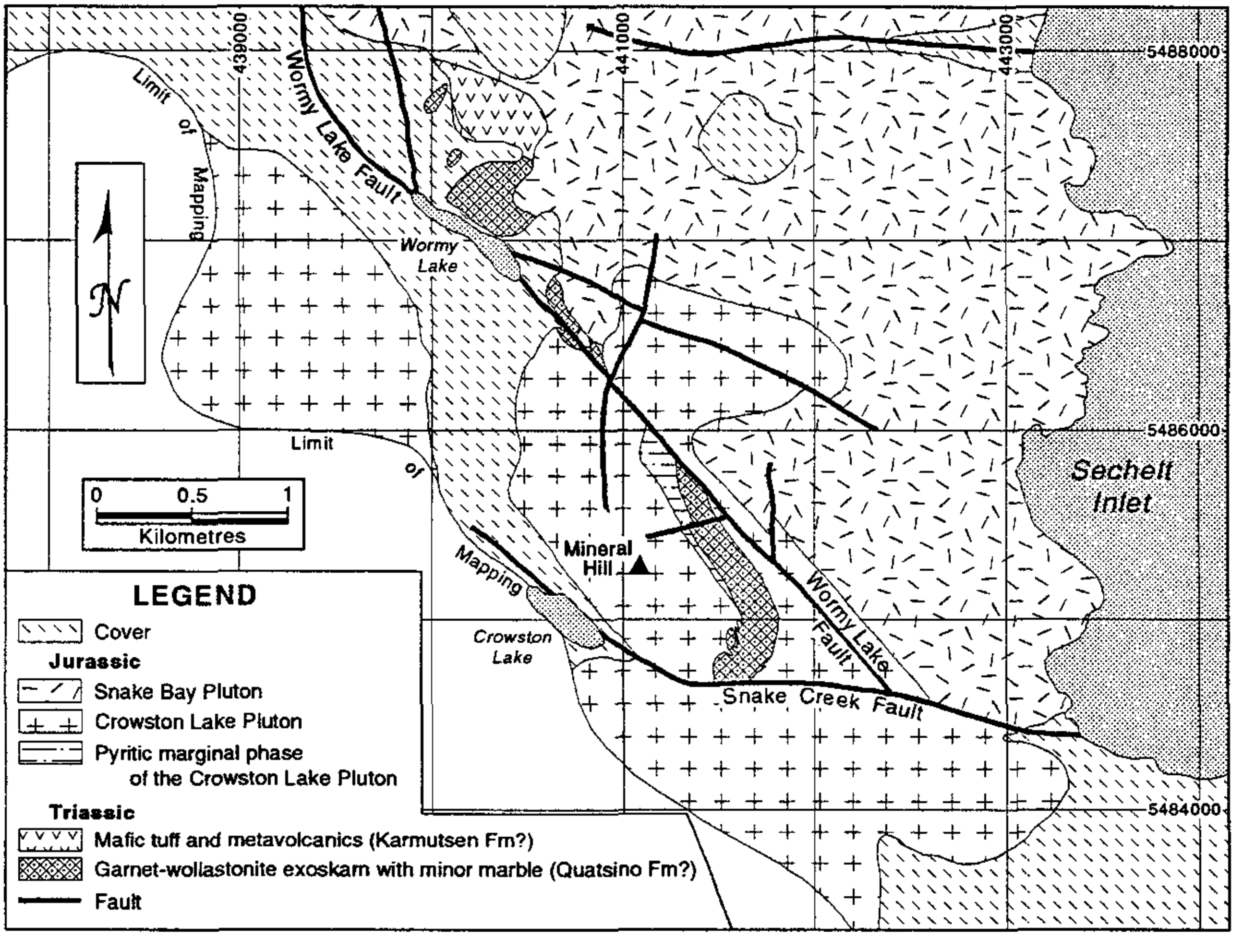

Figure 2: Geology of the Mineral Hill - Wormy Lake area (adapted from Ray and Kilby, 1995).

show evidence of intense ductile and flow folding as well as boudinage structures.

Apart from some marble remnants, most of the calcareous sedimentary rocks have been converted to skarn containing various quantities of garnet, wollastonite, epidote, clinopyroxene and, less commonly, vesuvianite. Adjacent to the Crowston Lake pluton, much of the original limestone has been replaced by massive garnetite. However, well layered garnet-wollastonite-pyroxene-epidote skarns are common and this layering is also believed to mark transposed bedding.

METAVOLCANICS AND TUFFS

An unusual unit of mafic rocks outcrops approximately 500 to 800 metres north of Wormy Lake. It probably represents metamorphosed and skarn-altered volcanics and bedded calcareous tuffs of either the Triassic Karmutsen Formation or the Lower to Middle Jurassic Bowen Island Group, as defined by Friedman *et al.* (1990). In appearance and texture these rocks vary from fine to medium grained and from massive to well layered. The layering, which generally ranges from 1 to 10 centimetres in thickness, often consists of alternating units of mafic-rich and felsic-rich material; we believe it represents original bedding. Where skarn alteration is intense, some layers have been almost entirely replaced by brown garnet with minor pyroxene. Crosscutting garnet veinlets are also present but no wollastonite has been seen in these rocks. The more massive exposures are generally highly mafic and are believed to be altered volcanics.

In thin section, the mafic layers are seen to consist of between 30 and 50% dark green hornblende crystals that reach 0.3 millimetre in length and which have a subparallel alignment. Freshly recrystallized plagioclase and strained quartz make up most of the groundmass. The amphibole is intergrown with small brown-coloured and isotropic garnets. Minor constituents include clinopyroxene, biotite, chlorite, epidote, zircon, sphene and opaque minerals.

INTRUSIVE ROCKS

The geology of the area is dominated by parts of two major Jurassic intrusive bodies that, for this study, are informally named the Crowston Lake and Snake Bay plutons. No conclusive field evidence was seen to determine their age relationships: it is possible that they form part of a single, compositionally zoned intrusion, although the mafic Crowston Lake body probably predates the more felsic Snake Bay pluton.

The skarn-altered metasediments are cut by numerous gabbroic sills and dikes that are genetically and temporally related to the Crowston Lake pluton. In addition, both the plutons, and the exoskarn packages, are cut by two compositionally distinct suites of minor intrusions that form narrow sills and dikes.

CROWSTON LAKE PLUTON

The Crowston Lake pluton occupies the western and southern parts of the mapped area (Figure 2). Its full extent is unknown but our mapping indicates that it outcrops over an area of 6 square kilometres. The pluton comprises medium to very coarse grained, massive to weakly foliated mafic rocks. Hornblende, lesser pyroxene and rare olivine are the dominant mafic minerals; they total between 10 and 60% by volume.

Whole-rock analyses (Table 1) and plots (Figure 3A and B) indicate that the Crowston Lake pluton is calcalkaline and subalkaline, and that it varies compositionally from gabbro to quartz diorite (Figure 3C). Trace element plots (Figure 3D) indicate that the pluton represents a volcanic arc granitoid as defined by Pearce *et al.* (1984). Small mafic xenoliths occur rarely, and locally the body is cut by narrow dikes of highly mafic microgabbro as well as by veins and irregular patches of mafic pegmatitic material containing hornblende and plagioclase crystals up to 2 centimetres long. Both the microgabbro dikes and pegmatitic segregations probably represent late phases of the pluton. Where the pluton is intersected by fault fractures, or overprinted by endoskarn alteration, it tends to be extensively epidotized, and carries minor garnet. Immediately northeast of Mineral Hill, the margin of the pluton adjacent to its contact with exoskarn is marked by a zone of fine to medium-grained mafic rocks, 100 metres thick, that carries disseminated pyrite and minor magnetite. It is uncertain whether this zone represents a unit of (?Karmutsen Formation) metabasalt or a strongly altered marginal phase of the pluton, however, the latter interpretation is preferred.

In thin section the more mafic gabbroic rocks are seen to contain between 40 and 60% unaltered plagioclase that forms crystals up to 2 millimetres in length in the groundmass and up to 5 millimetres long as phenocrysts. Twinning indicates that the plagioclase is of labradorite composition (An_{50-58}). Most of the plagioclase is fresh but the cores of some crystals are cloudy and altered and some labradorite phenocrysts display optical zoning in plane polarized light.

Pyroxene makes up to 20% by volume in some mafic gabbroic samples, and both clinopyroxene and orthopyroxene are present. The latter forms prismatic crystals up to 3 millimetres long that are characterized by low birefringence and lamellar twinning. Clinopyroxene tends to be more common and widespread than orthopyroxene.

Most pyroxenes are partially rimmed by, or completely altered to, brown or pale green hornblende which can comprise over 25% of the rock. Locally, the pyroxene and hornblende are partially altered to tremolite-actinolite and pale green chlorite which also occurs in late, crosscutting veins. In addition, light brown biotite crystals occur as aggregates, as rims around opaque minerals or as a partial replacement of hornblende and pyroxene. Generally, however, the biotite content of the gabbro is less than 1%.

Olivine-bearing gabbros are exposed in some localities, such as the eastern shore of Crowston Lake. The olivine is commonly strongly corroded and rimmed with pyroxene, amphibole and opaque iron minerals. The olivine-bearing rocks are often characterized by abundant laths of plagioclase with subparallel orientation due to igneous flow.

Accessory minerals include apatite, magnetite, ilmenite and leucoxene. In addition, some of the gabbros contain trace quantities of pyrrhotite, chalcopyrite, pyrite and hematite.

Calcareous metasediments close to the pluton are intruded by swarms of gabbroic sills and dikes. Areas of intense endoskarn development, either in the main pluton or in these smaller bodies, are commonly bleached and variably altered to epidote, plagioclase and minor garnet.

SNAKE BAY PLUTON

Part of Snake Bay pluton occupies the eastern and northeastern portions of the mapped area (Figure 2) and its coarse-grained, massive to weakly foliated rocks are well exposed along the western shore of Sechelt Inlet from Carlson Point to Snake Bay. Along the shore of the inlet, the rocks are leucocratic, containing between 4 and 8% mafic minerals, and biotite tends to be more common than hornblende. Westwards from the shore however, the pluton becomes more mafic; compared to the rocks along Sechelt Inlet they contain less potassium feldspar and biotite and more hornblende, which can comprise between 8 and 15%.

Whole-rock analyses (Table 1) and plots (Figure 3A and B) indicate that the rocks in the Snake Bay pluton are calcalkaline and subalkaline and that they vary compositionally from quartz diorite to granodiorite (Figure 3C). Trace element plots (Figure 3D) indicate that the pluton represents a volcanic arc granitoid as defined by Pearce *et al.* (1984).

Immediately adjacent to its contact with the Crowston Lake gabbro, the Snake Bay body becomes noticeably more mafic (up to 20% hornblende) and it tends to contain less quartz. Xenoliths are relatively rare in the pluton, but shoreline exposures along Sechelt Inlet and rocks close to the pluton margins commonly contain small (<0.3 m wide), rounded fragments of microgabbro, amphibolite and silicified metasediments. However, no xenoliths of exoskarn have been identified in the Snake Bay body, even in areas such as southeast of Wormy Lake, where the xenolith-bearing pluton outcrops less than 15 metres from garnet-wollastonite exoskarn.

TABLE 1. COMPARATIVE MAJOR AND TRACE ELEMENT ANALYSES OF VARIOUS INTRUSIVE ROCKS, MINERAL HILL - WORMY LAKE AREA

	Crowston Lake Pluton						Snake Bay Pluton			
	GR94-84	GR94-85	GR95-12	GR95-14	GR95-60	GR95-92	GR95-16	GR95-17	GR95-45	GR95-47
CaO	6.85	6.83	11.20	10.27	8.93	11.45	4.96	3.87	2.31	7.05
K_2O	1.10	1.19	0.13	0.20	0.60	0.61	1.80	2.44	3.39	1.36
P_2O_5	0.15	0.20	0.24	0.10	0.58	0.18	0.12	0.09	0.05	0.34
SiO_2	58.20	58.08	49.34	50.94	51.08	44.72	64.81	67.12	72.62	55.66
Fe_2O_3*	6.63	6.60	9.36	8.76	10.10	12.95	4.46	3.46	1.81	8.37
Al_2O_3	17.73	17.62	19.00	18.94	17.08	16.44	15.86	15.07	14.10	16.99
MgO	3.41	3.41	6.06	5.75	5.11	7.80	2.18	1.46	0.67	3.99
Na_2O	3.77	3.70	3.04	3.09	3.59	2.33	3.64	3.64	3.42	3.35
TiO_2	0.63	0.62	0.91	0.86	1.49	1.78	0.48	0.39	0.20	1.12
MnO	0.12	0.14	0.15	0.16	0.17	0.15	0.11	0.08	0.05	0.14
Cr_2O_3	0.01	0.01	0.01	0.01	0.01	0.02	0.01	0.01	0.01	0.01
LOI	0.90	0.93	1.17	0.89	1.46	2.09	0.85	0.84	0.54	1.22
SUM	99.50	99.33	100.61	99.97	100.20	100.52	99.28	98.47	99.17	99.60
Fe_2O_3	ND	ND	3.36	2.93	2.57	4.54	1.89	2.14	0.67	2.75
FeO	3.07	4.16	5.40	5.25	6.78	7.57	2.31	1.19	1.03	5.06
Ba	474	479	119	148	317	157	656	943	1722	427
Rb	23	25	<5	<5	12	5	38	48	66	28
Sr	502	503	733	707	557	575	409	360	273	543
Y	32	33	14	15	32	41	37	23	18	38
Zr	119	126	14	12	59	77	164	161	104	157
Nb	5	<5	6	<5	10	17	6	5	<5	20
V	133	135	259	192	125	376	106	67	<5	188
Sn	<5	<5	<5	<5	5	13	9	<5	6	<5

	1st generation minor intrusions					2nd generation minor intrusions					
	GR95-37	GR95-40	R95-42A	GR95-51	GR95-54	GR95-29	GR95-38	GR95-42	GR95-43	GR95-53	GR95-59
CaO	4.48	4.81	4.6	4.64	4.71	10.95	7.47	10.84	11.13	10.02	7.38
K_2O	1.75	1.42	0.97	1.53	1.77	1.63	0.72	1.61	0.60	0.57	0.58
P_2O_5	0.22	0.22	0.21	0.22	0.22	0.18	0.17	0.18	0.19	0.18	0.22
SiO_2	65.12	65.35	65.31	64.93	64.42	51.83	50.36	51.80	49.56	50.57	56.37
Fe_2O_3*	3.45	3.37	3.67	3.18	3.41	7.12	8.45	7.25	7.49	7.02	7.64
Al_2O_3	17.52	17.02	17.39	17.48	17.36	17.07	18.32	17.04	18.26	17.87	18.37
MgO	1.12	1.11	1.14	1.08	1.23	5.91	5.76	5.91	6.29	6.21	3.24
Na_2O	4.78	4.90	4.84	4.73	4.71	2.76	3.94	2.82	3.02	3.08	3.57
TiO_2	0.28	0.25	0.28	0.25	0.26	0.67	0.76	0.66	0.68	0.65	0.65
MnO	0.05	0.11	0.14	0.10	0.12	0.13	0.16	0.12	0.16	0.13	0.10
Cr_2O_3	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.01
LOI	0.98	1.20	1.30	1.08	0.97	1.78	3.79	1.97	2.86	2.35	1.53
SUM	99.76	99.77	99.86	99.23	99.19	100.04	99.91	100.21	100.25	98.67	99.66
Fe_2O_3	2.34	1.20	1.05	1.22	0.88	2.35	2.42	2.42	1.30	1.32	3.41
FeO	1.00	1.95	2.36	1.76	2.28	4.29	5.43	4.35	5.57	5.13	3.81
Ba	941	742	623	792	843	986	179	981	430	402	257
Rb	32	24	18	24	26	28	21	31	11	12	12
Sr	664	630	611	663	636	831	571	820	693	644	567
Y	17	20	22	18	19	21	26	20	25	20	25
Zr	131	130	135	124	128	58	64	65	54	49	93
Nb	15	9	10	7	9	10	12	7	12	7	13
V	24	19	25	35	21	144	168	140	172	133	246
Sn	<5	<5	6	8	6	20	14	15	<5	5	18

Fe_2O_3* = Total iron as Fe_2O_3. Major elements in weight %; trace elements in ppm. ND = sample not analysed.

Analytical Methods

CaO, K_2O, P_2O_5, SiO_2, Fe_2O_3*, Al_2O_3, MgO, Na_2O, TiO_2, MnO, Cr_2O_3 and Fe_2O_3 = Fused disc - X-ray fluorescence.

FeO = Titration.

Ba, Rb, Sr, Y, Zr, Nb, V and Sn = Pressed pellet - x-ray fluorescence.

Analyses completed at Cominco laboratory, Vancouver, B.C.

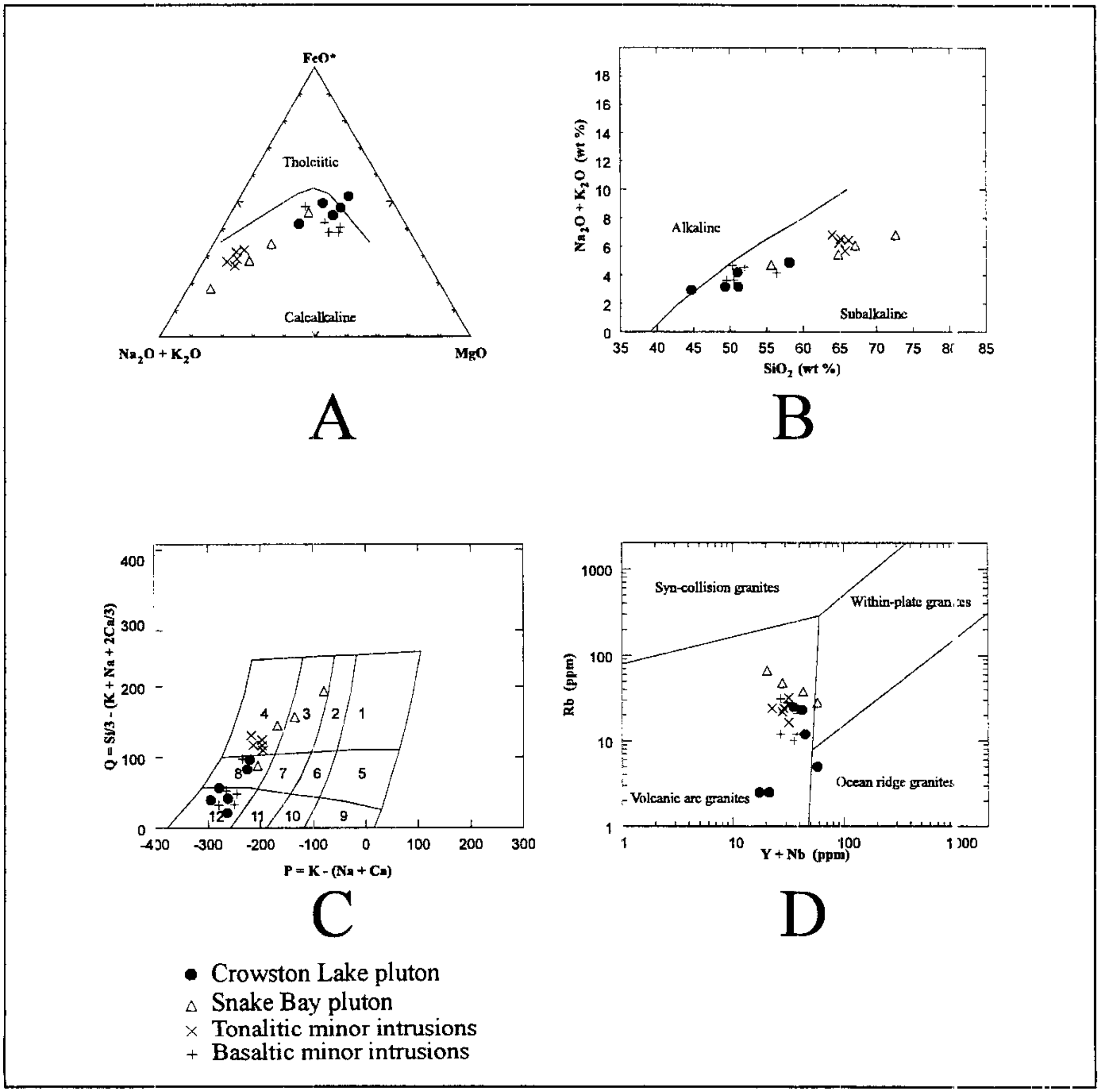

Figure 3. Plots comparing the geochemistry of the various intrusive rocks in the Mineral Hill - Wormy Lake area. A. AFM plot. B. Alkali-silica plot. C. Plot (after Debon and Le Fort, 1983) showing the compositions of the intrusive rocks. Rock compositions are as follows: 1. granite, 2. adamellite, 3. granodiorite, 4. tonalite, 5. quartz syenite, 6. quartz monzonite, 7. quartz monzodiorite, 8. quartz diorite, 9. syenite, 10. monzonite, 11. monzogabbro, 12. gabbro. D. Trace element discrimination plot (after Pearce *et al.*, 1984).

MINOR INTRUSIVE ROCKS

Several generations of minor intrusions are seen throughout the area. The oldest are gabbroic sills and dikes related to the Crowston Lake pluton. This suite commonly forms swarms of sills and dikes that, where they intrude the calcareous metasediments, are spatially associated with the development of extensive garnet-wollastonite-pyroxene skarn assemblages. They are medium to coarse-grained rocks that vary from mafic to highly mafic. In thin section, many are seen to be variably altered to epidote, particularly where they have been deformed by boudinage structures or overprinted by garnet-bearing endoskarn alteration.

The next recognized phase of minor intrusions is narrow sills and dikes which are most commonly seen intruding the garnet-wollastonite-bearing exoskarns east of Mineral Hill. Chemical plots indicate they are subalkaline and that they have a tonalitic composition (Figure 3B and C). They are fine-grained porphyritic to equigranular dark-coloured rocks that are commonly altered, siliceous and locally crosscut by veins of garnet and epidote; no wollastonite has been identified in these veins.

In thin section the less altered samples are seen to contain phenocrysts of hornblende and potassic feldspar up to 3 millimetres in length. The latter have fine optical zoning and are variably altered; the corroded and ragged amphibole phenocrysts are extensively chloritized. The very fine grained groundmass comprises abundant altered plagioclase lathes up to 0.2 millimetre in length with lesser amounts of quartz, chlorite, epidote and opaque minerals.

A subsequent phase of minor intrusion resulted in swarms of easterly striking sills and dikes. They tend to occupy fractures related to the east-trending Snake Bay fault and are most abundant east of Mineral Hill. They are seen cutting both the Snake Bay and Crowston Lake plutons as well as the exoskarns and marbles. Where they intrude marble their margins are commonly marked by thin zones of exoskarn containing garnet and wollastonite. Geochemical plots indicate this youngest generation of minor intrusions has a basaltic composition (Figure 3C); it is believed to be related to the Cretaceous Gambier Group volcanic and extensional event.

In thin section these fine-grained rocks are seen to be moderately to strongly altered. Elongate and altered phenocrysts of plagioclase, hornblende and augite reach 2 millimetres in length; the clinopyroxene is commonly rimmed by amphibole. The fine-grained groundmass consists largely of subparallel aligned plagioclase laths up to 0.2 millimetre long. Other minerals in the groundmass include crystals of altered, pale coloured hornblende with variable epidote, chlorite, biotite and opaques. Many of these rocks are extensively epidotised.

SKARN

Elongate bodies of exoskarn outcrop discontinuously along a 4.5 kilometre strike length of the Wormy Lake fault zone between Wormy Lake in the north and Mineral Hill in the south (Figure 2). Endoskarn, by contrast, is far less extensive, although it is locally important along the margins of the Crowston Lake pluton and in gabbroic dikes and sills that intrude calcareous metasediments.

The intensity of exoskarn development varies from weak in the marbles, where minor amounts of garnet, clinopyroxene and epidote are seen, to intense where the original impure calcareous metasediments are entirely replaced by skarn minerals. The principal exoskarn minerals are: garnet, wollastonite, epidote, clinopyroxene, plagioclase, quartz and calcite. Accessory minerals include vesuvianite, rhodonite and prehnite as well as the local and rare development of sulphides such as pyrite, sphalerite and chalcopyrite.

Generally, exoskarns throughout the area are characterized by high garnet:pyroxene ratios (approximately 10:1 to 2:1) although thin layers of pyroxene-dominant skarn are locally present. Exoskarns vary texturally from massive to very well layered. Massive garnetite is locally developed, particularly in limestone protoliths or close to the Crowston Lake plutonic rocks. It consists of between 50 and 100% garnet that is generally pale to medium brown in colour. However, dark reddish brown, green, amber and black garnets are also seen. Layered exoskarn comprises alternating layers up to 1 metre thick that are either white, brown or pale green in colour. Colour variations are related to individual layers being rich in either wollastonite, garnet, pyroxene, epidote or quartz-calcite-plagioclase assemblages.

Three episodes of exoskarn formation are recognised, all of which resulted in garnet-epidote assemblages; wollastonite, however, was only developed in the first and third of these skarn episodes.

The first episode was the dominant skarn-forming event. It was spatially and genetically related to the syntectonic emplacement of the Crowston Lake pluton and its gabbroic sill-dike swarm. It resulted in the pervasive and widespread wollastonite-garnet-pyroxene-vesuvianite assemblages that are of economic industrial mineral interest. Accompanying movements along the precursor structure of the Wormy Lake fault zone generated ductile deformation fabrics in the exoskarns as well as boudin structures in the gabbro sills and dikes.

At least two phases of garnet and wollastonite growth took place during the first skarn-forming event. The earliest phase resulted in the coeval development of garnet and wollastonite-rich layers that have selectively replaced original lithologies. Most of the wollastonite formed during this first phase occurs as crystals less than 0.5 centimetre long. They occur either as disseminations with garnet, pyroxene and carbonate, or in massive layers of up to 80% wollastonite. Microprobe analyses of garnets, pyroxene and wollastonite are presented in Tables 2 to 4. The garnets are grossularitic (Figure 4A) with an average composition of Gr^{67}-Ad^{29}-$Pyral^{4}$ (Table 2) and the diopsidic pyroxenes (Figure 4B) average Di^{85}-Hd^{12}-Jo^{3} (Table 3).

A second phase of garnet and wollastonite generally occurs in crosscutting veins, although some late porphyroblasts of wollastonite, which locally overgrow sphalerite, also formed at this time. The garnet and wollastonite veins seldom exceed 12 centimetres in thickness. Vein garnet is generally lighter brown in colour than the earlier garnet, which varies from medium to very dark brown to black. The second phase wollastonite, in both veins and porphyroblasts, is much coarser grained; individual crystals reach 3 centimetres in length.

Subsequently, a second and minor skarn-forming event accompanied the intrusion of early tonalitic dikes. Both the dikes and the immediately adjacent calcareous hostrocks are cut by narrow, fracture-filled veins of garnet-epidote skarn. No wollastonite was produced during this second skarn-forming event.

The third skarn episode was related to subsequent intrusion of a swarm of basaltic dikes and sills, and is developed immediately adjacent to these bodies where, they intrude marbles. Exoskarn alteration seldom exceeds 15 centimetres in thickness but a well defined mineralogical zoning is apparent. From dike to marble, this skarn zoning consists of: (1) proximal garnet-rich skarn; (2) distal wollastonite-rich

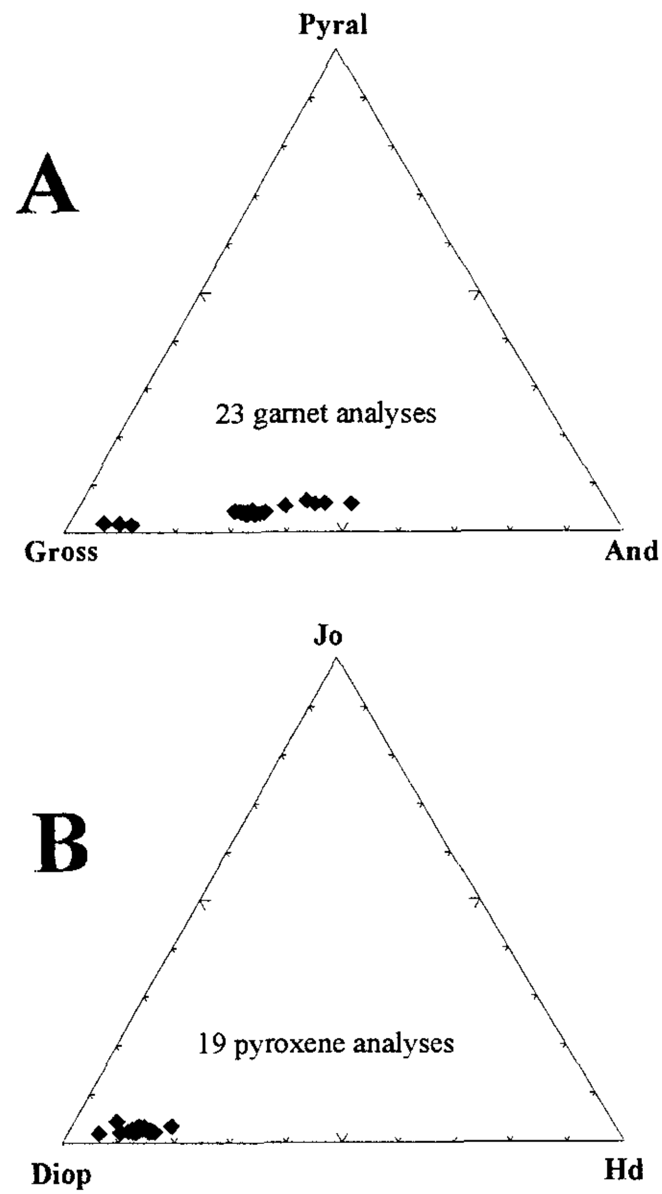

Figure 4. Composition of garnets (A) and pyroxene (B) at the Mineral Hill skarn, Sechelt, B.C.

skarn; (3) strongly bleached marble with pyrite cubes; and (4) grey to white marble without sulphides. Each mineralogical zone seldom exceeds 5 centimetres in thickness. The proximal garnet-rich zone locally includes an inner layer of yellow, amber or green garnet and an outer layer of dark red garnet. The dark red garnet crystals are often elongate, suggesting that they may have pseudomorphed early wollastonite.

Endoskarn alteration throughout the area occurs mainly in the Crowston Lake pluton and its gabbroic dikes and sills. To a far lesser extent, it is also present in extensional and boudin-related fractures developed in the early tonalitic dikes, but it has not been identified in the later basaltic dikes. Endoskarn in the Crowston Lake pluton and its related minor intrusions is commonly characterized by epidote occurring pervasively or in veins, and by plagioclase and rhodonite. Garnet in endoskarn is relatively uncommon; it tends to form in veins and is usually darker than the typically light brown garnet developed in exoskarn.

WOLLASTONITE MINERALIZATION

The wollastonite-rich skarns at Mineral Hill have been the focus of work since their wollastonite content was recognised in 1986 by prospector Rudy Riepe. Wollastonite, a member of the pyroxenoid mineral group, is a calcium metasilicate ($CaSiO_3$). It is the only naturally occurring, nonmetallic, white acicular mineral. Its acicularity, together with other physical properties, has

TABLE 2. REPRESENTATIVE MICROPROBE ANALYSES OF EXOSKARN GARNETS AT MINERAL HILL

Spot	3a	4a	3	6	7	54	56	57	60	62			
Sample	R94-74	R94-74	R94-74	R94-74	R94-74	R94-75	R94-75	R94-75	R94-75	R94-75	Avg**	Max**	Min**
Na_2O	0.02	0.04	0.02	0.00	0.06	0.00	0.02	0.06	0.00	0.00	0.02	0.06	0.00
FeO	9.72	8.89	9.41	9.03	8.56	10.84	3.41	2.82	13.00	11.88	8.76	13.00	2.82
K_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01	0.00
SiO_2	37.98	38.10	37.72	38.02	38.17	37.07	38.52	39.16	36.43	36.76	37.79	39.16	36.43
CaO	35.26	34.74	34.33	34.78	34.54	32.84	36.34	36.49	32.14	32.66	34.41	36.49	32.14
Al_2O_3	14.37	15.05	14.85	14.48	15.23	13.09	18.81	19.92	11.82	12.49	15.01	19.92	11.82
TiO_2	0.63	0.64	0.71	0.88	0.82	1.54	0.97	0.26	1.30	1.01	0.88	1.54	0.26
MgO	0.33	0.52	0.43	0.40	0.49	0.36	0.02	0.05	0.37	0.40	0.34	0.52	0.02
MnO	1.05	0.96	0.97	0.94	1.11	1.74	0.66	0.72	2.02	2.17	1.23	2.17	0.66
TOTAL	99.35	98.94	98.44	98.53	98.98	97.48	98.77	99.50	97.08	97.38	98.44	99.50	97.08
Na	0.003	0.007	0.003	0.000	0.009	0.000	0.003	0.009	0.000	0.000	0.00	0.01	0.00
Fe	0.635	0.580	0.618	0.593	0.558	0.723	0.220	0.180	0.877	0.798	0.58	0.88	0.18
K	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.00	0.00	0.00
Si	2.965	2.973	2.962	2.983	2.975	2.958	2.970	2.987	2.939	2.951	2.97	2.99	2.94
Ca	2.950	2.904	2.888	2.924	2.884	2.807	3.003	2.982	2.779	2.810	2.89	3.00	2.78
Al	1.322	1.385	1.374	1.339	1.399	1.231	1.711	1.791	1.124	1.182	1.39	1.79	1.12
Ti	0.037	0.038	0.042	0.052	0.048	0.092	0.056	0.015	0.079	0.061	0.05	0.09	0.02
Mg	0.039	0.061	0.050	0.047	0.057	0.043	0.002	0.006	0.044	0.048	0.04	0.06	0.00
Mn	0.069	0.063	0.064	0.062	0.073	0.117	0.043	0.046	0.138	0.148	0.08	0.15	0.04
Sum	8.02	8.01	8.00	8.00	8.00	7.97	8.01	8.02	7.98	8.00	8.00	8.02	7.97
Mole %													
Pyral	3.68	4.20	3.83	3.77	4.44	5.48	1.57	1.77	6.07	6.60	4.14	6.60	1.57
Grossularit	63.89	66.27	65.17	65.55	67.05	57.52	87.03	89.10	50.11	53.11	66.48	89.10	50.11
Andradite	32.43	29.53	31.00	30.68	28.51	37.00	11.40	9.14	43.83	40.29	29.38	43.83	9.14

Avg**, Max** and Min** = average, maximum and minimum of 23 analyses

made it an industrial mineral with expanding uses and increasing demand.

Within the study area, wollastonite-bearing skarn alteration is located in two main zones; (1) south of the Wormy Lake fault, along the southeastern slope of Mineral Hill (Figures 2 and 5; MINFILE 092GNW052), and (2) north of the Wormy Lake fault, where it occurs in a zone trending at approximately 335°, which is irregularly exposed and open to the north (Figure 2; MINFILE 092GNW053). The southern zone is up to 250 metres in outcrop width, and the northern zone reaches a maximum outcrop width of approximately 400 metres.

In 1987 and 1988, Tri-Sil Minerals Inc. conducted an exploration program on the southern half of zone 1 (Figure 5). Twenty-four drill holes, totaling 1719 metres in length, were put down to test the grade and continuity of the wollastonite-rich skarns southeast of Mineral Hill. This work, which included geological mapping at a scale of 1:1250, has been described by Goldsmith and Logan (1987) and Goldsmith and Kallock (1988).

A program of road building and trenching was undertaken on the skarn (zone 2) north of the Wormy Lake fault during the period 1989 to 1990 by Performance Minerals of Canada Ltd. During mapping, we identified a new area of wollastonite skarn 500 metres north of the northern tip of Wormy Lake. Well layered wollastonite-garnet skarn is exposed along the crest of a prominent hill for over 15 metres and consists of light brown garnet and fine to coarse (5 mm) wollastonite, in parts up to 80%.

Wollastonite is widespread throughout the skarn rocks in both zones. Grain size and mode of occurrence vary widely between outcrops and as reported in drill holes. Visually estimated grades in outcrops range from less than 0.5% up to 80% wollastonite. Wollastonite crystals are generally white to buff in colour. Massive 2 to 3-centimetre layers of wollastonite fibres up to 0.5 centimetre in length are common, or wollastonite may occur closely intergrown with grossular garnet and pyroxene over greater widths. In veins and porphyroblasts, wollastonite is much coarser grained and fibrous, reaching 3 centimetres in length. In rare instances garnet-wollastonite-pyroxene skarn float with light to dark brown garnet carries wollastonite crystals up to 11 centimetres long. Comparative analyses of wollastonite from Mineral Hill and from elsewhere are given in Table 4. These indicate that the Mineral Hill wollastonite has a very low iron content but is enriched in manganese (up to 1.13% MnO).

Goldsmith and Logan (1987) and Goldsmith and Kallock (1988) report visual estimates of wollastonite grade in drill-hole intersections from zone 1. These vary

TABLE 3. REPRESENTATIVE MICROPROBE ANALYSES OF EXOSKARN PYROXENES AT MINERAL HILL

Spot	1	9	10	12	13	66	67	68	70	73			
Sample	GR94-74	GR94-74	GR94-74	GR94-74	GR94-74	GR94-75	GR94-75	GR94-75	GR94-75	GR94-75	Avg**	Max**	Min**
Na_2O	0.00	0.07	0.00	0.03	0.00	0.22	0.07	0.00	0.04	0.07	0.04	0.22	0.00
FeO	3.79	4.21	3.74	4.42	3.50	5.55	1.99	2.45	4.12	3.78	3.80	5.55	1.99
K_2O	0.01	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.02	0.01	0.02	0.00
SiO_2	52.07	50.54	52.14	50.35	53.13	52.98	54.78	54.52	54.28	54.47	52.76	54.78	49.65
CaO	25.38	25.24	25.60	25.00	25.63	24.86	25.79	25.81	25.72	25.77	25.50	25.96	24.86
Al_2O_3	2.41	4.08	2.03	4.43	1.68	0.99	0.18	0.05	0.10	0.19	1.72	5.05	0.05
TiO_2	0.32	0.53	0.13	0.41	0.17	0.07	0.00	0.01	0.02	0.01	0.16	0.53	0.00
MgO	14.57	13.50	14.70	13.74	14.94	13.71	16.85	15.75	15.14	15.38	14.71	16.85	13.29
MnO	0.84	0.75	0.66	0.72	0.83	1.06	0.33	1.37	0.94	0.91	0.82	1.37	0.33
TOTAL	99.40	98.92	99.01	99.11	99.88	99.48	99.99	99.96	100.36	100.60	99.52	100.85	97.85
Na	0.000	0.005	0.000	0.002	0.000	0.016	0.005	0.000	0.003	0.005	0.00	0.02	0.00
Fe	0.118	0.132	0.117	0.138	0.108	0.173	0.061	0.075	0.127	0.116	0.12	0.17	0.06
K	0.001	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.001	0.00	0.00	0.00
Si	1.932	1.890	1.942	1.879	1.958	1.978	1.996	2.001	1.996	1.995	1.95	2.00	1.86
Ca	1.009	1.011	1.022	1.000	1.012	0.995	1.007	1.015	1.013	1.011	1.01	1.03	0.99
Al	0.105	0.180	0.089	0.195	0.073	0.044	0.008	0.002	0.004	0.008	0.08	0.22	0.00
Ti	0.009	0.015	0.004	0.012	0.005	0.002	0.000	0.000	0.000	0.000	0.00	0.01	0.00
Mg	0.806	0.752	0.816	0.764	0.820	0.763	0.915	0.862	0.830	0.839	0.81	0.92	0.74
MN	0.026	0.024	0.021	0.023	0.026	0.034	0.010	0.043	0.029	0.028	0.03	0.04	0.01
Sum	4.01	4.01	4.01	4.01	4.00	4.01	4.00	4.00	4.00	4.00	4.01	4.02	4.00
Mole %													
Jo	2.78	2.61	2.18	2.47	2.73	3.46	1.05	4.36	2.96	2.86	2.69	4.36	1.05
Dp	84.83	82.87	85.59	82.61	85.96	78.66	92.81	87.97	84.19	85.36	84.93	92.81	78.66
Hd	12.39	14.52	12.23	14.92	11.31	17.88	6.14	7.67	12.85	11.78	12.38	17.88	6.14

Avg**, Max** and Min** = average, maximum and minimum of 19 analyses

significantly from hole to hole and within holes. For example, hole 88-8(B) has a total length of 63.7 metres. Visual estimates of wollastonite between 9.8 to 17.0 metres depth (7.2 m length) can be summarized as follows: 1.9 metres garnet+wollastonite grading 65% wollastonite; followed by 0.7 metre quartz and epidote, grading less than 5% wollastonite; followed by 2.5 metres wollastonite+garnet, grading 75% wollastonite; followed by 2.2 metres limestone grading 5% wollastonite.

Goldsmith and Kallock made preliminary estimates of drill-indicated possible and probable reserves for their "central" section (Figure 5; approximately 125 metres north and south of 5 485 000 N) of the skarn (zone 1) southeast of Mineral Hill. These estimates total approximately 196 000 cubic metres of material grading 52% wollastonite; equivalent to 291 000 tonnes of wollastonite. There are other significant drill intersections outside this central section; for example, a 14.6-metre intercept in hole 88-2 with a visual estimate of 85% wollastonite, which is part of a 39.8-metre interval visually estimated to average 52% wollastonite.

During 1991-1992 Tri-Sil quarried nearly 30 000 tonnes and shipped approximately 20 000 tonnes of run-of-mine crushed rock to the Tilbury cement plant in Delta, British Columbia. This wollastonite-garnet mix was used as a cement additive (R. Riepe, personal communication, 1995).

SULPHIDE MINERALIZATION

Minor amounts of sulphide are locally present in the area. Four styles of mineralization are recognized on the basis of sulphide content and hostrock lithology:

- Pyrite±chalcopyrite veinlets in fractures cutting the Snake Bay pluton,
- Pyrite±magnetite±chalcopyrite as disseminations or veinlets in the Crowston Lake pluton.
- Disseminations, layers and deformed pods and lenses of pyrite±sphalerite±chalcopyrite hosted by garnet-wollastonite exoskarn.
- Pyrite±pyrrhotite pods and lenses in marble.

Assays of mineralized grab samples representative of all four types of mineralization are presented in Table 5.

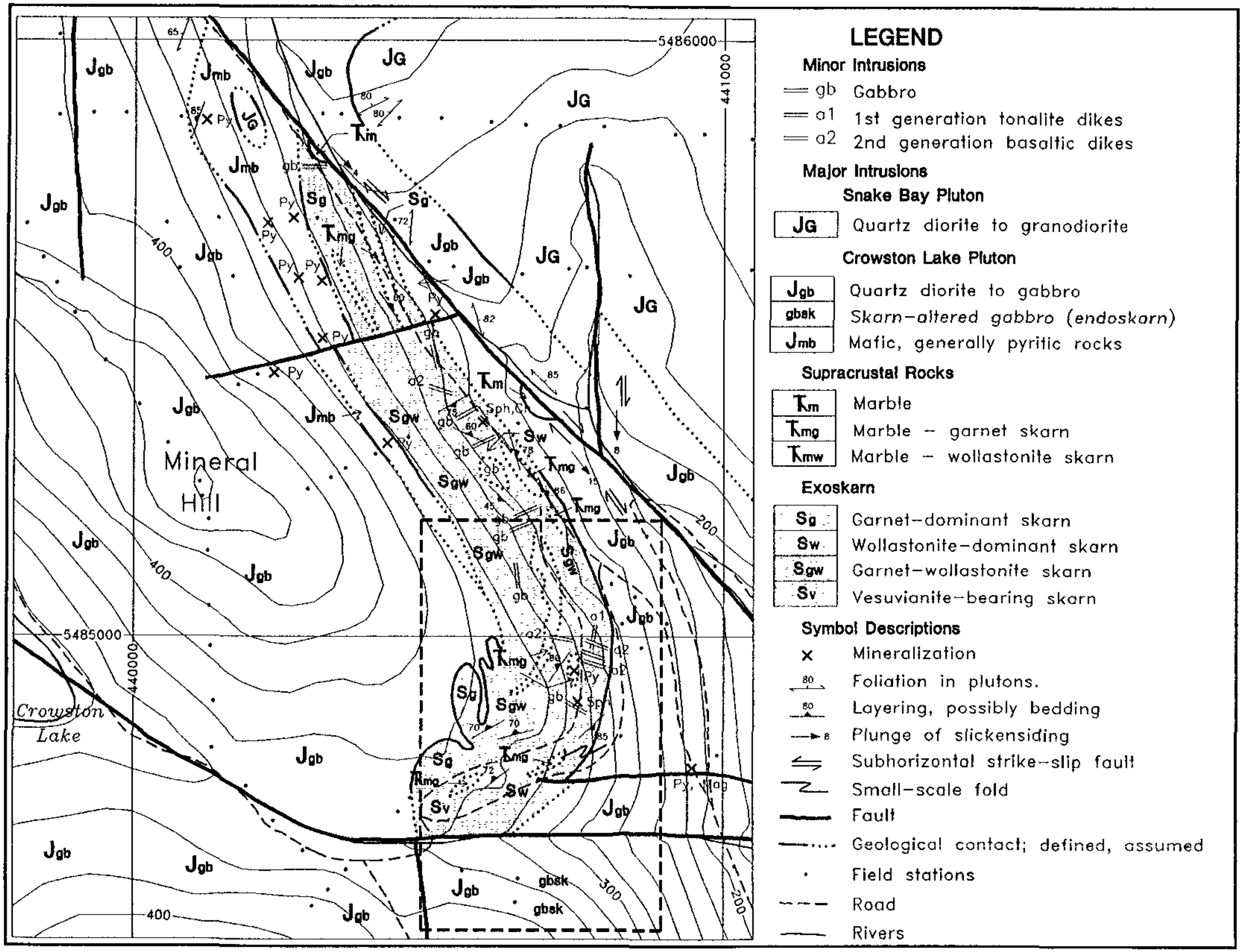

Figure 5. Map of the wollastonite skarn (zone 1) southeast of Mineral Hill (adapted from Ray and Kilby, 1995). Dashed box in lower right-hand corner is approximate boundary of mapping and drilling reported on by Goldsmith and Logan (1987) and Goldsmith and Kallock (1988). Mineralization includes; Py = pyrite, Sph = sphalerite, Ch = chalcopyrite, and Mag = magnetite.

TABLE 4. COMPARATIVE ANALYSES OF WOLLASTONITE CRYSTALS FROM THE MINERAL HILL SKARN AND ELSEWHERE

MINERAL HILL WOLLASTONITE (Samples GR94-74 & 75)

Crystal	5a	6a	7a	12a	13a	5.00	15	16	17	18	19	74	Avg
Na_2O	0.00	0.00	0.00	0.00	0.00	0.02	0.03	0.01	0.00	0.02	0.00	0.04	0.01
SiO_2	51.49	51.60	51.55	51.30	50.93	51.33	51.25	51.11	51.67	51.44	51.54	51.2[illegible]	51.37
Al_2O_3	0.01	0.01	0.04	0.09	0.02	0.08	0.05	0.03	0.03	0.03	0.03	0.0[illegible]	0.04
MgO	0.07	0.05	0.14	0.16	0.10	0.05	0.06	0.07	0.11	0.07	0.12	0.0[illegible]	0.09
FeO	0.14	0.12	0.14	0.17	0.12	0.22	0.21	0.19	0.22	0.09	0.14	0.2[illegible]	0.17
MnO	0.54	0.49	0.50	0.53	0.48	0.53	0.49	0.52	0.53	0.55	0.54	1.1[illegible]	0.57
K_2O	0.00	0.00	0.02	0.00	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.0[illegible]	0.00
CaO	48.16	47.44	47.83	47.43	47.54	47.52	47.86	47.45	47.43	47.69	47.60	47.1[illegible]	47.59
TiO_2	0.02	0.00	0.01	0.02	0.01	0.01	0.02	0.00	0.04	0.00	0.02	0.0[illegible]	0.01
Cr_2O_3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.0	0.00
Total	100.43	99.72	100.22	99.70	99.22	99.76	99.97	99.38	100.06	99.89	100.00	99.9[illegible]	99.86

OTHER WOLLASTONITE

Sample	EMT1*	DHZ1*	DHZ3*	DHZ5*	W-3*	IW-2*
Na_2O	0.02	0.00	0.24	0.00	0.08	0.10
SiO_2	51.26	51.10	50.53	50.00	51.32	48.69
Al_2O_3	0.02	0.12	0.67	ND	0.07	0.71
MgO	0.07	ND	0.61	ND	0.10	0.57
FeO	0.28	0.64	0.51	10.32	1.11	9.54
MnO	0.28	0.13	0.02	1.22	0.10	1.92
K_2O	0.00	ND	0.12	ND	0.12	0.03
CaO	47.67	47.86	47.01	38.86	46.22	38.04
TiO_2	0.01	ND	ND	ND	0.05	0.06
Cr_2O_3	0.00	ND	ND	ND	ND	ND
Total	99.61	99.85	99.71	100.40	99.17	99.66

ND = element not analysed. FeO = Total iron as FeO.

Microprobe analyses of wollastonite from Mineral Hill and Emerald Tungsten by S. Cornelius @ Dept. of Geology, Washington State University, Pullman, WA 99164

EMT1* = average of eleven wollastonite analyses from Emerald Tungsten Mine, Salmo, B.C.

DHZ1* = Pale green wollastonite, Willsboro, New York (Deer, Howie and Zussman, 1963).

DHZ3* = Wollastonite from a limestone-granodiorite contact, Adamello, Italy (Deer, Howie and Zussman, 1963).

DHZ5* = White iron-wollastonite, around chert nodules in meta-dololomite, Skye, Scotland (Deer, Howie and Zussman, 1963).

W-3* = Wollastonite, Sampo mine, Japan (Matsueda, 1973).

IW-2* = Iron-wollastonite, Sampo mine, Japan (Matsueda, 1973).

Gold values are generally low in all samples. The highest gold (423 ppb) occurs in thin (<2 cm) veinlets that cut the Snake Bay pluton (Table 5); these veinlets contain minor chalcopyrite, pyrite, quartz, carbonate and sericite. Generally, however, no significant metal enrichment is seen in any of the plutonic rocks.

The third type of sulphide mineralization, hosted in layered garnet-wollastonite exoskarn, can be separated into two subtypes. The first is characterized by silicification and fine-grained disseminated pyrite. Assays on two samples (GR95-23 and 24) indicate no significant metal enrichment (Table 5).

The other subtype occurs as thin layers or small tectonized pods and lenses of black sphalerite with lesser pyrite and chalcopyrite. This style of mineralization is seen in drill-road exposures southeast of Mineral Hill, at several localities farther north along the Wormy Lake fault zone, and in an old exploration pit approximately 200 metres southeast of the southern end of Wormy Lake. At this pit, a zone 1 to 5 metres thick is marked by extensive, black secondary manganese oxides and sphalerite. Individual sphalerite-bearing layers are generally only 1 to 6 centimetres thick and are separated by layers of barren skarn dominated either by wollastonite, dark brown garnet, clinopyroxene or carbonate.

In drill-road exposures east of Mineral Hill, this type of mineralization occurs either as weak disseminations of sphalerite in skarn or as discontinuous and narrow (1 m by 10 cm) tectonized lenses in layered, boudinaged garnet skarn. Assays of four grab samples of sphalerite-bearing rock are presented in Table 5. Most samples

TABLE 5. ASSAYS OF MINERALIZED GRAB SAMPLES FROM THE MINERAL HILL-WORMY LAKE AREA

		Sulphides in Snake Bay pluton				Sulphides in Crowston Lake pluton		
Sample		GR95-18	GR95-19	GR95-35	GR95-68	GR95-20	GR95-61	GR95-62
UTM	North	5487695	5488099	5486790	5487577	5484526	5485599	5485604
UTM	East	440865	438766	439694	438639	440980	440318	440277
Mo	ppm	4	< 2	5	< 2	< 2	< 2	3
Cu	ppm	16943	198	55	419	77	258	388
Pb	ppm	< 5	< 5	10	10	9	7	10
Zn	ppm	103	58	22	39	76	35	49
Ni	ppm	30	26	11	53	50	63	79
Mn	ppm	112	1119	515	1264	1111	1322	1670
Sr	ppm	2	144	385	305	631	326	412
Cd	ppm	3.2	1.2	0.5	1	2.1	0.8	1
Bi	ppm	14	< 5	< 5	< 5	< 5	< 5	< 5
V	ppm	4	75	116	151	192	175	185
P	%	0.01	0.05	0.11	0.05	0.35	0.04	0.04
Ba	ppm	40	39	148	111	65	41	75
Zr	ppm	3	24	4	14	33	18	35
Sn	ppm	< 2	< 2	< 2	3	< 2	< 2	< 2
Y	ppm	3	11	6	12	28	17	17
Nb	ppm	< 2	< 2	< 2	< 2	2	< 2	< 2
Be	ppm	< 1	< 1	< 1	< 1	< 1	< 1	< 1
Hg	ppb	95	5	5	<5	15	<5	<5
S	%	7.94	2.94	4.17	2.42	3.95	2.51	2.88
Se	ppm	ND	ND	0.2	0.6	ND	4.2	3.2
Te	ppm	ND	ND	<0.1	1.2	ND	<0.1	0.1
Au	ppb	423	<2	<2	24	6	<2	<2
Ag	ppm	<5	<5	<5	<5	<5	<5	<5
As	ppm	130	42	5.6	5.6	16	5.8	11
Br	ppm	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5
Co	ppm	330	79	59	85	51	86	110
Cr	ppm	8	91	16	140	220	140	150
Cs	ppm	<1	<1	2	<1	<1	<1	<1
Hf	ppm	<1	<1	3	<1	2	<1	<1
Ir	ppb	<5	<5	<5	<5	<5	<5	<5
Rb	ppm	22	<15	35	<15	<15	<15	<15
Sb	ppm	<0.1	1.6	<0.1	0.6	1.1	1.6	2.6
Sc	ppm	0.9	25	16	41	18	40	38
Th	ppm	1.1	<0.2	2.7	0.9	2.8	<0.2	1.4
U	ppm	<0.5	1.5	2.3	<0.5	21	<0.5	<0.5
La	ppm	2.5	5	21	4.5	18	4.3	6.2
Ce	ppm	6	10	44	12	25	11	17
Nd	ppm	7	<5	24	<5	11	<5	7
Sm	ppm	0.6	1.4	4.1	1.6	3.3	1.6	1.9
Eu	ppm	<0.2	0.7	1.3	0.7	1.7	0.8	0.7
Tb	ppm	<0.5	<0.5	<0.5	<0.5	1	0.8	0.8
Yb	ppm	0.8	2.4	2.8	2	3.5	3.3	3.1
Lu	ppm	0.011	0.35	0.42	0.26	0.54	0.52	0.53
F	ppm	180	70	480	920	410	540	400

TABLE 5. Continued

		Sulphides in garnet-wollastonite skarn						Sulphides in marble	
Sample		GR95-23	GR95-24	GR95-30	GR94-82	GR94-70	GR94-73	GR95-85	GR95-86
UTM	North	*5486252*	*5486204*	*5485362*	*5486694*	*5484890*	*5484890*	*5484942*	*5484942*
UTM	East	439684	439866	440590	439623	440751	440751	440745	440745
Mo	ppm	8	< 2	< 2	<2	<2	<2	43	38
Cu	ppm	28	245	2864	65	5223	3770	79	34
Pb	ppm	10	10	< 5	4	7	7	< 5	10
Zn	ppm	40	23	6756	6604	99999	88617	160	89
Ni	ppm	6	16	321	24	236	318	75	30
Mn	ppm	412	396	1849	51212	4546	4170	4685	1704
Sr	ppm	191	1211	57	27	16	118	35	183
Cd	ppm	0.8	1.1	47.5	49.5	1104.2	758	2.4	1.9
Bi	ppm	< 5	< 5	5	<5	<5	<5	< 5	< 5
V	ppm	20	103	38	98	49	49	338	170
P	%	0.05	0.11	0.29	0.13	0.10	0.08	0.29	0.52
Ba	ppm	263	13	124	<10	<10	<10	12	230
Zr	ppm	43	31	54	12	18	13	35	29
Sn	ppm	< 2	< 2	< 2	<2	<2	<2	< 2	< 2
Y	ppm	23	16	10	13	7	8	15	22
Nb	ppm	21	< 2	2	3	3	3	6	8
Be	ppm	1	< 1	< 1	1	1	1	< 1	< 1
Hg	ppb	10	15	15	80	5410	8135	10	10
S	%	0.7	3.74	10.11	0.68	12.62	8.32	10.5	4.51
Se	ppm	ND	ND	3	4	2.6	5	2.8	10.4
Te	ppm	ND	ND	0.3	<0.1	<0.1	<0.1	<0.1	<0.1
Au	ppb	<2	<2	160	102	60	2	43	67
Ag	ppm	<5	<5	<5	4.1	12.7	14.2	<5	<5
As	ppm	60	10	150	32	87	110	54	30
Br	ppm	<0.5	<0.5	<0.5	0.25	0.5	0.6	<0.5	<0.5
Co	ppm	37	64	540	6	820	760	41	15
Cr	ppm	28	22	69	50	95	83	82	61
Cs	ppm	3	<1	2	<1	<1	<1	<1	<1
Hf	ppm	11	3	2	<1	<1	<1	<1	<1
Ir	ppb	<5	<5	<5	<5	<5	<5	<5	<5
Rb	ppm	99	<15	<15	<5	<5	<5	<15	17
Sb	ppm	2.5	<0.1	4.1	0.5	1.1	0.2	2.5	8.6
Sc	ppm	14	16	8.8	3	3.8	4.2	2.6	3.3
Th	ppm	14	3.5	<0.2	0.5	0.2	1.5	1.4	1.4
U	ppm	3.9	1.8	<0.5	6.1	0.7	7.8	41	38
La	ppm	51	32	8.4	6	5.4	8.3	7.6	18
Ce	ppm	98	59	13	8	10	14	14	24
Nd	ppm	40	24	9	7	8	2.5	11	10
Sm	ppm	6.9	5.4	1.3	1.2	0.7	0.8	1.8	2.5
Eu	ppm	1.4	1.6	<0.2	0.5	0.5	0.4	0.8	1
Tb	ppm	1.4	0.9	<0.5	<0.5	<0.5	<0.5	<0,5	0.7
Yb	ppm	5.2	3	0.9	1.1	0.1	0.1	1	1.6
Lu	ppm	0.76	0.4	0.16	ND	ND	ND	0.17	0.24
F	ppm	420	480	1500	380	400	330	1700	2200

Analytical methods:

Mo, Cu, Pb, Zn, Ni, Mn, Sr, Cd, Bi, V, P, Ba, Zr, Sn, Y, Nb and Be by mixed acid digest - ICP @ Acme Analytical Labs. Ltd., Vancouver, B.C.

Fluorine by specific ion electrode @ Actvation Labs. Ltd., @ Ancaster, Ontario.

Au, Ag, As, Br, Co, Cr, Cs, Hf, Ir, Rb, Sb, Sc, Th, U, La, Ce, Nd, Sm, Eu, Tb, Yb and Lu by thermal neutron activation @ Activation Labs. Ltd., Ancaster, Ontario.

Hg by cold vapour AAS and sulphur by Leco analyser @ Acme Analytical Labs. Ltd., Vancouver, B.C

Se and Te by flame AAS @ Chemex Labs Ltd., Vancouver, B.C.

ND = sample not analysed

contain anomalous quantities of zinc, cadmium, copper and cobalt; the two samples collected from the drill-road exposures east of Mineral Hill carry the highest silver values (up to 14 ppm). These samples are also strongly anomalous in mercury (5410 and 8135 ppb Hg) which is most unusual for skarn and suggests that the zinc mineralization is not related to the skarn-forming hydrothermal event.

The fourth type of mineralization occurs as disseminations, clusters and pods of coarse pyrite±pyrrhotite hosted by strongly deformed marbles. The sulphide pods seldom exceed 15 centimetres in diameter; they occasionally contain crystalline masses of a glassy, brilliant green mineral which x-ray defraction analysis indicates is diopside (M.A. Chaudhry, personal communication, 1995). Assays of two sulphide-rich samples collected from the marbles show no significant metal enrichment although anomalous quantities of fluorine are present (Table 5).

GEOLOGICAL HISTORY OF THE AREA

Due to deformation and skarn alteration and the consequent lack of fossils, the precise age of the narrow unit of metasedimetary rocks along the Wormy Lake fault zone is unknown. A supracrustal succession assigned to the Lower to Middle Jurassic Bowen Island Group by Friedman *et al.* (1990) crops out immediately north of the mapped area, and on strike with the fault zone. However, this central part of the Sechelt Peninsula, north of the mapped area, also contains pendants of strongly foliated marble that have been correlated with the Upper Triassic Quatsino Formation (Roddick and Woodsworth, 1979). Thus, on the basis of lithology, the marbles and other skarn-altered metasediments along the Wormy Lake fault zone probably belong to the Quatsino Formation rather than Bowen Island Group.

At least three structural episodes have been recognised on the Sechelt Peninsula and in the surrounding Coast Range area (J.W.H. Monger, personal communication, 1995). These are:

1. A post-180 Ma, pre-155 Ma (Middle to Late Jurassic) event that affected the Bowen Island Group and older rocks, and produced isoclinal folding.
2. Extensional movements that accompanied the Early Cretaceous Gambier Group volcanism, and
3. An Early to Late Cretaceous contractional event that produced shear zones such as those near the Brittania massive sulphide deposit on Howe Sound.

This suggests that the structural and intrusive history of the Mineral Hill - Wormy Lake area includes the following five stages:

1. The Late Jurassic, syntectonic emplacement of the Crowston Lake pluton into Quatsino limestones, accompanied by development of the main garnet-wollastonite-pyroxene skarn assemblages at Mineral Hill and Wormy Lake. Deformation included tight folding with development of axial planar penetrative fabrics. Flattening was accompanied by boudinage of the gabbro sills, skarn and marble horizons, as well as sinistral ductile transcurrent movements along incompetent carbonate horizons within the Wormy Lake fault zone. This deformation probably coincided with the regionally developed post-180 Ma, pre-155 Ma structural event described by J.W.H. Monger (personal communication, 1995).
2. Syntectonic intrusion of the Snake Bay pluton which, like the Mineral Hill gabbro, is weakly foliated locally. It is uncertain whether the Snake Bay body was emplaced immediately after the Crowston Lake pluton, in which case the two intrusions may represent part of the same magmatic episode and therefore be related, or whether the two bodies are separated by a considerable time break.
3. Brittle, subhorizontal and dextral movement along the Wormy Lake fault.
4. Extensional tectonism producing easterly striking normal faults that are downthrown to the south. This faulting was accompanied by, and controlled, an early set of porphyritic tonalitic sills and dikes which were themselves fractured and partially altered to garnet-epidote endoskarn.
5. Continued extensional tectonism and easterly trending faulting coincided with the emplacement of narrow basaltic dikes.

The deformation continuing throughout stages 4 and 5 is probably correlative with Early Cretaceous extensional movements related to the Gambier Group. It is likely that the early tonalitic and later basaltic dikes are feeders for some of the Gambier volcanics which have presumably been removed by erosion in the Mineral Hill - Wormy Lake area.

CONCLUSIONS

The following conclusions are drawn with respect to the Mineral Hill - Wormy Lake area:

1. Significant thicknesses of high-grade (>50%) wollastonite are present not only at Mineral Hill but also east and north of Wormy Lake where new wollastonite-rich outcrops were discovered.
2. The wollastonite-garnet-pyroxene skarns are concentrated in elongate and deformed roof pendants that probably represent altered calcareous sediments of the Triassic Quatsino Formation.
3. Massive to well layered mafic rocks in the area are interpreted to represent altered tuffs and volcanics of either the Triassic Karmutsen Formation or the Jurassic Bowen Island Group.
4. The skarn-altered roof pendants are partly controlled by the northwesterly trending Wormy Lake fault.
5. Slickenslides and offset measurements suggest that the Wormy Lake fault underwent an early period of ductile and sinistral movement. This was followed by brittle, dextral subhorizontal displacement, and later brittle vertical movements. Similar episodes of early sinistral and later dextral horizontal movements have

been recognized on Texada Island (Webster and Ray, 1990) and in the Yalakom River area (Schiarizza *et al.*, 1990).

6. Several generations of intrusive-related skarn are recognized. However, the dominant garnet-wollastonite skarn-forming event was related to the emplacement of the gabbroic Crowston Lake pluton and its coeval dike-sill swarm.

7. Major and minor element analyses indicate all the major and minor intrusions in the area are subalkaline and calcalkaline, and represent "volcanic arc" granitoids. They vary compositionally from gabbro to quartz diorite to tonalite to granodiorite.

8. Microprobe analyses on skarn assemblages indicate the presence of grossularitic garnets, diopsidic pyroxenes and wollastonites with a very low iron content (avg. 0.17% total iron as FeO).

9. The sulphide content of the skarns and intrusive rocks is generally low. Assay results indicate the area offers little gold or base metal potential. Minor quantities of sphalerite-bearing skarn have sporadically high mercury values (up to 8135 ppb Hg) which suggests that the sulphides are not related to a skarn hydrothermal system.

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