GEOLOGY AND MINERAL CHEMISTRY OF TIN-BEARING SKARNS RELATED TO THE SURPRISE LAKE BATHOLITH, ATLIN, NORTHERN BRITISH COLUMBIA.

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INTRODUCTION

The Silver Diamond, Atlin Magnetite and Daybreak Sn (W) skarns (B.C. Minfile numbers 104N 069, 126 and 134 respectively) in the Atlin district of northern B.C, are related to the Cretaceous-age Surprise Lake plutonic suite.

This paper describes the geology of these skarns and presents assay results on the mineralization and microprobe analytical chemical data on their garnet, clinopyroxene and vesuvianite assemblages. In addition, major and trace element data of the Surprise Lake Batholith is presented. The Daybreak occurrence, a recent discovery by prospector William Wallis of Atlin, is distinct in containing wrigglite textures in the proximal skarn (Webster *et al.*, 1992). Some of its garnets and vesuvianites contain anomalous quantities of F, Sn, Cl and Cr and the concentration of some of these trace elements is distinctly different in the proximal and distal mineral assemblages.

These three skarns are believed to have a relatively low economic potential, due to their small size and the current poor world market for tin and tungsten. However, because Sn skarns are very rare in B.C., these Atlin occurrences have considerable scientific interest. Moreover, if world markets improve, these occurrences indicate that the margins of the Surprise Lake Batholith, and correlative rocks elsewhere, have an exploration potential for tin, tungsten and fluorite.

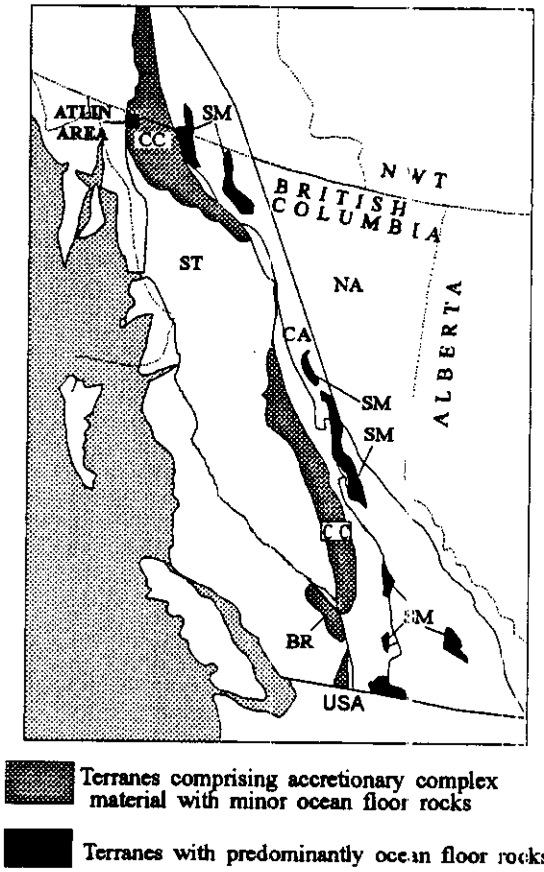

Figure 1. Location of the study area and its relationship to the northern portion of the Cache Creek Terrane in northern B.C. (after Monger, 1977).

REGIONAL GEOLOGY

The skarns described in this paper are situated in north-western British Columbia (Figure 1), approximately 20 kilometres east-northeast of Atlin and a few kilometres north and west of Surprise Lake (Figure 2) The area lies in the Intermontane Belt and is largely underlain by rocks of the allochthonous Cache Creek Terrane (Figure 1). The terrane consists predominantly of accretionary and subduction-related complexes of Mississippean to early Jurassic age (Monger, 1975, 1984; Monger *et al.*, 1982; Cordey *et al.*, 1991; Orchard, 1991). Also present are some ophiolitic ultramafic rocks related to the obduction of oceanic crust (Ash, 1994) and minor reefal limestones that may have formed in an oceanic island or seamount environment (Monger, 1975, 1977; Souther, 1977). The latter represent some of the host rocks for the Silver Diamond, Atlin Magnetite and

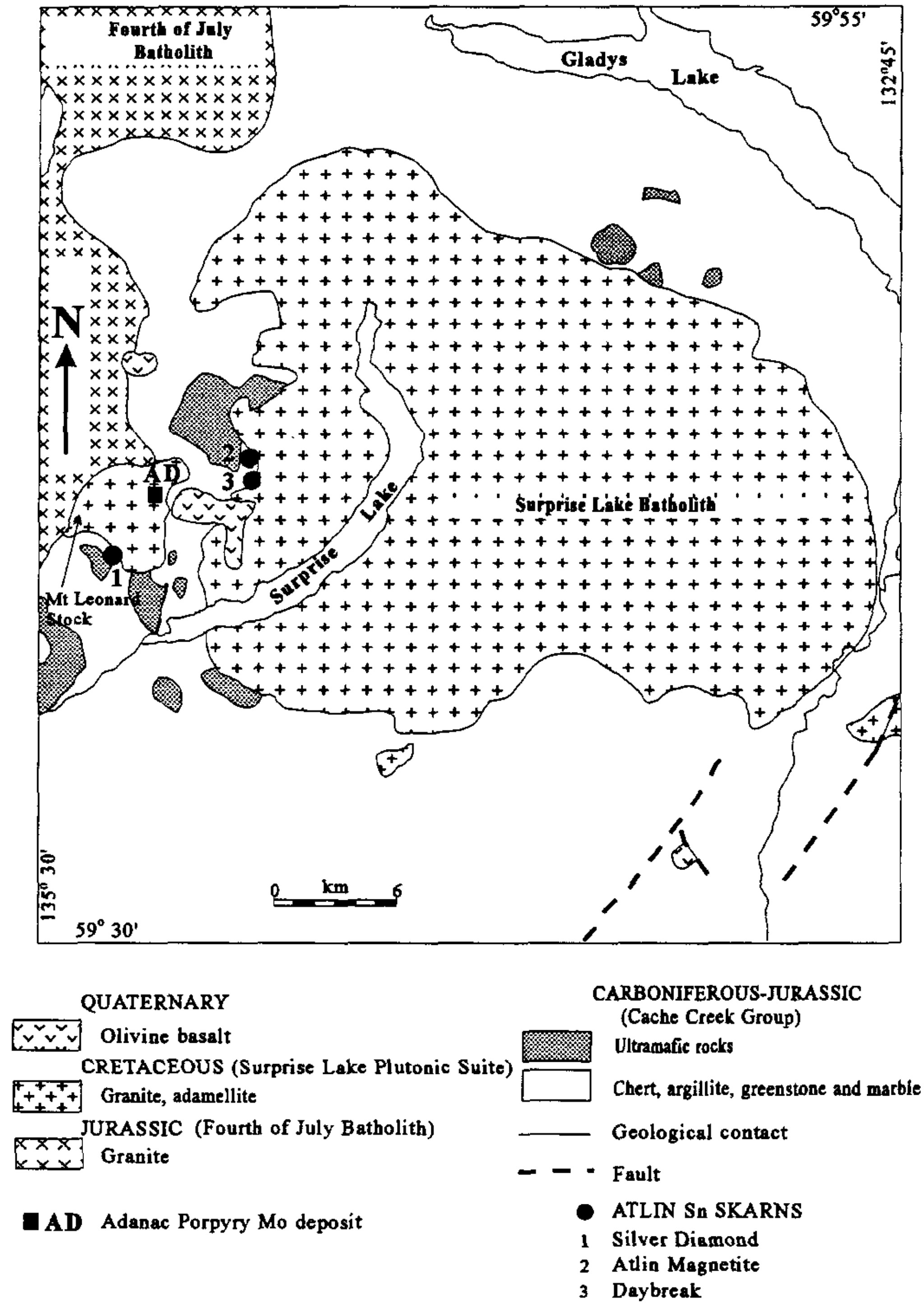

Figure 2. Geology and location of skarns associated with the Surprise Lake plutonic suite near Atlin, northwest B.C. (geology after Aitken, 1959).

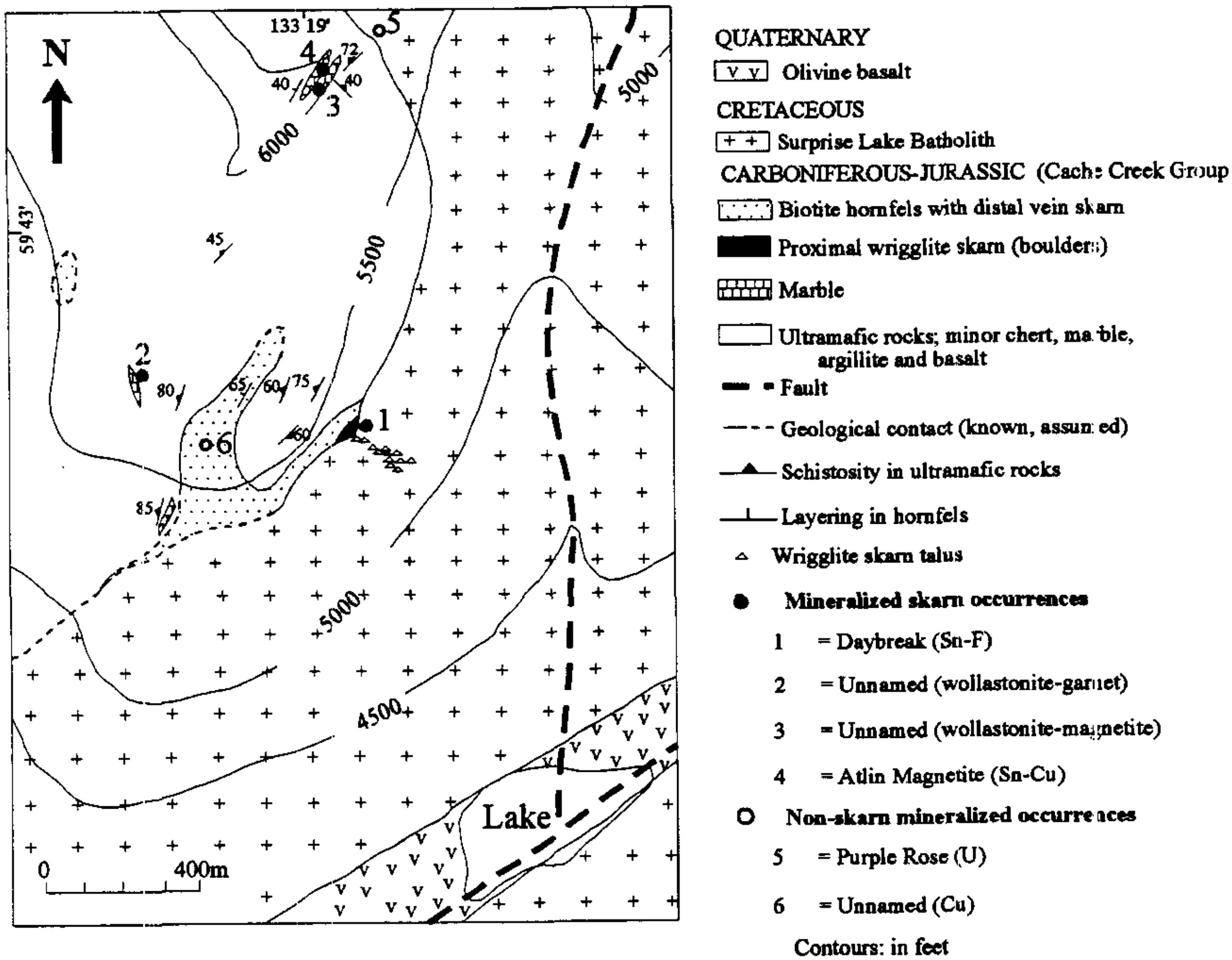

Figure 3. Geology in the vicinity of the Atlin Magnetite and Daybreak skarn occurrences, Surprise lake area (geological mapping by G.E. Ray and C.E. Kilby, 1995).

Daybreak skarns. Typically, the Cache Creek rocks at Atlin have undergone folding with intense brittle deformation and have been metamorphosed to subgreenschist grade (Monger, 1984; Bloodgood *et al.*, 1989a and b).

In the Surprise Lake area, the Cache Creek rocks are intruded by several plutons and smaller stocks. These include multiple phases of the Fourth of July Batholith (Figure 2; Aitken, 1959) which varies in composition from granite to granodiorite to diorite (Bloodgood *et al.*, 1989a and b). U-Pb zircon dating indicate a middle Jurassic age for this suite (Mihalynuk *et al.*, 1992).

A subsequent, regionally developed Cretaceous plutonic episode resulted in a number of major intrusions, including the Surprise Lake Batholith. The batholith forms an oval body approximately 30 kilometres by 20 kilometres in diameter (Figure 2). It has several small satellite bodies, the most westerly of which is the Mount Leonard stock. This stock hosts the Adanac porphyry molybdenum deposit (Figure 2; Christopher *et al.*, 1972; White *et al.*, 1976; Christopher and Pinsent, 1979) which has open pittable reserves of 152 million tonnes grading 0.063 percent molybdenum. The Mount Leonard stock is also associated with the Silver Diamond Sn (W) skarn. It includes coarse granitic and finer grained aplitic phases and, unlike the Surprise Lake Batholith, it locally contains hornblende (Bloodgood *et al.*, 1989a and b).

The much larger Surprise Lake Batholith is associated with a number of Sn-W-F-bearing veins (Bloodgood *et al.*, 1989a and b) as well as several low grade uranium showings (Ballantyne and Littlejohn, 1982) including the Purple Rose occurrence (Figure 3). The batholith is also genetically related to the Atlin Magnetite and Daybreak skarns (Figures 2 and 3). Age dating by various techniques indicates a Late Cretaceous age for the Surprise Lake body; Christopher and Pinsent (1979) report an average biotite K-Ar age of 70.6 Ma whereas U-Pb zircon dating by Mihalynuk *et al.*, (1992) gave an age of 83.8 Ma.

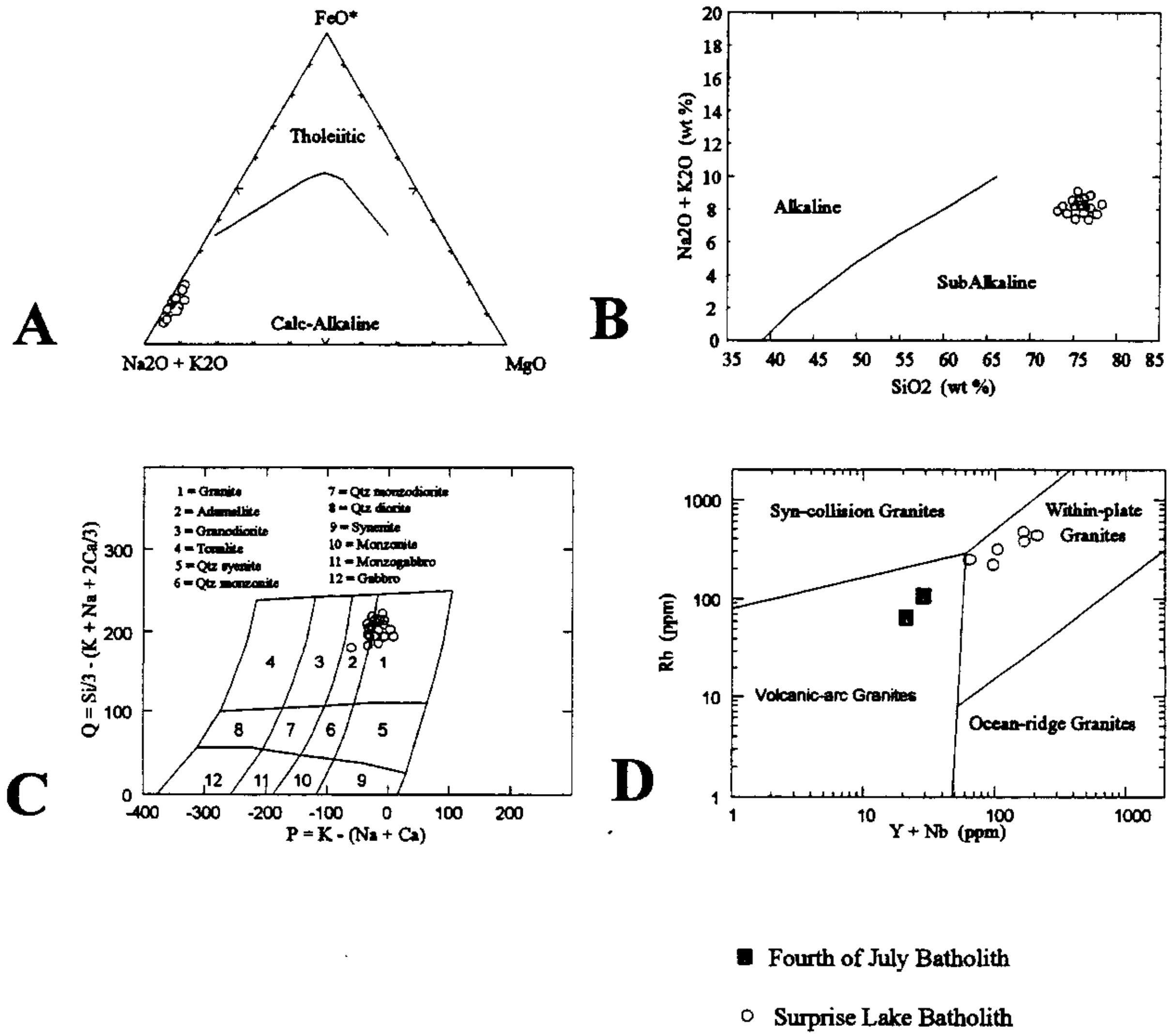

Figure 4. Geochemical plots of the Surprise Lake Batholith samples.
(A) Triangular $Na_2O + K_2O$ - FeO - MgO plot (after Irvine and Baragar, 1971).
(B) Alkali-silica plot (after Irvine and Baragar, 1971).
(C) Q - P plot (after Debon and Le Fort, 1983).
(D) Log Rb versus Log Y+Nb tectonic discrimination plot (after Pearce *et al.*, 1984) illustrating the volcanic arc character of the Fourth of July Batholith (data from Mihalynuk et al., 1992) and the within plate character of the Surprise Lake Batholith (data from Ray and Webster, in press).

The Surprise Lake Batholith largely comprises coarse to very coarse grained equigranular rocks with feldspar crystals up to 2 centimetres in length. It consists of sodic plagioclase, quartz and potassium feldspar with only minor amounts of coarse biotite; dark smoky quartz is a characteristic of the batholith (Bloodgood *et al.*, 1989a). Accessory minerals include zircon, apatite and late sericite and chlorite. Marginal phases of the batholith tend to be more quartz-rich and have a finer grained groundmass.

CHEMISTRY OF THE SURPRISE LAKE BATHOLITH

Major and trace element data of six samples of unaltered, coarse grained rocks collected from the batholith northeast of the Atlin Magnetite skarn are listed in Table 1; this data, together with analyses on another 13 samples presented by White *et al.*, (1976) and Christopher and Pinsent (1979) are used in Figure 4. Plots show that the Surprise Lake Batholith comprises

TABLE 1: Major and trace element chemistry of the Surprise Lake Batholith, Atlin, B.C.

Sample	GR91-145	GR91-146	GR91-147	GR91-148	GR91-165	GR91-166
SiO_2	76.19	76.47	77.00	76.45	75.51	75.58
TiO_2	0.09	0.10	0.11	0.10	0.20	0.06
Al_2O_3	12.45	12.42	12.00	12.39	12.46	13.08
Fe_2O_3*	1.40	1.29	1.52	1.30	2.07	1.19
MnO	0.02	0.01	0.03	0.03	0.05	0.02
MgO	0.03	0.02	0.02	0.02	0.15	0.00
CaO	0.62	0.63	0.54	0.54	0.48	0.37
Na_2O	3.30	3.32	3.24	3.56	3.17	4.01
K_2O	4.47	4.30	4.50	4.55	4.53	4.81
P_2O_5	0.01	0.01	0.01	0.01	0.04	0.01
LOI	0.83	0.95	0.77	0.58	0.84	0.47
Sum	99.41	99.52	99.74	99.53	99.50	99.60
FeO	1.07	0.66	1.04	0.79	1.27	0.66
Fe_2O_3	0.21	0.56	0.36	0.42	0.66	0.46
Fe_2O_3/FeO	0.20	0.84	0.35	0.53	0.52	0.69
K_2O/Na_2O	1.35	1.30	1.39	1.28	1.43	1.20
Ba	153	155	251	333	382	40
Ce	86	99	91	97	86	45
Cr	10	>10	14	>10	>10	>10
Cs	7	6	<5	<5	<5	<5
F	3860	3580	2940	2720	1580	1920
La	41	40	42	40	34	7.5
Nb	34	33	24	19	19	69
Rb	429	396	315	240	250	402
Sc	<5	<5	<5	<5	<5	<5
Sn	25	<15	21	<15	23	<15
Sr	20	19	27	28	45	<5
Th	34	31	34	25	21	33
U	<15	<15	<15	<15	<15	<15
V	<5	<5	<5	<5	<5	<5
Y	126	128	89	87	41	123
Zr	144	146	178	133	177	141

Samples collected by G.E. Ray and I.C.L. Webster, 1991.
Samples are of a coarse-grained, equigranular, biotite-bearing granite
Fe_2O_3* = total iron as Fe_2O_3.
Major elements in percent; trace elements in ppm.
For analytical methods etc. see Ray et al., 1995

calcalkaline, subalkaline rocks of adamellite-granite composition (Figure 4A, 4B and 4C). A trace element tectonic discrimination plot after Pearce *et al.* (1984) indicates that the batholith represents a "within-plate granitoid" in contrast to the older Fourth of July Batholith whose magma source probably had a "volcanic arc" characteristic (Mihalynuk *et al.*, 1992; Figure 4D).

The Surprise Lake Batholith has a markedly different chemistry to the arc-generated plutonic suites related to Fe, Cu, Au and Mo skarns in British Columbia (Ray *et al.*, 1995). On average, it contains less Ca, Fe, Mg, Ba, Cr, Sr, V and more Si, alkalis, Ce, F, La, Nb, Rb, Sn, U and Y than the other suites; this is consistent with it representing a highly differentiated melt derived from continental crust. In much of its overall major and trace element chemistry, the Surprise Lake Batholith closely resembles many of the peraluminous plutons responsible for W skarns in British Columbia (Ray *et al.*, 1995); both suites, for example, are comparatively enriched in Rb and depleted in Sc and Ba (Figure 5). However, the Surprise Lake rocks are distinct in having

TABLE 2A: Assay results of mineralized grab samples from the Silver Diamond skarn, Atlin, B.C.

Sample	GR91-149*	GR91-154A*	GR91-150*	GR91-154*	GR91-155**
Au-ppb	25	29	97	5	55
Ag	169	17	82	15	459
Cu	6600	1400	6200	1400	10200
Pb	1200	62	820	64	10400
Zn	165000	2900	369	2700	20500
Co	6	5	58	5	24
Ni	21	4	48	3	61
Mo	<3	<3	<3	<3	<3
As	37	1	1	1	36
Sb	7	1	16	1	3
Bi	396	32	2400	37	900
Cd	2900	73	14	78	410
Te	6.0	0.7	81.0	0.6	7.0
Se	9.0	<5	<5	<5	13.0
Ba	110	200	<100	330	<100
Cr	25	24	82	32	150
Rb	<30	330	150	350	54
Sn	<300	<300	<300	<300	<400
W	2	4600	3000	4600	5500
F	520	55000	59500	48900	50900

Samples collected by G.E. Ray, I.C.L. Webster and C.E.Kilby, 1991 and 1995.

Analytical methods etc. *see* Ray and Webster, in press.

Analyses in ppm except where stated in ppb

* Pyrrhotite-fluorite samples from Silver Diamond trench.

** Float of mineralized quartz vein, Silver Diamond skarn.

unusually high quantities of F (Figure 6), averaging 2767 ppm F compared to W skarns-related plutons which average less than 400 ppm F (Ray *et al.*, 1995; Ray and Webster, in press).

GEOLOGY AND MINERALOGY OF THE SKARNS

Silver Diamond skarn

The Silver Diamond skarn lies close to the southwest margin of the Mount Leonard stock (Webster *et al.*, 1992; Figure 2) about 4.5 kilometres southwest of Ruby Mountain. Trenches expose mineralized skarn which occurs as pods, veins and irregular lenses of massive to disseminated sulphide, up to 1 metre wide. This mineralization occurs mainly along the contact between a crystalline, massive to thinly layered marble and a unit of greenstone and ultramafic rocks. In parts, the greenstone unit is strongly brecciated and the angular fragments are surrounded and cut by sulphide veinlets. Mineralization consists largely of pyrrhotite and sphalerite with minor chalcopyrite, pyrite, scheelite and fluorite. Locally, the colourless to purple fluorite forms over 50 percent by volume of the rock. It occurs either as large crystalline masses, that are stained with black manganese oxides and intergrown with sericite, or as isolated crystals growing within the massive sulphides.

Assays of mineralized grab samples (Table 2A) indicate that the Silver Diamond skarn contains, in addition to W, Cu, Zn and Pb, anomalous quantities of Ag, Bi, Cd, Te and Se. Float material of vein quartz containing sphalerite and galena also occurs near the skarn. Also, a short distance northeast of the Silver Diamond skarn in what may be a separate occurrence, MINFILE reports some scheelite, cassiterite, molybdenite and tetrahedrite mineralization.

Brown and red coloured garnet is relatively uncommon; it occurs as veinlets cutting the marble and greenstone as well as thin layers that commonly develop

TABLE 2B: Assay results of mineralized grab samples from the Daybreak and Atlin Magnetite skarns, Atlin, B.C.

Sample	GR91-159*	GR95-141*	GR95-142**	GR95-150***	GR95-152***	GR91-140***	GR91-144***
Occurrence	Daybreak	Daybreak	Daybreak	Atlin Magnetite	Atlin Magnetite	Atlin Magnetite	Atlin Magnetite
Au-ppb	19	660	61	201	287	305	646
Ag	1.0	6	19	69	<5	65.0	36.0
Cu	4	13	3463	4362	592	8800	6300
Pb	10	< 5	64	63	28	114	58
Zn	640	556	607	429	1405	539	1300
Co	8	16	92	55	86	56	81
Ni	7	24	187	13	68	23	16
Mo	11	2	< 2	< 2	< 2	<3	<3
As	70	95	12	47	72	87	210
Sb	18	< 5	< 5	< 5	< 5	2	3
Bi	70	917	341	57	64	68	210
Cd	0.4	<0.4	5.1	2.6	8.9	3.6	5.1
Te	0.30	8.4	<0.6	<0.6	<0.6	<0.3	<0.3
Se	<5	2.4	2.4	0.8	0.8	5	<5
Ba	<100	10	193	119	25	<100	<100
Cr	44	< 2	451	19	112	140	70
Rb	<30	<15	<15	55	<15	35	<30
Sn	<200	1754	459	1787	2003	2100	2000
W	550	190	110	89	95	9	39
F	47000	140000	1400	390	350	300	160
Hg ppb	-	15	25	225	30	-	-
U	-	26	13	< 10	< 10	-	-
Nb	-	3	19	< 2	< 2	-	-
Be	-	394	< 1	15	12	-	-
S %	-	0.02	0.02	0.29	0.01	-	-

Samples collected by G.E. Ray, I.C.L. Webster and C.E.Kilby, 1991 and 1995.

Analytical methods etc. see Ray and Webster, in press.

Analyses in ppm except where stated in ppb or percent

* Proximal magnetite-garnet-fluorite-vesuvianite wrigglite skarn, Daybreak.

** Distal garnet-pyroxene-vesuvianite vein skarn cutting hornfels, Daybreak.

*** Magnetite-rich mineralization, Atlin Magnetite.

between marble and green pyroxene-rich skarn. In addition, variable amounts of amphibole, biotite, sericite and very coarse grained clinopyroxene are present in the skarn. The greenstone adjacent to the sulphide-fluorite skarn is bleached, silicified and contains some secondary pyroxene and amphibole. Greenstone adjacent to marble contains remnant patches of a black to dark purple-brown coloured biotite hornfels that have locally been overprinted by skarn alteration. Transition from marble to hornfels is often marked by the following mineral zoning: (1) marble, (2) garnet-rich skarn, (3) pyroxene-rich skarn and (4) hornfels.

In thin section the pyroxene-rich skarn contains very large, well cleaved and tabular crystals of clinopyroxene up to 8 millimetres in length. The moderate to high birefringent pyroxene is intergrown with well twinned sodic plagioclase and is weakly altered to carbonate and sericite. Many pyroxenes are cut by sulphide veinlets and contain small, rounded inclusions of quartz, plagioclase and garnet. Garnet crystals are generally anhedral and seldom exceed 2 millimetres in diameter. They

TABLE 3: Microprobe analyses of pyroxenes from the distal vein skarn, Daybreak occurrence, Atlin, B.C.

	Oxide Weight Percent					
	2	3	4	5	6	18
Na_2O	0.06	0.38	0.23	0.21	0.08	0.20
FeO*	15.03	13.14	13.65	13.51	13.63	14.61
K_2O	0.00	0.00	0.00	0.00	0.00	0.00
SiO_2	51.67	51.38	51.19	51.41	51.85	51.59
CaO	23.80	23.85	24.00	24.20	24.29	24.22
Al_2O_3	0.23	1.21	0.84	0.79	0.16	0.95
TiO_2	0.02	0.11	0.05	0.09	0.00	0.08
MgO	8.40	9.52	9.15	9.37	9.23	8.66
MnO	0.58	0.41	0.36	0.31	0.48	0.39
Total	99.80	100.00	99.48	99.88	99.72	100.69
	Number of ions on the basis of 6 oxygens and 0 OH					
Na	0.00	0.03	0.02	0.02	0.01	0.01
Fe	0.49	0.42	0.44	0.43	0.44	0.47
K	0.00	0.00	0.00	0.00	0.00	0.00
Si	2.00	1.97	1.98	1.98	2.00	1.98
Ca	0.99	0.98	0.99	1.00	1.00	0.99
Al	0.01	0.05	0.04	0.04	0.01	0.04
Ti	0.00	0.00	0.00	0.00	0.00	0.00
Mg	0.49	0.54	0.53	0.54	0.53	0.49
Mn	0.02	0.01	0.01	0.01	0.02	0.01
Total	3.99	4.01	4.01	4.01	4.00	4.01
Hedenbergite	49.13	43.06	45.03	44.26	44.58	47.98
Diopside	48.95	55.58	53.77	54.72	53.83	50.72
Johannsenite	1.92	1.36	1.20	1.02	1.59	1.31
Fassite	1.07	5.60	3.87	3.61	0.75	4.31

Microprobe analyses by G.E. Ray and S. Cornelius.
FeO* = total iron as FeO

commonly have pale brown margins and dark cores due to abundant opaque inclusions, and are mostly isotropic with very thin, weakly birefringent margins.

Many of the pyroxenes at the Silver Diamond skarn are hedenbergitic and plot as johannsenite-hedenbergite solid solutions (Figure 7). However, a few pyroxenes are diopsidic (Figure 7). Microprobe analyses of garnets from the Silver Diamond indicate they are mostly low-Mn and grossularitic (Figure 7) averaging 82 mole percent grossularite. They are weakly enriched in Sn (up to 0.25 weight percent Sn) but unlike some garnets at the Daybreak skarn, no anomalous Cr or Cl values are recorded and, apart from two crystals containing 0.2 and 0.1 weight percent F respectively, most garnets samples contain no detectable F.

Discrimination plots using garnet-pyroxene composition data as outlined by Einaudi (1982), together with the high pyrrhotite/pyrite ratios of the mineralization suggests that the Silver Diamond formed in a relatively reduced environment.

Atlin Magnetite skarn

The Atlin Magnetite skarn lies approximately 8 kilometres northeast of the Silver Diamond skarn and 1 kilometre north of the Daybreak skarn (Figures 2 and 3) at about 1830 metres (6000 feet) elevation. It is situated approximately 200 metres from the margin of the Surprise Lake Batholith and is hosted mainly by thin, deformed units of marble which are within a thermally

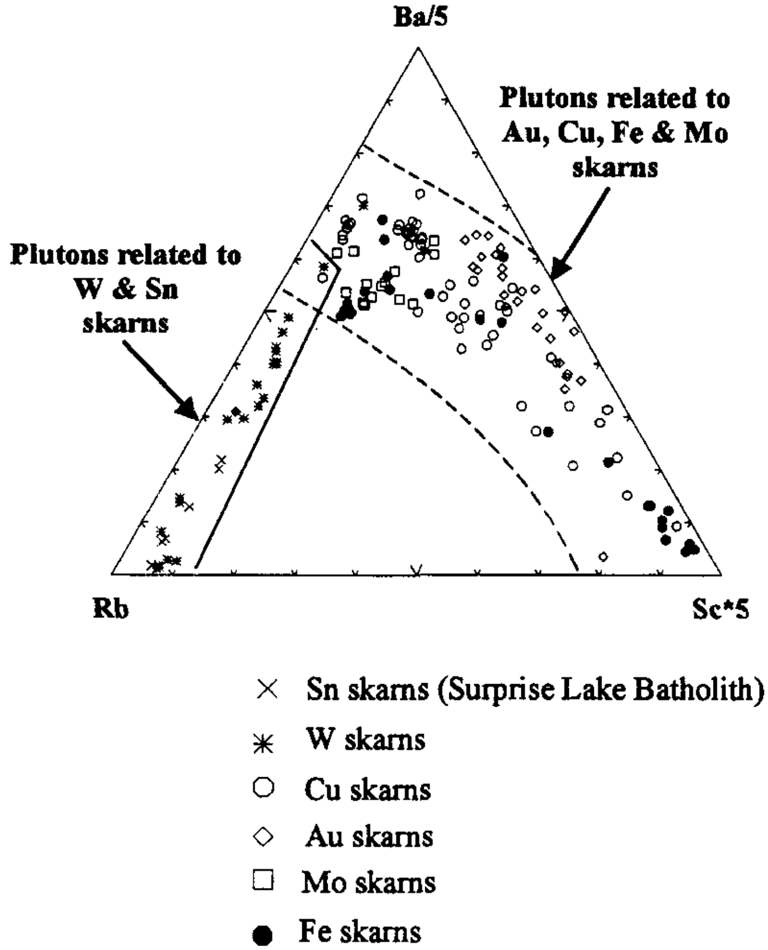

Figure 5. Triangular Rb-Ba/5-Sc*5 discrimination plot of plutonic rocks related to Sn skarns (Surprise Lake Batholith) and W, Au, Cu, Mo and Fe skarns in B.C. (data from Ray and Webster, in press).

altered package of sheared greenstone, talcose and serpentinized ultramafic rocks and biotite hornfels. The marginal phase of the batholith is a rusty-weathering, medium grained quartz porphyry which is texturally distinct from the coarser grained rocks seen in the more interior portions of the batholith. It hosts the Purple Rose uranium occurrence (MINFILE number 104N 005) which lies approximately 250 metres north-northeast of the Atlin Magnetite skarn (Figure 3).

Mineralization is dominated by layers and masses of massive magnetite, up to 0.6 metre thick, that have replaced the moderately dipping marble layers. Massive magnetite is both intimately intergrown with garnet and cut by veinlets of amber-coloured garnet. Locally, both the magnetite layers and the marble display a cleavage which strikes northwest and dips 40 degrees northeast. Lesser amounts of chalcopyrite and sporadic pyrrhotite and pyrite occur within the magnetite. Azurite and malachite staining is widespread. Assays of sulphide-bearing magnetite samples presented in Table 2B indicate that the Atlin Magnetite mineralization contains up to 646 ppb Au as well as anomalous quantities of Sn, Cu, Ag, Bi and Zn. However, in contrast to both the Silver Diamond and Daybreak skarns, it is not enriched in F, Te or Se.

Layers, masses and veins of garnet are present with lesser amounts of pyroxene, actinolite, coarse green epidote and some late veins of rhodonite. In hand sample, garnets vary in colour from red, orange and yellow-green to dark green, brown, amber and black. Some of the sugary textured marbles contain euhedral crystals of black garnet up to 1 centimetre across. Immediately east of the main showing is an area of purple-brown coloured, fine grained biotite hornfels. The hornfels is cut by veins of bright green pyroxene and dark green garnet, which in turn are cut by veins containing radiating crystals of wollastonite up to 3 centimetres long. Float is also seen in which the coarse wollastonite is separated from marble by thin layers of dark green garnet.

At the main occurrence, passage from hangingwall to footwall is marked by the following mineralogical and

TABLE 4: Representative microprobe analyses of garnets in the proximal wrigglite skarn, Daybreak occurrence, Atlin, B.C.

	DBB2	DBB3	DBB4	DBB5	DBB6	DBB7	DBB8	DBB9	DBB10	DBB12	DDB20
	Oxide Weight Percent										
F	0.29	0.18	0.33	0.48	0.19	0.27	0.25	0.55	0.25	0.62	0.74
Na_2O	0.02	0.00	0.01	0.02	0.03	0.03	0.03	0.02	0.02	0.03	0.03
MgO	0.13	0.00	0.10	0.11	0.02	0.00	0.10	0.03	0.09	0.09	0.12
Al_2O_3	16.12	16.28	16.38	16.51	17.02	16.59	16.00	17.00	15.75	14.98	17.45
SiO_2	37.69	37.92	37.65	37.48	37.76	37.55	37.46	37.88	37.36	37.58	37.70
Fe_2O_3*	14.06	13.79	13.56	13.03	13.17	13.29	14.03	13.33	13.96	15.03	11.78
MnO	0.94	0.92	1.02	0.89	0.98	1.01	1.09	1.04	0.96	1.01	0.97
Cr_2O_3	0.03	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Cl	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
K_2O	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00
Sn_2O	0.07	0.11	0.09	0.15	0.12	0.15	0.09	0.13	0.07	0.09	0.09
CaO	31.54	31.66	31.34	31.77	31.24	31.25	31.04	31.09	31.60	31.04	31.45
TiO_2	0.00	0.01	0.02	0.00	0.03	0.00	0.00	0.04	0.02	0.00	0.01
Total	100.90	100.87	100.51	100.45	100.55	100.15	100.08	101.12	100.08	100.47	100.34
	Number of ions per calculated formula unit on the basis of 12 oxygens and 0 OH										
F	0.07	0.04	0.08	0.12	0.05	0.07	0.06	0.14	0.06	0.15	0.18
Na	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00
Mg	0.02	0.00	0.01	0.01	0.00	0.00	0.01	0.00	0.01	0.01	0.01
Al	1.47	1.49	1.50	1.52	1.55	1.52	1.47	1.55	1.45	1.39	1.60
Si	2.92	2.94	2.93	2.92	2.92	2.93	2.93	2.93	2.93	2.95	2.93
Fe	0.82	0.80	0.79	0.76	0.77	0.78	0.83	0.78	0.82	0.89	0.69
Mn	0.06	0.06	0.07	0.06	0.06	0.07	0.07	0.07	0.06	0.07	0.06
Cr	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cl	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
K	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sn	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Ca	2.62	2.63	2.61	2.65	2.59	2.61	2.60	2.57	2.65	2.61	2.62
Ti	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Total	8.00	7.96	8.00	8.05	7.96	7.98	7.98	8.04	8.00	8.07	8.11
Pyralspite	2.85	2.26	2.93	2.63	2.50	2.49	3.10	2.70	2.72	2.91	2.88
Grossularite	79.07	80.65	80.80	80.86	85.12	82.91	79.33	85.10	77.27	74.40	86.04
Andradite	18.08	17.09	16.28	16.51	12.37	14.60	17.57	12.20	20.01	22.68	11.08

Microprobe analyses by S.B. Cornelius

Fe_2O_3* = total iron as Fe_2O_3

textural zoning: (1) cleaved ultramafic rocks and biotite hornfels, (2) a 2 metre-thick unit of massive, sugary textured and bleached marble with isolated black garnets, (3) a 15 to 20 centimetre-thick carbonate layer with calcite crystals up to 2.5 centimetres in length, (4) a 1 to 2 centimetre-thick layer of rhodonite, (5) a 0.6 metre-thick unit of massive, crystalline magnetite with minor garnet, pyroxene, sulphides and malachite staining, and (6) massive bleached marble in the footwall.

Some of the anhedral to euhedral garnets exhibit a fine optical zoning comprising thin, alternating bands of colourless and pale brown material. This zoning is matched by the mainly isotropic crystals containing numerous thin zones of weakly birefringent garnet; the garnet margins are invariably occupied by thin rims of moderately birefringent grossular garnet. Some garnet crystals are cut by veinlets of magnetite and sulphides. Microprobe analyses indicates that the garnets are low-Mn andradites (Figure 7) with an average composition of 94 mole percent andradite. In contrast to the garnets at the nearby Daybreak skarn, they show no enrichment in either F, Cr, Cl or Sn.

Pyroxenes at the Atlin Magnetite skarn form well cleaved, moderately altered crystals up to 1 millimetre long; they occur as inclusions in the garnet or as intergrowths with quartz or magnetite. Microprobe

TABLE 5: Representative microprobe analyses of distal vein garnets cutting biotite hornfels, Daybreak occurrence, Atlin, B.C..

Crystal	158-3	158-5	158-7	158-9	158-10	158-14	158-15	158-21	158-27	158-23	158-24	Average of F-rich garnets n = 14	Average of F-poor garnets n = 14
F	1.43	1.15	1.64	2.07	1.73	0.00	0.03	0.05	0.18	0.42	0.69	1.47	0.03
Cr_2O_3	0.03	0.01	0.03	0.12	0.03	1.12	1.05	1.19	0.61	0.48	1.02	0.14	0.87
Na_2O	0.20	0.21	0.19	0.22	0.17	0.01	0.02	0.01	0.03	0.00	0.00	0.17	0.03
Fe_2O_3*	5.20	5.25	5.12	5.26	5.32	11.36	9.98	11.36	10.96	10.66	13.49	6.21	10.74
K_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.01
SiO_2	36.44	36.65	36.32	36.52	36.38	38.13	38.48	37.88	37.96	38.51	37.24	36.69	38.23
CaO	34.78	34.94	34.88	35.06	34.97	32.07	33.09	32.33	32.87	32.92	32.87	34.65	32.90
Al_2O_3	15.57	15.23	15.13	14.87	15.26	15.43	16.17	15.64	15.72	16.73	13.29	15.21	15.92
TiO_2	2.84	3.03	3.07	3.68	2.75	0.74	0.71	0.64	0.74	0.40	0.54	2.73	0.67
MgO	1.59	1.68	1.53	1.68	1.62	0.15	0.13	0.13	0.14	0.14	0.07	1.42	0.15
MnO	0.15	0.10	0.04	0.11	0.13	0.77	0.56	0.77	0.68	0.64	0.73	0.19	0.64
TOTAL	98.23	98.25	97.95	99.59	98.36	99.78	100.22	100.01	99.89	100.90	99.94	98.87	100.18
	Number of ions per calculated formula unit based on 12 oxygen and 0 OH												
Na	0.031	0.032	0.030	0.034	0.026	0.002	0.003	0.002	0.005	0.000	0.000	0.03	0.00
Fe	0.312	0.314	0.309	0.314	0.320	0.672	0.585	0.672	0.646	0.620	0.812	0.37	0.63
K	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.00	0.00
Si	2.905	2.914	2.912	2.899	2.909	2.996	2.998	2.977	2.973	2.976	2.980	2.92	2.98
Ca	2.971	2.976	2.997	2.982	2.997	2.700	2.762	2.722	2.758	2.726	2.818	2.95	2.75
Al	1.463	1.427	1.430	1.391	1.439	1.429	1.485	1.449	1.451	1.524	1.254	1.43	1.46
Ti	0.170	0.181	0.185	0.220	0.165	0.044	0.042	0.038	0.044	0.023	0.032	0.16	0.04
Mg	0.189	0.199	0.183	0.199	0.193	0.018	0.015	0.015	0.016	0.016	0.008	0.17	0.02
Mn	0.010	0.007	0.003	0.007	0.009	0.051	0.037	0.051	0.045	0.042	0.049	0.01	0.04
Sum	8.05	8.05	8.05	8.05	8.06	7.91	7.93	7.93	7.94	7.93	7.95	8.04	7.93
Mole %													
Pyralspite	7.47	7.88	7.11	8.06	7.65	2.18	1.68	2.09	1.95	1.80	1.87	6.87	1.88
Grossularite	74.95	74.10	75.12	73.53	74.14	65.85	70.06	66.24	67.25	69.29	58.81	72.86	68.01
Andradite	17.57	18.02	17.77	18.41	18.21	31.97	28.26	31.67	30.79	28.91	39.32	20.27	30.11

Microprobe analyses by S.B. Cornelius and G.E. Ray

Fe_2O_3* = total iron as Fe_2O_3

analyses indicate they are diopsidic in composition (Figure 7).

Abundant magnetite together with the garnet-pyroxene compositions suggest that the Atlin Magnetite system may have been relatively depleted in sulphur and that it formed in more oxidized conditions than the Daybreak and the Silver Diamond skarns.

Daybreak skarn

The Daybreak occurrence is situated approximately 1 kilometre south of the Atlin Magnetite skarn (Figure 3) at an elevation of 1650 to 1730 metres (approximately 5400 to 5700 feet). The area is underlain by altered greenstone, serpentinized ultramafic rocks, schistose hornfelsic metasediment and mafic tuff and thin units of

TABLE 6: Representative microprobe analyses of skarn vesuvianites, Daybreak occurrence, Atlin, B.C..

Sample	Vesuvianites in proximal wrigglite skarn: 29157	30157	31157	32157	33157	Avg. of wrigglite skarn
F	1.77	1.45	1.50	1.48	1.52	1.54
Na_2O	0.00	0.01	0.01	0.01	0.06	0.02
MgO	0.95	1.49	1.78	0.32	1.06	1.12
Al_2O_3	15.45	14.08	14.08	15.55	16.97	15.23
SiO_2	35.63	35.55	35.43	35.48	36.12	35.64
Fe_2O_3*	8.63	9.62	9.18	10.05	6.46	8.79
MnO	0.38	0.32	0.24	0.42	0.24	0.32
Cr_2O_3	0.01	0.01	0.01	0.06	0.03	0.02
Cl	0.29	0.33	0.37	0.32	0.36	0.33
K_2O	0.00	0.00	0.00	0.00	0.00	0.00
Sn_2O	0.13	0.15	0.12	0.08	0.04	0.10
CaO	34.77	34.97	35.16	34.45	35.41	34.95
TiO_2	0.00	0.01	0.05	0.01	0.02	0.02
OH	2.40	2.39	2.39	2.40	2.45	2.41
Total	100.41	100.38	100.32	100.63	100.74	100.49

Sample	Vesuvianites in distal vein skarn: 10158	11158	12158	13158	14158	15158	16158	Avg. of distal skarn
F	1.28	1.23	1.52	1.40	1.48	1.11	1.36	1.34
Na_2O	0.18	0.17	0.17	0.23	0.23	0.23	0.22	0.20
MgO	1.57	1.74	1.70	1.65	1.64	1.64	1.63	1.65
Al_2O_3	15.56	15.62	15.74	14.91	15.59	15.72	15.51	15.52
SiO_2	36.43	36.65	36.56	36.63	36.63	36.60	36.52	36.57
Fe_2O_3*	5.33	5.12	5.11	5.19	5.05	5.15	5.03	5.14
MnO	0.13	0.15	0.17	0.11	0.16	0.15	0.13	0.14
Cr_2O_3	0.03	0.04	0.04	0.01	0.00	0.04	0.01	0.02
Cl	0.06	0.04	0.04	0.13	0.04	0.05	0.04	0.06
K_2O	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Sn_2O	0.02	0.01	0.03	0.01	0.01	0.01	0.01	0.01
CaO	35.03	34.97	35.12	35.00	34.67	34.93	35.09	34.97
TiO_2	2.35	2.44	2.51	3.19	2.61	2.65	2.64	2.63
OH	2.47	2.48	2.48	2.48	2.47	2.48	2.47	2.48
Total	100.44	100.66	101.19	100.94	100.58	100.76	100.66	100.74

Microprobe analyses by G.E. Ray.

Fe_2O_3* = total iron as Fe_2O_3

marble; some of the latter are associated with minor amounts of wollastonite-garnet skarn.

The occurrence includes a small area of proximal wrigglite-textured skarn and a larger extent of barren distal skarn comprising veins of garnet, pyroxene and lesser vesuvianite which partially replaces a biotite hornfels. The term "wrigglite" to describe rhythmically layered skarn was first used by Askins (1976) and later by Kwak and Askins (1981) although the texture has been recognized since the early part of this century. Kwak (1987) discusses the origin of wrigglite textures and notes it is a characteristic of Fe and F-rich tin skarns, most of which contain fluorine in excess of 9 weight per cent. Wrigglite skarn is commonly associated with fault structures and, unlike most Sn skarns which generally form at deep levels, it is believed to develop in relatively near-surface conditions such as over the cupolas of high-level granites (Kwak, 1987). Its presence in the Daybreak skarn is consistent with other high-level features in the Surprise Lake Batholith such as miarolitic cavities and the finer grained chilled margins.

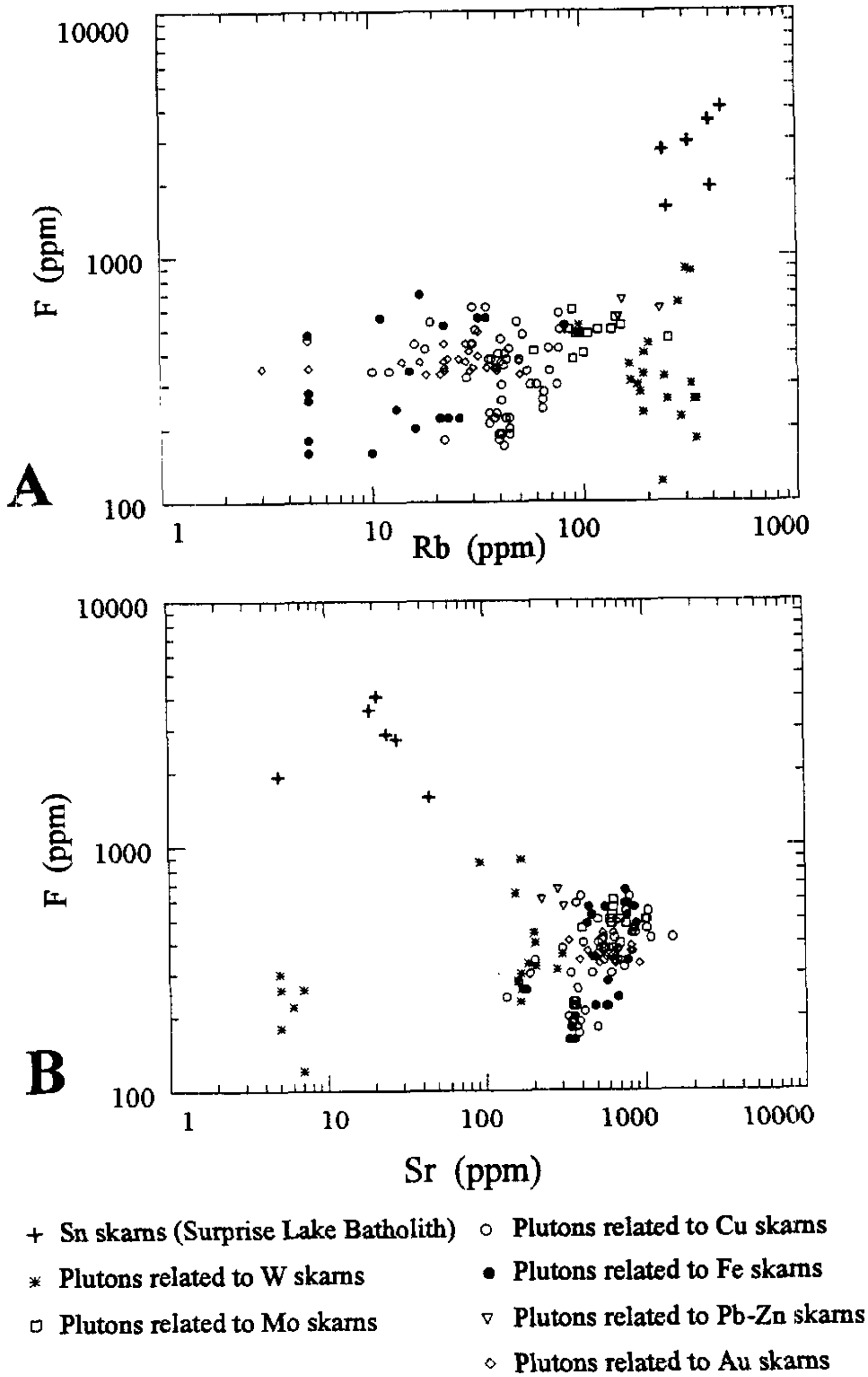

Figure 6. Geochemical plots of plutonic rocks related to Sn skarns (Surprise Lake Batholith), and W, Au, Cu, Mo, Pb-Zn and Fe skarns in B.C. (data from Ray and Webster, in press). The Surprise Lake Batholith and the plutons related to W skarns have similar Rb and Sr contents, but the batholith can be discriminated by its high F content.
(A) Log F versus Log Rb.
(B) Log F versus Log Sr.

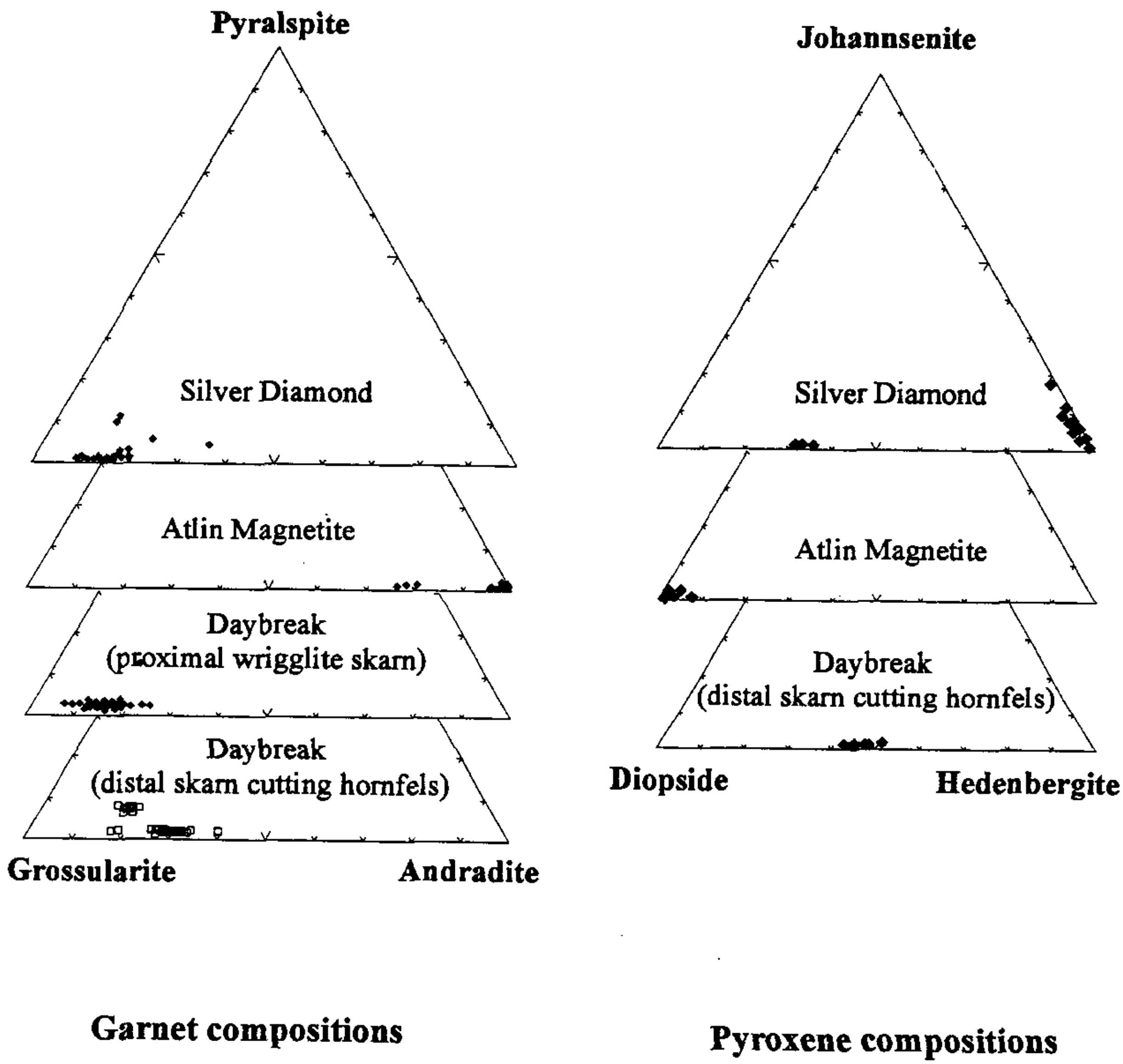

Figure 7. Mole percent compositions of garnets and pyroxenes in the Silver Diamond, Atlin Magnetite and Daybreak skarns.

The proximal wrigglite skarn at Daybreak is weakly mineralized and is developed immediately adjacent to the margin of the batholith (Figure 3). It occurs as large frost-heaved angular boulders up to 3 metres in diameter; a talus trail of wrigglite-bearing float is traceable for several hundred metres downslope from the boulders (Figure 3). The wrigglite is characterized by thin, rhythmic layering that ranges between 0.25 mm and 1 cm thick; each layer is dominated by either pale green to colourless fluorite, black magnetite, white to pale brown vesuvianite or clear reddish-brown garnet (Webster *et al.*, 1992). The gneiss-like mineral layering is locally crosscut by veins of garnet, and is complexly deformed. There are spheroid structures as well as open to tight disharmonic and irregular fold-like structures, some of which appear to have sheared limbs. Rare vugs up to 10 cm in diameter are present; these contain calcite and elongate, green crystals of clinozoisite. Sulphides are generally rare but microprobe and x-ray diffraction studies indicate the wrigglite skarn contains traces of scheelite, cassiterite (SnO_2), canfieldite ($4Ag_2S.SnS_2$), gahnite ($ZnAl_2O_4$), acanthite (Ag_2S) and stannite (Cu_2FeSnS_4). No beryl has been identified although the wrigglite is enriched in beryllium (up to 394 ppm Be; Table 2B), possibly as a non-essential element in the vesuvianite or garnet.

Assay results of magnetite-rich garnet-fluorite-vesuvianite wrigglite skarn are presented in Table 2B. These show that the proximal skarn at Daybreak contains anomalous amounts of Sn, Cu, W, Te, Se, Be and Bi, as well as up to 660 ppb Au and 26 ppm U. An assay of a single grab sample of distal garnet skarn with minor

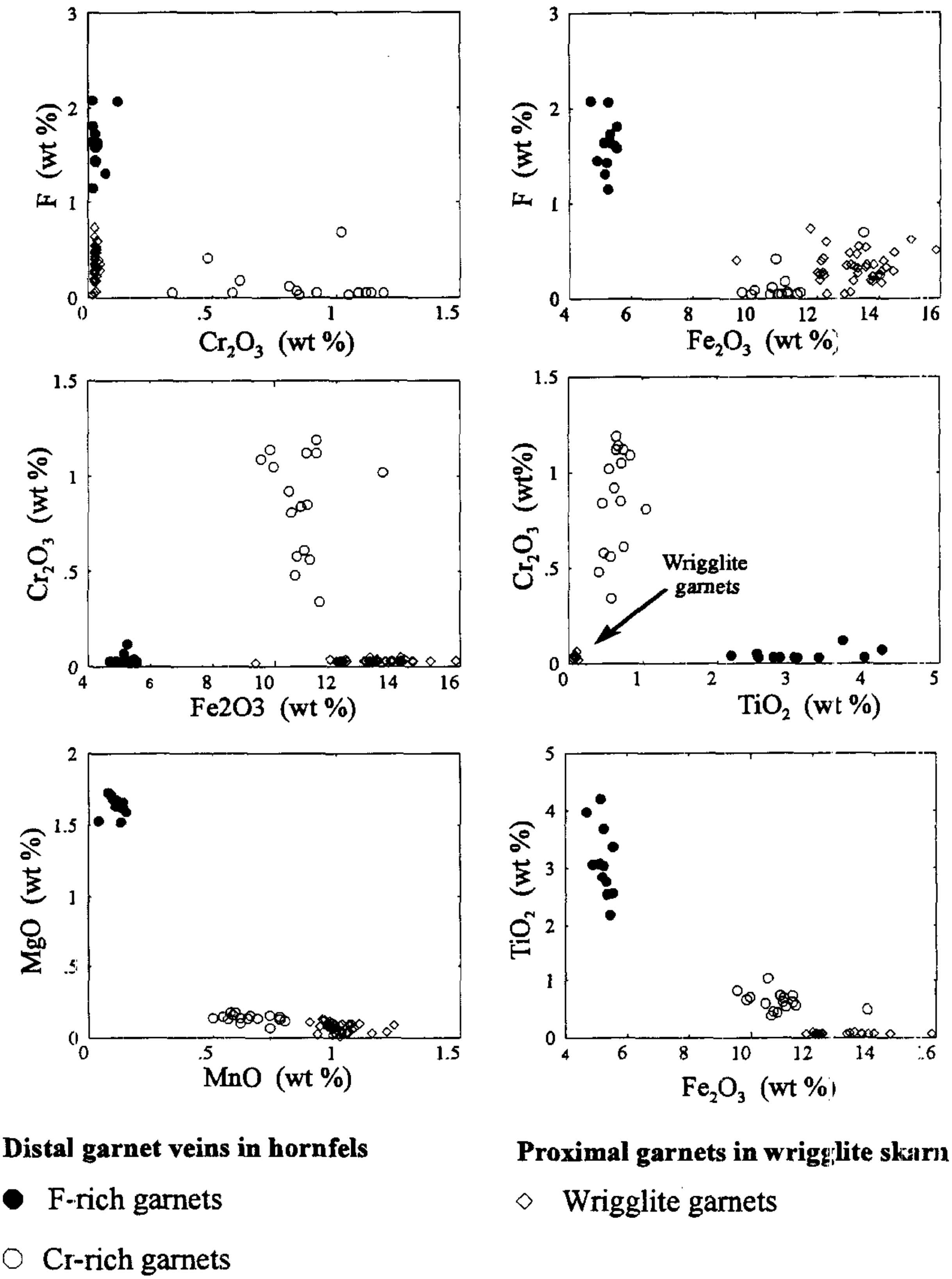

Figure 8. Plots illustrating the variable F, Cr, Fe, Mg, Mn and Ti chemistry of garnets in the proximal wrigglite and distal vein skarn, Daybreak occurrence.

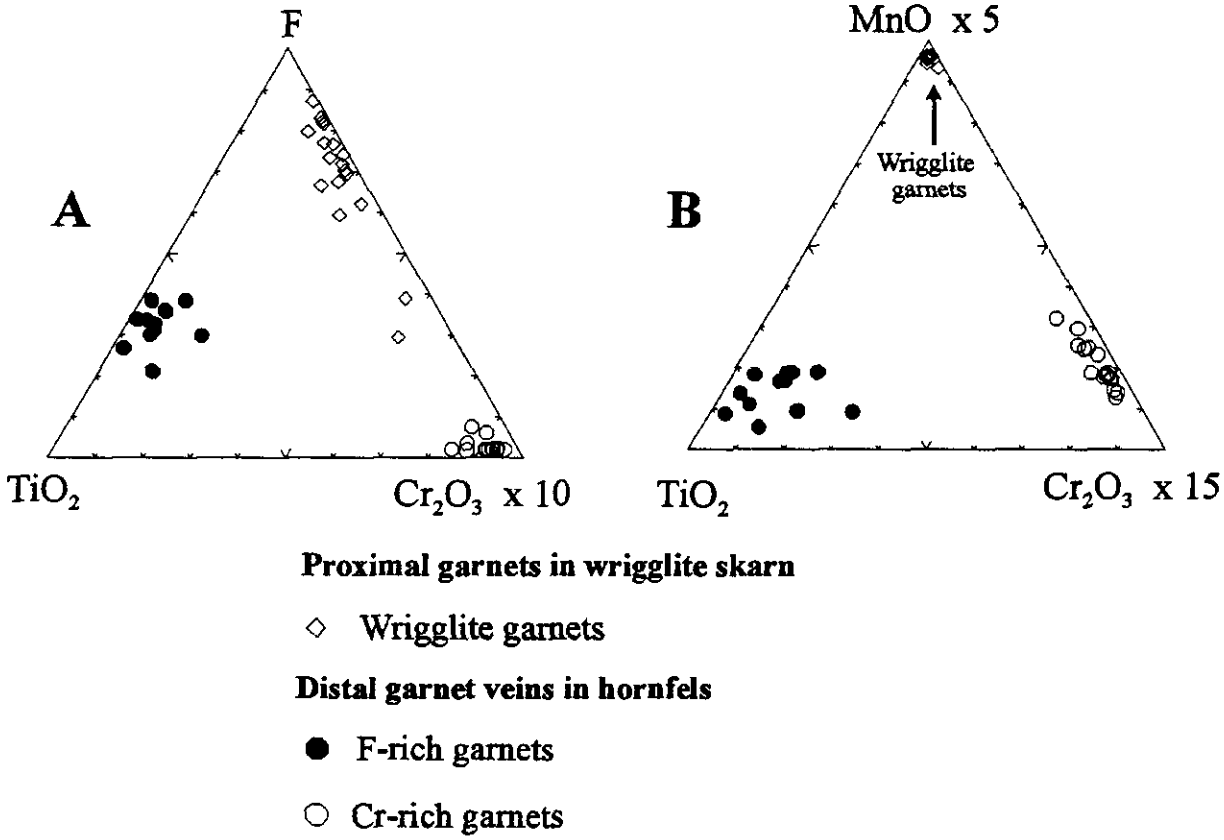

Figure 9. Triangular plots illustrating the contrasting F, Ti, Cr and Mn chemistry of garnets in the proximal wrigglite and distal vein skarn, Daybreak occurrence.

disseminated sulphides contains anomalous amounts of Cu, Bi and Sn (Table 2B).

Most of the garnets in the wrigglite skarn occur as massive, anhedral layers that are pale pinkish brown and isotropic to moderately birefringent. They contain small inclusions of quartz, plagioclase and fluorite. Where individual and euhedral garnet crystals are present, they seldom exceed 1 millimetre in diameter. They are optically similar to the massive garnet except they commonly contain minute opaque inclusions. The vesuvianite, which occurs as low birefringent crystals up to 3 millimetres in size, contains some small inclusions of pyroxene. Generally, however, pyroxene is very rare in the wrigglite skarn. Fluorite occurs as a colourless, well cleaved mineral. Accessory silicates identified petrographically include quartz, plagioclase, sericite, chlorite and epidote.

The distal veined skarn overprints an area of hornfels and extends up to 400 metres west and southwest of the wrigglite skarn (Figure 3). Protoliths of the fine grained, schistose biotite hornfels are probably argillites and minor basaltic tuffs. Vague layering in the hornfels may represent remnant bedding. The rocks are intruded by several irregular sills and dikes of leucogranite and aplite, that are in turn cut by thin quartz veins, some of which carry minor fluorite. The sills, dikes and quartz veins are believed to be related to the nearby batholith. The hornfels is also cut by numerous irregular layers and veins of skarn up to 0.5 m thick. This distal vein skarn alteration consists largely of pale green pyroxene and orange-red garnet with lesser amounts of brown vesuvianite, plagioclase, quartz, chlorite, zoisite and trace fluorite. The pale green, anhedral to subhedral crystals of pyroxene are generally less than 0.2 millimetres in diameter, and many are partially altered to chlorite. Garnet generally postdates the pyroxene and commonly contains small pyroxene inclusions. It occurs as irregular masses, blebs and veinlets; it is pale pinkish brown in colour and is mostly isotropic although some weakly birefringent crystals are also present.

Microprobe analyses of pyroxenes in the distal skarn indicate they are low in Mn and range between 48 and 55 mole percent diopside (Table 3; Figure 7). Garnets in the

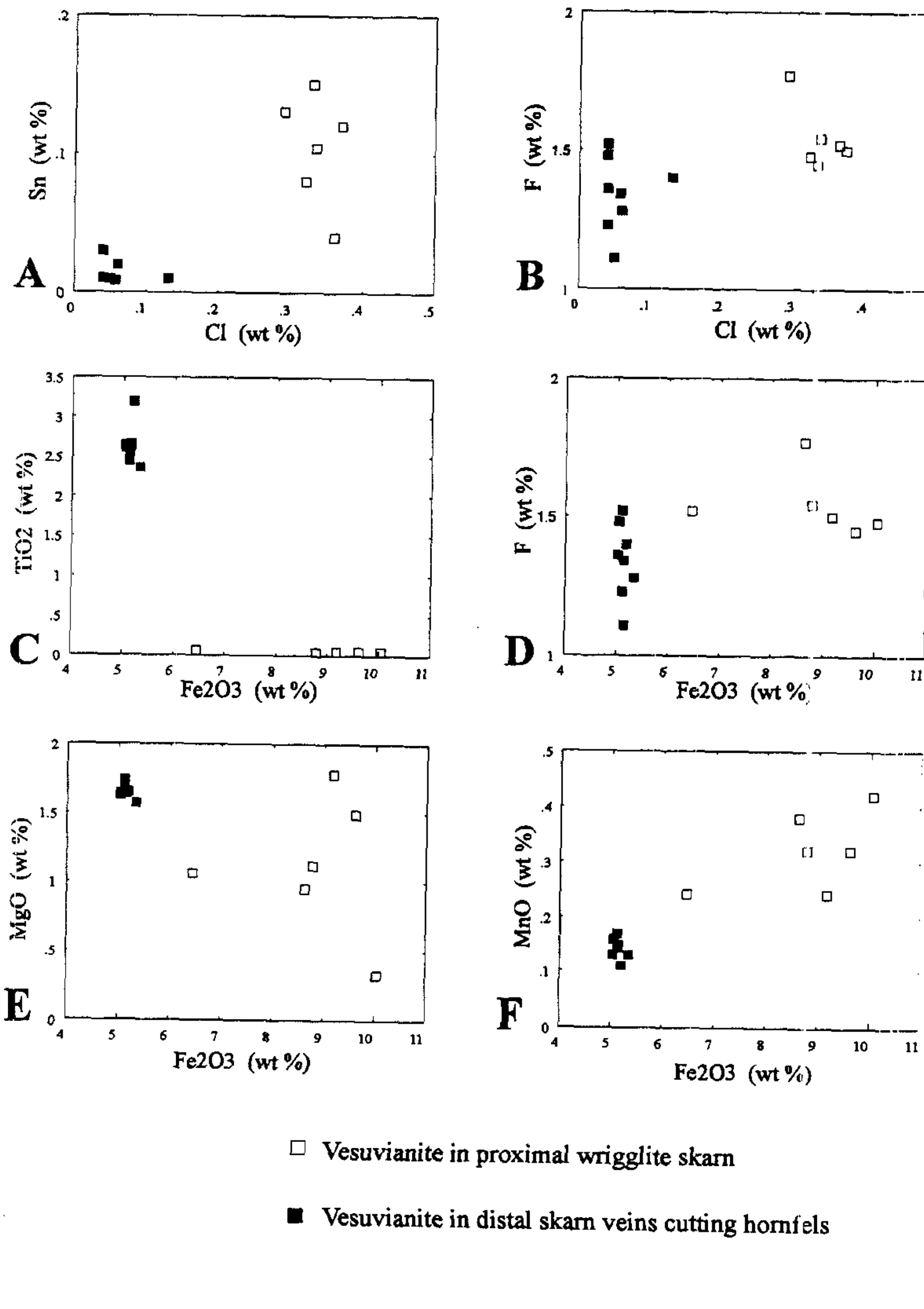

Figure 10. Plots illustrating the variable Sn, Cl, F, Fe, Mg, Mn and Ti chemistry of vesuvianites in the proximal wrigglite and distal vein skarn, Daybreak occurrence.

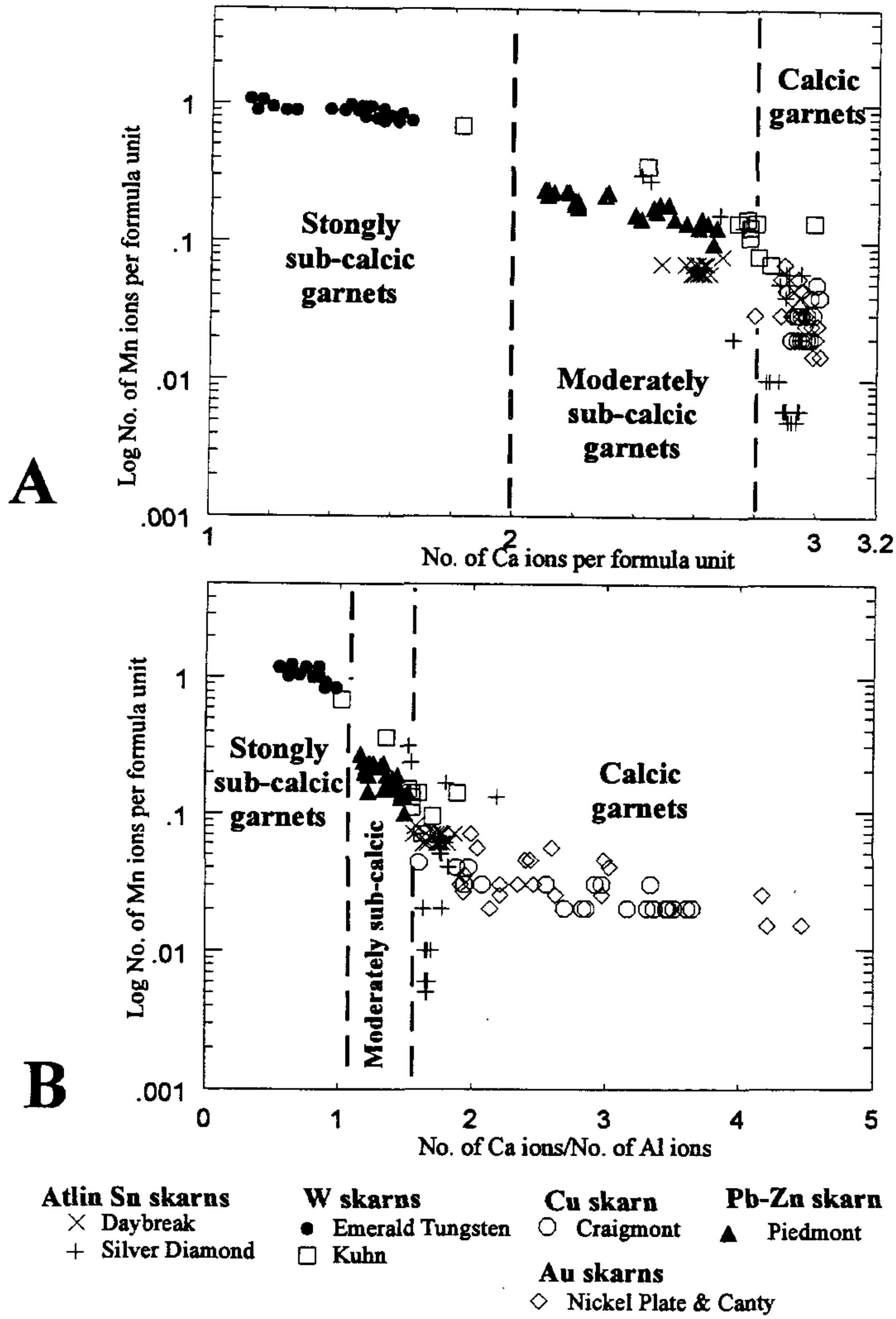

Figure 11. Plots comparing the Ca and Mn contents of garnets from selected skarns in B.C. (data from Ray and Webster, in press).
(A) Log number of manganese atoms per formula unit versus number of calcium atoms per formula unit.
(B) Log number of Mn atoms per formula unit versus number of calcium atoms per formula unit/number of aluminum atoms per formula unit.
Note that the garnets at the Daybreak skarn are moderately sub-calcic, whereas most of those at the Silver Diamond skarn are calcic and have very low quantities of manganese.

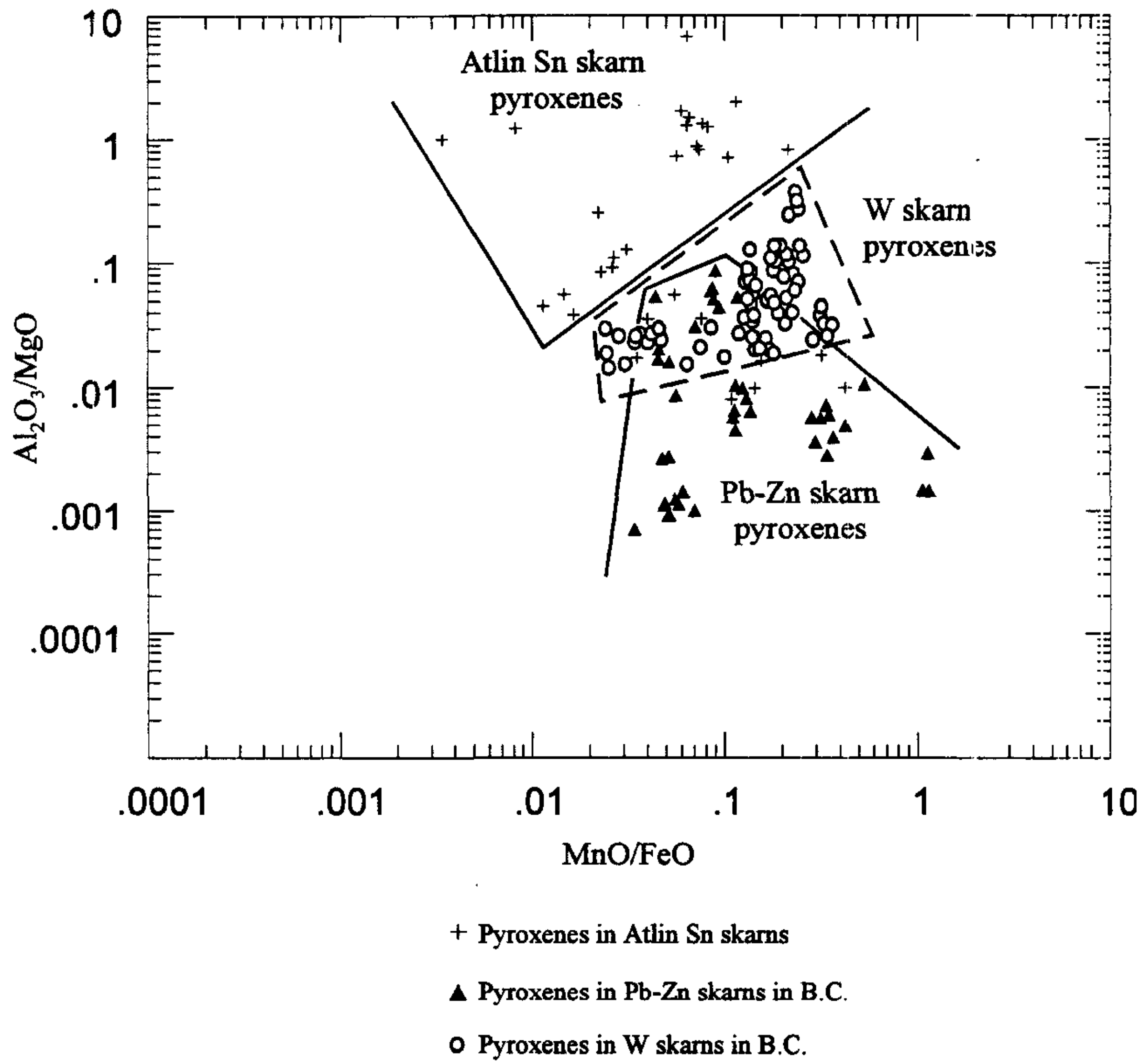

Figure 12. Plot of weight percent Al_2O_3/MgO *versus* MnO/FeO illustrating different compositional fields for pyroxenes in the Atlin Sn skarns and W and Pb-Zn skarns in B.C. (data from Ray and Webster, in press). Note: pyroxene compositional fields have been empirically drawn around main clustering of points.

proximal and distal skarns are similar in their overall compositions, being low in Mn and grossularitic (Tables 4 and 5; Figure 7). However, in some of their major and trace element chemistry they show great differences. Compared to some of the garnets in the distal skarn, those in the proximal wrigglite generally contain very low quantities of Cr and Ti, low to moderate amounts of F (maximum is 0.74 weight percent F), and higher quantities of Fe and Mn (Table 4; Figure 8). By contrast, garnets in the distal vein skarn contain two chemically distinct populations, one of which is F-rich and the other is Cr-rich (Table 5; Figure 8). As well as containing up to 1.21 weight percent Cr, the latter population has higher amounts of Mn and Fe and no Cl whereas the F-rich garnets (with up to 2.07 weight percent F) contain higher quantities of Ti, Mg (Figure 8) and Cl (up to 0.19 weight percent Cl). Some of the chemical differences between the garnets in the wrigglite and distal vein skarn are illustrated in Figure 9.

The distribution of the two chemically distinct garnet populations in the distal skarn is interesting because they are optically and texturally indistinguishable in thin section. Indeed, single garnet masses often contain zones of both F-rich, Cr-poor and F-poor, Cr-rich material. Because garnets only occur as irregular blebs, masses and veinlets, it is difficult to identify positively any chemical zoning that may exist in individual crystals. However, the most Cr-rich and F-poor material tends to occur in the core portions of a garnet mass.

Comparative microprobe analyses were completed on vesuvianites present in the proximal wrigglite and distal vein skarn (Table 6). Although the latter contains considerably less fluorite than the wrigglite, vesuvianites in both the distal and proximal skarns are rich in F, averaging 1.54 and 1.34 weight percent respectively (Table 6). However, in other elements, the vesuvianites in the two types of skarn show significant differences and, on average, vesuvianites in the wrigglite contain more Fe, Mn, Sn and Cl but less Ti and Mg than those in the distal skarn (Figure 10). There appears to be no correlation between Sn, Cl or F in the vesuvianites in either skarn-type.

GARNET COMPOSITIONS OF THE ATLIN AND OTHER SKARNS.

Microprobe analyses of garnets from a number of Au, Fe, Cu, Mo, Pb-Zn, W and Sn skarns in British Columbia indicate that the majority contain less than 1 weight percent MnO and are andradite-grossularite solid solutions with less than 3 mole percent pyralspite (Ray and Webster, in press). However, a few Sn, W and Pb-Zn skarns include some garnets that contain more than 5 mole percent pyralspite. These include the Daybreak and Silver Diamond skarns as well as the Piedmont Pb-Zn skarn (082FNW 129) and the Kuhn and Emerald-Dodger W skarns (104P 071; 082FSW 010 and 011 respectively). Garnets from the Emerald Tungsten-Dodger deposits in the Salmo district of southeastern British Columbia (Ball *et al.*, 1953; Rennie and Smith, 1957; Fyles and Hewlett, 1959; Webster *et al.*, 1992) are distinct in being the most manganiferous skarn garnets identified in the province (Figure 11); they contain up to 25 weight percent MnO and up to 48 mole percent pyralspite (Ray and Webster, in press).

Most garnets in Cu, Au, Mo and Fe skarns in British Columbia are calcic and, on the basis of 12 oxygens and 0 OH, typically contain three calcium ions per calculated formula unit (Figure 11). Garnets in the Atlin Magnetite Sn skarn are calcic and average 3 calcium ions. However, some garnets in the Daybreak and Silver Diamond skarns are moderately subcalcic and contain between 2 and 2.8 calcium ions per calculated formula unit (Figure 11; Tables 4 and 5).

The garnets in some Pb-Zn and W skarns in British Columbia are also subcalcic (Figure 11), a feature that appears to be more common in skarns formed in reducing environments and/or where dolomitic hostrocks are present. The most subcalcic garnets yet recognized in any skarn in British Columbia, with less than two calcium ions per calculated formula unit, occur in the Emerald Tungsten-Dodger W skarns (Figure 11), a feature that was first recognized by Newberry (1983). This, together with the fact that these deposits were the largest tungsten metal producers in the province, is consistent with the conclusions of Newberry (1983) that a relationship exists between subcalcic garnets, reduced states and the size and grade of W skarn deposits. Most skarn garnets in British Columbia contain less than 0.4 weight percent MgO (Ray and Webster, in press). However, some garnets in the Daybreak distal vein skarn (Table 5; Figure 8) and at the Emerald Tungsten-Dodger deposit contain more than 1 weight percent MgO.

PYROXENE COMPOSITIONS OF THE ATLIN AND OTHER SKARNS

Microprobe analyses presented by Meinert (1984), Ettlinger and Ray (1989), Ettlinger (1990), Ray and Dawson (1994) and Dawson (1994) and Ray and Webster (in press) indicate that most skarn pyroxenes in British Columbia are diopside-hedenbergite solid solutions, although varying amounts of the johannsenite component are present in the pyroxene of some Fe, Au, Pb-Zn and W skarns

Nakano *et al.* (1994), in a study of 46 skarn deposits in Japan, has noted that most pyroxenes in Cu-Fe skarns have low Mn/Fe ratios (<0.1), those in Pb-Zn skarns have high Mn/Fe ratios (>0.2) and those in W skarns have intermediate ratios (*circa* 0.15). Data collected from British Columbia skarns (Ray and Webster, in press) indicates that the pyroxenes in Pb-Zn skarns have the highest MnO/FeO ratios (average 0.22), similar to Nakano's (1994) data for Japan. Pyroxenes in the Coxey Mo skarn (082FSW140) have the lowest MnO/FeO ratios (average 0.02) whereas those in W, Cu and the Atlin Sn skarns have intermediate ratios. The study also suggests that the pyroxenes in W, Pb-Zn and the Atlin Sn skarns can be differentiated on their Al_2O_3/MgO ratios (Figure 12). Essentially, pyroxenes in the Atlin Sn skarns are characterized by high Al_2O_3/MgO and low MnO/FeO ratios, those in Pb-Zn skarns have low Al_2O_3/MgO and higher MnO/FeO ratios whereas the W skarn pyroxenes cluster in an intermediate field (Figure 12). The oxidation state of these skarns, as estimated from their mineralogy, also appears to correlate with variation in Al_2O_3/MgO ratios of the pyroxenes. The Pb-Zn skarns with pyroxenes having the lowest Al_2O_3/MgO ratios have mineral assemblages suggesting they formed in oxidized environments, whereas the Silver Diamond and Daybreak occurrences are more reduced and have the highest Al_2O_3/MgO ratios in their pyroxenes.

CONCLUSIONS

The Cretaceous Surprise Lake Batholith is a highly differentiated subalkaline body of adamellite-granite composition. The Rb, Y and Nb contents indicates it to be a "within plate" granitoid as defined by Pearce *et al.* (1984). This, together with the batholith's high F content and its genetic association with Sn-bearing skarns suggests that the pluton was derived as a melt from continental crust, although a lack of inheritance in zircons and its anomalously low initial Sr ratios (Mihalynuk *et al.*, 1992; Mihalynuk, personal communication, 1996) does not support this conclusion. The contrast in chemistry between the Cretaceous Surprise Lake Batholith and the Jurassic Fourth of July Batholith, which plots as a "volcanic arc granitoid" (Figure 4D; Mihalynuk *et al.*, 1992), raises problems and implications regarding the tectonic history of the Cache Creek Complex and the character of its basement rocks at Atlin.

The Surprise Lake Batholith is chemically distinct from other plutons associated with Cu, Au, Fe, and Mo skarns in British Columbia, but it shows many chemical similarities to the peraluminous intrusions related to W skarns. However, the Surprise Lake Batholith averages more than 2700 ppm F, whereas plutons related to W skarns average less than 400 ppm F (Ray and Webster, in press).

The Silver Diamond, Atlin Magnetite and Daybreak Sn skarns are all related to the high level Surprise Lake plutonic suite, although there are significant differences in their mineralization, oxidation states and garnet chemistry. All three skarns contain sporadically anomalous amounts of Cu and Bi. The Daybreak and Atlin Magnetite skarns are enriched in Sn, and cassiterite is reported from parts of the Silver Diamond occurrence. Unlike the other two skarns, the Atlin Magnetite has very low amounts of W and F whereas the Silver Diamond mineralization contains elevated quantities of Ag, Pb, Zn, Cd, Se. The Daybreak magnetite-garnet-wrigglite skarn is enriched in Be and U.

Garnet-pyroxene chemistry and skarn mineralogy suggest that the Atlin Magnetite occurrence formed in more oxidized conditions than the other two skarns. Its garnets are calcic and andraditic; by contrast, garnets at the Daybreak are grossularitic and are moderately subcalcic, averaging 2.8 calcium ions per calculated formula unit. The Silver Diamond includes both calcic and moderately subcalcic garnets. Pyroxenes in the Atlin Sn skarns can generally be discriminated from many pyroxenes in W and Pb-Zn skarns by their higher Al_2O_3/MgO ratios and lower MnO/FeO ratios.

Some garnets at the Daybreak skarn contain anomalous amounts of Cr, F and Cl, and there are distinct differences in the major and trace element chemistry (notably Cr, F, Ti and Mg) of garnets formed in the proximal and distal skarns. Optically indistinguishable garnets in the distal skarn are separable into two chemically different populations that are either rich in Cr or F. It is possible that the Cr-rich material represents early hornfels garnets that crystallized during batholith emplacement and that Cr was derived from ultramafic rocks in the Cache Creek complex. The F-rich and Cr-poor material, which also contains minor amounts of Cl, represents skarn garnet related to the Daybreak hydrothermal system that possibly overgrew the earlier hornfels garnet.

Although many Sn-W skarns world-wide contain F-bearing garnets, Cr-rich garnets in such rocks are highly unusual. Their presence at the Daybreak occurrence reflects a tectonic history that enabled oceanic and ultramafic rocks of the Cache Creek Terrane to be intruded by the highly evolved and peraluminous Surprise Lake Batholith.

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