AN INVESTIGATION OF SELECTED MINERALIZED SKARNS IN BRITISH COLUMBIA

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KEYWORDS: Economic geology, skarn, metallogeny, geochemistry, mineralogy, wrigglite.

INTRODUCTION

A number of skarn deposits and occurrences throughout the province were examined and sampled during the 1991 field season (Figure 2-2-1). The season represented the final part of a 4-year field program to map, study and compile data on some of the 700 or more mineralized skarns recorded in MINFILE. It is hoped to determine relationships between these skarns and their metal content, geochemistry, mineralogy, age, associated intrusions and lithostructural setting. Preliminary geochemical results and descriptions of the mineralized skarn samples collected this season are presented in Tables 2-2-1a and b. Whole-rock and additional trace element analytical results, together with data on microprobe analyses, will be published at a later date.

Earlier work in this program focused on the province's gold and iron skarns, such as those in the Hedley, Texada Island and Merry Widow camps, and in the Iskut River area; publications include those by Ray *et al.* (1988, 1991), Ettlinger and Ray (1989), Ray and Webster (1991), Webster and Ray (1991), and Ray and Dawson (in preparation). The 1991 research concentrated on some of British Columbia's copper, zinc-lead, tungsten, molybdenum and tin skarns (Figure 2-2-1). The final results of the study will eventually be published in bulletin form (Ray and Webster, in preparation).

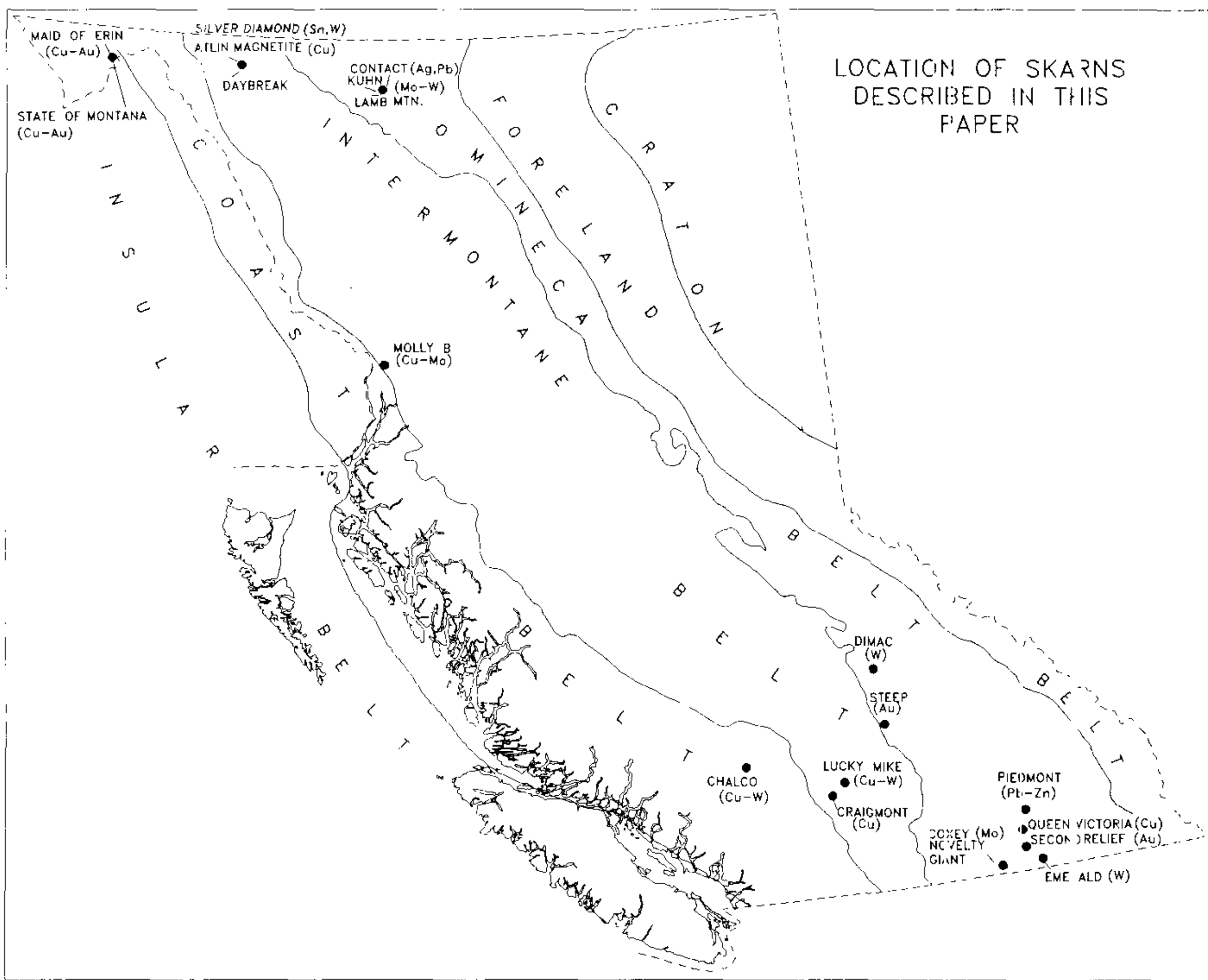

Figure 2-2-1. Location of mineralized skarns examined during the 1991 field season, showing their relationship to the tectonic belts.

TABLE 2-2-1a

PRELIMINARY GEOCHEMICAL RESULTS OF MINERALIZED SKARN GRAB SAMPLES. ALL UNITS ARE IN PPM EXCEPT WHERE STATED AS PPB OR PER CENT. VALUES PENDING FOR BLANK SPACES

LABNO	LOCATION	Ag	As	Au ppb	Ba	Bi	Cd	Ce	Co	Cr	Cu	Mn	Mo	Ni	Pb	Rb	Sb	Se	Th	W	Zn
043058	Maid of Erin			177	<100	1300		6	18	62						<30		48	0.5	19	
043059	Maid of Erin			89	<100			6	56	71						<30		48	0.5	4	
043060	Maid of Erin	0.8		<5	850	<5		100	13	70						68		<5	12.0	8	
043062	Maid of Erin	18		13	<100	22		18	42	44						<30		<5	0.6	33	
043063	Adams	2.2		41	200	53		12	14	36						<30		<5	2.3	8	
043064	Majestic	5		40	<100	101		5	210	46						<30		27	0.5	42	
043065	State of Montana			141	<100			11	16	69						<30		160	2.5	4	
043066	State of Montana			45	<100			6	46	62						<30		210	1.1	4	
043067	State of Montana	2		6	1500	<5		84	29	50						<30		<5	9.6	4	
043068	Lawrence	15		<5	<100	27		<3		29						<30		17	0.5	4	
043069	Rainy Hollow	<0.4		<5	280	<5		23	25	59						<30		<5	3.0	4	
043070	Rainy Hollow	<0.4		<5	320	<5		23		96						46		<5	3.6	4	
043072	Rainy Hollow	<0.4		<5	2800	<5		38	7	190						33		<5	5.2	4	
043073	Rainy Hollow	<0.4		<5	400	<5		40	19	98						34		<5	5.6	4	
043077	Chalco	2.2		27	<100	14		4	62	120						<30		<5	0.5	2600	
043078	Chalco	4		273	<100	77		<3	20	99						<30		<5	0.5	920	
043079	Chalco	3.2		287	<100	112		16	46	150						<30		<5	1.9	1200	
042818	Craigmont			19	<100			37		19						47		<5	0.5	86	
042548	Eric	<0.5	7	<2	<50	<5	<0.3	<3	23	70	0.10%	325	5	17	3	<5	2	<5	0.2	1	26
042544	Lucky Mike	22	13	61	110	<5	10	<3	75	160	1.13%	0.56%	29	7	3	<5	1	<5	1.0	450	540
042823	Molly B	1.6		39	1900	<5		14	36	100						55		<5	1.5	38	
042824	Molly B	10		55	<100	<5		8	620	58						<30		35	1.3	5800	
042825	Molly B	6		57	3000	<5		8	105	38						46		27	0.5	240	
042826	Oral M			4170	1600	<5		9	19	150						32		<5	1.3	11	
042827	Oral M			7910	3800	<5		7	7	110						100		<5	2.0	8	
043048	Atlin Magnetite	65		305	<100	68		<3	56	140						35		<5	<0.5	9	
043049	Atlin Magnetite	36		646	<100	210		<3	81	70						<30		<5	<0.5	39	
043050	Silver Diamond	185		25	110	396		<3	6	25						<30		9	<0.5	4	
043052	Silver Diamond	98		97	<100	2300		<3	58	82						150		<5	<0.5	3000	
043053	Silver Diamond	13		<5	330	37		<3	5	32						350		<5	<0.5	4600	
043054	Silver Diamond	31		55	<100	900		6	24	150						54		13	1.0	5500	
043055	Daybreak	23		42	<100	137		7	7	47						<30		<5	3.3	870	
043056	Daybreak	1		19	<100	70		14	8	44						<30		<5	3.1	550	
043057	Daybreak	0.4		49	<100	140		5	6	33						<30		<5	3.5	900	
042573	Coxey	1.5	36	35	2300	<5	<0.3	78	10	120	820	960	3.18%	56	38	170	1	<5	4.1	1900	62
042557	Coxey	4	13	110	1500	42	1	190	93	120	0.16%	0.114%	722	61	57	170	2	<5	11.0	160	131
042559	Coxey A pit	1.25	22	67	2600	<5	<0.3	51	92	87	0.135%	447	585	68	18	210	1	10	3.3	160	46
042560	Coxey E pit	8	30	220	1100	67	0.5	80	137	77	0.30%	891	0.46%	207	13	110	2	10	7.8	23000	74
042561	Coxey F pit	10	17	141	450	84	0.7	54	92	74	0.35%	0.18%	93	98	7	24	2	<5	2.1	4300	172
042563	Novelty	3	13.8%	47200	860	3500	<0.3	120	4.84%	100	11	82	1.40%	1.27%	23	150	103	35	3.9	30	6
042564	Novelty	1.5	4.11%	9070	550	1850	<0.3	26	0.11%	41	21	512	445	0.60%	20	41	15	9	3.1	65	43
042565	Novelty	0.75	4.48%	13000	2100	440	<0.3	32	0.48%	100	29	572	0.53%	186	31	240	47	28	1.6	39	27
042572	Novelty	3	12.6%	22900	1200	3800	<0.3	29	0.26%	73	9	295	0.17%	59	11	240	25	34	8.4	10	22
042568	Giant	2	30.5%	7530	1000	1400	0.8	27	1.26%	100	0.21%	73	1.06%	0.11%	16	75	59	100	3.6	17	40
042566	Vein - Coxey	143	136	16100	<50	80	775	<3	42	220	0.21%	647	7	8	3.71%	<5	54	<5	0.2	8	1.63%
042584	2nd Relief	2	17	356	110	<5	0.5	4	24	250	0.25%	175	7	16	13	8	0.6	<5	0.3	1	53
042585	2nd Relief	0.5	74	72	1000	<5	25	24	6	88	318	0.286%	5	7	20	84	2	<5	3.2	1	0.12%
042586	2nd Relief	2	259	119	77	<5	0.7	8	4	240	0.14%	488	23	10	13	14	2	<5	0.6	2	55
042588	2nd Relief	3	5.00%	10200	440	<5	510	17	9	100	0.107%	483	5	6	70	50	25	<5	2.5	4	1.78%
042556	Emerald W	<0.5	4	<5	93	8	1	55	10	110	32	2.40%	475	19	441	<5	1	<5	6.7	7900	470
042553	Dodger	19	1.78%	1380	160	<5	<0.3	6	140	90	720	0.19%	10	27	51	48	185	11	1.3	820	45
042554	Dodger	1	6	21	420	<5	<0.3	220	101	40	740	724	80	23	11	170	1	<5	19.0	14	65
042578	Queen Vic	76	5	602	<50	<5	15	<3	68	64	9.40%	0.45%	5	46	4	<5	<0.5	16	0.3	1	560
042579	Queen Vic	19	3	75	<50	<5	11	<3	40	37	2.07%	0.60%	5	55	5	<5	<0.5	<5	0.3	2	360
042580	Queen Vic	14	5	147	84	<5	3	<3	30	290	1.37%	595	5	41	17	12	<0.5	<5	0.2	3	120
042581	Piedmont	110	64	4	1100	<5	0.22%	10	12	97	770	0.98%	35	212	4.69%	100	135	7	2.0	2	12.4%
042582	Piedmont	124	2	3	61	350	0.24%	<3	43	17	950	741	5	610	4.18%	8	4	28	0.2	2	13.0%
042583	Piedmont	80	240	12	1500	<5	0.16%	9	12	80	480	0.99%	72	184	2.59%	81	111	12	0.9	7	9.20
042828	Steep	<0.4		23	<100	<5		44	147	79						<30		<5	10.0	19	
042829	Steep	1.4		23	<100	<5		180	45	96						<30		<5	18.0	12	
042819	Dimac			7	<100			52		43						71		<5	6.8	68000	
042820	Dimac			7	<100			18		130						<30		<5	2.9	23000	
042822	Dimac	<0.4		<5	<100	<5		23	18	57						<30		<5	6.4	70000	
043080	Contact	110		<5	<100	<5		<3	3	49						36		<5	0.5	15	
043082	Contact	162		6	420	<5		24	6	69						54		<5	5.2	24	
043083	Kuhn	1.4		<5	<100	10		420	14	390						380		<5	45.0	480	
043084	Kuhn	0.6		<5	260	<5		57	77	59						35		<5	6.7	35	
043085	Dead Goat	1		<5	250	<5		4	192	53						<30		<5	0.5	1800	
043086	Dead Goat	1.6		<5	340	35		<3	170	59						<30		<5	1.1	440	
043087	Lamb Mountain	1.2		<5	<100	<5		9	24	56						<30		<5	0.7	430	
043088	Lamb Mountain	<0.5		<5	260	17		33	14	46						530		<5	150.0	320	
043089	Lamb Mountain	<0.5		<5	250	<5		42	10	76						210		<5	34.0	1100	
043074	Unnamed	1.4		<5	<100	6		4	10	66						<30		<5	0.5	10	
043075	Unnamed	0.8		<5	<100	<5		13	15	120						34		<5	0.5	7	
043076	Unnamed	<0.4		<5	<100	<5		18	11	120						<30		<5	0.5	14	

TABLE 2-2-1b
DESCRIPTIONS OF SAMPLES LISTED IN TABLE 2-2-1a

LABNO	DEPOSIT	SAMPLE DESCRIPTION
043058	Maid of Erin	Bornite ore with yellowish green garnet.
043059	Maid of Erin	Massive bornite ore.
043060	Maid of Erin	Below deposit; rusty silicified float with disseminated po.
043062	Maid of Erin	Mineralization on road east of deposit.
043065	State of Montana	Massive bornite and garnet ore.
043066	State of Montana	Massive bornite and garnet ore.
043067	State of Montana	Disseminated po in banded garnet skarn.
043063	Adams	Minor py, po and aphl in siltstone and phyllite
043068	Lawrence	Sphl with minor cpy and gal with green garnet in marble.
043064	Majestic	Massive po vein with minor cpy and quartz veinlets.
043069	Rainy Hollow	Disseminated po in rusty siliceous siltstone on road into deposit
043070	Rainy Hollow	Disseminated po in rusty siliceous siltstone on road into deposit.
043072	Rainy Hollow	Disseminated po in schist; east side of Mineral Mountain.
043073	Rainy Hollow	Disseminated po in hornfelsed schist; Inspector Creek float.
043077	Chalco	Po, cpy and mgt in garnet pyroxene skarn.
043078	Chalco	Po, cpy and mgt in garnet pyroxene skarn.
043079	Chalco	Po and mo in skarn altered schist.
042818	Craigmont	Mgt, hem and cpy in epidote-chlorite skarn
042548	Eric	Mgt, hem, malachite and potassium feldspar in garnet skarn.
042544	Lucky Mike	Cpy, scht and calcite in brown garnetite.
042823	Molly B	Po in garnet-pyroxene skarn
042824	Molly B	Po, cpy and py in garnet-pyroxene skarn, mine dump
042825	Molly B	Sphl, po and cpy in pyroxene-garnet skarn; upper cut
042826	Oral M	Py and cpy in quartz vein.
042827	Oral M	Py and cpy in quartz vein.
043048	Atlin Magnetite	Mgt, cpy and po in garnet skarn
043049	*Atlin Magnetite*	*Mgt, cpy and azurite in garnet skarn*
043050	Silver Diamond	Coarse sphl,po and cpy mineralization
043052	Silver Diamond	Po, cpy and fluorite with sericite
043053	Silver Diamond	Black manganese in granular crystalline fluorite
043054	Silver Diamond	Sphl and gal veinlets with minor coarse py in quartz vein
043055	Daybreak	Wrigglite skarn
043056	Daybreak	Wrigglite skarn.
043057	Daybreak	Wrigglite skarn.
042557	Coxey	D pit; Po veinlets in pyroxene-amphibole skarn
042573	Coxey	Mo in pyroxene hornfels; uA pit
042559	Coxey	Mo and po matrix in diorite breccia; A pit
042560	Coxey	Mo and py veins in skarn, E pit.
042561	Coxey	Mo and py veins in skarn-altered siltstones, F pit.
042563	Novelty	Asp, mo, py ore with cobalt bloom
042564	Novelty	Asp and mo in silicified sedimentary breccia
042565	Novelty	Asp, cpy and cob ore
042572	Novelty	Asp in siliceous sediment.
042568	Giant	Asp, mo with minor po, py and garnet ore, upper adit dump
042566	Vein north of Coxey	Gal and py in thin, subhorizontal quartz vein.
042584	2nd Relief	Py, po, and cpy in quartz vein
042585	2nd Relief	Sulphide-rich pyroxene hornfels with minor garnet in wallrock.
042586	2nd Relief	Sulphide-rich quartz vein with dark green mineral.
042588	2nd Relief	Sphl and asp-rich quartz vein.
042556	Emerald W	Scht, and mo in garnet skarn inside portal
042553	Dodger	Po, py and asp at limestone-granite contact in portal
042554	Dodger	Po and py and equigranular quartz in granite at portal.
042578	Queen Victoria	Cpy and py in garnetite.
042579	Queen Victoria	Cpy and py in garnetite
042580	Queen Victoria	Sulphide-rich quartz vein
042581	Piedmont	Massive gal, sphl and po ore
042582	Piedmont	Massive po and sphl from inside adit.
042583	Piedmont	Gal sphl and po ore
042828	Steep	Po in garnet skarn
042829	Steep	Po and cpy in skarn
042819	Dimac	Po and scht in quartz-garnet skarn.
042820	Dimac	Coarse scht with po in garnet-pyroxene-quartz skarn
042822	Dimac	Scht and po in garnet-pyroxene-quartz skarn
043080	Contact	Mgt, po and sphl ore
043082	Contact	Mgt, po sphl ore.
043083	Kuhn	Mo and minor po in actinolite, garnet quartz skarn
043084	Kuhn	Po and cpy in float.
043085	*Dead Goat*	*Coarse po and py with minor sphl and mgt in coarse garnet skarn.*
043086	Dead Goat	Sphl and po in pyroxene skarn.
043087	Lamb Mountain	Minor po and cpy in actinolite skarn
043088	Lamb Mountain	Disseminated po in rusty, siliceous quartz monzonite
043089	Lamb Mountain	Disseminated po in rusty, siliceous quartz monzonite
043074	Unnamed	Garnet-pyroxene skarn with py and po (#6 in Figure 6).
043075	Unnamed	Garnet-pyroxene skarn with py and po (#6 in Figure 6).
043076	Unnamed	Endo skarn with py, po and mo (#5 in Figure 6).

Abbreviations; mo = molybdenite, py = pyrite, cpy = chalcopyrite, po = pyrrhotite, asp = arsenopyrite, hem = hematite, scht = scheelite, cob = cobaltite, gal = galena, sphl = sphalerite

Analytical methods:

Au,Ba,Ce,Cr,Rb,Se,Sn,Th,W; neutron activation, Activation Laboratories Ltd Ancaster, Ont

Ag,Bi,Cd,Co,Cu,Mn,Mo,Ni,Pb,Zn; atomic absorption spectroscopy, Anaytical Sciences Laboratory, B C Geological Survey Branch, M E M P R

As,Sb; atomic absorption-hydride generation, Anaytical Sciences Laboratory, B C Geological Survey Branch, M.E.M.P R..

INSULAR BELT

A number of skarns, including the Maid of Erin and State of Montana deposits, are located in the Rainy Hollow area in the northwest corner of the province (Figure 2-2-1) approximately 70 kilometres northwest of Haines, Alaska. They occur within the Alexander Terrane and are hosted by Upper Paleozoic sediments that are intruded on the west and east by Oligocene rocks of the Tkope River intrusions (Campbell, 1983). A suite of Squaw-Datlaska gabbroic sills and dikes also occurs in the area (Figure 2-2-2). Skarn alteration and silicification, with zones of massive and disseminated sulphides, are exposed over a wide area. Intermittent underground mining took place, mostly at the Maid of Erin between 1907 and 1956; approximately 244 tonnes of copper, 1.5 tonnes of silver and minor gold were produced (Table 2-2-2). Minor production is also reported from the State of Montana claim. In addition to these two producers, several small skarn occurrences are exposed in old pits and exploratory adits in the area; they include the Lawrence, Adams, Victoria, Hibernia, Wonderful and Majestic skarns (McConnell, 1913; Hudson, 1927; Watson, 1948).

MAID OF ERIN (MINFILE 114P 007)

The Maid of Erin skarn lies less than 200 metres from the northeast margin of a hornblende-biotite quartz diorite body belonging to the Tkope River intrusions. This large massive stock, which underlies the skarn, is cut by numerous narrow, white quartz veins. The skarn is hosted by an altered and silicified package of tuff, argillite and marble that dips moderately northeastwards; these rocks are locally cut by narrow, endoskarn-altered sills and dikes that are believed to originate from the nearby diorite.

The endoskarn intrusions and exoskarn lenses largely comprise banded, massive and crystalline garnet with lesser pyroxene; banding in the exoskarn probably represents remnant bedding. The garnet includes pale brown, red, lime-green and yellow varieties, some of which are optically zoned. Several phases are recognized in the marble an early, brown garnet is overgrown, in turn, by dark green and yellow crystals. Also present are coarse, radiating crystals of vesuvianite and wollastonite as well as lesser epidote, sericite and biotite. The fine-grained biotite mainly occurs in remnant patches of dark, siliceous, hornfels-like rock that is cut by veinlets of pyroxene and later garnet. Watson (1948) reports the presence of zoisite, clinozoisite, monticellite, anorthite and blue gahnite spinel in the skarn.

Mineralization is found both in the exoskarn and endoskarn. It consists of veins and blebs of mainly bornite, chalcocite and lesser chalcopyrite with sporadic and minor azurite, black sphalerite, molybdenite and magnetite. Wittichenite (Cu_3BiS_3) has also been identified in some ore as well as trace covellite and native silver (Watson, 1948). Mineralized samples of sulphide-rich skarn contain high values of copper, silver and bismuth with some gold (Ettlinger and Ray, 1989; Table 2-2-1a). Extensive silicified and albitized zones containing disseminated pyrrhotite occur adjacent to the Maid of Erin skarn and on Mineral Mountain (Figure 2-2-2), however, samples of this material contained no gold (Table 2-2-1a).

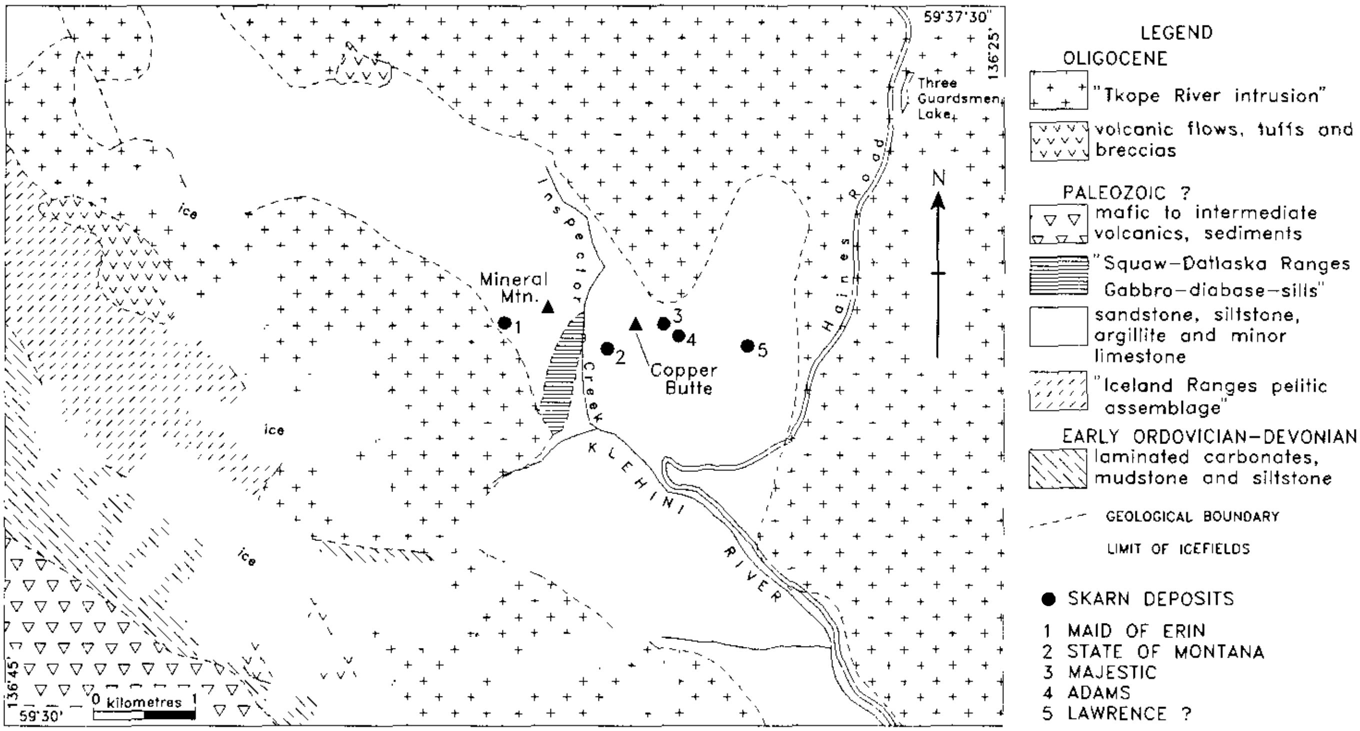

Figure 2-2-2. Geology and location of skarns in the Rainy Hollow area, northwest B.C. (geology after Campbell,1983).

TABLE 2-2-2
SKARNS VISITED DURING THE 1991 FIELD SEASON GIVING TECTONIC BELT, LITHOTECTONIC TERRANE AND PRODUCTION

Skarn name	Belt	Terrane	Ore (t)	Au (kg)	Ag (kg)	Cu (t)	Pb (t)	Zn (t)	Mo (t)	Fe (t)	W(t)
Maid of Erin	Ins	Alex	3 285	0.3	1 487	244	-	-	-	-	-
State of Montana	Ins	Alex	9	-	14	2	-	-	-	-	-
Victoria	Ins	Alex	none	-	-	-	-	-	-	-	-
Adams	Ins	Alex	none	-	-	-	-	-	-	-	-
Lawrence	Ins	Alex	none	-	-	-	-	-	-	-	-
Chalco	Cst	BrdgR	none	-	-	-	-	-	-	-	-
Craigmont	Int	Ques	29 325 342	78	242	402 704	-	-	-	141 634	-
Lucky Mike	Int	Ques	5	0.6	4.3	0.9	0.8	-	-	-	-
Molly B	Int	Stik	290	0.7	3.5	2	-	-	-	-	-
Oral M	Int	Stik	12	0.3	1.5	1	-	-	-	-	-
Silver Diamond	Int	Cache	none	-	-	-	-	-	-	-	-
Atlin Magnetite	Int	Cache	none	-	-	-	-	-	-	-	-
Day Break	Int	Cache	none	-	-	-	-	-	-	-	-
Coxey	Omn	SldMtn	1 035 509	-	-	-	-	-	1 749	-	-
Novelty	Omn	SldMtn	unknown production		-	-	-	-	-	-	-
Giant	Omn	SldMtn	*4 131	113	23	1.3	-	-	-	-	-
Second Relief	Omn	Ques	207 023	3 118	866	20	1	0.1	-	-	-
Emerald camp**	Omn	ANA	7 683 190	-	-	-	-	-	-	-	7 416
Queen Victoria	Omn	Ques	45 352	8	950	673	-	-	-	-	-
Piedmont	Omn	Ques	479	-	71	-	24	71	-	-	-
Steep	Omn	Koot	none	-	-	-	-	-	-	-	-
Dimac	Omn	Bark	105	-	-	-	-	-	-	-	105
Contact	Omn	Cass	25		10	0.02	2	-	-	-	-
Kuhn	Omn	Cass	none	-	-	-	-	-	-	-	-
Dead Goat	Omn	Cass	none	-	-	-	-	-	-	-	-
Lamb Mtn.	Omn	Cass	none	-	-	-	-	-	-	-	-

Abbreviations: Belts: Ins = Insular, Cst = Coast, Int = Intermontane, Omn = Omineca.
Terranes: Ques = Quesnellia, Stik = Stikinia, Cass = Cassiar, Bark = Barkerville, Alex = Alexander, Koot = Kootenay, SldMtn = Slide Montain, Cache = Cache Creek, ANA = Ancestral North America, BrdgR = Bridge River
* = Giant and California claims production.
** = Emerald Tungsten, Dodger, Feeney, Invincible: tungsten production figure from Jersey Mine records.

State of Montana (MINFILE 114P 008)

The alteration and mineralization at this property are similar to that at the Maid of Erin skarn, approximately 1 kilometre to the east (Figure 2-2-2). The skarn consists mainly of green and brown garnet with minor amounts of coarse, radiating actinolite crystals. It is hosted by layered, steeply dipping marbles and siliceous and albitized metasediments close to small bodies of mafic diorite.

Mineralization appears to be confined to the green garnet skarn. It consists of veins and layers of massive bornite and chalcocite up to 10 centimetres thick; Watson (1948) notes that wittichenite occurs in bornite as microscopic grains. Like the Maid of Erin skarn, some of the silicified and albitized metasediments contain fine disseminated pyrrhotite.

Other Skarn Occurrences in the Rainy Hollow Area

The **Victoria, Adams and Lawrence** (MINFILE 114P 009, 010 and 011) occurrences are characterized by variable amounts of brown and green garnet with some minor wollastonite. Mineralization is dominated by black sphalerite with lesser galena (Hudson, 1927; Watson, 1948); some pods of massive pyrrhotite were also documented at the Adams where the skarn follows a marble-argillite contact, close to thin diorite sills. The Victoria skarn was not visited during this season because its location is uncertain.

The **Majestic** lies on the east side of Copper Butte (Figure 2-2-2) where it is hosted by grey marbles. At least two adits were driven on an east-trending zone of massive pyrrhotite. A narrow lens of crystalline brown and green garnet skarn is developed on the north side of the zone, between it and the marble.

The pyrrhotite zone contains garnet as well as rare veinlets of quartz and chalcopyrite. A pyrrhotite-rich sample from the Majestic is weakly anomalous in bismuth and cobalt but contains no gold (Table 2-2-1a).

To summarize, our examination of the Rainy Hollow area suggests that the numerous mineralized skarn deposits and occurrences are part of a major skarn system. This system, which probably resulted in a discontinuous but extensive alteration envelope that exceeds 1 square kilometre in outcrop area, covers parts of the Mineral Mountain and Copper Butte areas. It is uncertain whether it is related to the large Oligocene Tkope River intrusions or to a gabbroic sill suite forming part of the Squaw - Datlaska Ranges complex (Figure 2-2-2). The envelope contains copper and silver-rich skarn close to the Tkope River intrusion at the Maid of Erin deposit. Farther from the intrusion it contains some zinc-lead skarns as well as extensive alteration zones that are silicified and albitized with massive and disseminated pyrrhotite.

Past mining and exploration drilling at Rainy Hollow were concentrated on the proximal copper-rich skarn, while the possible existence of distal gold-rich and copper-poor skarn mineralization, similar to that at the Fortitude deposit in Nevada (Wotruba *et al.*, 1988; Myers, 1990), has largely been ignored. Although our samples of this pyrrhotite alteration were barren of gold (Table 2-2-1a), other features suggest that gold skarn mineralization could exist at Rainy Hollow. These features include the localized enrichment of gold, cobalt and bismuth in the hydrothermal system as well as the low Cu/Ag ratio (250) of the Maid of Erin ore; such a low ratio is atypical of most copper and iron skarns but is a characteristic of many gold-skarn systems (Ettlinger and Ray, 1989).

COAST BELT

Chalco (MINFILE 92JNE043)

The Chalco 5 skarn is located 11 kilometres southeast of Bralorne in the Bridge River Terrane of southwestern B.C. (Figure 2-2-1). The area is underlain by biotite schist, banded amphibolite and marble of the Bridge River Group and the skarn is hosted by a northwest-trending pod of coarsely crystalline marble and schist 200 metres in length. An adit and open cut expose a section of marble containing a skarn zone up to 3 metres wide. The hornblende diorite Bendor batholith outcrops 100 metres to the north and is probably responsible for the skarn; it has yielded a Tertiary age of 64 Ma (Church and Pettipas, 1989). Small dikes of altered hornblende diorite crosscut the schist adjacent to the skarn.

Skarn minerals include coarse brownish red to black garnet with lesser pyroxene, actinolite and epidote. Garnet generally forms an interlocking mass of subhedral crystals up to 3 centimetres in diameter and often shows noticeable growth zoning; minor sericite is interstitial to the garnet. Locally the garnet skarn is banded with, or contains clots of, pyroxene and actinolite. Some crosscutting veins of quartz and carbonate contain euhedral crystals of garnet and pyroxene.

The disseminated metallic mineralization is sparse; it includes pyrrhotite, chalcopyrite and some magnetite with rare molybdenite. Geochemical analyses indicate sporadic minor enrichment in gold, bismuth and tungsten (Table 2-2-1a).

INTERMONTANE BELT

Craigmont Mine (MINFILE 92ISE035)

The Craigmont copper skarn is situated in the Quesnel Terrane of southern British Columbia (Figure 2-2-1), approximately 13 kilometres northwest of Merritt. It is the largest copper skarn deposit in the province having produced over 400 000 tonnes of copper and 140 000 tonnes of magnetite iron ore (Table 2-2-2) from open-pit and underground workings. Mining took place between 1961 and 1982; since 1983 magnetite has been recovered from the tailings for use by the coal industry.

The Craigmont orebody was located on a major fault and was hosted mainly by volcanics, bedded tuffs and limestones of the Late Triassic Nicola Group adjacent to the southern margin of the Guichon Creek batholith. This batholith, which represents a high-level intrusion, was coeval with the Nicola Group volcanism and is associated with porphyry copper mineralization in the Highland Valley (McMillan, 1976, 1978). Quartz dioritic rocks of the batholith are exposed on the north wall of the open pit. They comprise dark, coarse-grained, epidote-altered rocks that contain up to 20 per cent hornblende.

The skarn silicate assemblage includes abundant chlorite, actinolite, epidote, calcite and quartz with minor red garnet and pink orthoclase. Sulphides occur mostly in the chlorite-actinolite exoskarn and the ore zones were generally concordant with the batholith margin and bedding in the Nicola Group. Exoskarn mineralization comprises masses and irregular veins of chalcopyrite up to 3 centimetres wide, together with magnetite and coarse specular hematite; pyrite is rare. Rennie (1962) notes that mineralization in the deposit was dominated by magnetite at its eastern end and by hematite farther west. The best copper grades occurred where there were equal amounts of magnetite and hematite. The mineral assemblages indicate that overall, the deposit formed in oxidized conditions although the magnetite to hematite zoning suggests that conditions towards the eastern end of the deposit were more reduced. Production data (Table 2-2-2) and geochemical analyses (Table 2-2-1a) indicate that this copper skarn has a very low gold content.

Minor amounts of endoskarn mineralization are observed; the altered diorite contains subcircular masses of chalcopyrite, up to 30 centimetres across, with patches of coarse, pink calcite and orthoclase, small euhedral quartz crystals and green epidote. This endoskarn includes thin magnetite layers that trend subparallel to the margins of the diorite, as well as rare, irregular veinlets of dark red garnet.

Two periods of mineralization are recognized (Johnson, 1973); an early magnetite-chalcopyrite assemblage, related to the main skarn-forming event, and later hematite-chalcopyrite mineralization that occurs mostly in chloritic shears. Some of the chalcopyrite veins are intergrown with pink orthoclase.

Morrison (1980) concluded that the metals were derived from the Nicola Group and not from the Guichon Creek batholith. However, the genetic relationship between the batholith and porphyry copper mineralization, and the spatial association of the skarn with the batholith margin suggests that the Craigmont deposit and the batholith are related. Moreover, approximately 2.5 kilometres east of the deposit, at the **Eric** occurrence (MINFILE 92ISE036), minor copper-magnetite mineralization is also developed along the batholith margin. This mineralization is associated with abundant orthoclase and lesser clinopyroxene, epidote, sphene and honey-coloured, optically isotropic garnet.

Lucky Mike Deposit (Minfile 92ISE027)

The Lucky Mike skarn is located approximately 20 kilometres north of Merritt within the Quesnel Terrane of southern British Columbia (Figure 2-2-1). Between 1917 and 1924 it produced minor amounts of silver, copper, lead and gold (Table 2-2-2). The area is underlain by Late Triassic Nicola Group volcanics, tuff and minor limestone (Moore and Pettipas, 1990). These contain a concordant, northerly striking zone of mineralized garnetite skarn that probably replaced a lens of clastic limestone. Both the footwall and hangingwall rocks comprise relatively fresh, massive andesitic crystal and lapilli tuffs with some agglomeratic layers. Locally, the hangingwall is occupied by a small body of hornblende-porphyritic mafic diorite; this intrusion is probably related to the skarn mineralization.

The garnetite zone is up to 3 metres wide and 30 metres long. It consists largely of medium-grained crystals of brownish red garnet. Irregular blebs of chalcopyrite, 2 to 3 centimetres long, are present in the garnetite; they are associated with patches of coarse calcite and quartz. Crystals of scheelite up to 0.5 centimetre across, as well as pyrite, pyrrhotite, sphalerite and magnetite are also present. Trace geochemical analyses of a mineralized grab sample are presented in Table 2-2-1a.

Molly B and Oral M (Minfile 103P 085)

The Molly B and Oral M deposits lie within the Stikine Terrane of northwestern British Columbia, close to the eastern margin of the Intermontane Belt (Figure 2-2-1). They are situated on the east side of the Bear River, opposite the town of Stewart. The Molly B adit was driven immediately above the river bank and the Oral M adit lies approximately 200 metres farther upslope. The geology and mineralization of the area are described by Grove (1971, 1986) and Alldrick (in preparation).

The Molly B deposit is a copper skarn whereas the Oral M is an auriferous, sulphide-rich quartz vein that cuts barren skarn and hornfels; both have had minor production of copper, gold and silver (Table 2-2-2). They are hosted by Early Jurassic Hazelton Group tuffs, argillites and minor limestones close to the intrusive contact of the Eocene granodioritic Hyder batholith. Extensive and irregular zones of biotite hornfels containing minor disseminated pyrrhotite occur in the vicinity of the two prospects. Hornfelsed tuffs are cut by veins of quartz and epidote, the cores of which locally contain pale brown garnet.

The Oral M prospect is a shear-hosted quartz vein that carries disseminated chalcopyrite, pyrite and gold; geochemical analyses on two vein samples are presented in Table 2-2-1a. The wallrock includes both hornfels and a garnet-dominant skarn with lesser pyroxene, actinolite and biotite. It is uncertain whether the mineralized quartz vein was genetically related to the formation of the wallrock skarn.

Close to the Molly B adit, massive to layered garnet-dominant skarn is associated with remnant, purplish coloured biotite hornfels that is cut by thin irregular pyroxene veinlets. An intense tectonic cleavage is developed locally; this is generally orientated subparallel to layering in the skarn which is believed to represent remnant bedding. Garnet forms veins, layers and pods up to 10 centimetres across. It occurs as euhedral light red, dark brown, amber and black crystals up to 1 centimetre in size. Pyroxene, epidote, actinolite, quartz and coarse carbonate are also present.

The skarn contains disseminations and irregular veins of pyrrhotite with lesser chalcopyrite, pyrite and molybdenite. Garnets in the sulphide-rich skarn are darker than those in the unmineralized skarn. Geochemical analyses of mineralized samples from the adit dump are anomalous in tungsten but, unlike the Oral M, they contain no gold (Table 2-2-1a).

Two dikes of unaltered leucocratic biotite granodiorite, up to 2 metres thick, are exposed in the Molly B adit. They are enveloped by banded garnet-pyroxene skarn, but it is uncertain whether the dikes are related to the skarn. However, float of endoskarn-altered intrusive was seen around the adit entrance. It consists of a coarse leucogranodiorite containing clots of red garnet and green epidote. Approximately 15 metres above the adit, several overgrown pits expose coarse garnet-pyroxene skarn with pyrrhotite, chalcopyrite and black sphalerite.

To summarize, the Oral M and Molly B deposits are distinct from one another in their morphology, mineralization and metal content. It is not known if they were coeval and related to the nearby Eocene Hyder pluton or whether they represent older Jurassic deposits as discussed by Alldrick (*in preparation*). The Oral M is a gold-bearing quartz vein, but it is uncertain whether it and the barren skarn-altered wallrock were formed during the same event. The Molly B, by contrast, is a gold-poor copper skarn that carries some local zinc, molybdenum and tungsten enrichment.

ATLIN CAMP

The **Silver Diamond, Atlin Magnetite** (MINFILE 104N 069 and 126) and the newly discovered **Daybreak** skarn occurrences are hosted by rocks of the Cache Creek Terrane, approximately 20 kilometres east-northeast of Atlin in northern British Columbia (Figure 2-2-1). They are spatially associated with the western margin of the Late Cretaceous Surprise Lake batholith where it intrudes calcareous rocks of the Cache Creek Group (Figure 2-2-3). The batholith consists largely of a leucocratic quartz monzonite.

The Silver Diamond skarn lies close to the southwest margin of a satellite stock of the Surprise Lake batholith (Figure 2-2-3) about 4.5 kilometres southwest of Ruby Mountain and west of Boulder Creek. It occurs mainly along the contact between a white, crystalline marble and altered greenstone and ultramafic rocks. Garnet is relatively uncommon and forms thin layers and veinlets of red and brown crystals. Variable amounts of pyroxene, fluorite, amphibole, biotite and sericite are also present. The greenstones adjacent to the skarn are bleached and silicified, whereas those adjacent to marble locally contain remnant patches of a dark biotite hornfels. Transition from marble to hornfels is often marked by the following mineral zoning: marble, garnet skarn, pyroxene skarn and hornfels.

The occurrence is characterized by pods, veins and irregular lenses of massive to disseminated sulphide, up to 1 metre wide, that are generally concordant with the marble contact. Locally, the greenstones are brecciated and cut by sulphide veinlets. Mineralization consists largely of pyrrhotite and sphalerite with minor chalcopyrite, pyrite and scheelite; some quartz-vein float with sphalerite and galena was noted at the occurrence. Locally, the colourless and purple fluorite is abundant. 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. Analyses of mineralized samples (Table 2-2-1a) indicate that the Silver Diamond skarn is geochemically anomalous in silver, bismuth and tungsten.

There are reports in MINFILE of sporadic scheelite, cassiterite, molybdenite and tetrahedrite mineralization a short distance northeast of the occurrence.

The **Atlin Magnetite** skarn is situated approximately 8 kilometres northeast of the Silver Diamond prospect (Figure 2-2-3) between Ruby and Cracker creeks at about 1800 metres elevation. It is hosted by a deformed package of marble, sheared greenstone and talcose ultramafic rocks, approximately 200 metres south of their contact with the Surprise Lake batholith. In this area, the marginal phase of the batholith is a rusty-weathering quartz porphyry that hosts the Purple Rose uranium occurrence (MINFILE 104N 005); it lies approximately 250 metres north-northeast of the Atlin Magnetite skarn.

Skarn alteration and mineralization at the Atlin Magnetite occurrence are concentrated in marble layers close to their contact with sheared ultramafic rocks. Layers, masses and veins of garnet are present with lesser amounts of pyroxene, actinolite and coarse green epidote; minor late veins of rhodonite, and float containing coarse white wollastonite crystals, up to 2.5 centimetres long, were also seen. 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.

Mineralization is dominated by layers and masses of magnetite, up to 0.5 metre thick, that are generally concordant with the foliated marbles. Magnetite is often intergrown with garnet although locally it is cut by garnet veins. Lesser amounts of chalcopyrite, pyrrhotite and sporadic pyrite occur with some azurite and abundant malachite staining. Geochemical analyses of mineralized samples indicate the skarn is weakly anomalous in silver and gold (Table 2-2-1a).

The **Daybreak** occurrence was recently discovered by an Atlin prospector, Mr. W. Wallis, and is of interest because it includes some ribbon-banded wrigglite skarn. It is situated at an elevation of 1550 to 1600 metres, east of Ruby Creek and 1 kilometre south of the Atlin Magnetite skarn (Figure 2-2-3) at UTM 595000E; 6620250N. The area is underlain by altered greenstone, schistose hornfelsic metasediment and minor mafic tuff and marble. These are intruded by several large, irregular sills and dikes of leucocratic quartz monzonite that are cut by narrow quartz veins, some of which carry minor fluorite. The sills and dikes are probably related to the nearby Surprise Lake batholith.

West and southwest of the occurrence there is a large area of garnet-pyroxene-biotite exoskarn, with lesser amounts of unaltered intrusive. This skarn contains layers and irregular veins of orange-red garnet and green pyroxene, up to 0.3 metre thick, that cut a schistose biotite hornfels. The eastern end of the skarn is covered by a scree that contains numerous large boulders of layered wrigglite skarn (Plate 2-2-1). Wrigglite was not seen in outcrop but some of the float represents frost-heaved boulders, suggesting that it subcrops in the immediate vicinity.

The wrigglite skarn is characterized by thin, rhythmic, mineral layering; each layer is either green, brown or black, depending upon the quantity of fluorite, vesuvianite, garnet or magnetite present. The layers, which are between

0.5 millimetre and 10 centimetres thick, are locally folded and sheared (Plate 2-2-1), and some are crosscut by veins of garnet. Rare vuggy cavities up to 10 centimetres in diameter are present; these are lined with elongate crystals of green clinozoisite. Microprobe and x-ray diffraction studies by the Geological Survey of Canada (S.B. Ballantyne, personal communication, 1991) indicate the wrigglite contains gahnite and trace cassiterite, and is enriched in beryllium. No beryl has yet been identified, and it is likely that much of the beryllium is contained as a non-essentail element within the vesuvianite and garnet.

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 texture and notes it is a characteristic of iron and fluorine-rich tin skarns, most of which contain fluorine in excess of 9 per cent by volume. Wrigglite skarns are commonly associated with fault structures; unlike most tin skarns which generally form at deep levels, they are believed to develop under relatively near-surface conditions such as above the cupolas of high-level granites. Thus, its presence in the Daybeak skarn suggests the Surprise Lake batholith is a relatively high-level and structurally controlled intrusion. Moreover, the presence of the fluorine-beryllium-tin skarn assemblages at both the Daybreak and Silver Diamond occurrences are characteristic of highly evolved granitic melts derived from continental crust. This indicates the oceanic Cache Creek Terrane may be underlain by continental basement in the Atlin area.

OMINECA BELT

The **Coxey, Novelty** and **Giant** skarns are hosted by rocks of the Slide Mountain Terrane, and lie within the Rossland mining camp in southeastern British Columbia (Figure 2-2-1). The camp has a long mining history and many of its important deposits are on Red Mountain, west of Rossland township (Figure 2-2-4). Immediately east of Red Mountain, the geology is characterized by Early Jurassic Rossland Group supracrustal rocks and several suites of Jurassic intrusions. On Red Mountain, these rocks are structurally overlain by a thrust sheet comprising Pennsylvanian to Permian metasediments of the Mount Roberts Formation (Höy and Andrew, 1991a and b).

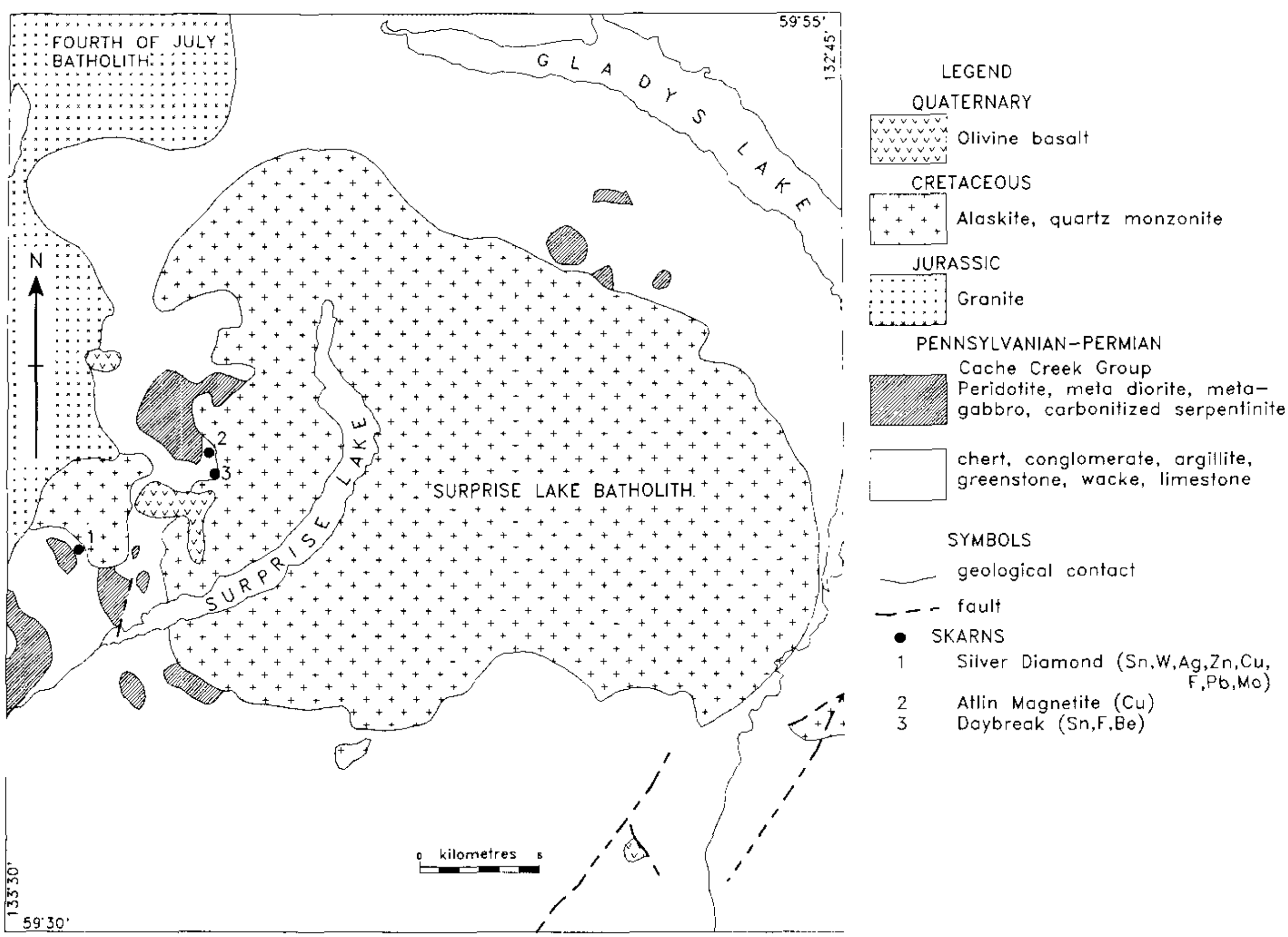

Figure 2-2-3. Geology and location of skarn occurrences associated with the Surprise Lake batholith, Atlin camp (geology after Aitken, 1960).

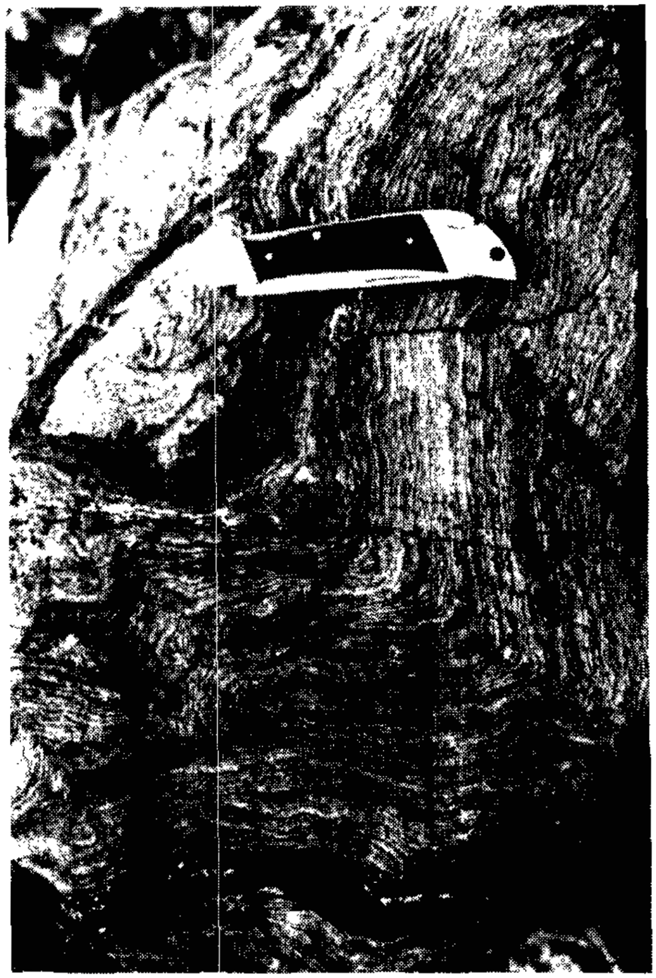

Plate 2-2-1. "Wrigglite" skarn with alternating layers rich in fluorite, magnetite, vesuvianite and grossular garnet. This skarn contains minor cassiterite and gahnite and is geochemically anomalous in beryllium (S.B. Ballantyne, personal communication, 1991). Daybreak tin skarn occurrence, Atlin camp, B.C.

Two types of mineralization are recognized in the camp; each in different hostrock packages, with contrasting mineralogies, and are believed to be of different ages (Dunne and Höy, 1992, this volume; Höy *et al.*, 1992, this volume). The oldest and most economically important deposits are in extensive, steeply dipping pyrrhotite-rich veins that contain gold, silver, arsenic and copper. The veins cut the Rossland Group sediments, volcanics and coeval plutonic rocks that underlie the lower eastern slope of Red Mountain. They were worked in numerous underground mines, mainly between 1890 and 1930, and include the Le Roi, I.X.L., Evening Star and Gertrude veins (Figure 2-2-4). Some of these vein deposits are associated with weak skarn alteration (Wilson *et al.*; 1990, Höy *et al.*, 1992, this volume).

The other major deposit type is younger than the veins and is represented by molybdenum skarns that were mined by open pit, mainly between 1966 and 1972; they include the Coxey, Novelty and the Giant orebodies. These are hosted by the thrust package of siltstones and tuffs belonging to the Mount Roberts Formation and in younger dioritic intrusions (Höy and Andrew, 1991a and b). There are, however, important geochemical differences between these molybdenum skarns; The Coxey orebodies are barren of gold while the Novelty and Giant deposits contain elevated values of gold, cobalt, bismuth, arsenic and nickel (Table 2-2-1a). It is not known if this variation represents a geochemical zoning in the molybdenum skarns, or whether the fluids responsible for the Novelty and Giant mineralization scavenged gold, arsenic and cobalt from the older vein mineralization in the underlying thrust plate.

The Mount Roberts Formation in the Rossland area also contains rare galena-sphalerite veins of unknown age. One narrow quartz vein with pyrite, galena and sphalerite outcropping north of Coxey (Figure 2-2-4) assayed 16 grams per tonne gold (Table 2-2-1a).

Geology of the Red Mountain Area

Early geological work in the Rossland area includes that by Drysdale (1915), Stevenson (1935), White (1949) and Little (1963). More recent publications include those by Little (1982), Fyles (1984), Höy and Andrew (1991a and b) and Höy *et al.*, (1992, this volume).

Two structural packages, separated by the easterly directed Rossland thrust fault (Figure 2-2-4), are recognized on the mountain (Höy and Andrew, 1991a and b). The oldest of these is the Permo-Carboniferous Mount Roberts Formation that comprises thin-bedded siltstones, bedded tuffs, minor volcanics and very rare, thin carbonate units. They form a subhorizontal to gently dipping sequence exposed on the upper part of Red Mountain. Structurally underlying these rocks are alkalic tuffs, volcanics and subvolcanic intrusions of the Early Jurassic Rossland Group.

A variety of intrusive rocks are recognized in the Red Mountain area. The oldest is the Rossland monzonite, an Early Jurassic pluton that is intrusive into and cogenetic with the Rossland Group (Dunne and Höy, 1992, this volume). It is probably genetically related to the gold-bearing sulphide veins and associated gold-skarn envelopes on the mountain, but it has not been mapped in the overlying Mount Roberts Formation. This and an inferred thrust contact between Mount Roberts Formation and Rossland monzonite south of Rossland, suggest a pre-faulting age for the Rossland monzonite.

A subsequent major plutonic event (*ca.* 16? Ma) resulted in the emplacement of the dioritic to monzonitic Rainy Day and Trail plutons. This event resulted in the extensive silicification, skarning and development of hornfels in the Mount Roberts Formation on Red Mountain (Fyles, 1984). A variety of equigranular to porphyritic quartz diorite sills and dikes, that cut both the Mount Roberts and underlying Rossland rocks, are believed to be related to this plutonism. They produced only localized barren garnet-pyroxene-epidote skarn in the lower structural package but resulted in the development of the molybdenum skarn orebodies in the Mount Roberts Formation.

Coxey Mine (Minfile 82FSW110)

The Coxey mine was worked from six open pits that extend from the lower western slopes almost to the summit of Red Mountain (Figure 2-2-4). Skarn alteration of the

Mount Roberts Formation increases towards the upper pits (E and F pits) as does the amount of sulphide mineralization. Here the skarn assemblage comprises veinlets of reddish brown garnet and green pyroxene. At a lower elevation, in pits D and B, garnet is rare but pyroxene and lesser biotite hornfels are abundant. Radiating crystals of actinolite are also locally present.

Mineralization consists primarily of molybdenite with minor scheelite; pyrite, pyrrhotite and chalcopyrite are generally uncommon. Analyses of five mineralized samples indicate enrichment in molybdenum, tungsten and copper, but no anomalous gold (Table 2-2-1a). Molybdenite generally occurs as thin smears, irregular patches and veinlets. In pits A and E, molybdenite is widely distributed in the exoskarn but at a slightly lower elevation, in pits A and uA, some mineralized endoskarn is seen. Molybdenite with pyrrhotite occurs along the margins of, and within, a brecciated dioritic body, particularly in the breccia matrix. The breccia mostly contains rounded to angular clasts of diorite up to 0.5 metre in diameter, many of which have bleached reaction rims. Adjacent to the country rocks however, it contains angular fragments of hornfelsed Mount Roberts Formation. Molybdenite is more abundant in the sedimentary breccia while pyrrhotite dominates in the dioritic breccia.

Molybdenite-rich mineralization is not always associated with pyrrhotite and pyrite, and the genetic relationship between the molybenite and the other sulphides is uncertain. Some pyrrhotite and pyrite are relatively early as they are cut and overgrown by veins of molybdenite. However, a later generation of coarse pyrite veining along late faults postdates the molybdenite.

Novelty (Minfile 82FSW107)

The Novelty open pit is at an elevation of 1370 metres on the south side of Red Mountain and south of the Coxey orebodies (Figure 2-2-4). Mineralization is hosted by thin-bedded and east-dipping metasediments of the Mount Roberts Formation. These are extensively silicified and hornfelsed with lesser amounts of epidote-pyroxene alteration and rare masses of brown, crystalline garnet. A small body of bleached, endoskarn-altered diorite cuts and brecciates the hornfelsed metasediments and the clasts of country rock have marked reaction rims.

Mineralization comprises irregular masses of anhedral arsenopyrite intergrown with minor pyrrhotite, molybdenite, cobaltite and pyrite. Some mineralized boulders are marked by minor chalcopyrite and erythrite staining; Fyles (1984) reports the presence of bismuthinite and uraninite. As well as gold, arsenic, cobalt, molybdenum and bismuth enrichment in the mineralization, geochemical analyses

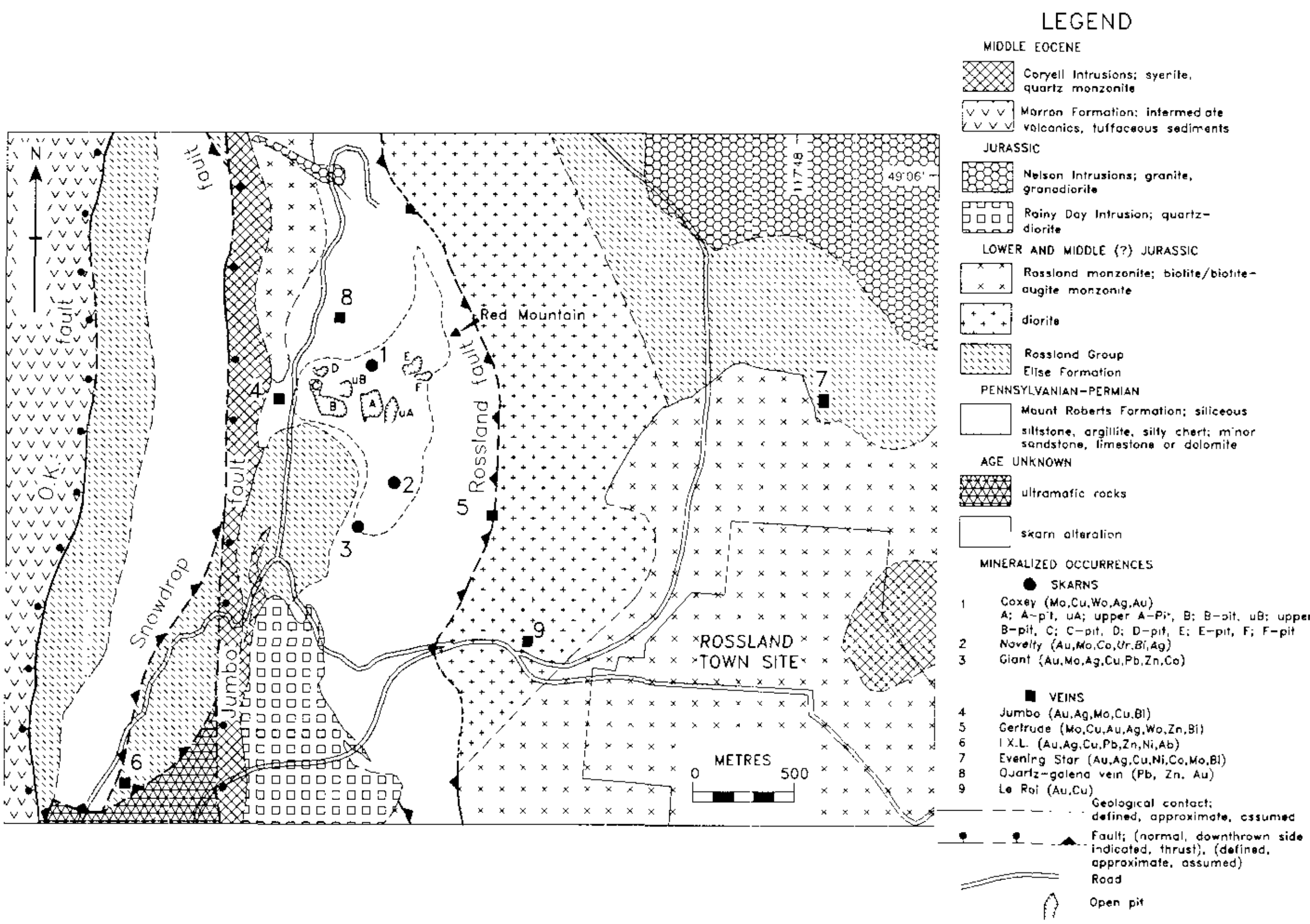

Figure 2-2-4. Geology and location of skarn and vein deposits in the Rossland Camp (geology after Höy and Andrew, 1991b).

indicate anomalous nickel (Table 2-2-1a), suggesting the presence of nickel arsenide minerals.

GIANT MINE (MINFILE 82FSW109)

The Giant mine, situated southwest of the Novelty deposit, produced copper, silver and gold (Table 2-2-2) from two adits between the years 1898 and 1903. The area is underlain by subhorizontal, thinly bedded, hornfelsed siltstone of the Mount Roberts Formation. No mineralization was seen in outcrop but rocks on the dump at the blocked entrance to the upper adit contain massive arsenopyrite intergrown with coarse molybdenite flakes, minor pyrrhotite and chalcopyrite. Minor garnet and some calcite veining occurs with the sulphides. Pyrrhotite-bearing rocks in the waste dump outside the lower adit contain epidote, lesser pyroxene, rare layers of brown garnet and narrow veins of quartz.

The geochemistry of an arsenopyrite-rich sample from outside the upper adit is similar to that of the Novelty mineralization; it contains anomalous gold, bismuth, cobalt and nickel (Table 2-2-1a).

SECOND RELIEF MINE (MINFILE 82FSW187)

The Second Relief mine is located 42 kilometres south of Nelson in southeastern British Columbia (Figure 2-2-1). Hostrocks are Early Jurassic Rossland Group rocks close to their contact with Jurassic Nelson granodiorite (Höy and Andrew, 1989). Between 1900 and 1959 the mine produced gold and copper with minor lead, zinc and silver (Table 2-2-2). Mineralization is contained within several parallel northeast-striking, steeply dipping quartz veins that reach up to 4 metres in width. The veins also contain arsenopyrite, pyrite, pyrrhotite, chalcopyrite and magnetite with trace, sphalerite, molybdenum and native gold; minor garnet and epidote is also present.

The veins are surrounded by an extensive envelope of pervasive and siliceous garnet-pyroxene skarn alteration that overprints both the Rossland Group and the porphyritic diorite. The exoskarn also contains pyrrhotite, epidote, amphibole, clinopyroxene, carbonate, biotite and trace tourmaline; microprobe analyses indicate the garnets are iron rich and low in manganese (Ettlinger and Ray, 1989).

It is uncertain whether formation of the mineralized veins at the Second Relief mine was coeval and related to the skarn-altered wallrock. Some samples of sulphide-rich quartz vein contains anomalous gold, arsenic, copper and zinc, but the skarn-altered wallrock has no gold enrichment (Table 2-2-1a).

EMERALD TUNGSTEN CAMP

The Emerald Tungsten camp, located 22 kilometres south of Salmo in southeastern British Columbia (Figure 2-2-1) is hosted by rocks of ancestral North America. It includes two Paleozoic, stratabound lead-zinc deposits worked at the **Jersey** and **Emerald Lead-Zinc** mines, as well as several Cretaceous tungsten skarn deposits that were worked from the **Emerald Tungsten** (MINFILE 82FSW010), **Feeney** (MINFILE 82FSW247), **Invincible** (MINFILE 82FSW218) and **Dodger** (MINFILE 82FSW011) mines (Figure 2-2-5). Between 1906 and 1972, 7.6 million tonnes of ore were mined from this camp (Table 2-2-2). Production records for the entire camp were grouped and reported as coming from the stratabound Jersey deposit; thus the comparative amount of metals obtained from the younger skarns and older stratabound deposits is uncertain. However, it is a reasonable assumption that no tungsten was derived from the Jersey or Emerald Lead-Zinc mines and none of the tungsten skarns produced any lead, zinc, silver or cadmium.

The geology of the camp is shown in Figure 2-2-5 and has been described by Hedley (1943), Ball *et al.* (1953), Rennie and Smith (1957) and Fyles and Hewlett (1959). Skarn is developed along the margins of the Cretaceous Emerald and Dodger stocks where they intrude the Early Cambrian Laib Formation, particularly along the contact of the Reeves limestone and the Emerald argillite. The stocks comprise a leucocratic, quartz-rich granite containing biotite and lesser muscovite. Close to the skarns they are cut by parallel sets of milky quartz veins up to 8 centimetres wide, as well as by veins of coarse pyrite and extensive patches of quartz-muscovite greisen.

Most of the skarn, which is dominated by garnet, is developed in the sedimentary rocks. The skarn includes both massive and banded varieties; the latter represents remnant bedding consisting of alternating layers rich in red and brown garnet, green pyroxene, quartz and carbonate. Locally, it contains layers of coarse wollastonite. The exoskarn is commonly cut by veinlets of amphibole, and includes minor amounts of epidote, orthoclase, sericite and biotite. Some remnant areas of dark, biotite-rich hornfels-like alteration are cut by pyroxene veinlets.

Three styles of mineralization related to the granitic stocks are identified: quartz veins, sulphide-rich pods and skarns. Some quartz veins cutting the stock are locally enveloped by thin, dark halos of altered feldspar and thicker patches of muscovite-rich greisen. Both the veins and the wallrock alteration contain coarse molybdenite and pyrite. Some quartz veins also contain elongate, dark tourmaline crystals.

Pods, lenses and irregular veins of massive to disseminated sulphide are locally developed within the granite close to its contact with either marble or exoskarn. One pyrrhotite-rich grab sample from a massive pod at the Dodger mine portal assayed anomalous gold, arsenic and tungsten (Table 2-2-1a).

Economic skarn mineralization is dominated by disseminated to irregular masses of scheelite that occur either with disseminated pyrrhotite or in sulphide-lean garnet skarn. Minor amounts of molybdenite were noted as well as rarer wolframite and powellite. Locally, the mineralized skarn is cut by late veinlets of pyrite. Geochemical analyses of a scheelite-bearing skarn sample from Emerald Tungsten adit are presented in Table 2-2-1a.

QUEEN VICTORIA MINE (MINFILE 82FSW082)

The Queen Victoria copper skarn deposit is located approximately 12 kilometres west of Nelson within rocks of the Quesnel Terrane, (Figure 2-2-1). Intermittent open-pit

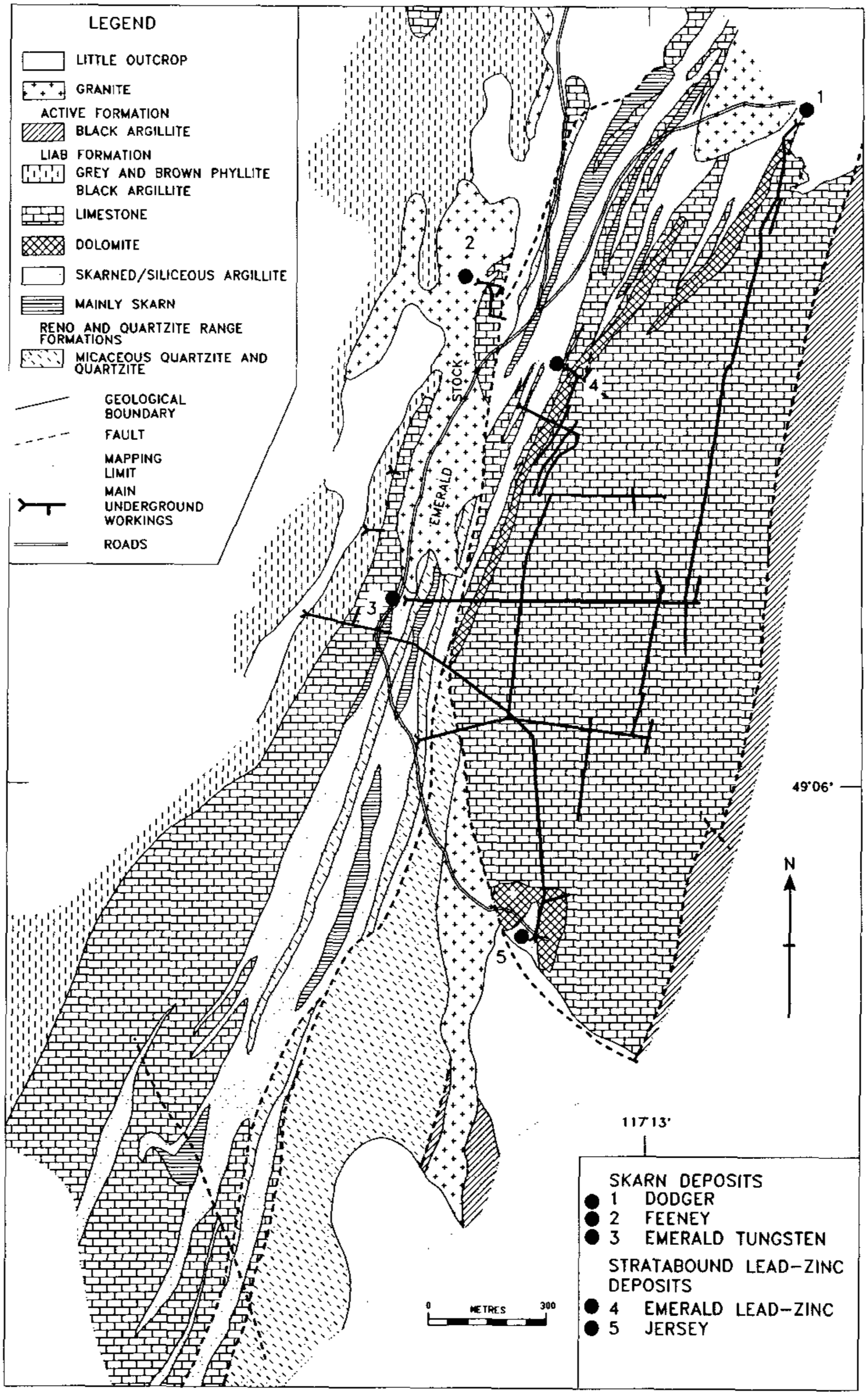

Figure 2-2-5. Geology of the Emerald Tungsten camp showing locations of the skarn deposits (geology after Fyles and Hewlett, 1959).

mining between 1907 and 1956 resulted in the production of copper with minor amounts of silver and gold (Table 2-2-2). The skarn is hosted by Early Jurassic sedimentary rocks of the Ymir Group close to its contact with a quartz diorite to granodiorite intrusion that is probably part of the Jurassic Nelson plutonic suite. Near the mine, this intrusion comprises a hornblende (25-35%) quartz diorite that is moderately bleached and veined with epidote; this body is cut by narrow, altered diorite dikes.

The deposit is hosted by limestone and impure calcareous sedimentary rocks that are interlayered with schistose quartzite and argillite. Most of the alteration appears to represent exoskarn although minor remnants of strongly altered porphyritic endoskarn are present.

The garnet-dominant exoskarn reaches 150 metres in length and 30 metres in width. It consists mainly of massive brown and red garnetite although towards the footwall, there is some subhorizontally layered, siliceous exoskarn, with remnant bedding. The garnetite is cut by several generations of veining. These include early bands and veins of green pyroxene and amphibole up to 10 centimetres wide. Some of these have dark centres containing pyroxene and amphibole and outer, light green margins that x-ray diffraction indicates contain actinolite, albite and microcline (M.Chowdry, personal communication, 1991). The garnetite is also cut by younger veins rich in either yellow-green, crystalline epidote or white quartz. The quartz veins, which reach 10 centimetres in thickness, contain lesser carbonate, crystalline epidote, black amphibole, pyrite and minor chalcopyrite. Locally they are enveloped by magnetite-rich zones that separate the vein from the garnetite host.

Mineralization consists of disseminations, masses and veins of chalcopyrite and pyrite, up to 40 centimetres thick, with minor bornite, magnetite and rare pyrrhotite. The high pyrite:pyrrhotite ratio of the ore suggests the Queen Victoria copper skarn formed in a relatively oxidized environment. Geochemical analyses of mineralized grab samples (Table 2-2-1a) indicate high copper values with a moderate silver but low gold content.

Piedmont Mine (Minfile 82FNW129)

The Piedmont lead-zinc skarn deposit is located 6 kilometres southeast of Slocan in rocks of the Quesnel Terrane, (Figure 2-2-1). Intermittent operations between 1928 and 1959 resulted in the production of minor zinc, lead and silver (Table 2-2-2). The Piedmont was the province's largest zinc-lead skarn producer and production was from underground and open-pit operations.

The mine area is largely underlain by an intrusive body of the Middle to Late Jurassic Nelson plutonic suite. It comprises multiple phases that include older mafic diorites intruded by both equigranular and potassium feldspar megacrystic, biotite hornblende granodiorite and quartz diorite; these form larger bodies as well as sills and dikes that vary from massive to weakly gneissic. Layers, disseminations and lenticular masses of mineralized exoskarn occur close to the contact between the batholith and several pendants of Late Triassic Slocan Group rocks; the latter comprise schistose quartzite, meta-argillite and minor brown marble. The largest mineralized pod, close to the old glory hole, is approximately 20 metres long and up to 2 metres thick (Allen, 1984). It lies adjacent to altered granodiorite dikes that are probably related to the nearby batholith.

The exoskarn is dominated by fine to coarse-grained black sphalerite and lesser galena in a matrix of red, yellow and green garnet, with quartz and patches of coarse calcite. Pyrrhotite generally forms crosscutting veinlets, however, in one adit it occurs intergrown with minor sphalerite in a narrow, massive sulphide zone. Most of the pyrrhotite postdates the sphalerite and galena although one post-pyrrhotite veinlet of coarse sphalerite was observed. Some coarse, euhedral crystals of sphalerite and galena form inclusions in the large calcite blebs. However, locally, the calcite is rimmed and separated from adjacent pyrrhotite by a narrow layer of sphalerite. Geochemical analyses of sulphide-rich grab samples (Table 2-2-1a) indicate high values of zinc, lead, cadmium and silver. The minor enrichment in antimony and copper suggests tetrahedrite may be present in the ore.

Steep Occurrence

The Steep skarn occurrence is located in southeastern British Columbia (Figure 2-2-1) on the west side of Adams Lake approximately 55 kilometres northeast of Kamloops. It is hosted by Paleozoic Sicamous Formation argillaceous limestones and black calcareous phyllites of the Kootenay Terrane (Schiarizza and Preto, 1984, 1987). A concordant zone of skarn alteration, that reaches several hundred metres in width, is traceable for at least 10 kilometres along strike (Ettlinger and Ray, 1989). It is structurally underlain by a strongly foliated unit that contains quartz phenocrysts, fine muscovite and quartz veinlets This unit is at least 500 metres thick and may represent a Devonian orthogneiss that generated the skarn. The orthogneiss contains lenses of less deformed granite.

The skarn assemblage includes garnet, clinopyroxene, epidote and amphibole with lesser biotite, sphene, chlorite, and apatite. Mineralization tends to be close to the outer margins of the skarn zone. It includes pyrrhotite and lesser chalcopyrite with magnetite, sphalerite, galena and trace gold (Miller *et al.*, 1988). The fine gold is associated with minute grains of native bismuth and bismuth tellurides.

Dimac (Silence Lake Mine; Minfile 82M 123)

The Dimac tungsten skarn is located (Figure 2-2-1), 37 kilometres northeast of Clearwater in rocks of the Barkerville Terrane. Minor tungsten production was recorded in 1982 (Table 2-2-2) from a small open-pit mine.

The area is underlain by east-northeast-striking, steeply dipping metasedimentary gneisses and schists of the Shuswap Metamorphic Complex. These amphibolite-facies rocks, which are strongly deformed and isoclinally folded, include some calcsilicate gneisses and thin marbles. The metasediments are cut by a postmetamorphic, Paleocene stock and some sills that vary in composition from granite to quartz monzonite to alaskite. The intrusions comprise a coarse to medium-grained, leucocratic two-mica granite that are generally massive although some sills are weakly foliated. The alaskitic rocks contain irregular segregations of coarse quartz, plagioclase, muscovite and rare biotite, the latter up to 1.5 centimetres in diameter, as well as small patches of greisen. This alteration is associated with quartz-sericite veins, up to 2 centimetres wide, that are bordered by narrow bleached halos.

Texturally, the exoskarn varies from massive to layered, the latter representing the replacement of remnant gneissic layering. At least three types of skarn are developed in calcsilicates adjacent to the intrusions: wollastonite-garnet-carbonate skarn, pyroxene-carbonate-quartz skarn and garnet-idocrase-quartz skarn. Scheelite is generally absent in the wollastonite skarn (White, 1989). Some of the garnet-idocrase skarn is extremely coarse grained and pegmatitic. It is dominated by large euhedral crystals of garnet, up to 7 centimetres across, and brownish green to amber vesuvianite that reaches 15 centimetres in length; these are often set in a matrix of white quartz (Plate 2-2-2). This skarn contains anhedral to subhedral scheelite, up to 1.5 centimetres across, that occurs either as clusters or scattered individual white crystals. Scheelite is also seen as small inclusions in both garnet and vesuvianite.

In outcrop, some of the large garnets are zoned from brown cores, containing small inclusions of quartz, scheelite and rare pyrrhotite, out to red rims that are inclusion free. Garnets are mostly red and brown but some dark brownish green to amber varieties were observed. They seldom form veins but mostly occur as isolated crystals, masses or layers, parallel to the remnant gneissic foliation. Vesuvianite forms massive bands and pods up to 5 centimetres thick, as well as isolated crystals.

The pyroxene-rich skarn varies from banded to massive; it contains small, euhedral hedenbergite crystals, generally in a carbonate matrix, together with variable amounts of scheelite, but garnet and wollastonite are uncommon. The wollastonite-rich skarn is commonly banded, consisting of alternating layers rich in garnet, pyroxene, amphibole and wollastonite. Coarse wollastonite, up to 5 centimetres long, commonly surrounds crystals of pink to red garnet, separating the garnet from carbonate.

Crystal relationships suggest that garnet formed early, followed by vesuvianite and wollastonite. However, some scheelite either predates, or was coeval with garnet as it occurs as inclusions in these crystals. Virtually no suphides were seen in the Dimac deposit apart from pyrrhotite that occurs either as minute, rare inclusions in garnet or as disseminations and veinlets in the quartz-garnet-vesuvianite skarn. A small coating of erythrite was noted on one outcrop and locally the skarn is cut by late veins of quartz and gypsum.

Geochemical analytical results on samples of scheelite-bearing skarn are presented in Table 2-2-1a. In addition, very large garnet and vesuvianite crystals were hand picked from the skarn for trace element analyses. X-ray diffraction analysis (with a detection limit of 15 ppm Sn) indicates that the vesuvianite and garnet contain up to 2106 and 317 ppm tin respectively. However, no anomalous tin values are recorded in the samples of scheelite-bearing skarn.

To summarize, the Dimac tungsten skarn is associated with a two-mica granite, is characterized by scheelite but carries virtually no sulphides except rare pyrrhotite. This suggests it developed in a reduced, low-sulphur system. The extremely coarse grained garnet, vesuvianite and scheelite crystals indicate that the skarn formed at a deep level and crystallized over a considerable length of time.

Cassiar Camp

Several skarns occur in the Cassiar area, north of Cassiar township in northern British Columbia (Figure 2-2-1) where they are hosted by rocks of the Cassiar Terrane; the geology of the area has been described by Panteleyev (1979, 1980) and Nelson and Bradford (1989). They include the **Contact, Dead Goat, Lamb Mountain** and **Kuhn** skarns as well as several unnamed mineralized skarn occurrences (Figure 2-2-6). The Contact and Dead Goat skarns are hosted by the Hadrynian Stelkuz Formation, comprising phyllites, quartzites and limestones, close to its contact with the eastern margin of the Late Cretaceous Cassiar stock. The stock is a coarse-grained, biotite-hornblende granite and quartz monzonite that contains potassium feldspar megacrysts. The

Plate 2-2-2. Coarse, euhedral garnet crystals in a quartz matrix, Dimac (Silence Lake) tungsten mine, Clearwater district, B.C.

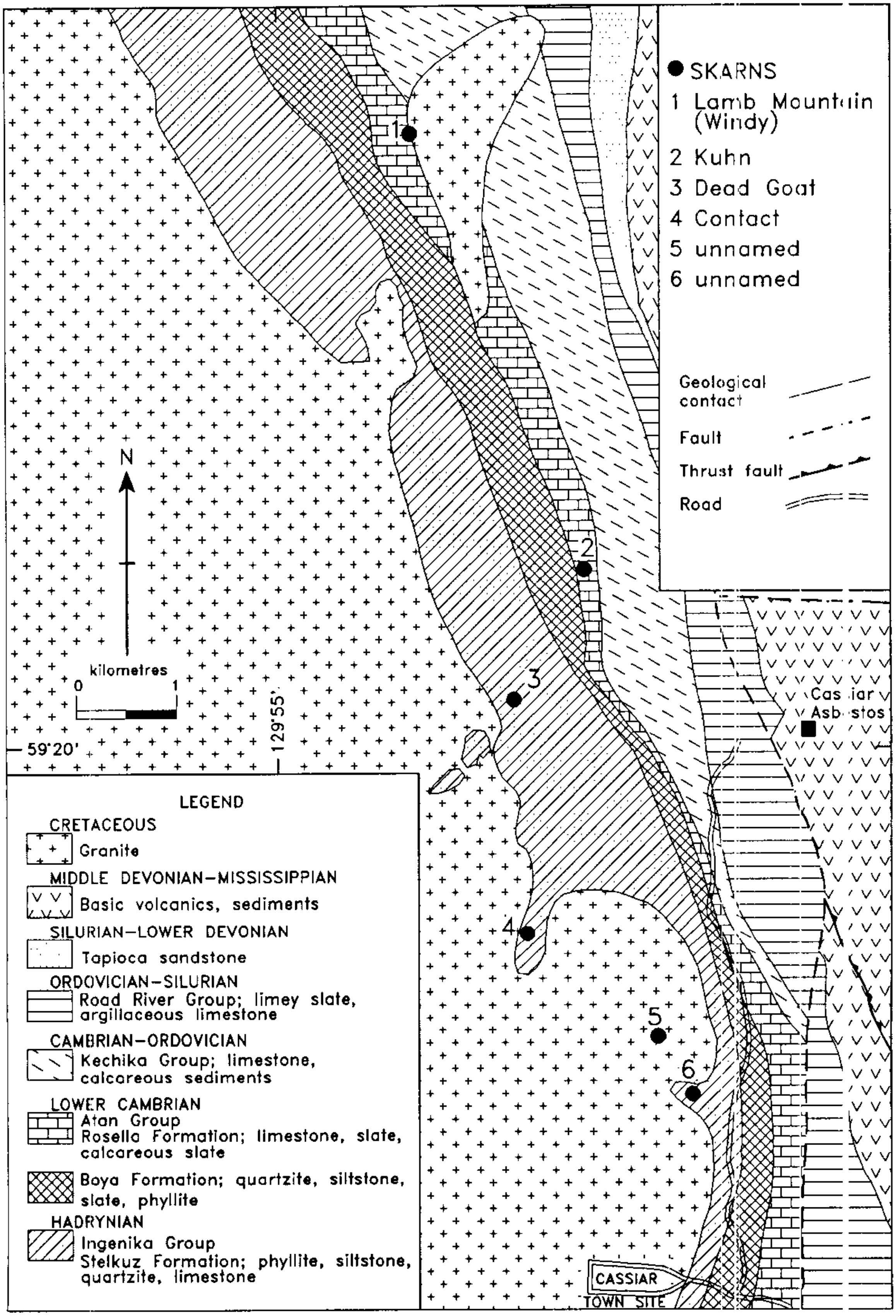

Figure 2-2-6. Geology and location of skarn occurrences in the Cassiar camp (geology after Nelson and Bradford, 1989).

Lamb Mountain and Kuhn skarns also lie close to the Cassiar stock and are hosted by limestone, dolostone and calcareous shale of the Lower Cambrian Rosella Formation (Nelson and Bradford, 1989).

CONTACT MINE (TELEMARK; MINFILE 104P 004)

The Contact skarn deposit is located 2 kilometres east of Cassiar asbestos mine (Figure 2-2-6). In 1956 it produced minor amounts of silver, lead and copper (Table 2-2-2). The main ore zone is a steeply dipping massive magnetite body that reaches 2 metres in thickness. This horizon, which is hosted by and concordant to layered marbles, lies approximately 200 metres east-southeast of the contact with the feldspar megacrystic Cassiar stock. Between the stock and the magnetite layer is a zone of layered garnet-pyroxene-biotite exoskarn 150 to 200 metres wide that represents altered, thinly bedded siltstones. This banded skarn contains remnant patches of biotite hornfels cut by veinlets of garnet and pyroxene; it is generally unmineralized except for minor disseminated pyrrhotite and late veins of pyrite.

The magnetite zone apparently formed at the outer margins of the skarn, probably along the contact between the skarn-altered siltstone unit and a limestone. It includes some patches of biotite hornfels and rare, coarse euhedral crystals of dark brown to black garnet. The western, footwall contact is concordant to the banded skarn, but its eastern hangingwall contact is irregular and locally crosscutting; veinlets of magnetite have been injected into the adjacent marble. The massive magnetite is cut by blebs and veinlets of pyrrhotite, sphalerite, chalcopyrite and galena; galena tends to separate sphalerite from pyrrhotite. There are reports in MINFILE of trace molybdenite, arsenopyrite, tetrahedrite and bismuthinite (McDougall, 1954). Some of the marbles close to the skarn contain veins of rhodonite.

KUHN (MINFILE 104P 071)

The geology and mineral assemblages of the Kuhn skarn has been described by Cooke and Godwin (1984). The skarn is hosted by a package of hornfelsed and silicified siltstones and argillites with minor coarse white marble; the biotite hornfels is cut by veinlets of pyroxene. The exoskarn assemblage comprises coarse actinolite, garnet and clinopyroxene. The garnets, which include pale or reddish brown, amber and black varieties, are commonly intergrown with actinolite and coarse, euhedral crystals of quartz. No endoskarn was identified.

The actinolite-rich skarn contains abundant disseminated pyrrhotite with minor pyrite, chalcopyrite and veins of coarse molybdenite. Cooke and Godwin (1984) report the presence of scheelite, powellite and fluorite.

DEAD GOAT (MINFILE 104P 079)

The area is underlain by hornfelsed argillite and some units of grey to white marble. The latter vary from massive and granular to layered and strongly deformed. The marble is associated with large masses of banded garnet-epidote-actinolite-pyroxene skarn up to 1 metre in thickness, that contain small, remnant patches of biotite hornfels. Some garnet crystals are coarse and euhedral and reach 1 centimetre in diameter; they vary in colour from pale brown to amber.

Mineralization includes patches of massive pyrrhotite cut by veins of pyrite. Also present are masses of black sphalerite with minor disseminated scheelite and magnetite. Marble adjacent to the skarn is cut by veinlets of rhodonite.

LAMB MOUNTAIN (WINDY; MINFILE 104P 003)

This skarn is hosted by marbles and hornfelsed argillites close to the western margin of a small body of feldspar megacrystic quartz monzonite that represents a satellite intrusion of the Cassiar stock (Figure 2-2-6). Adjacent to the intrusion, the hornfels contains cordierite and is cut by irregular veinlets of pyroxene.

Two types of exoskarn are seen. One is dominated by very coarse actinolite that forms crystals up to 3 centimetres long. This actinolite skarn, which is developed immediately adjacent to the intrusion, contains minor epidote and clots of coarse calcite. The other type is a generally thin-banded garnet-pyroxene-epidote-quartz skarn, although some of the massive garnet bands exceed 1 metre in thickness. Garnet forms euhedral pale red, dark brown and amber-coloured crystals up to 1 centimetre in diameter. This skarn also contains some white elongate crystals, up to 2.5 centimetres, that x-ray studies indicate to be the scapolite mineral meionite (M. Chowdry, personal communication, 1992).

Mineralization in the exoskarn includes disseminated pyrrhotite, molybdenite, scheelite and rare chalcopyrite. The quartz monzonite immediately adjacent to the skarn is silicified and contain minor amounts of disseminated pyrrhotite.

UNNAMED SKARNS (NOS. 5 AND 6, FIGURE 2-2-6)

Two unnamed skarns, marked by rusty weathering outcrops, are exposed north of Cassiar township (Figure 2-2-6) at elevations of 1740 and 1430 metres. It is uncertain whether the most northerly of the two skarns is hosted by the Cassiar stock or an altered metasedimentary screen within the intrusion. It contains actinolite and clinopyroxene with pyrrhotite and traces of fine molybdenite.

The other skarn farther south is hosted in calcareous metasediments close to the stock. It contains coarse subhedral reddish brown garnet, pyroxene, quartz and carbonate, with minor disseminated pyrrhotite. Geochemical analyses of samples from these two skarn show no evidence of gold, copper or tungsten mineralization (Table 2-2-1a).

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