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Ministry of Energy, Mines
and Petroleum Resources
Hon. Anne Edwards, Minister

MINERAL RESOURCES DIVISION
Geological Survey Branch

BEDROCK GEOLOGY OF THE GERMANSEN LANDING - MANSON CREEK AREA, BRITISH COLUMBIA (94N/9, 10, 15; 94C/2)

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Fieldwork for this research was carried out during the period 1987 to 1989

ABSTRACT

The Germansen Landing-Manson Creek area is located within the southern Omineca Mountains of north-central British Columbia. This region straddles the Intermontane-Omineca Belt boundary and encompasses rocks from five tectonostratigraphic terranes and subterranes. These are: North American siliciclastics and carbonates of the Cassiar Terrane, represented by the Upper Proterozoic Ingenika Group through to the Devonian to Permian Big Creek group; pericratonic clastics of the Kootenay Terrane, comprised of the Upper Proterozoic to Paleozoic(?) Boulder Creek group; the oceanic Slide Mountain Terrane, which is made up of deep water argillites, cherts and basalts of the Mississippian to Permian Nina Creek group; arc volcanics and sediments of the Triassic to Jurassic(?) Takla Group of the Quesnel Terrane; and the Harper Ranch Subterrane, represented by Mississippian(?) to Permian arc volcanics and sediments of the Lay Range assemblage.

These rocks were polydeformed and strongly metamorphosed beginning in the Mesozoic as a result of collision and obduction of exotic terranes from the west. Middle Jurassic, northeast-verging D_1 deformation was accompanied by regional metamorphism which reached sillimanite grade within the Wolverine Metamorphic Complex. Rocks of the Nina Creek group were imbricated and emplaced on top of North American rocks during this time period. Middle to Late(?) Jurassic D_2 deformation refolded these rocks into upright to northeast and southwest(?)-verging structures. D_3 deformation broadly warped and uplifted these rocks during the Early to Middle Cretaceous. Late Cretaceous to Tertiary right-lateral movement along the Manson fault zone was accompanied by dip-slip motion on the brittle-ductile, southwest-side-down Wolverine fault zone in response to uplift of metamorphic rocks within the Wolverine Complex. Rapid uplift of these rocks is recorded by early Tertiary K-Ar cooling dates. Rocks in the hangingwall of the Wolverine fault zone cooled relatively early in the deformational sequence (Middle Jurassic).

The map area contains a wide variety of mineral occurrences which reflect the long and complex history recorded by these rocks. The most abundant are polymetallic veins genetically related to the Manson fault zone and spatially related to strongly altered ultramafic bodies. Carbonate-hosted lead-zinc mineralization in the Otter Lakes group is locally important.

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INTRODUCTION

Mapping in the Manson Creek-Germansen Landing area was undertaken by the British Columbia Ministry of Energy, Mines and Petroleum Resources in order to provide a detailed geological database for a poorly understood belt of rocks long known to host lode gold and base metal occurrences. The main aims of this project were:

- To produce 1:50 000-scale geological maps for all or parts of map sheets 93N/9 (Manson Lakes), 93N/10 (Germansen Lake), 93N/15 (Germansen Landing) and 94C/2 (End Lake).
- Revise the mineral inventory database (MINFILE).
- Place known mineral occurrences within a geological framework.
- Complementing this was the augmentation of existing Regional Geochemical Survey (RGS) coverage or the initiation of new RGS surveys in areas lacking previous coverage.

GEOGRAPHIC SETTING

The study area is located some 200 kilometres north-northwest of Prince George and contains the settlements of Manson Creek and Germansen Landing (Figure 1). Primary access is by all-season gravel roads from Fort St. James or Mackenzie. These roads connect to secondary roads along the Manson River, Germansen River and Germansen Lake, Osilinka River and the Nina Creek-Nina Lake drainage systems. This road system provides access to approximately 50% of the area. The remainder of the area can be reached on foot, or by boat or helicopter.

The study area lies within the Swannell Ranges of the Omineca Mountains (Figure 1). The eastern side of the area is bounded by the Wolverine Range with its eastern slopes falling off into the Rocky Mountain Trench (now occupied by Williston Lake). The northern and southern boundaries roughly coincide with the Osilinka and Manson rivers, respectively (Figure 2). The western part of the map area is occupied by the Hogem Ranges with the Germansen Range to the southwest and a rugged, unnamed range of mountains to the northwest.

A large part of the southern section is drift covered. Glaciofluvial material is widespread along the Manson and Germansen River drainage systems. Most of the slopes are tree covered in the south with alpine vegetation covering less than 20% of the land area. To the north the topography is more rugged and the amount of alpine area increases substantially. The highest peaks in the area are slightly over 2150 metres in elevation with the Omineca River valley being roughly 750 metres above sea level at the settlement of Germansen Landing. The best outcrops are restricted to alpine areas, steeper slopes, hill tops and steep-sided creeks.

GEOLOGIC FRAMEWORK

The study area lies along the boundary between the Intermontane and Omineca belts, two of the five geomorphological belts of the Canadian Cordillera (Wheeler and McFeely, 1991). It is underlain by rocks of the Intermontane Superterrane (*i.e.*, accreted, Monger *et al.*, 1982) and rocks representing the displaced North American margin (Wheeler and McFeely, *ibid.;* Figures 3 and 4). Rocks of ancestral North America (Foreland Belt) lie to the east, across the Rocky Mountain Trench.

In this area, the Intermontane Superterrane is represented by volcanic and sedimentary rocks of the Quesnel and Slide Mountain terranes (Figure 5). Quesnel rocks comprise a volcanic and sedimentary assemblage assigned to the Middle Triassic to Lower Jurassic(?) Takla Group, and a poorly defined sedimentary and volcanic suite belonging to the upper Paleozoic Lay Range assemblage which is believed to be part of the Harper Ranch Subterrane (Gordey *et al.*, 1991; Figures 4 and 5). The Slide Mountain Terrane is represented by upper Paleozoic oceanic rocks of the Nina Creek group and the Manson Lakes ultramafics. The west side of the Quesnel Terrane is intruded by the multiphase, Triassic to Cretaceous Hogem batholith (Garnett, 1978), bounded on its west side by the Pinchi fault, which separates Quesnel Terrane from middle Paleozoic to Triassic rocks of the Cache Creek and Stikine terranes.

Rocks of North American affinity within the map area are part of the para-autochthonous Cassiar Terrane and pericratonic Kootenay Terrane. These terranes are displaced portions of the ancestral North American margin. The Cassiar Terrane is represented by a Proterozoic to Permian carbonate and siliciclastic wedge which includes strata of the Proterozoic Ingenika Group to the Devonian to Permian Big Creek group (Figure 6, Table 1). The lower parts of the Ingenika Group are metamorphosed to upper amphibolite grade and polydeformed, and are included within the Wolverine Complex, one of several core complexes found along the length of the Omineca Belt.

The Kootenay Terrane is composed of the Boulder Creek group, of uncertain age. Rocks of the Manson Lakes ultramafic suite have been thrust onto it and its margins are believed to be splays of the Manson fault zone.

Rocks in the study area trend northwesterly and, as a general rule, dip to the southwest. In the southeast, the contact between the Cassiar Terrane and Intermontane Superterrane is a west-side-down normal fault which is termed the Wolverine fault zone. It is believed to be an Eocene normal fault related to uplift of the Wolverine Complex. In the southwest it places middle to upper amphibolite grade rocks of the Ingenika Group and Wolverine Complex against greenschist facies rocks of the Nina Creek group. Northwest of Manson Creek the Wolverine fault zone veers northward, following the edge of the Wolverine Range, and juxtaposes Ingenika rocks of different metamorphic grade.

In the northern part of the map area, fossil data confirm that the apparent conformable contact between the Cassiar Terrane and the Intermontane Superterrane is a major, layer-parallel, thrust fault.

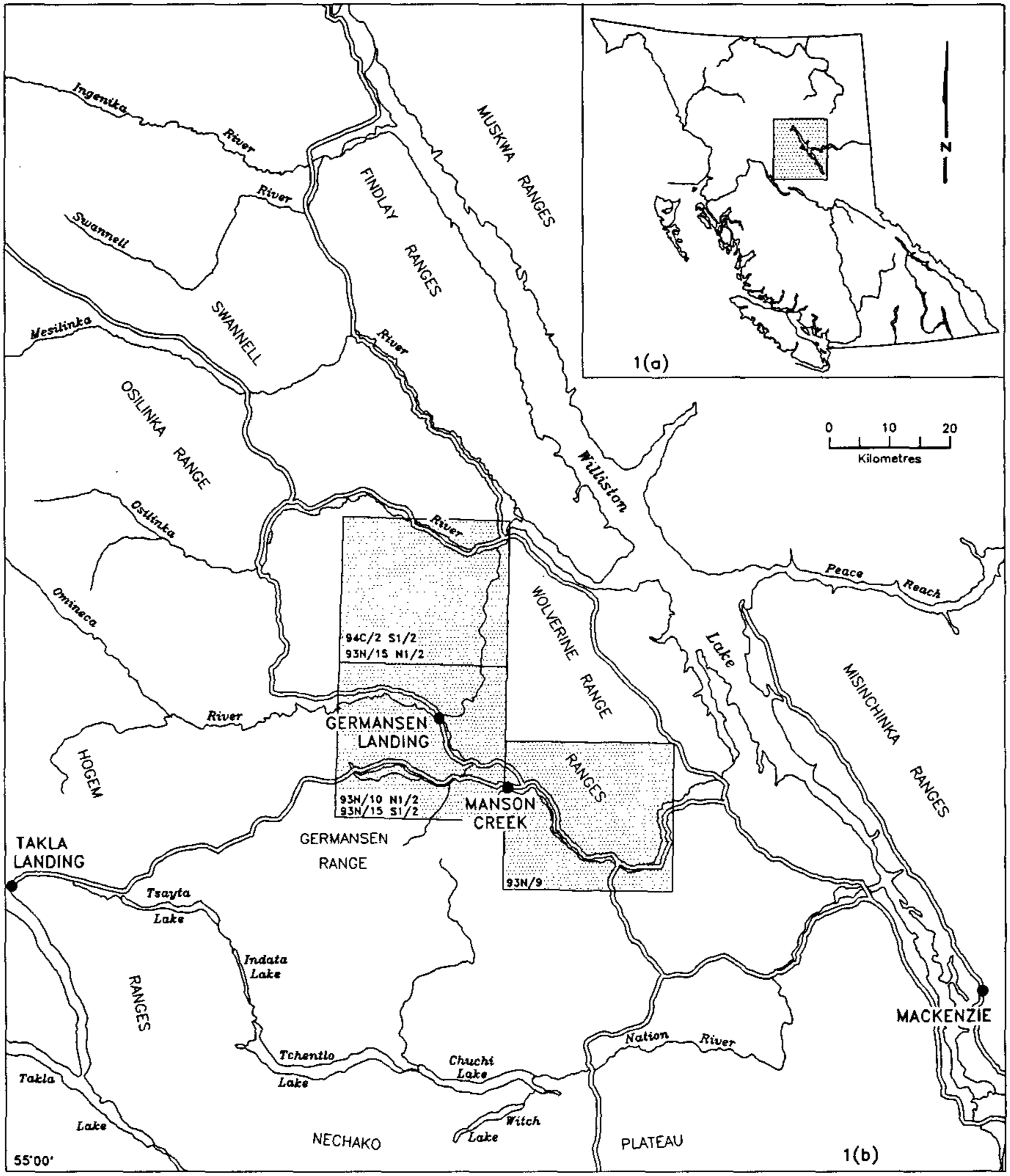

Figure 1. Location of the study area with main physiographic features indicated.

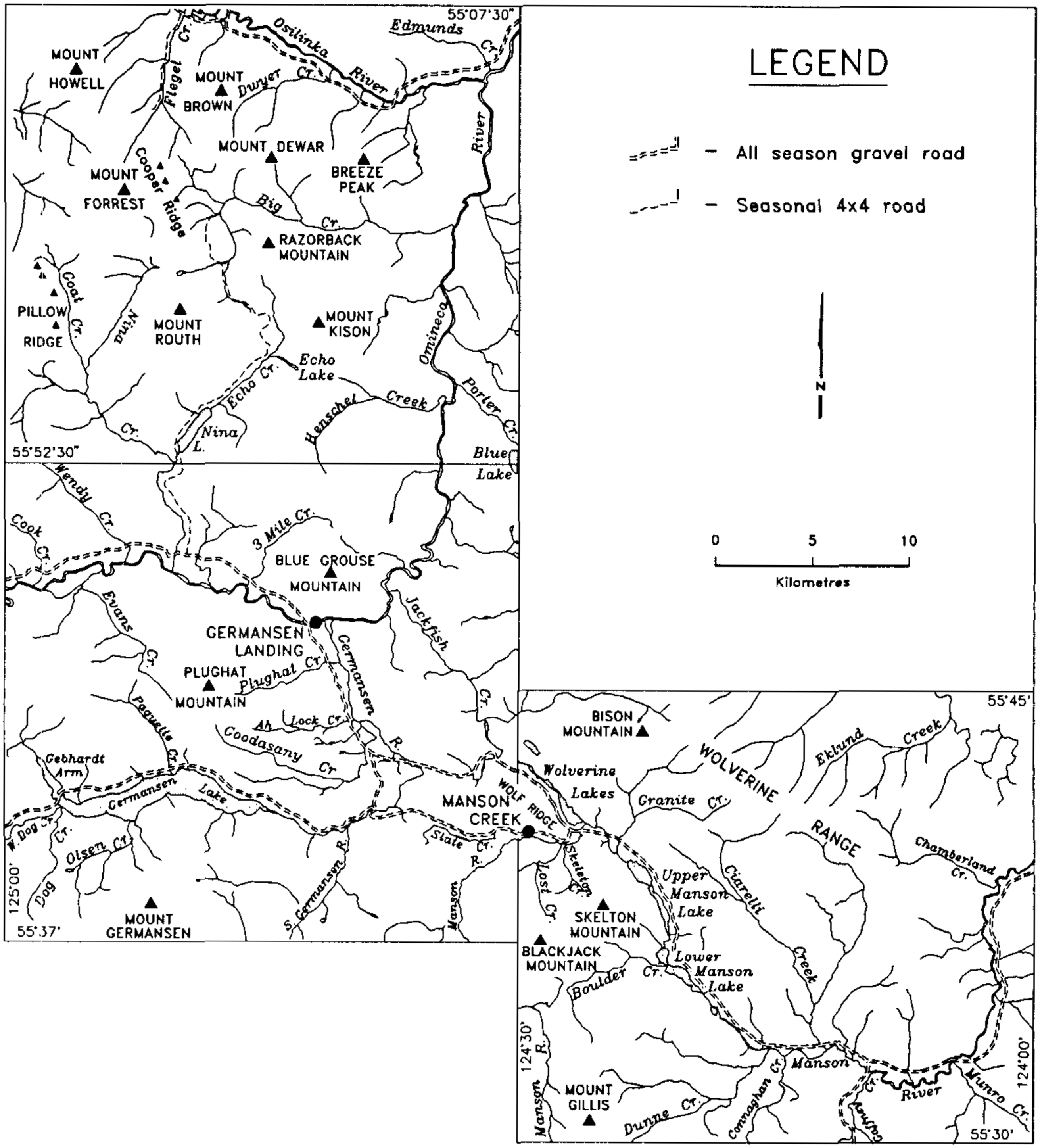

Figure 2. Physiography of the study area.

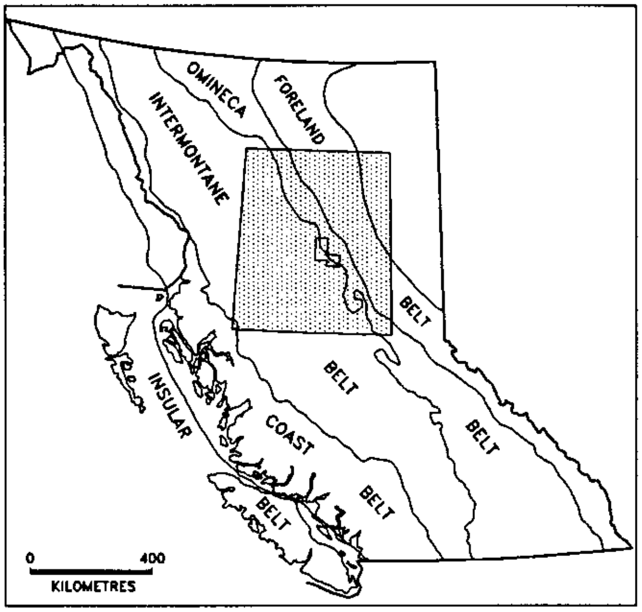

Figure 3. Location of map area within geomorphological belts of the Canadian Cordillera. Shaded area represents region portrayed in Figures 4 and 5.

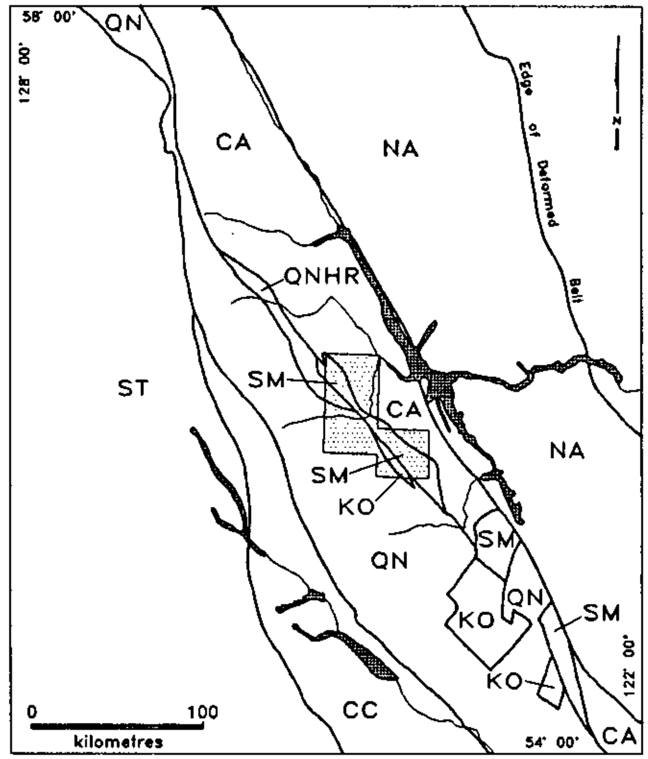

Figure 4. Terrane map centred on the map area. NA - Cratonic North America; CA - Cassiar Terrane; KO - Kootenay Terrane; SM - Slide Mountain Terrane; QN - Quesnel Terrane; QN_{HR} - Harper Ranch Subterrane; CC - Cache Creek Terrane; ST - Stikine Terrane.

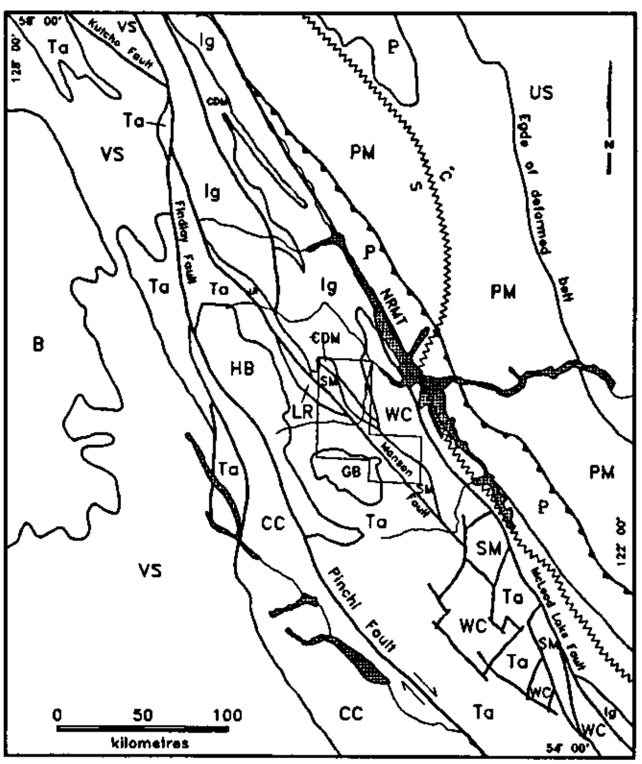

Figure 5. Regional geology in the vicinity of the map area. WC - Wolverine Complex; Ig - Ingenika Group; Ta - Takla Group; CC - Cache Creek Group; B - Bowser Lake Group; VS - Mesozoic to Cenozoic volcanic and igneous rocks; CDM - Lower Paleozoic sequence; HB - Hogem batholith; GB - Germansen batholith; LR - Lay Range assemblage; SM - Nina Creek group and equivalents; P - Proterozoic to Lower Cambrian sediments; PM - Paleozoic to Mesozoic sediments; US - undeformed Mesozoic sediments. 'Zig-zag' line roughly corresponds to the westward shale-out of Lower Paleozoic platformal carbonates; c - carbonates, s - shale.

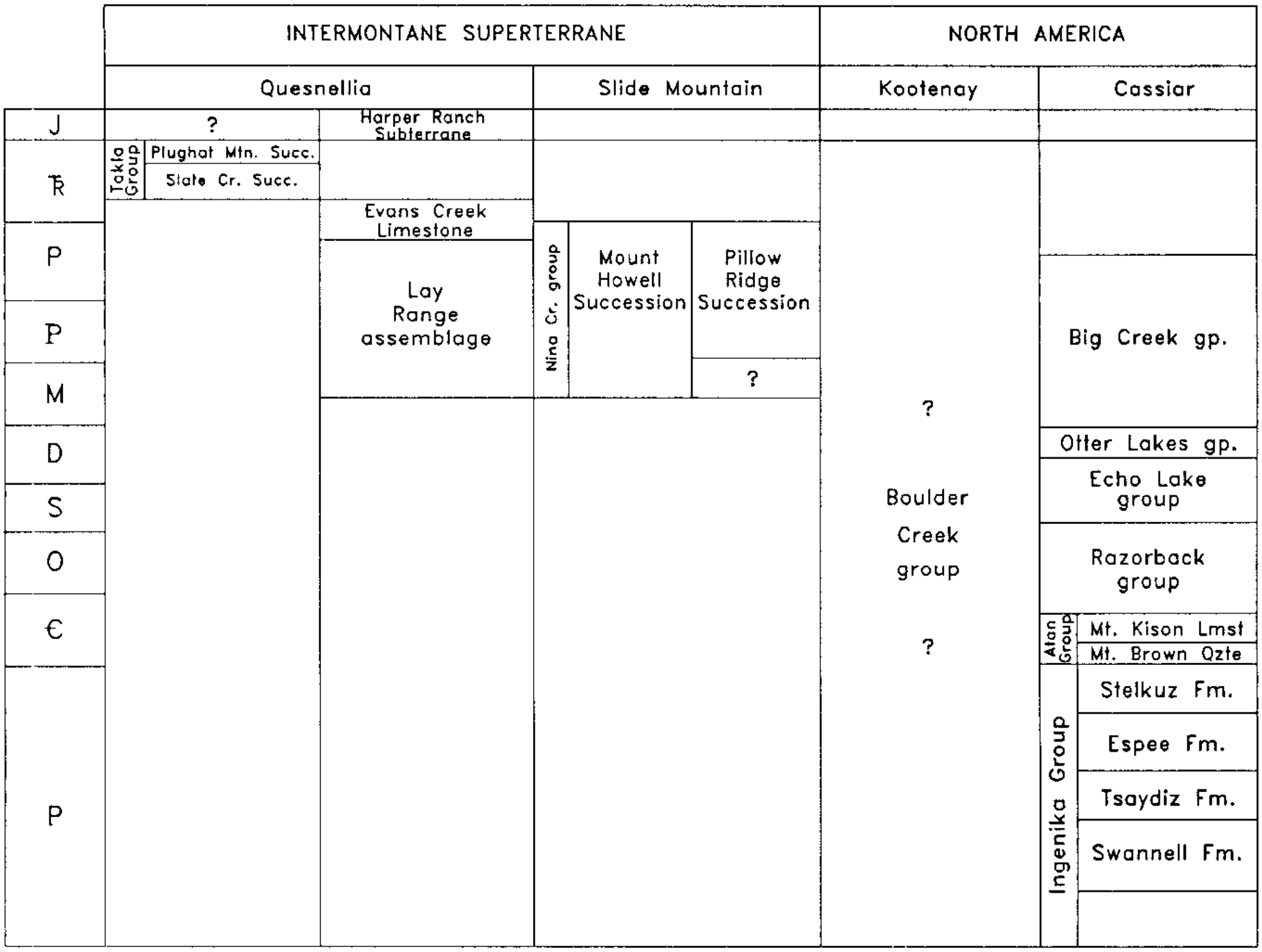

Figure 6. Position of main stratigraphic units of the study area within the terrane hierarchy of the Canadian Cordillera.

The most notable structure in the area is the Manson fault zone, a vertical, right-lateral fault of unknown displacement. The age of movement on this fault is believed to be from Cretaceous to early Tertiary (*see* Structure chapter). The fault zone trends to the northwest and follows segments of the Manson Lakes, Germansen River and Nina Creek drainage systems (Figure 7, in pocket). This structural zone is economically important as all known placer operations and precious metal showings in the area are associated with it.

METHODS

The area was mapped during the summers of 1987, 1988 and 1989 at a scale of 1:25 000 using enlargements made from 1:50 000 NTS topographic sheets. Data and sample points were located on maps and air photos. Traverses were made primarily along ridge crests and, to a lesser extent, along creek valleys. Alpine areas were reached primarily by helicopter. The lower timbered slopes were accessed by logging roads or boat. Use of binoculars, camera and sketch book were both helpful and necessary, especially in the rugged terrain to the northwest.

Approximately 445 thin sections were cut from samples collected in the study area. These were very helpful in determining mineral composition, metamorphic mineral assemblages and textural relationships of metamorphic minerals.

Samples were collected for uranium-lead (U-Pb), potassium-argon (K-Ar) and fission-track analysis. The U-Pb and K-Ar analyses were performed at laboratories at the University of British Columbia and the fission track analyses were carried out at the Rensselaer Polytechnic Institute of Troy, New York.

Some of the lead-bearing mineral showings were sampled for lead isotope analysis. These analyses were carried out at the University of British Columbia.

Several hundred samples were collected for whole-rock lithogeochemical analyses; most were analyzed by the Ministry of Energy, Mines and Petroleum Resources laboratory in Victoria. Some whole-rock and trace element analyses were performed at laboratories of Cominco Ltd. and Memorial University of Newfoundland.

Chemical analyses used in geothermometry calculations were performed using the ARL microprobe at the University of Calgary.

TABLE 1
STRATIGRAPHIC TABLE OF FORMATIONS FOR ALL UNITS WITHIN THE MAP AREA

ERA	PERIOD	GROUP or FORMATION		MAP UNIT	THICKNESS (metres)	LITHOLOGY
Cenozoic	Quaternary to Recent			Qal		Unconsolidated sands, silt, gravels, fluvial-glacial
	Tertiary			Tvi		*Subvolcanic feldspar andesites, monzonites, quartz monzonites, dikes and irregular bodies*
		Blue Lake volcanics		Tvb		Basalt; volcanic breccia; related to mafic dikes
Mesozoic	Cretaceous or Younger	Wolverine Range intrusions		KTwri		Granodiorite to granite, pegmatite, dikes, sills; muscovite-biotite and garnet bearing
	Cretaceous	Germansen batholith		Kg		(a) Granite to granodiorite; two mica, megacrystic with related garnet bearing pegmatite. (b) Foliated hornblende biotite megacrystic granodiorite
	Triassic or Jurassic			TrJw		Wehrlite, mafic gabbro
	Jurassic(?)			Jg		Gabbro; pyroxene-hornblende bearing
	Middle to Upper Triassic	Takla Group	Plughat Mountain succession	Trtp4		Augite phyric basalt, agglomerate, tuff, tuffaceous siltstones
				Trtp3	1000	Polymict volcanic sandstone and conglomerate
				Trtp2	2000 - 3000	(a) Augite phyric basalt, basaltic andesite, (al) limestone, (b) agglomerate, tuff, (c) maroon feldspar porphyry
				Trtp1	0 - 1000	Volcanic sandstone, conglomerate, siltstone, tuffaceous argillite, siltstone, tuff, argillite
			Slate Creek succession	Trts	500 - 2000	(a) Argillite, slate, siliceous argillite, volcanic siltstone with lesser volcanic wacke, sandstone, conglomerate; rare quartz siltstone to sandstone, (c) basalt
Mesozoic to Paleozoic	Permian to Triassic	Evans Creek limestone		PTrec	500	Limestone, grey, massive, finely recrystallized
Paleozoic	Upper Paleozoic or Younger(?)	Wolf Ridge gabbro		uPwr		Foliated hornblende-pyroxene-biotite gabbro, may be pegmatitic
	Mississippian to Permian	Nina Ck group	Pillow Ridge succession	PPnp	5000+	(a) Basalt, massive to pillowed, volcanic breccia, gabbro, (b) chert, cherty argillite
			Mt. Howell succession	MPnh	1000 - 2500	(a) Cherty argillite, chert, argillite, gabbro, siltstone, basalt, wackes, dacite, (b) gabbro
		Manson Lakes ultramafics		MPml		(a) Serpentinite (b) talc-serpentine (c) talc-ankerite-serpentine schist (listwanite)
		Lay Range assemblage		MPlr	2000+	(1) Tuff to volcanic sandstone or conglomerate, argillite, siltstone, (2) augite-plagioclase phyric agglomerate and tuff
	Upper Devonian to Permian	Big Creek group		DPb	600 - 800	(a, b) Shale, argillite, slate, calcareous argillite, limestone, tuffaceous argillite, sandstone, wacke, (c) dacite, tuffaceous
	Devonian to Mississippian			DMc		Carbonatites
	Middle Devonian	Otter Lakes group		Do	150 - 200	Dark grey to black limestone and dolomite, fossiliferous
	Ordovician to Lower Devonian	Echo Lake group		ODe	800 - 1000	Sandy Dolomite: dolomite, sandy dolomite, sandstone to quartzite. Lower Member: massive to poorly bedded limestone and dolomite
	Cambrian to Ordovician	Razorback group		COrb	50 - 75	Thinly layered and interbedded argillaceous limestone and dolomite, shale, slate
	Lower Cambrian	Atan Group	Mt. Kison limestone	lCak	200 - 230	Basal part: thin platy limestone; Upper part: thick bedded to massive limestone and rare dolomite
			Mt. Brown quartzite	lCab	200 - 375	Basal part: orthoquartzite; Upper part: olive green to grey siltstone, shale, sandstone
Paleozoic? and Proterozoic		Boulder Creek group		PPbc		Sandstones, impure quartzites, siltstones, argillites, marble and minor amphibolite; metamorphosed to schists
Upper Proterozoic		Ingenika Group	Stelkuz Formation	Pist	400 - 500	Grey green slate, siltstone, impure quartzite, sandstone, dolomite
			Espee Formation	Pie	200 - 400	Moderately to thinly bedded limestone to dolomitic limestone, marble
			Tsaydiz Formation	Pit	300 - 750	Greenish grey slates, phyllites, limestone, argillaceous limestone
			Swannell Formation	Pisw	2000+	Quartz and feldspathic wackes, sandstones, siltstones, slate, limestone; metamorphosed to schists
				Pisq	1000+	Impure metaquartzite, quartz-mica schist, metaquartzite, minor amphibolite
				Pisp	1000+	Quartzo-feldspathic paragneiss, quartz-feldspar-mica schist, micaceous quartzite, calcisilicate, amphibolite gneiss
				Pipi		Paragneiss, quartz-feldspar schist, minor amphibolite gneiss
				Pia		Paragneiss, amphibolite and calcisilicate gneiss, schist, (a) marble

Standard stream sediment and moss-mat samples were collected throughout the area. Heavy mineral separates were collected in the southern two-thirds of the region. Samples were taken to supplement an existing Regional Geochemical Survey in the southern three-quarters of the map area. Analyses were performed by ACME Analytical Laboratories Ltd. in Vancouver, B.C. Analytical results are tabulated in appendices to this report. Sample locations are plotted on Figure 8 a, b, c (in Appendix III).

Equal-area plots were produced using the personal computer software program SPLOT.

PREVIOUS WORK

The first geological reconnaissance of the area was carried out by McConnell (1896) who examined the geology along the Finlay and Omineca rivers. Camsell (1916), Kerr (1934) and Lay (1926, 1934, 1936 and 1939) described placer deposits and bedrock geology in the Manson Creek and Germansen Landing areas. Lang (1941, 1942) produced preliminary maps of the Manson Creek area which also documented the known mineral occurrences.

The first comprehensive description of the geology in the area was written by Armstrong (1949). His memoir includes a geological map (Fort St. James) which covers NTS sheets 93K and 93N at a scale of 6 miles to the inch.

The northern part of the map area was first systematically mapped (at a scale of 1:250 000) by Gabrielse (1975) who described rocks in the Fort Grahame map area (94C, east half; Figure 9). The geology of the west half of the Fort Grahame sheet had been previously described by Roots (1954). The Halfway River sheet (94B) was mapped by Irish (1970) and later in more detail by Thompson (1989). To the east, the Pine Pass sheet (93O) was mapped at a scale of 1:250 000 by Muller (1961).

Specific geological studies within the project area have been carried out by Monger (1973, 1977a) and Monger and Paterson (1974) who examined Paleozoic rocks near Nina Lake. Monger and Ross (1971) and Ross and Monger (1978) described upper Paleozoic fusulinids from the Nina Lake area. Meade (1975a,b, 1977) carried out a detailed examination of the Takla Group in the vicinity of Germansen Landing. Garnett (1978) provided a detailed description on the southern part of the Hogem batholith which is situated immediately east of the study area. Preliminary results of the current program have been published by Ferri and Melville (1988, 1989, 1990a, b,) and Ferri *et al.* (1988, 1989).

Geologic studies in nearby areas include a Ministry of Energy, Mines and Petroleum Resources of British Columbia mapping project to the southeast, near Mount Milligan, which examined Takla Group rocks (Nelson *et al.* 1991, 1992, 1993a, b). Struik and Northcote (1991) recently completed mapping in the Pine Pass area. Preliminary mapping of the McLeod Lake sheet was described by Struik (1989a, b and 1990), Struik and Fuller (1988), Deville and Struik (1990), Pohler *et al.*, (1989) and Taite (1989). Struik (1985) carried out reconnaissance mapping in the Prince George and McBride map areas. Mansy and Gabrielse (1978) described Proterozoic rocks of the northern Cassiar Terrane and proposed the present nomenclature for these rocks. Preliminary reports of the geology of the Finlay and Swannell Ranges include Mansy (1971, 1972, 1974) and Mansy and Dodds (1976). Evenchick (1988) compared Proterozoic stratigraphy and structures within the Deserters and Sifton ranges (on each side of the northern Rocky Mountain Trench). Bellefontaine (1989, 1990) and Bellefontaine and Minehan (1988) described Ingenika Group rocks within the Swannell Ranges and unraveled the kinematic relationships between the Omineca and Intermontane belts. Parrish (1976) carried out a detailed structural, metamorphic and geochronological study of the Ingenika Group near Aiken Lake. This was followed by a more regional synthesis (Parrish, 1979) of rocks in the northern part of the Omineca Belt. Monger (1977b) described Takla Group volcanics northwest of the study area, in the McConnell Creek area.

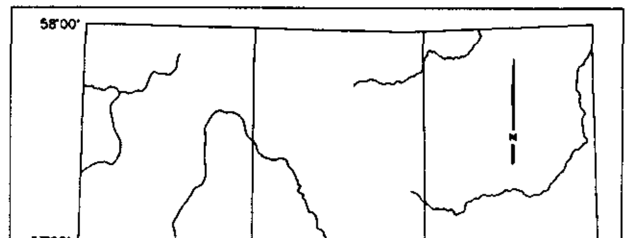

Figure 9. Location of published geologic maps in the vicinity of the map area, (a) Muller and Tipper (1969), Struik (1985, 1989a, b and 1990), Struik and Fuller (1988), Struik and Northcote (1991), Pohler *et al.* (1989), Taite (1989). (b) Armstrong (1949). (c) Muller (1961). (d) Gabrielse (1978). (e) Roots (1954). (f) Irish (1970), Thompson (1989). (g) Monger (1977b). (h) Nelson *et al.* (1991). (i) Nelson *et al.* (1992). (j) Nelson *et al.* (1993a, b). (k) Ferri *et al.* (1992a, b). (l) Ferri *et al.* (1993a, b). (m) Garnett (1978) and (n) Study area.

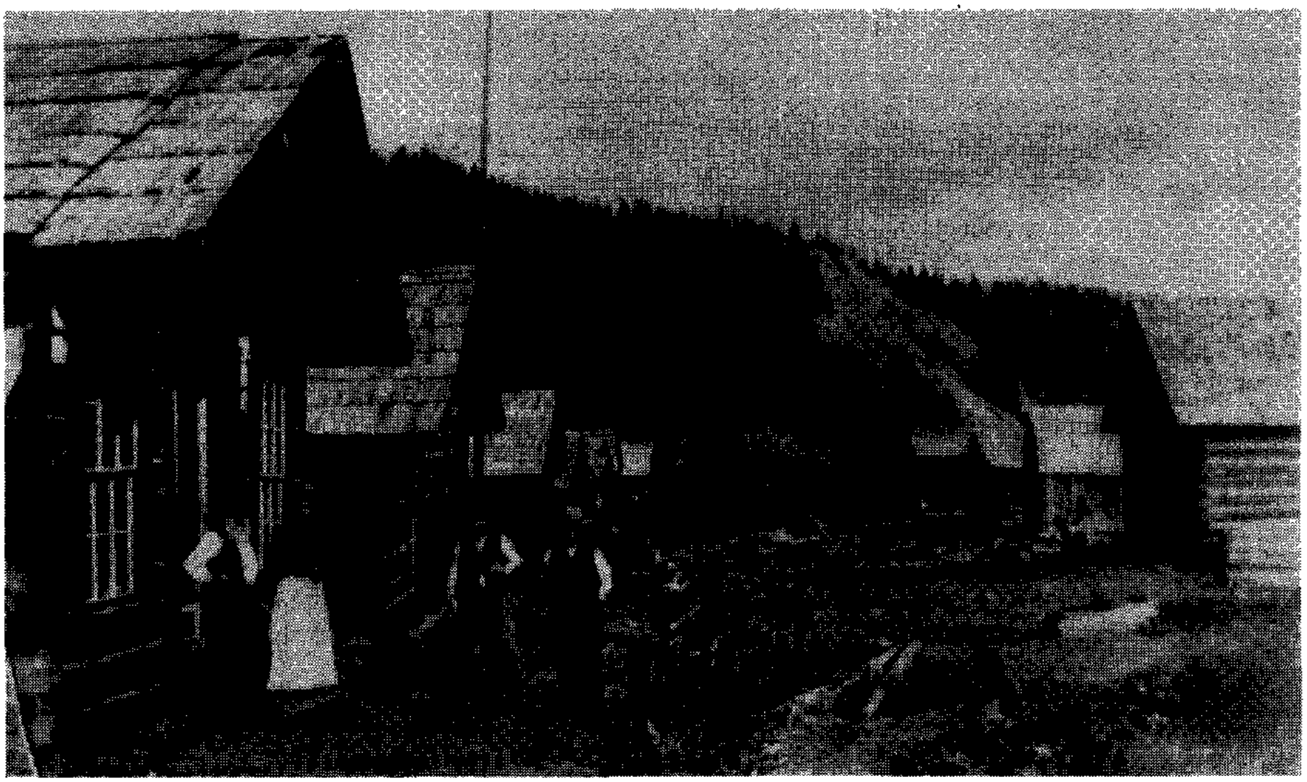

Plate 1. The old town site of Germansen, *ca.* 1890s. This location is 2 kilometres upstream from the mouth of the Germansen River. It was close to rich placer fields which were worked by large hydraulic operations. (Reproduced with permission from the British Columbia Archives and Records Service; catalogue number HP28531).

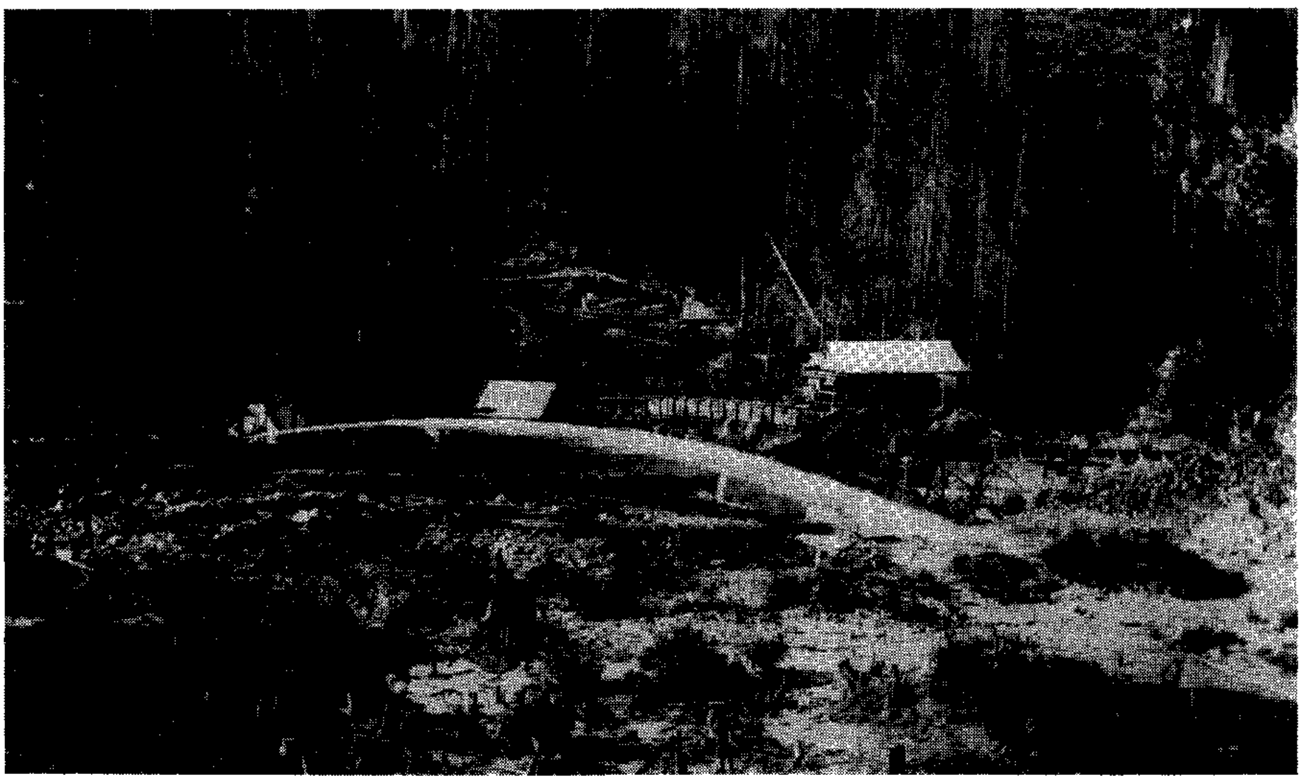

Plate 2. A hydraulic operation, probably along the Germansen River. These workings obtained their water through large wooden flumes or aqueducts. Numerous hydraulic operations were setup in the 1930s and the remains of several flumes can be found along the Germansen and South Germansen rivers. (Reproduced with permission from the British Columbia Archives and Records Service; catalogue number HP29400).

EXPLORATION HISTORY

The exploration heritage in the study area is dominated by placer gold prospecting (Plates 1 and 2). The Manson Creek and Germansen Landing area has long been known as an important placer gold producer in the province. Gold was first discovered in the region in 1868 and most of the rich deposits were mined out by the turn of the century (Armstrong, 1949). There was renewed interest in the placer fields during the depression years when several operations were assembled capable of processing large quantities of gravel. Mining ceased with the outbreak of the Second World War and since then most production has been from small diggings.

Hardrock prospecting was sporadic prior to construction of the main road into the area in 1937 (Armstrong and Thurber, 1945). Increased accessibility and the discovery of the Pinchi mercury deposit led to further exploration up to and just after the Second World War. Most of the significant showings along the Manson fault zone were discovered during this period. During the 1970s and 80s exploration interest was renewed with activity concentrated on the carbonate-hosted lead-zinc showings north of Nina Lake and precious metal and sulphide occurrences along the Manson fault zone.

ACKNOWLEDGMENTS

This final product of the Manson Creek project was made possible by the hard work and thoughtful input from many people over the years. Cheerful and competent assistance was given in the field by Neil R. Swift and Grant M. Malensek (1987), Ron L. Arksey (1988) and Jack Whittles and Mike Holmes (1989). A special mention is given to Sean Horgan for his timely assistance during the 1988 field season. Logistical support was provided by Gary Arsenault, Allan Gilmour and Mike Fournier.

Special thanks goes out to Northern Mountain Helicopters, particularly the staff at the Mackenzie base. These include pilots Brian Dougherty and Jim Franklin who were very patient and provided excellent service. We also thank Okanagan Helicopters (now Canadian Helicopters) for their help during the 1987 field season.

We would also like to thank the people in and around the towns of Manson Creek and Germansen Landing who were helpful and made our stay in the area pleasant. Special mention goes to Don and Irene Gilliland of the Gilliland Lodge where the project was based during the summers of 1988 and 1989. We thank the Muller family of Germansen Landing for their help and friendship during the 1989 field season.

Fossils were identified by B.S. Norford and M. J. Orchard of the Geological Survey of Canada and by R. Ludvigsen. Potassium-argon age determinations were carried out by J. Harakal of the University of British Columbia. Uranium-lead dates were generated by D. Murphy, J. Gabites and J. Mortensen also of the University of British Columbia. Apatite fission track analyses were provided by D.S. Miller of the Rensselaer Institute. Geothermometry calculations were carried out by Kim Bellefontaine on minerals kindly analyzed by Mitch Mihalynuk. Cartography was by Martin Taylor of the Geological Survey Branch.

The writing of this manuscript was made much easier through the help of many colleagues at the Geological Survey Branch in Victoria and at the Geological Survey of Canada in Vancouver. Geological concepts evolved from numerous and interesting discussions with JoAnne Nelson, Mitch Mihalynuk, Kim Bellefontaine, Bert Struik, Hugh Gabrielse, Andre Panteleyev and Chris Rees. The stratigraphy of North American Paleozoic rocks benefited from numerous discussions with A.B. Mawer of Cominco Ltd. and Dunham Craig. John Newell and Brian Grant provided excellent editorial comments on style and content through the various versions of this manuscript. Mitch, Kim and JoAnne also read versions of this paper and provided very helpful and appreciated input. Special mention goes to Bert Struik of the Geological Survey of Canada who sacrificed some spare time to critically review the manuscript and whose suggestions helped improve the final product. All of the interpretive sections within this paper are a 'snap-shot' of our ideas *circa* 1990. Newer information obtained by further mapping to the northwest of the study area is only partially incorporated into the descriptive parts of the paper.

Finally, the senior author thanks Kim Bellefontaine for her needed and much appreciated support while writing this manuscript.

ANCESTRAL NORTH AMERICAN CRATON

Rocks of North American affinity belong to the Cassiar and Kootenay terranes which represent pieces of displaced continental margin. In the map area North American rocks are dominated by those of the Cassiar Terrane with only a small fault-bounded area of Kootenay Terrane sediments in the southeast.

KOOTENAY TERRANE

BOULDER CREEK GROUP (informal, Proterozoic to Paleozoic ?)

A series of sandstones, impure quartzites, siltstones, argillites, marbles and minor amphibolite assigned to the Boulder Creek group are exposed along the creek of the same name. These sediments are in fault contact with surrounding rocks of the Slide Mountain and Quesnel terranes. Good exposure extends up to the Skeleton Mountain region. This unit also crops out along the ridges south of Lower Manson Lake and disappears beneath Quaternary cover along Dunne Creek in the southeastern part of the map area.

The Boulder Creek group forms an enigmatic package of strata exposed along the Manson fault zone. Armstrong (1949) assigned them to the Wolverine Complex based on characteristics similar to rocks in the Wolverine Range. Ferri and Melville (1988) and Ferri *et al* (1988) placed these rocks within the Nina Creek group based on the presence of thin, discontinuous layers of siliciclastic rocks similar to those seen elsewhere in the Nina Creek group of the area. Subsequent mapping in the Nina Lake area indicates that they are not characteristic lithologies of the Nina Creek group, but rather form a unique lithologic package.

Age and Correlation

Lithologically, these rocks have the closest affinities with the Ingenika Group. This is not only based on the abundant amount of siltstone, sandstone and impure quartzite, but also on the presence of amphibolite-grade metamorphic mineral assemblages and polyphase deformation that regionally are found only within the Ingenika Group. The simplest interpretation is that these rocks represent a fault sliver of Ingenika Group incorporated in the Manson fault zone. This is consistent with structural relationships seen to the south in the Pine Pass and McLeod Lake map areas (L. C. Struik, personal communication, 1990).

These fine-grained clastic rocks and impure carbonates are believed to represent pericratonic strata (*i.e.*, Kootenay Terrane) and to be equivalent to the Proterozoic to Paleozoic(?) Snowshoe Group of the Barkerville Terrane (Struik, 1985, 1988a). Although they have similarities with the Ingenika Group, the overall stratigraphy is quite different. The Boulder Creek group is dominated by fine clastic rocks with lesser sandstone, limestone and amphibolite. These rocks bear little resemblance to the coarse, thick-bedded feldspathic wackes and sandstones of the Swannell Formation. Comparable thick sequences of fine clastics within the Ingenika Group are found within the Tsaydiz to Stelkuz section. This section also contains the thick Espee Formation carbonate, which has no equivalent in the Boulder Creek group. Furthermore the thinly bedded phyllites and limestones of the Tsaydiz Formation are not present in the Boulder Creek succession. Only the Stelkuz Formation has similar sections of sandstone and limestone. However, the sandstones of the Stelkuz Formation are much purer than those of the Boulder Creek group and the entire Stelkuz section is considerably thinner than the Boulder Creek section.

The correlation of Boulder Creek strata with the Kootenay Terrane is further substantiated, in part, by their spatial relationship with other stratigraphic groups in the map area. Its position relative to other rocks is very similar to that of the Snowshoe Group between Prince George and Barkerville (Struik, *ibid.*) where it lies west of the Slide Mountain and Cariboo (Cassiar) terranes. The Snowshoe Group is flanked on the west by the black phyllite unit which is equivalent to the Slate Creek succession (lower succession of the Takla Group). Sheared mafic and ultramafic pods of the Crooked amphibolite are found intermittently along the contact between the black phyllite and the Snowshoe Group. The Crooked amphibolite is exposed sporadically along this boundary from Clearwater to near Prince George (Struik, 1988a). It is part of the Slide Mountain Terrane and has been correlated with the Antler Formation (Struik, *ibid.*), an equivalent of the Nina Creek group. The Crooked amphibolite is also seen to sit structurally above the Snowshoe Group in the Quesnel Lake area (Rees, 1987).

A very similar relationship exists in the map area. The Boulder Creek group is bounded on the west by the Slate Creek succession. This contact contains pods of Manson Lakes ultramafics (equivalent to the Crooked amphibolite) which also sit structurally above the Boulder Creek group.

The implications of this are that the western margin of the Boulder Creek group may be a thrust fault which is termed the Eureka thrust to the south (Struik, 1985). Thrust fault relationships are seen between ultramafic rocks and the Boulder Creek group, but we believe (for reasons which will be discussed in a later section on the Manson fault zone) that the western margin is now part of a strike-slip fault related to the Manson fault zone.

Lithology

The Boulder Creek group is characterized by grey-green to green siltstones, silty phyllites and phyllites which are thin to moderately bedded. Sequences of thin to thickly bedded, grey to beige, very fine to fine-grained argillaceous sandstone, feldspathic sandstone or quartzite up to 100 metres thick occur within these lithologies. These sandstones are sometimes interlayered with thinly bedded grey-green phyllite to siltstone. Minor recrystallized limestone or marble and amphibolite schist also occur within this package.

Impure quartzites and sandstones, which tend to be brown weathering, moderately to thickly bedded, and fine to medium grained, are well exposed along Boulder Creek. They are commonly cut by large (up to 1 metre thick) quartz-carbonate veins. Bedding, which is typically wavy, is difficult to distinguish in these rocks and outcrops have a massive appearance.

Interlayered, thinly bedded siltstones, fine-grained sandstones and phyllites occur along Skeleton Mountain. Bedding in these lithologies is strongly planar. The siltstones and shales are greenish grey to green in colour and commonly crenulated. These clastic sequences give way northwestward to assemblages dominated by grey-green to greenish phyllites with minor buff-weathering marble bands.

Greenish phyllites, grey to beige siltstones and minor sandstones are exposed south of Lower Manson Lake. Bedding tends to be very fine and indistinct which, in the coarser lithologies, may produce massive outcrops. The phyllites and siltstones have a layer-parallel fabric which is cut by a later upright cleavage causing these rocks to weather into rod-shaped fragments. The phyllites become increasingly metamorphosed to the southwest, displaying a schistose fabric and containing porphyroblasts of biotite, chloritoid, garnet, tourmaline and staurolite.

Minor grey, cream or buff-weathering, medium to coarsely crystalline marbles with indistinct bedding are also found in the Boulder Creek group. They form layers up to several metres thick within both the phyllitic sequences southwest of Skeleton Mountain and the clastic sequences along Boulder Creek.

A section of amphibolite up to 10 metres thick is exposed along Boulder Creek. It is characterized by dark green, fine to medium-grained crystalline amphibole in association with chlorite and feldspar, sometimes segregated to produce a gneissic texture.

CASSIAR TERRANE

Proterozoic to Permian rift-related and miogeoclinal rocks of the Cassiar Terrane are dominated by siliciclastic rocks with carbonates becoming more abundant toward the top of the sequence. These rocks are represented by the Proterozoic Ingenika Group, the Lower Cambrian Atan Group, the Cambrian to Ordovician(?) Razorback group, the Ordovician to Lower Devonian Echo Lake group, the Middle Devonian Otter Lakes group and the Upper Devonian to Permian Big Creek group. The lower parts of the Proterozoic succession contain regional metamorphic culminations which are termed the Wolverine (Metamorphic) Complex. This sequence of strata is very similar to North American stratigraphy described in the northern Cassiar Terrane of British Columbia (Gabrielse, 1963; Nelson and Bradford, 1987, 1993; *see* Table 2).

Within the map area Paleozoic carbonate rocks of the Cassiar Terrane were initially placed within the Cache Creek Group by Armstrong (1949) and Roots (1954), though they noted that some of these limestones were older than typical Cache Creek carbonates. These authors also recognized Lower Cambrian quartzites and minor limestones but grouped them with the Tenakihi Group, Ingenika Group and the Wolverine Complex. Monger (1973) and Monger and Paterson (1974) realized that all carbonates of this package were early Paleozoic in age and not part of the Cache Creek Group. Gabrielse (1975), working in the northern part of the map area, attempted to separate the Lower Cambrian units from rocks of Proterozoic age. He also noted the similarities of these rocks to lower Paleozoic rocks farther north in the Cassiar Mountains. Gabrielse, together with Monger and Paterson, believed the Mount Kison carbonates were younger than Lower Cambrian. Economically these rocks are important in that they contain significant carbonate-hosted lead-zinc-barite occurrences in the uppermost carbonate units.

Ferri and Melville (1990a, b) applied formational and group names from the Cassiar area to this package of rocks due to their similarities with those of the Cassiar Mountains (Gabrielse, 1963; Nelson and Bradford, 1987, 1993, Table 2). Although these rocks have affinities to those of the northern Cassiar Terrane, they are sufficiently different to warrant a local nomenclature. Furthermore this Paleozoic succession is essentially restricted to the Manson Creek and Germansen Landing area. It is truncated to the north and south by sections of the Wolverine fault zone. Due to its restricted extent and unique character, new names have been proposed for many of these units. These are, in ascending order, the Razorback group, Echo Lake group, Otter Lakes group, and Big Creek group (Figure 13).

INGENIKA GROUP
(Upper Proterozoic)

Upper Proterozoic sediments in the map area were first described by Armstrong (1949) who carried out a cursory examination of these rocks and placed all of them within the Wolverine Complex. Roots (1954), working north of the study area, further subdivided these Proterozoic sediments into the Tenakihi Group, Ingenika Group and Wolverine Complex. The last was reserved for the strongly metamorphosed rocks where stratigraphic correlations with less metamorphosed strata are tenuous. Both Armstrong and Roots included Lower Cambrian strata within these units.

Gabrielse (1975), working in the study area and in the Swannell Ranges to the north, found Roots' (1954) two-fold subdivision of the Proterozoic sediments unworkable in that there is little distinction between the Tenakihi Group and the Ingenika Group, save for metamorphic grade. Gabrielse therefore referred to these rocks as the Ingenika Group and recognized a four-fold subdivision similar to that used here. He did not map out the various units of the Ingenika Group and he also included parts of the Lower Cambrian succession with the uppermost Ingenika Group.

TABLE 2
CORRELATION CHART OF NORTH AMERICAN PALEOZOIC STRATIGRAPHY WITHIN THE STUDY AREA AND PALEOZOIC STRATA SEEN ELSEWHERE ALONG THE CORDILLERA.

<table>
<tr><th></th><th colspan="2">CASSIAR MOUNTAINS</th><th colspan="2">OMINECA MOUNTAINS</th><th>MCLEOD LAKE (East of McLeod Lake Fault)</th><th colspan="2">CARIBOO MOUNTAINS</th></tr>
<tr><td></td><td colspan="2">(Gabrielse, 1963; Nelson and Bradford, 1993; Nelson et al, 1988)</td><td colspan="2">(This study)</td><td>(Struik, 1989a, 1990)</td><td colspan="2">(Struik, 1988a)</td></tr>
<tr><td>Mississippian(?) to Permian</td><td colspan="2">chert, argillite</td><td colspan="2" rowspan="2">Big Creek group</td><td>tuff, sandstone</td><td colspan="2">Sugar Limestone</td></tr>
<tr><td>Lower Mississippian to Upper Devonian</td><td colspan="2">Earn Group</td><td>slate, argillite, tuff(?), dolostone at base</td><td rowspan="3">Black Stuart Group</td><td>Greenberry Formation
Guyet Formation</td></tr>
<tr><td>Middle Devonian</td><td colspan="2">McDame Group</td><td colspan="2">Otter Lakes group</td><td>dolostone</td><td>Waverly Formation</td></tr>
<tr><td>Lower Devonian to Silurian</td><td colspan="2">Tapioca Sandstone, Sandpile Group</td><td colspan="2">Echo Lake group</td><td>limestone, dolostone, quartzose dolostone, quartzite, slate</td><td>Un-named Units</td></tr>
<tr><td>Cambrian to Ordovician</td><td colspan="2">Road River Group
Kechika Group</td><td colspan="2">Razorback group</td><td>Sandpile Group
slate limestone, sandy limestone</td><td rowspan="3">Cariboo Group</td><td>Dome Creek Formation</td></tr>
<tr><td rowspan="2">Lower Cambrian</td><td rowspan="2">Atan Group</td><td>Rosella Formation</td><td rowspan="2">Atan Group</td><td>Mt. Kison limestone</td><td>limestone, dolostone</td><td>Mural Formation</td></tr>
<tr><td>Boya Formation</td><td>Mt. Brown quartzite</td><td>quartzite</td><td>Midas Formation
Yanks Peak Formation</td></tr>
</table>

Mansy and Gabrielse (1978) proposed a four-fold subdivision for the Ingenika Group (*see* Table 3) based on detailed stratigraphic work in the northern part of the Omineca Mountains. They divided the group into four formations, in ascending order, the Swannell, Tsaydiz, Espee and Stelkuz formations.

Proterozoic sediments in the map area can be traced directly into lithologies underlying the Swannell Ranges to the north and are correlated with the Ingenika Group as proposed by Mansy and Gabrielse (1978).

A continuous section of the Ingenika Group is exposed between the Omineca and Osilinka rivers, where all four formations can be traced for a distance of over 30 kilometres. In the southern part of the map area, near Granite Creek, only a small fault sliver of the upper part of the Ingenika Group is preserved. The bulk of the succession in the southern parts of the map area is represented by the lower parts of the Ingenika Group.

The Ingenika Group is predominantly a clastic sequence with lesser carbonate and is in excess of 3.5 kilometres thick in the study area (Figures 5, 10 and 11). All formations of the Ingenika Group are recognized in the map area and are compositionally very similar to the type area. The Swannell Formation is composed of sandstone, feldspathic wacke, slate and minor carbonate; the Tsaydiz Formation is made up of slate, carbonate and lesser sandstone; The Espee Formation is a thick carbonate sequence and the Stelkuz Formation is predominantly sandstone, slate and lesser limestone.

Ingenika Group rocks east of the Wolverine fault zone in the southern part of the map area have been subdivided into four units: impure metaquartzite and schist

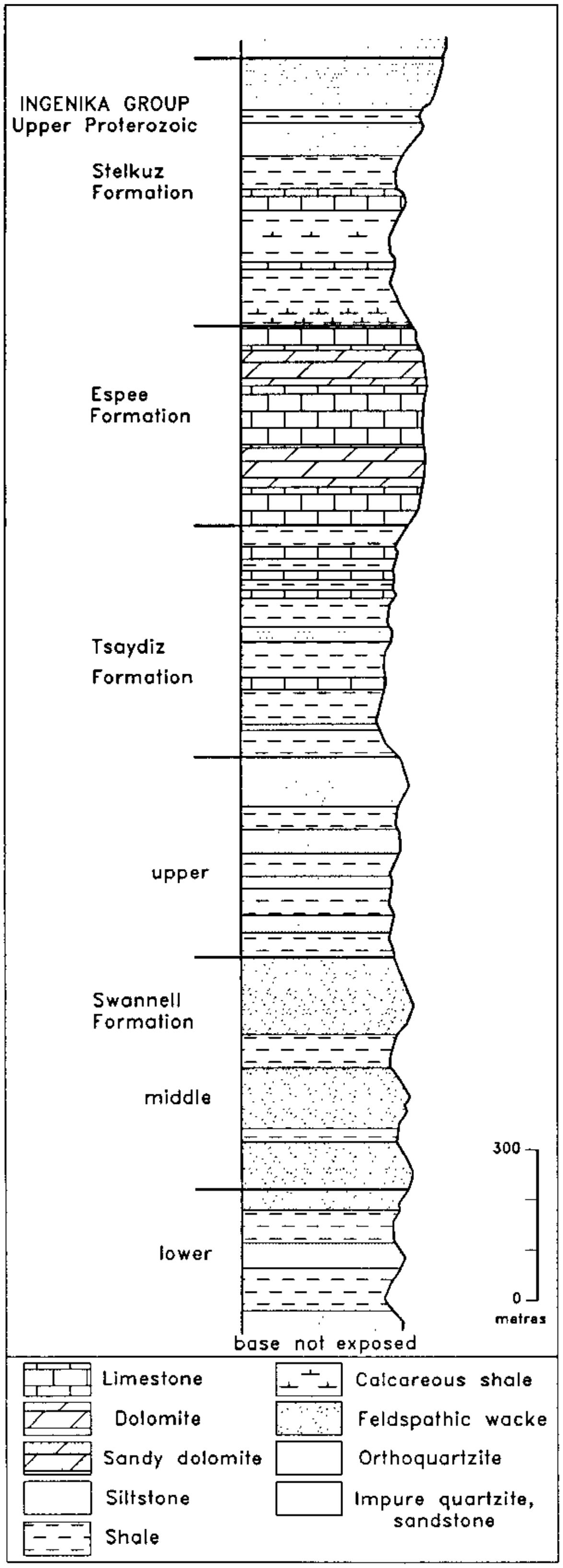

Figure 10. Stratigraphic column of the Ingenika Group in the vicinity of the Osilinka River.

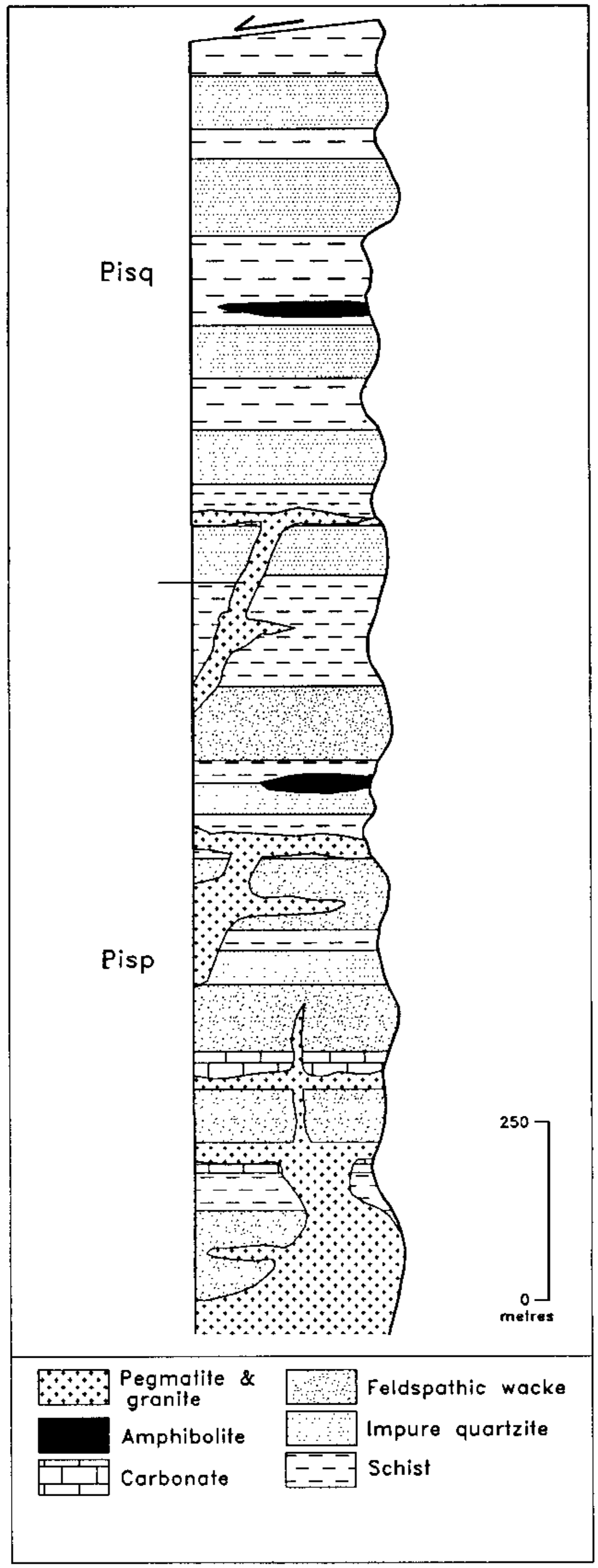

Figure 11. Stratigraphic column of the lower Ingenika Group in the southern part of the map area.

(Pisq); paragneiss and schist (Pisp); paragneiss, schist and intrusive (Pipi); and amphibolite and calcsilicate gneiss (Pia). Accurate correlation of these units with Ingenika rocks in the northern part of the map is not possible. This is due, primarily, to the inability to trace these units continuously northward into known stratigraphy. This inability to correlate units from south to north may also be a function of metamorphic grade. Ingenika rocks in the southern part of the map area are at considerably higher grade than most of the rocks to the north and may appear as different units. Most rocks in the south are at sillimanite grade or higher and composed of coarsely crystalline schists and paragneisses. Most rocks in the northern part of the map area are between chlorite and garnet grade. The lithologies are phyllites, schists and metagrits with coarse schists and paragneisses restricted to the area along the Wolverine Range (within the sillimanite isograd).

Impure metaquartzite, schist and paragneiss of units Pisq and Pisp are broadly similar to the Swannell Formation and may be high-grade equivalents of this formation. Amphibolite and calcsilicate gneiss of unit Pia have no correlatives in the Swannell Formation and may represent a lower unit of the Ingenika Group. Thus Ingenika Group rocks in the southern part of the map area, east of the Wolverine fault zone, may represent the lowermost parts of this group. Their exposure in this area is related to displacement on the fault zone.

Within units Pia and Pipi, the dominant exposed rock type is pegmatite and granodiorite, which typically constitute 70% or more of total outcrop (Plate 3). Metasediments may be under represented as they tend to form recessive exposures. Compositionally units Pisp and Pipi are very similar and are differentiated primarily by the predominance of pegmatite and granodiorite in the latter. The contacts of unit Pipi are thus subjective. A more detailed description of the intrusive rocks is given in a later section.

The northwest margin of unit Pipi is marked by a series of steep, northeast-facing slopes. Within it, the ridges are fairly straight and consistently trend northeasterly, parallel to the dominant foliation in the granodiorites and pegmatites. This supports the inference that much of this area is underlain by these rock types.

In this report the terms 'Wolverine Complex' or 'Wolverine Metamorphic Complex' refer to high-grade metamorphic rocks (above sillimanite grade) or metamorphic culminations found within the Wolverine Range and immediately along strike with the Wolverine Range.

Age and Correlation

The Ingenika Group is part of the Upper Proterozoic Windermere Supergroup, which extends along the entire length of the Canadian Cordillera (Figure 12). This

Plate 3. Outline of metasedimentary raft within granodiorites of unit Pipi near Mount Bison. This picture exemplifies the relationship between intrusive material and metasediments within the high grade gneisses of the Ingenika Group in the Wolverine Range. Geologist standing lower right of sedimentary raft for scale.

sequence of strata is lithologically similar to other Windermere rocks located south and north of the study area. Regional correlations of the Ingenika Group have been established by Mansy and Gabrielse (1978) and Gabrielse and Campbell (1991) and a detailed account will not be attempted here. Table 3 is a correlation chart of the Ingenika Group and other Upper Proterozoic stratigraphy within the Cassiar Terrane and North American craton. It is modified from similar charts published by these authors.

Rocks in the study area, and in the Cassiar Mountains, can be correlated directly with units in the Cariboo Mountains (Struik, 1988a). The thick quartz and feldspathic wackes of the Swannell Formation are equivalent to similar lithologies in the Kaza Group. The succeeding slates and sandstones of the Isaac Formation, carbonates of the Cunningham Formation and slates, siltstones and sandstones of the Yankee Belle Formation are equivalent to the Tsaydiz, Espee and Stelkuz formations, respectively.

Correlations with Proterozoic sediments across the northern Rocky Mountain Trench, are somewhat more tenuous due to apparent facies changes. Directly northwest of the map area, within the Rocky Mountains, the Upper Proterozoic is represented by the Misinchinka Group

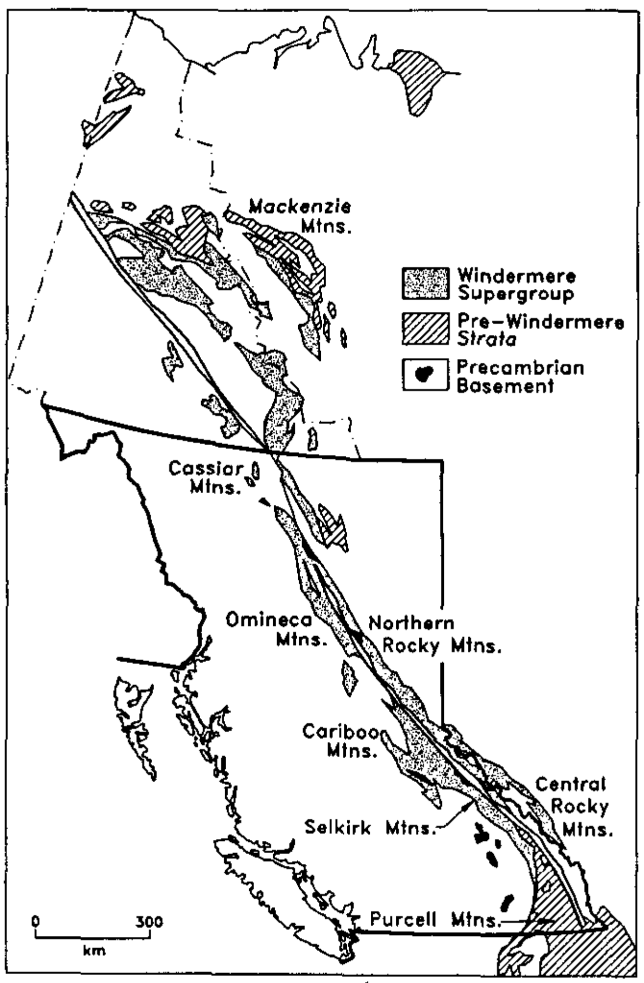

Figure 12. Distribution of Windermere stratigraphy along the Canadian Cordillera.

(Gabrielse, 1975; Evenchick, 1988). These rocks are floored by 728 Ma granitic basement (Evenchick, *ibid.*) and can be subdivided into three units; a lower clastic unit of phyllite, siltstone, feldspathic quartzite, diamictite and minor carbonate; a middle slate and carbonate unit with lesser quartzite and conglomerate; and an upper clastic unit of argillite, quartzite and siltstone. McMechan (1987) documented a similar succession south of the Peace River, with the only difference being a more developed middle carbonate unit. It seems likely that this middle carbonate unit is equivalent to the Espee Formation, and the Swannell and Tsaydiz formations are correlative with the lower unit and the Stelkuz Formation equivalent to the upper part of the Misinchinka Group.

Amphibolite and calcsilicate gneiss of unit Pia have no lower grade correlatives within the Ingenika Group of the map area. They disappear to the northwest as they plunge below metasediments of unit Pipi along a crudely defined F_3 antiform. These gneisses may be correlatives of amphibolite schist and marble units which sit above 1.85 Ga basement gneiss in the Sifton Ranges (Evenchick, *ibid.*) where amphibolites and marbles are associated with abundant metaquartzite which is lacking in the Wolverine Range.

Amphibolite and Calcsilicate Gneiss (Pia)

Near the Manson River, the Ingenika Group is characterized by the presence of marbles and calcsilicate gneisses associated with amphibolite gneiss. These rocks are thought to be at the lowest structural and stratigraphic level within the Ingenika Group. They terminate northwestward against a large body of granodiorite.

The marbles are grey to cream in colour, coarsely crystalline and contain phlogopite, garnet, diopside and calcite. They form bands 0.1 to 2 metres thick and are interlayered with calcsilicate rocks. Calcsilicate gneisses are predominantly diopside and plagioclase with lesser garnet and calcite. They are dark green to green and coarsely crystalline. These units typically occur in sections up to 10 or 15 metres thick. Near Munro Creek, a marble-calcsilicate band some 200 metres thick can be traced for over 10 kilometres. Its southern extension is lost due to poor exposure.

Amphibolite gneiss is prominent in this unit, making up to 30% of exposures southeast of the Manson River. This gneiss is very similar to that within units Pisp and Pipi.

Paragneiss, Schist and Intrusive (Pipi)

This unit occupies the northern part of the Wolverine Range east of Bisson Mountain with its southern termination against a large body of granodiorite. Exposure is excellent in the Bison Mountain area and diminishes somewhat to the southeast.

Paragneisses and schists of this unit are similar to those in unit Pisp. Dark brown, rusty weathering sillimanite-garnet-quartz-feldspar-muscovite-biotite schists occur in layers 0.1 to 1 metre thick. They are coarsely crystalline and sometimes slightly chloritized.

TABLE 3
CORRELATION DIAGRAM OF INGENIKA GROUP STRATA WITH OTHER PROTEROZOIC SEQUENCES IN THE CANADIAN CORDILLERA.

		CASSIAR MOUNTAINS (*Mansy and Gabrielse, 1978; Evenchick, 1988*)	OMINECA MOUNTAINS (*Mansy and Gabrielse, 1978; This Study*)	CARIBOO MOUNTAINS (*Struik, 1988a*)	SELKIRK MOUNTAINS (*Poulton and Simony, 1980*)	NORTHERN ROCKY MOUNTAINS (*Gabrielse, 1975; McMechan, 1987; Evenchick, 1988*)	CENTRAL ROCKY MOUNTAINS (*Campbell et al., 1973*)
Lower Cambrian		Atan Group	Atan Group	Cariboo Group: Yanks Peak Formation	Hamill Group	Gog Group	Gog Group
Upper Proterozoic	Windermere Supergroup	Ingenika Group: Stelkuz Formation	Ingenika Group: Stelkuz Formation	Cariboo Group: Yankee Belle Formation	Horsethief Creek Group: Upper Clastic	Misinchinka Group: Upper	Miette Group: Upper
		Espee Formation	Espee Formation	Cunnigham Formation	Carbonate Division	Middle	Middle
		Tsaydiz Formation	Tsaydiz Formation	Isaac Formation	Slate Division	Lower	
		Swannell Formation	Swannell Formation ? Wolverine Complex	Kaza Group	Grit Division		Lower
		Crystalline Basement				Crystalline Basement	

Dark grey to dark grey-brown gneisses are interlayered with the schists in sequences 0.1 to 2 metres thick. They tend to be quartz and feldspar rich (up to 80% combined) with garnet and sillimanite as the only metamorphic accessory minerals.

Amphibolite gneiss is composed of garnet, quartz, biotite, plagioclase and amphibole, with the amphibole content varying from 20 to almost 100%. These gneisses are often thickly layered and coarsely to very coarsely crystalline. Hornblende typically exhibits low-grade retrogression to actinolite.

Paragneiss and Schist (Pisp)

This unit is exposed within the Wolverine Ranges in the southern part of the study area. Its exact thickness is unknown but it is at least 1 kilometre thick. It is characterized by quartzofeldspathic paragneiss and quartz-feldspar-mica schist with lesser micaceous quartzite. Minor constituents are calcsilicate gneiss and amphibolite.

The schists are composed primarily of medium to coarse-grained muscovite and biotite which may be chloritized. Accessory minerals are commonly garnet and sillimanite with rare kyanite.

The quartzofeldspathic paragneisses are typically grey to grey-brown, medium to very coarsely crystalline and form layers 10 centimetres to 1 metre thick. They occur in intervals up to 10 metres thick and are interlayered with the schists. They commonly contain up to 25% white potassic and calcic feldspar. The least deformed of these sequences appear to be metamorphosed feldspathic to quartz wackes (grits). The metaquartzites are similar in appearance but contain less than 5% feldspar and mica.

Grey-green diopside-bearing calcsilicate gneisses are present in this unit. They are massively layered, coarsely crystalline and contain up to 50% diopside.

The strongly metamorphosed basal portions of this unit are injected by several generations of pegmatitic sills, dikes and related granodioritic and granitic bodies comprising over 50% of the outcrop. Many of the pegmatitic sills, primarily the thinner ones, are folded or boudinaged, but the larger pegmatite bodies are foliated only on their margins. Later generations of pegmatite crosscut the foliation and are undeformed. These rocks are also described in more detail under Wolverine Range intrusions.

Impure Metaquartzite (Pisq)

Unit Pisq comprises micaceous metaquartzite, quartz-mica schist, metaquartzite and minor amphibolite. It is poorly exposed along the west flank of the Wolverine Range in the southern part of the map area. It varies in thickness from some 500 metres near Granite Creek to well over 1 kilometre north of the mouth of Ciarelli Creek. Its lower contact is gradational, and placed at the first thick sequence of quartz-rich layers. Its upper contact is cut by the Wolverine fault zone.

The micaceous or impure metaquartzite is grey-brown and contains 5 to 10% micaceous material and less than 5% feldspar. It is fine to medium grained and present in layers 10 to 50 centimetres thick in sequences up to 5 metres thick. These quartzose bands are interlayered with silver to greyish silver-brown quartz-muscovite-biotite schist 10 centimetres to 1 metre thick. These schists may contain considerable quartz and are commonly chloritized. In general the upper part of the unit contains thicker sequences of impure metaquartzites.

The unit is intruded by sills and dikes of pegmatite very similar to those within units Pisp and Pipi (Plate 4). These bodies are small (less than a few metres thick) and constitute less than 5% of the unit.

Swannell Formation

The Swannell Formation is areally the most extensive of the Ingenika Group, occupying roughly the eastern third of the northern part of the map area. The thickness is difficult to deduce due to polyphase deformation and lack of continuous outcrop. It is at least 2 kilometres thick and is tectonically thickened to the east. The basal parts of the formation are polydeformed, metamorphosed to sillimanite grade and intruded by pegmatite and related granodiorite.

No continuous stratigraphic sequence of the Swannell Formation is exposed within the map area. This is due, in part, to the rather poor exposure, but is related more to displacement on the Wolverine fault zone.

Lithology: A poorly exposed, apparently continuous, relatively unmetamorphosed sequence of the Swannell Formation crops out on Breeze Peak, west of the Wolverine fault zone. A threefold subdivision of the formation is possible on the basis of these exposures (Figure 10). The ability to subdivide the Swannell Formation in this area is based primarily on the presence of a thick succession of feldspathic and quartz wackes forming the middle unit. This area is also complicated by folding such that lithologies assigned to the lower part of the Swannell Formation to the northeast may be part of the middle unit. The subdivisions proposed here are broadly similar to those described by Mansy and Gabrielse (1978) in the Swannell Ranges.

In the Breeze Peak area, the Swannell Formation is upwards of 2 kilometres thick and is tectonically thickened to the east. Rocks east of the Wolverine fault zone represent lower parts of the formation and the relationship of these rocks to units Pisq and Pisp is not known with certainty. In the northern part of the map area, schists and paragneisses in the Wolverine Range appear similar to those of unit Pisp. This similarity may simply reflect the similar metamorphic grade (sillimanite) of each package which may mask original differences. Yet it appears that metamorphic grade is generally related to stratigraphic

Plate 4. A pegmatitic sill 2 metres thick within paragneisses and schists of the Ingenika Group. This relationship is typical of unit Pisp and units Pipi and Pia where intrusive material constitutes up to 50% or more of the exposure.

level (*see* chapter on Metamorphism, and Gabrielse, 1975) and, if so, these two units may be equivalent.

In the Breeze Peak area the lowest member is at least 1 kilometre thick, though it appears substantially thicker due to polyphase deformation. Here relatively unmetamorphosed lithologies are exposed and are composed primarily of thin to thickly bedded, very fine to medium-grained quartz and feldspathic wackes. The feldspar content is typically less than 15%. Generally, the clastics of this unit are quartz rich in comparison to the lithologies of the middle unit. Subordinate lithologies are very fine grained impure sandstones, siltstones, grey to white marble (several metres thick), greenish slates and green to grey phyllite and schist. Phyllite and schist form sequences up to 3 metres thick. These rocks become more strongly metamorphosed to the east and the pelitic members are represented by garnet-biotite-feldspar-quartz schists. North of the Osilinka River, near Edmunds Creek, staurolite and metamorphic tourmaline are present as large porphyroblasts up to 2 centimetres long.

Along the Wolverine Range, basal rocks of this unit are metamorphosed to sillimanite grade. They are coarsely crystalline schists, micaceous quartzites, diopside-bearing calcsilicate, and quartzofeldspathic paragneisses. These rocks are injected by several generations of pegmatitic sills, dikes and related granodioritic material (*see* section on Wolverine Range intrusions).

The middle member of the Swannell Formation, some 300 to 400 metres thick, is characterized by massive beds (1 to 10 metres thick) of feldspathic wacke (Plate 5). These wackes are very coarse grained and approach granule conglomerates in some areas. They contain up to 30% chalky white feldspar crystal clasts and the quartz has a characteristic blue to purplish opalescence which disappears as the garnet isograd is approached. Greenish grey to silvery slate and phyllite, fine to coarse-grained quartz wackes to sandstones and their higher grade metamorphic equivalents make up the remainder of this unit.

The upper member is roughly 300 metres thick, although, in the vicinity of Henschel Creek, thick feldspathic and quartz wackes similar to the middle member outcrop immediately below the Tsaydiz Formation, making the upper member no more than 50 metres thick. This member is characterized by massively bedded, brown-weathering, fine to coarse-grained, impure quartzite and sandstone. These rocks may grade into, or be interbedded with, siltstones and slates. Of lesser importance are dark grey to greenish grey slates, phyllites and feldspathic wackes. This member is metamorphosed to amphibolite grade in the northeast and the schistose rocks contain garnet and tourmaline as accessory minerals.

The quartzite is typically impure and contains 5 to 10% micaceous material and less than 5% feldspar. The sandstone commonly contains 10 to 15% feldspar. The quartzose layers are 10 to 50 centimetres thick and found in sequences up to 5 metres thick. Interbedded pelitic layers are 10 to 100 centimetres thick and may form continuous sections up to 5 metres thick.

Tsaydiz Formation

The Tsaydiz Formation is poorly exposed and has been inferred throughout most of the northern part of the map area. In the south, it is exposed near Granite Creek. In this area it crops out in the core of an anticline outlined by the Espee Formation and in the upper plate of a small thrust fault.

The lower contact of the Tsaydiz Formation is placed at the top of the highest resistant layer in the Swannell Formation. The thickness of the formation varies from 300 metres near the Omineca River to approximately 750 metres south of the Osilinka River where it may be exaggerated by tectonism.

In the northeastern corner of the map area the Tsaydiz Formation is poorly exposed and is inferred from the presence of the Espee Formation (*see* under Espee Formation).

Lithology: The Tsaydiz Formation is typified by light greenish grey to grey, crenulated slates and phyllites that are commonly interlayered with thinly bedded, buff-weathering limestone to argillaceous limestone (Plate 6). Lesser siltstones, quartz and feldspathic wackes and recrystallized brown-weathering, grey limestone layers, 1 to 5 metres thick, are also present. Quartzose layers are thin to massively bedded and are commonly interlayered

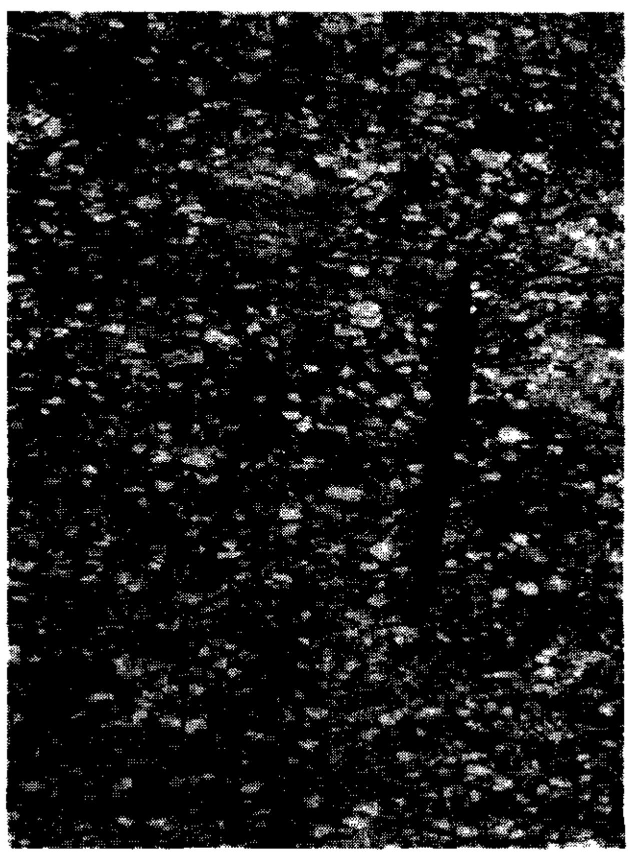

Plate 5. Coarse quartz to feldspathic wacke (grit) of the Swannell Formation on the west side of Breeze Peak. These beds are massive and typically show few internal features. Quartz grains commonly display a blue-purple opalescence.

with thin phyllite or slate bands. Limestones are more prevalent toward the base of the formation.

Espee Formation

The Espee Formation is a cliff-forming carbonate unit which ranges from 200 to over 400 metres in thickness. It is easily traced through the northern part of the map area and is structurally repeated in the vicinity of Granite Creek. It underlies Mount Dewar and forms spectacular cliffs east of Mount Kison. It is one of several excellent marker horizons in the stratigraphic succession of the map area (Plate 7).

A thick marble unit is present in the northeast corner of the map area and is assigned to the Espee Formation. It is in the order of 300 to 350 metres thick (based on structural cross-sections) and is assumed to be upright. A carbonate of this thickness is not typical of the Swannell Formation (*see* Mansy and Gabrielse, 1978). The unit can be traced regionally into a carbonate which is undoubtedly the Espee Formation (*see* Gabrielse, 1975). This carbonate is found within middle amphibolite facies metamorphic rocks which are not typical of the Espee Formation in the map area. Gabrielse (*ibid.*) also shows the Espee carbonate situated above garnet grade metamorphism in the Butler Range.

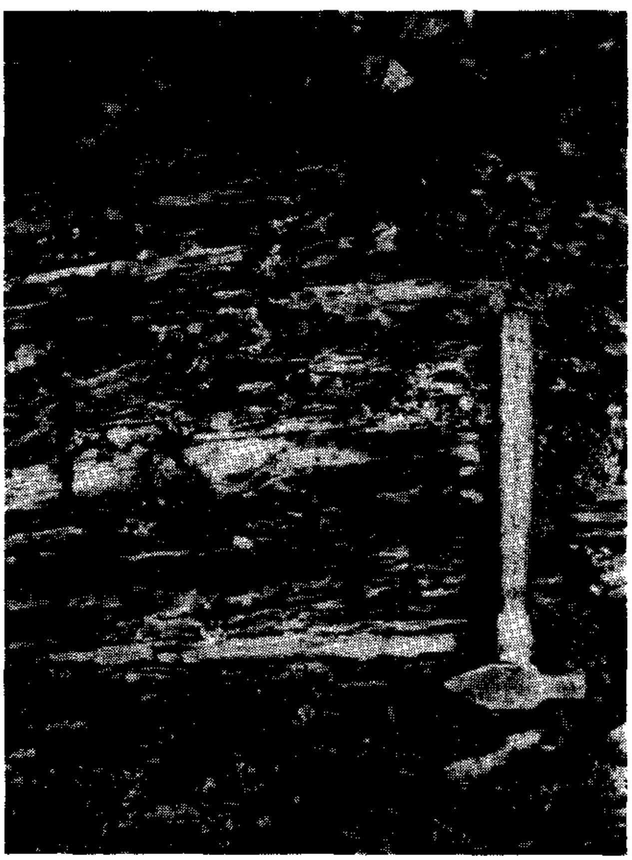

Plate 6. Finely interlayered calcareous shale and limestone of the Tsaydiz Formation as seen along Henschel Creek. These rocks are interlayered with thicker sequences of shale and limestone. These recessive lithologies account for the poor exposure of this unit.

Lithology: The Espee carbonates are white to grey, buff to tan-weathering limestones to dolomitic limestones which are moderately to thinly bedded and typically recrystallized to a coarse marble. These rocks rarely break along bedding but rather along joints or a cleavage produced by the preferential alignment of calcite crystals. Bedding, when seen, is typically marked by alternating light and dark grey bands.

The lower contact of the formation is rarely exposed but where observed, there is a transitional zone where interlayered slates and limestones of the Tsaydiz Formation give way to the more massive limestone of the Espee Formation. Similarly, at the upper contact with the Stelkuz Formation, buff-weathering, thickly layered Espee limestones are interlayered with green slates of the Stelkuz Formation across a zone some 50 metres thick.

Stelkuz Formation

The Stelkuz Formation is well exposed in the northern part of the study area, particularly below Mount Kison. Exposures are also present within the fold pair along Mount Brown. In the southeast, this formation forms good outcrops along Granite Creek.

Lithology: The Stelkuz Formation is composed of approximately 400 to 500 metres of green to grey slate and siltstone, brown to grey impure quartzite and sandstone with minor dolomitic limestone. Slate and siltstone predominate in the lower part of the formation whereas sandstone, which is characteristically fine grained and planar bedded, becomes predominant toward the top. A moderately bedded, brown to tan-weathering dolostone unit, 5 to 10 metres thick, locally occurs approximately 100 metres below the upper contact of the formation. In the Mount Kison area this carbonate can be traced for several kilometres.

The upper contact of the Stelkuz Formation appears to be conformable with the succeeding Atan Group. The upper part of the Stelkuz Formation contains a coarsening upward sequence up to 100 metres thick, in which the amount of sandstone increases toward the top of the formation where thickly bedded, coarse-grained, impure quartzites, light grey to grey in colour, are very similar to basal Atan Group quartzites (Plate 8). Typically though, Stelkuz quartzites are impure and lack the glassy appearance of Atan orthoquartzites. The top of the Stelkuz Formation (and of the Ingenika Group) is placed at the base of the first thick (greater than 2 metres) sequence of white to light grey orthoquartzite. Thin layers (0.5 metre or less) of light-coloured orthoquartzites occur below this contact, within the impure quartzites. The contact relationship is best exposed on the northeast face of Mount Kison.

ATAN GROUP
(Lower Cambrian)

Orthoquartzites, siltstones, shales, sandstones and a thick carbonate unit above the Stelkuz Formation are assigned to the Atan Group. This is based on the striking resemblance of these strata to lithologies of equivalent composition, age and stratigraphic position described by

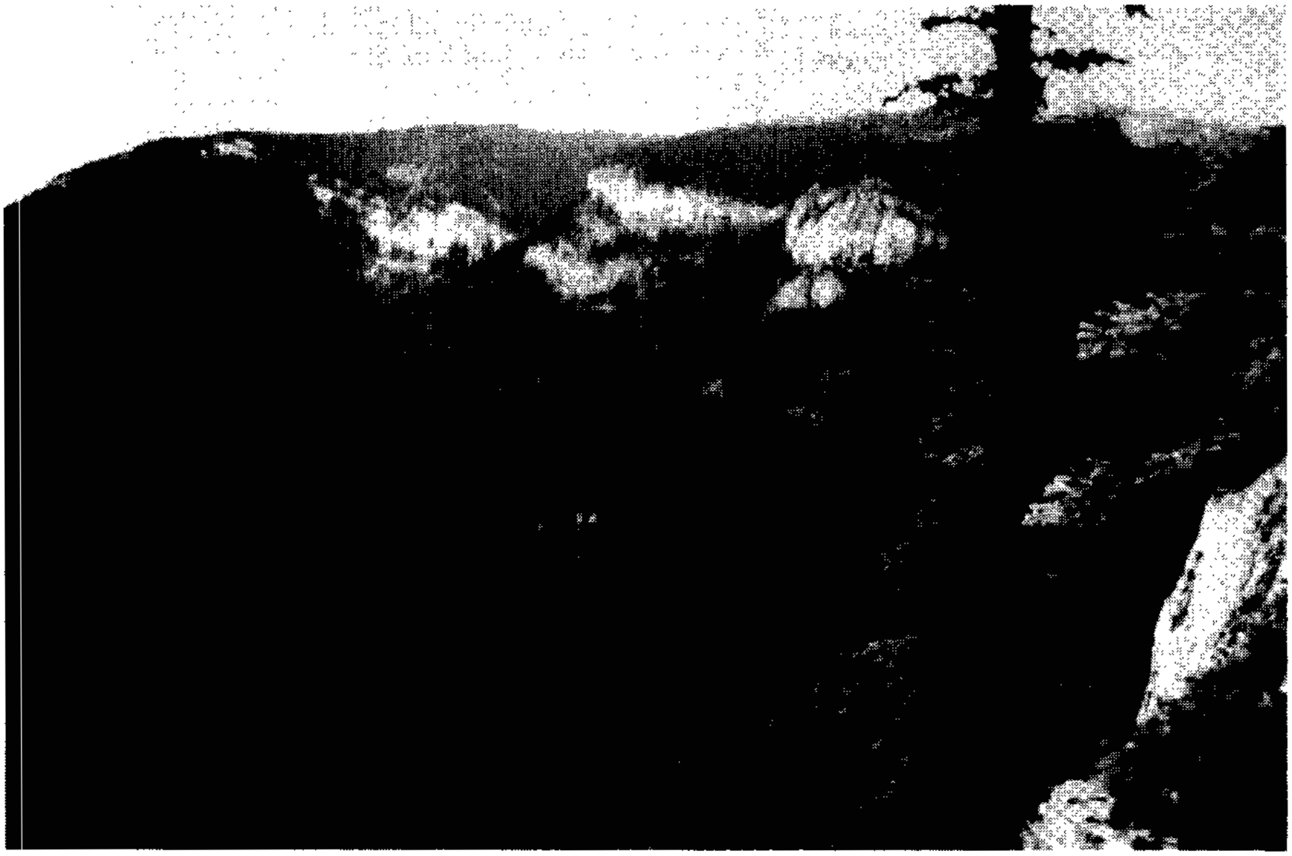

Plate 7. A view to the south from near Mount Brown, showing the excellent cliff-forming nature of Espee carbonates. These rocks dip moderately to the southwest.

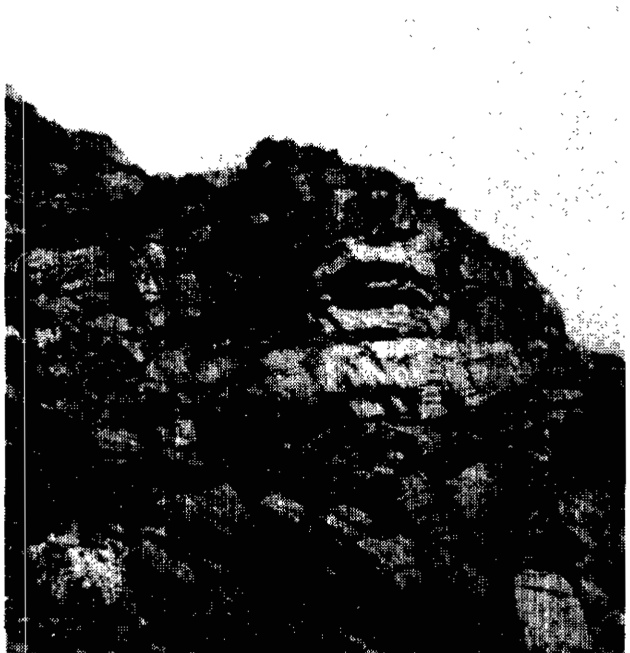

Plate 8. Massive to thickly bedded impure quartzites and sandstones of the uppermost Stelkuz Formation at the top of Mount Kison. These pass upwards into orthoquartzites of the Mount Brown quartzite 50 metres to the west.

Fritz (1980) in the Cassiar Mountains. In the Germansen Landing–Manson Creek area the Atan Group has been informally subdivided into the lower, Mount Brown quartzite composed of orthoquartzite, sandstone, shale and siltstone, and a succeeding thick carbonate assigned to the Mount Kison limestone (Figure 13). This group of rocks is confined to the northern part of the area and can be traced discontinuously from Blue Lake to the Osilinka River (Figure 7).

The Mount Brown and Mount Kison successions were originally assigned the rank of informal formations (Ferri *et al.*, 1992a, b; Ferri *et al.*, 1993a, b) Because the current data on these units do not satisfy the strict requirements for designation as formal formations, it is now felt that lithic modifiers would better serve to indicate the informal nature of these units.

Age and Correlation

Only one fossil locality was found within this group (Appendix I); it is an archaeocyathid-bearing limestone within the Mount Kison limestone. Gabrielse (1975) also noted archaeocyathids in limestone lenses of the Mount Brown quartzite(?) south of the Osilinka River.

Correlations of this group with similarly named lithologies in the Cassiar area are straightforward (*see* Table 2; Gabrielse, 1963; Nelson and Bradford, 1987,

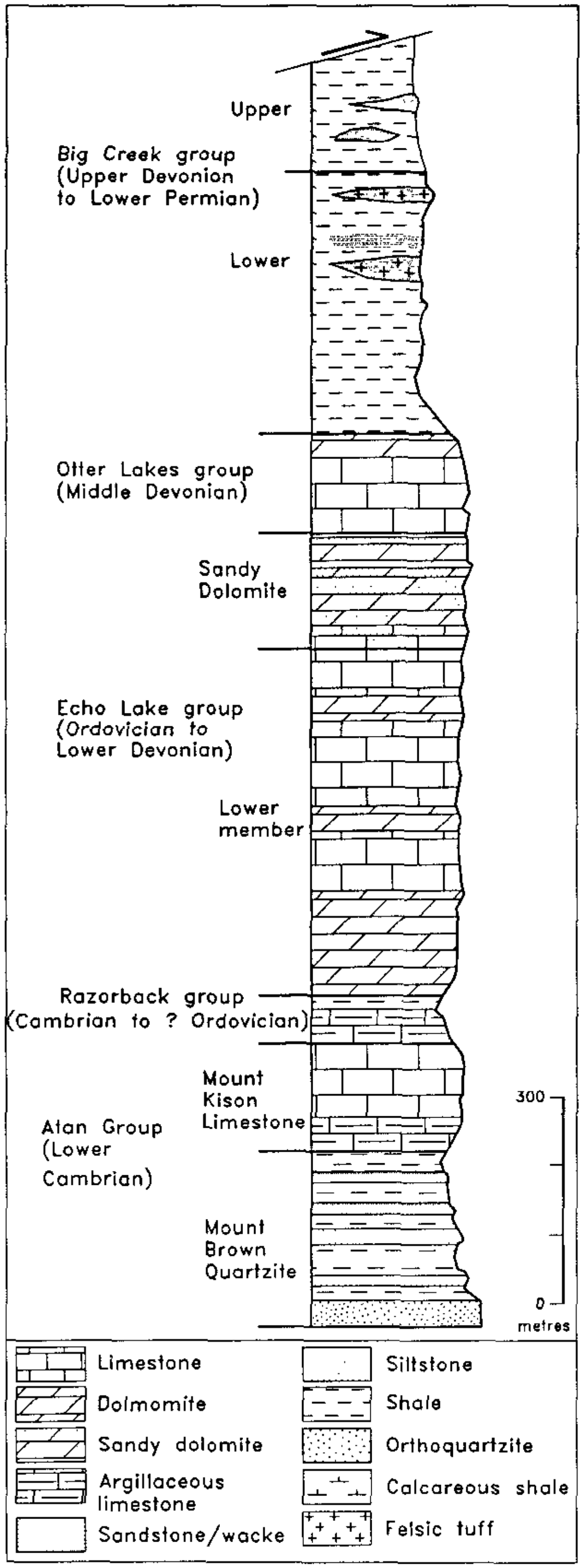

Figure 13. Stratigraphic column of Paleozoic stratigraphy as deduced in the northern part of the map sheet.

1993; Fritz, 1978, 1980). Quartzites, siltstones and shales of the Boya Formation are correlatives of the Mount Brown quartzite and carbonates of the Rosella Formation are equivalent to the Mount Kison limestone.

In the Cariboo Mountains, quartzites of the Yanks Peak Formation and shales to siltstones of the Midas Formation are probable correlatives of the Mount Brown quartzite (Struik, 1988a). The succeeding limestone and dolostones of the Mural Formation are equivalent to the Mount Kison limestone.

In the McLeod Lake area Struik (1989a, b), describes Lower Cambrian strata immediately east of the McLeod Lake fault. These interlayered quartzites and dolostones appear grossly similar to the Atan Group but share more similarities with Lower Cambrian strata east of the Rocky Mountain Trench.

The Atan Group in the study area shares some affinities with Lower Cambrian strata across the northern Rocky Mountain Trench (Gabrielse, 1975, McMechan, 1987, Thompson, 1989) but is by no means directly correlative to them. Directly northeast of the study area, Gabrielse (1975) describes a thick succession of quartzitic sandstones, siltstones, shales and minor carbonates, the base of which is not exposed. To the southeast of the map area Lower Cambrian strata are assigned to the Gog Group. The quartzites, shales and siltstones of the McNaughton Formation and the succeeding dolomitic sandstones, shales, and quartzites of the Mural Formation are probable correlatives of the Mount Brown quartzite and Mount Kison limestone, respectively.

Mount Brown Quartzite (Informal, Lower Cambrian)

The Mount Brown quartzite varies in thickness from 200 metres northeast of Echo Lake to upwards of 375 metres near Blue Lake. It is best exposed in the Mount Kison area with relatively good outcrops south of Henschel Creek and along Mount Brown.

Lithology: The succession is characterized by a white, grey, beige or brown, massive to thickly bedded orthoquartzite, 10 to 30 metres thick, at the base (Plate 9). It is typically fine to medium grained, but thin beds of quartz-granule conglomerate are also present. This basal unit is very distinct and an excellent marker.

Thin to moderately bedded olive-green to grey siltstone, shale and beige to tan, very fine to fine-grained sandstone comprise the remainder of the sequence. Typically the sandstone makes up less than 30% of the sequence, although sections of sandstone and quartzite up to 10 metres thick occur in the upper part. These massive sandstones occasionally contain vertical (*Skolithus?*) and bedding-parallel burrows. The basal shales may also contain tiny porphyroblasts of chloritoid.

Mount Kison Limestone (Informal, Lower Cambrian)

The Mount Kison limestone is best exposed near Mount Kison, for which it is named. It is an excellent marker and can be easily traced on air photographs. It forms good outcrops south of Henschel Creek and is well exposed along Flegel Creek. On outcrop scale this unit can be confused with carbonates of the lower Echo Lake group and the Espee Formation. Echo Lake carbonates generally contain quartz replacement and mottly or fenestral dolomitization not seen in the Mount Kison limestone. Espee carbonates contain areas of coarse-grained dolomitization and generally are more recrystallized than limestones of the Mount Kison sequence. The Espee Formation also tends to be more thinly bedded than the Mount Kison limestone.

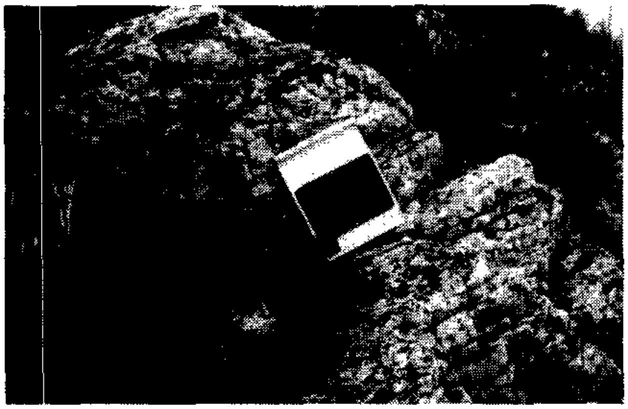

Plate 9. Highly resistant, white to grey orthoquartzites of the basal Mount Brown quartzite east of Henschel Creek. This unit is one of several excellent marker horizons within the sedimentary succession in the study area.

Lithology: The Mount Kison limestone is composed of approximately 200 to 230 metres of limestone and rare dolomite (Plate 10). The basal part of the succession comprises 20 to 50 metres of dark grey to grey, thin-bedded and platy, finely crystalline limestone and argillaceous limestone. This platy limestone is succeed by approximately 150 to 180 metres of massive, thick-bedded, fine to coarsely crystalline limestone and rare dolomite. Bedding in the upper part is outlined by thin, discontinuous to wispy argillaceous layers less than a metre long. Horizons of oolites, which may be silicified in the lower part of the section, are very rare. Archaeocyathids were found in this sequence immediately west of Mount Brown.

The lower contact of the Mount Kison limestone is transitional with the Mount Brown quartzite over a distance of approximately 5 metres; uppermost Mount Brown shales are succeeded by brown-weathering, nodular limestone and basal Mount Kison limestones.

RAZORBACK GROUP
(Informal, Middle Cambrian to Ordovician?)

The Razorback group is a poorly exposed sequence of argillaceous limestone and shale approximately 75 metres thick. Due to its recessive nature, only a handful of outcrops were mapped in the northern part of the study area. This unit was inferred throughout most of the north-

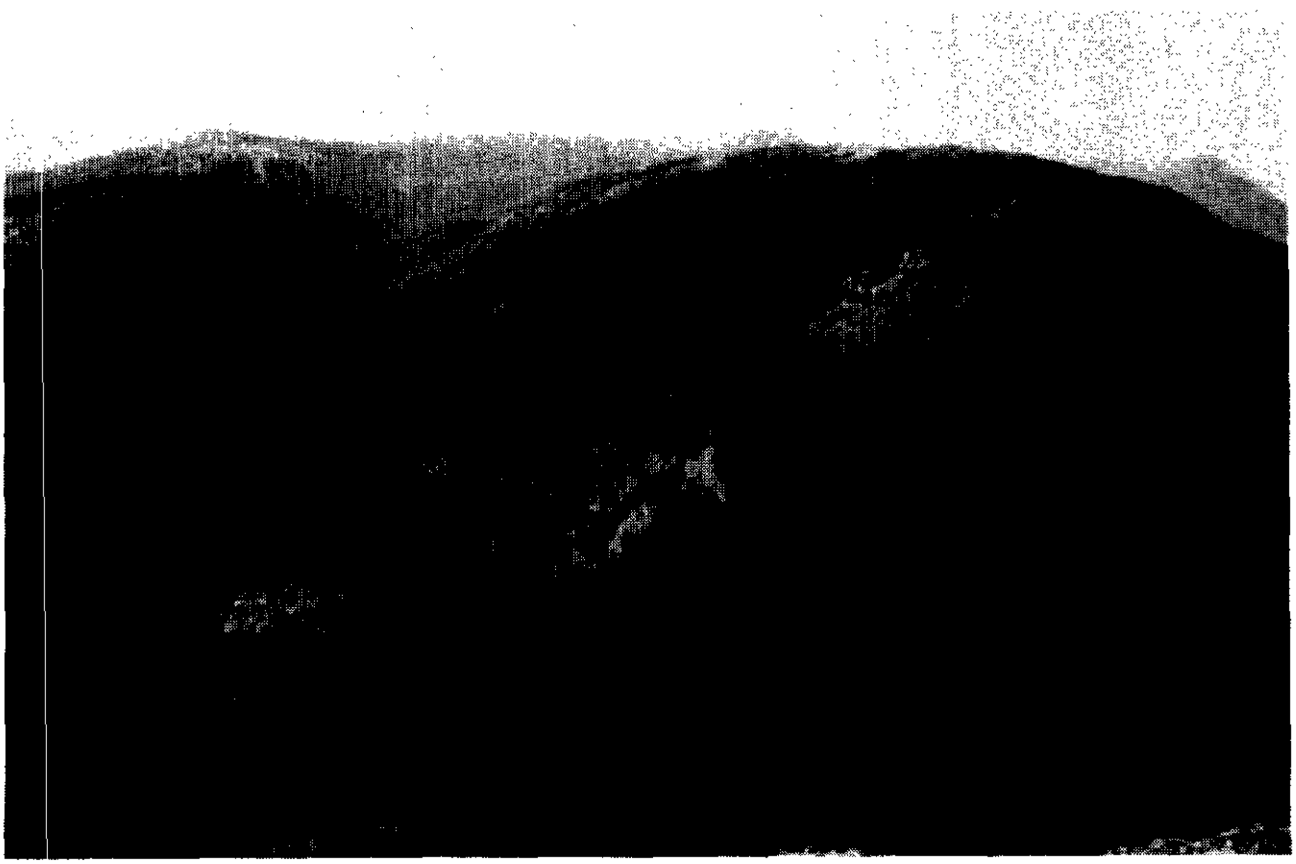

Plate 10. This picture shows the cliff-forming nature of the Mount Kison limestone as seen north of Mount Kison. This unit can be easily traced on air photos as it is the first major carbonate above the Espee Formation. The recessive slope between it and the Echo Lake group to the west, is underlain by the Razorback group.

ern part of the area by the recessive slope between the Mount Kison limestone and the Echo Lake group. Its best exposure occurs on a ridge running east from Razorback Mountain. It also outcrops along the ridge south of Henschel Creek and in the vicinity of Mount Kison.

Ferri and Melville (1990a, b) originally assigned rocks of the Razorback group to the Kechika and Road River groups based primarily on stratigraphic position of these argillaceous units between carbonates that were very similar to the Rosella Formation and Sandpile Group. They obtained fossil data from calcareous shales originally believed to be part of the upper section of the Razorback group indicating an Early Silurian age. These shales are now believed to be part of the lower Echo Lake group.

Age and Correlation

Lower Middle Cambrian trilobites have been recovered from the uppermost 10 metres of the Razorback group at Razorback Mountain (A.B. Mawer, R. Ludvigsen, personal communication, 1993; Appendix I). This suggests that the bulk of the Razorback group at Razorback Mountain is Middle Cambrian in age. To the northwest, along the Osilinka River and Wasi Creek, Ferri *et al.*, (1992a, b; 1993a, b) recovered Early to Middle Ordovician graptolites from argillaceous horizons thought to be equivalent to the Razorback group. Two possibilities may account for the discrepancies in age. If the rocks along the Osilinka River are Razorback equivalents then it suggests that Ordovician strata at Razorback Mountain have been removed by a pre-Echo Lake group unconformity. Alternatively the Ordovician shaly rocks may be tongues or thin lenses of argillaceous horizons within the Echo Lake group and are not equivalent to the Razorback group. This latter interpretation is more probable considering the lack of abundant carbonate horizons in the Ordovician shales in comparison to the Razorback section on Razorback Mountain. Further detailed work is needed to resolve this problem.

The Razorback Mountain succession represents the first documented occurrence of Middle Cambrian strata west of the northern Rocky Mountain Trench (Fritz *et al.*, 1991). If Razorback rocks are restricted to the Middle Cambrian then there are no correlatives to this unit within the northern part of the Cassiar Terrane. If the Razorback group is partly Ordovician in age then it would be equivalent to parts of the Kechika and possibly the Road River groups in the Cassiar Mountains (Gabrielse, 1963; Nelson and Bradford, 1987, 1993; Nelson *et al.*, 1988). This correlation is also based on the stratigraphic position of Razorback rocks above the Lower Cambrian Atan Group and below the Ordovician to Devonian Echo Lake group, a probable equivalent of the Sandpile Group exposed to the north (*see* Echo Lake group). Razorback strata bear more similarities with the Kechika Group than with rocks of the Road River Group. Fritz *et al.* (1991) noted the lack of Middle Cambrian strata within the northern Cassiar Terrane and suggested that it may be present as a condensed sequence within Kechika Group strata; a possibility that now seems quite likely.

The relative thinness of the Razorback group and the thick succession of younger carbonate rocks, reflects their probably position near the platformal facies of the carbonate belt (*see* Echo Lake group). The trilobite assemblage from the Razorback group suggests a slope setting (R. Ludvigsen, personal communication, 1993).

South of the map area, the time-equivalent of the Razorback group is the Dome Creek Formation of the Cariboo Group (Struik, 1988a; Table 2). This unit is relatively thin (less than 50 metres) and is dominantly argillaceous.

Middle Cambrian strata of similar thickness and composition are present east of the northern Rocky Mountain Trench in the middle part of the Kechika Trough (Fritz *et al.*, 1991). Kechika Group strata sit above the Middle Cambrian succession and reach thicknesses upwards of 1500 metres in the centre of the basin (Cecile and Norford, 1979). This suggests a different depositional environment for similar aged strata in the Germansen Landing area. Alternatively this may indicate that Kechika-like strata are missing in the Germansen Landing area or are a highly condensed sequence.

Lithology

In the Razorback Mountain area the basal 50 metres of the Razorback group is characterized by thin-bedded, grey to black argillaceous limestone separated by thinner, tan to brown-weathering argillaceous dolomite layers. The upper 25 metres of the group is typified by thinly bedded grey and dark grey shale and slate together with thin-bedded, dark grey to black argillaceous limestone. This argillaceous limestone can be up to 10 metres thick and is toward the top of the unit.

South of Henschel Creek, Razorback exposures are typified by grey to grey-green, brownish weathering strongly folded shales and calcareous shales. Thin to moderately bedded, strongly laminar, brown-weathering, dark grey argillaceous limestone is interlayered with thin dolomitic layers toward the top of the unit (Plate 11). Similar lithologies were mapped near Mount Kison.

ECHO LAKE GROUP
(Informal, Ordovician? to Lower Devonian)

The Echo Lake group takes its name from the spectacular cliffs it forms north of Echo Lake. It is the thickest carbonate sequence in the map area and can be traced from south of Blue Lake, northwestwards to the Osilinka River. It is upwards of 1000 metres thick (Plate 12) and is composed of two units; a lower limestone and dolomite sequence approximately 600 to 700 metres thick, followed by 100 to 200 metres of dolomite, sandy dolomite and quartzite referred to as the sandy dolomite unit.

This carbonate sequence was originally mapped as Sandpile Group by Ferri and Melville (1990a, b) based on its similarities with the Sandpile Group in the Cassiar Mountains (Gabrielse, 1963; Nelson *et al.*, 1988; Nelson and Bradford, 1987).

Plate 11. Thinly bedded and interlayered dolomitic and argillaceous limestone of the Razorback group east of Henschel Creek. These rocks grade upwards into limestones of the Echo Lake group.

Age and Correlation

Graptolites from shales at the base of this carbonate indicate an Early Silurian lower age limit. Conodonts recovered from the top of this unit in the Otter Lakes area, indicate an upper age limit of Early Devonian (Appendix I). The preceding discussion on the Razorback group indicated that Lower, and possibly Middle, Ordovician shaly horizons along Wasi Creek and Osilinka River (Ferri *et al.*, 1992a, b; 1993a, b) may be equivalent to the Razorback group. This suggests that the base of the Echo Lake carbonates may be as old as Middle Ordovician. Alternatively, if these shaly horizons are part of the Echo Lake group (as with the Lower Silurian graptolitic horizon) then the Echo Lake group is as old as the Early Ordovician, or possibly older.

This thick carbonate package, with its upper quartzites and quartzose dolomites, is very similar in age and lithology to the Sandpile Group of the Cassiar area (Gabrielse, 1963), but lacks the thick succession of fossiliferous reefal limestone which is typical of the Sandpile Group. This difference may be due to the depositional position of the Echo Lake carbonate with respect to the ancient carbonate platform.

The Echo Lake group is believed to represent part of the lower Paleozoic platformal or slope carbonate facies. A carbonate-to-shale facies transition occurs in the lower Paleozoic along the entire length of the Canadian Cordillera (Wheeler and McFeely, 1991, Figure 4). North of the map area, shales, argillites and argillaceous limestones of the basinal Ordovician to Silurian Road River Group are equivalent to thick carbonates farther east, across the transition boundary (Cecile and Norford, 1979). In the Cassiar area, Nelson *et al.* (1988) state that east of the Kechika fault the Road River Group is restricted to the Ordovician and appears much thinner. In this area (east of the Kechika fault), Upper Ordovician to Lower Devonian platformal carbonates are part of the Sandpile Group. West of the Kechika fault, thick Road River shales span the

Plate 12. Looking north at Razorback Mountain which is composed entirely of the Echo Lake group.

Ordovician to Silurian and the Sandpile Group is represented by the thinner Tapioca sandstone which is restricted to the Lower Devonian.

The Echo Lake group is Ordovician? to Early Devonian in age. This coupled with its extreme thickness and the relative thinness of the Razorback group indicates that it is part of a long-lived platformal carbonate sequence. The Sandpile Group in the Cassiar Mountains is extremely fossiliferous and believed to represent a reefal facies. Reefoid deposits are not observed in the Echo Lake group indicating off-reef, but not basinal facies.

On the east side of the McLeod Lake fault Struik (1989a, 1990) describes a sequence of carbonates and sandy dolomites which possibly span the Ordovician to Lower Devonian. The Ordovician Sandpile Group of the McLeod Lake area with its fossiliferous carbonate beds and quartzose layers, appears very similar to parts of the Sandpile Group of the Cassiar Mountains but has no correlatives in the study area. It is overlain by Lower Silurian limestone, dolostone and minor slate followed, in turn, by dolomite, sandy dolomite and quartzite thought to be Lower Devonian, based on similarities to the Tapioca sandstone in the northern Cassiar Terrane (Struik, 1989a). The Lower Silurian to Devonian sequence has similarities to the Echo Lake group in the map area.

Rocks of the Echo Lake group bear little resemblance to similarly aged lithologies of the Black Stuart Group in the Cariboo-Barkerville area (Struik, 1988a). They are thinner and composed primarily of slate with lesser chert and carbonate. Exceptions to this are the minor sandy carbonate, carbonate breccia and cherty dolomite of the chert-carbonate unit which bears similarities with the sandy dolomite unit.

Plate 13. Selective quartz replacement of carbonate of the Echo Lake group, near Razorback Mountain. These features appear organic in some localities and may represent algal structures.

Lower Member

The lower member of the Echo Lake group is characterized by sequences of light to medium grey, massively bedded limestone up to 2 metres thick. Sections of this carbonate member may be dolomitic as seen on Razorback Mountain where the lower few hundred metres of this unit is dolomite. Sections of bioclastic limestone several metres thick are found south of Echo Lake. The nature of the clasts is indeterminate, though some appear to be algal in origin.

Semicontinuous quartz lenses and "vugs" (replaced algal structures(?), 1 to 2 centimetres thick, occur within this member and sometimes form an interwoven network comprising up to 20% of the rock (Plate 13). These are well exposed on the ridge leading south from Razorback Mountain. Thin beds or lenses of grey chert and isolated bodies of polymict carbonate breccia up to 5 metres thick are also present along these horizons. Thickly bedded limestone of the lower member is interlayered with thinly bedded limestone and dolomite which commonly exhibits algal laminae and layers of silicified oolites and pisolites up to 2 centimetres in diameter (Plates 14, 15).

In the northern part of the map area the lower carbonate member of the Echo Lake group contains sections of grey to grey-brown shale and argillaceous limestone tens of metres thick. At one locality the shales contain monograptolites of Silurian age, perhaps from the Llandoverian stage.

Sandy Dolomite Unit

The sandy dolomite unit is some 100 to 200 metres thick and is characterized by moderately to thickly bedded dolomite, sandy dolomite and quartzite. The dolomite is usually massive though thin sections of algal laminae are occasionally present. The sandy dolomite is light grey to grey in colour, massive and comprised of up to 30% well-rounded medium-grained quartz grains. Grey to black quartzite layers, 1 to 2 metres thick, are present in the uppermost part of this unit. The quartzite is very pure, having greater than 95% well-rounded quartz grains with the remainder being carbonate cement. The quartzite is volumetrically a minor part of the unit (less than 5%) but an important feature, nevertheless. Dark grey to grey argillite and siltstone are also present, but rare in this unit.

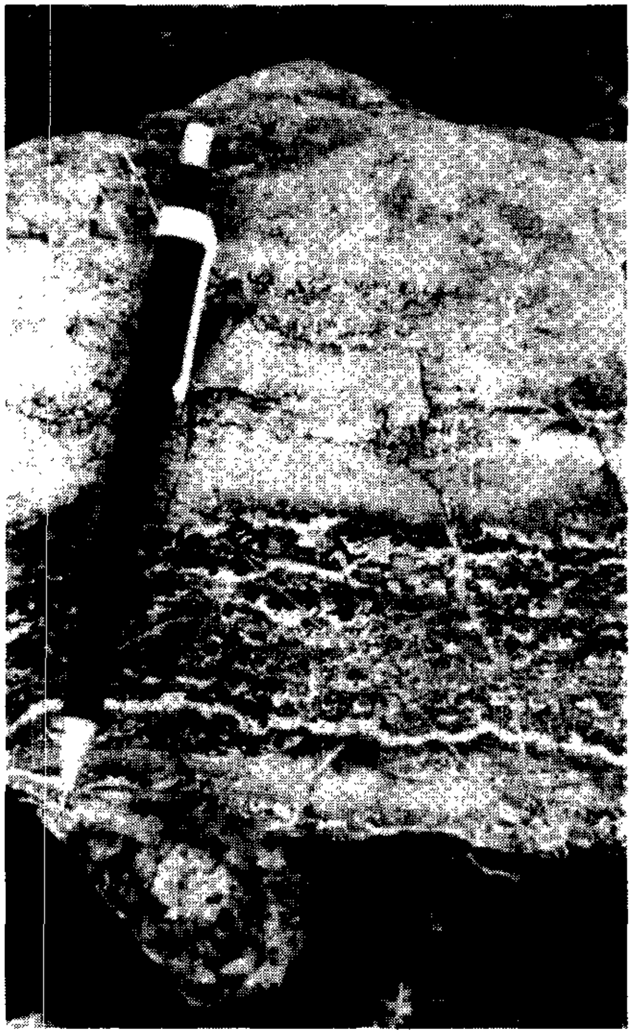

Plate 14. Variably dolomitized algal laminae in Echo Lake group, near Razorback Mountain. This dolomitization is typical of the lower part of the Echo Lake group.

Plate 15. Silicified pisolites in the Echo Lake group near Razorback Mountain. This lithology is only locally developed and is very distinct within the rather monotonous carbonate of the Echo Lake group.

OTTER LAKES GROUP (Informal, Middle Devonian)

The Otter Lakes group forms the top of the Paleozoic carbonate succession in this area. Monger and Paterson (1974) noted that its faunal assemblages are no younger than Middle Devonian and thus not part of the Cache Creek Group as theorized by Armstrong (1949) and Roots (1954). This dark grey, fetid, fossiliferous dolomite, with its abundant occurrences of replacement lead-zinc-barite mineralization, is very similar to McDame Group strata described farther north (Gabrielse, 1963; Nelson and Bradford, 1987, 1993; Nelson *et al.*, 1988). This led Ferri and Melville (1990a, b) to refer to these rocks as the McDame Group. They are now named after two small lakes centred within an area containing extensive lead-zinc mineralization (Figure 7).

Age and Correlation

The presence of twin-holed crinoid columnals, together with conodont data (Appendix I), indicates that these rocks are no younger than Middle Devonian. Their location above Lower Devonian carbonates (Echo Lake group) and their similarities with the McDame Group indicate that they are probably restricted to the Middle Devonian.

Direct correlatives of the Otter Lakes group within the Cassiar Terrane are carbonates of the McDame Group of the Cassiar area (Table 2). Nelson and Bradford (1987, 1993) describe fossiliferous, dark grey fetid dolostones and limestones that host several showings of lead-zinc-silver-barite mineralization.

In the McLeod Lake area, Struik (1990) notes grey and dark grey finely crystalline limestone of Middle Devonian age. In the Cariboo-Barkerville area only minor Middle Devonian carbonate occurs within rocks of the Black Stuart Group (Struik, 1988a).

Lithology

The Otter Lakes group is some 150 to 200 metres thick and is characterized by grey to black fetid limestone and dolomite. Exposures tend to be poor and, away from known mineral occurrences, the map trace is tentative. These strata are only present in the northern part of the map area, where they form a semicontinuous trace from south of Blue Lake, northwestward to the Osilinka River. Exposures are good around Otter Lakes and along Flegel Creek.

Two members of the Otter Lakes group are recognized. This distinction cannot always be made and in places lower Otter Lake group limestones crop out immediately below the Big Creek group. The lower part of the group is characterized by thin to thick-bedded, dark grey to black, fetid limestone. The limestone, although not abundantly fossiliferous, contains rugosan corals, brachiopods, gastropods, bryozoa(?), amphipora and beds of crinoid ossicles, some of which exhibit twin-holed columnals. Parts of the unit are coarsely recrystallized and contain vugs filled with calcite and pyrobitumen. The upper part of the group is characterized by a slightly fetid grey to tan, finely crystalline dolomite and minor limestone which may show faint bedding.

BIG CREEK GROUP
(Informal, Upper(?) Devonian to Lower Permian)

Shales, argillites, minor sandstones and tuffs (Gilliland tuff) of the Big Creek group were originally placed within the argillaceous member of the Cache Creek Group by Armstrong (1949) and Roots (1954). Gabrielse (1975) noted their similarity to Upper Devonian strata in the Cassiar Mountains but, due to poor fossil control, placed them with a group of rocks now equivalent to the Nina Creek group. Ferri and Melville (1990a, b) called the lower part of this succession the Earn Group due to its similarities to strata in the Cassiar Mountains (Gabrielse, 1963; Nelson and Bradford, 1987). Ferri *et al.,* (1993a, b) referred to the upper part of the Big Creek group as the Cooper Ridge group after an earlier version of the present work. It is now felt that there is not enough distinction between rocks of the Big Creek and Cooper Creek groups to classify them separately and the term Cooper Ridge group has been discarded. The Big Creek group now encompasses all rocks between the Otter Lakes and Nina Creek groups.

These rocks are well exposed near the headwaters of Big Creek. The unit also sporadically crops out south of the Otter Lakes in a series of small fault blocks, along the banks of the upper parts of Flegel Creek and along Cooper Ridge. The upper part of this sequence forms good exposures north and east of Mount Howell.

The upper part of the Big Creek group was originally placed within the Slide Mountain Group (unit PPsml) of Ferri and Melville (1990a, b), but is now believed to be part of Cassiar Terrane stratigraphy. This is based on several factors: conodonts recovered from the top of the unit indicate a continuous stratigraphic sequence between it and strata now interpreted as the lower part of the Big Creek group; the conodont species (Appendix I) are more indicative of a shallow marine environment rather than the ocean floor setting of the Nina Creek group (M. J. Orchard, personal communication, 1990; Struik, 1988a); argillites and shales of this unit apparently grade conformably into those of the lower Big Creek group and lithologically this unit has more similarities to the Big Creek argillites, shales and minor clastics than to the cherty sediments and igneous rocks of the Nina Creek group.

The overlying Pennsylvanian to Permian Nina Creek group must rest structurally above the Big Creek group. Rocks of the Nina Creek group are part of the allochthonous Slide Mountain Terrane. Therefore the upper part of the Big Creek group marks the top of North American stratigraphy in the area.

Argillites and carbonates of the upper Big Creek group were not recognized in the far northwestern part of the map area (west of Mount Howell). Their absence in this area may be due to non-deposition or, more likely, to faulting as shown in the cross-sections (Figure 8).

Highly tectonized argillites and calcareous argillites along the Manson fault zone and southwest of Munro Creek are tentatively assigned to the Big Creek group, but they may represent fault slices of argillites belonging to the Triassic Slate Creek succession. The strongly sheared nature of lithologies makes their assignment equivocal.

Age and Correlation

Microfossil collections have been recovered from an interlayered limestone and siliceous limestone unit in the uppermost part of the Big Creek group (Appendix I). These conodonts and fusulinids indicate an Early Permian upper age limit. Conodonts recovered from the middle part of the unit in the Otter Lakes area yielded an early Mississippian age (Appendix I). The stratigraphic position of the Big Creek group above the Otter Lakes group, and its similarity to the Earn Group farther north, suggest a lower age limit of Late Devonian. Dark grey to grey wavy argillites with minor limestone and rare tuff in the upper part of the unit sit stratigraphically above the early Mississippian fossil locality. Underlying rocks are typically blue-grey planar bedded argillites and shales with minor sandstones, wackes and felsic tuff.

Preliminary U-Pb geochronometry has been obtained from zircon concentrates from the Gilliland tuff (Appendix II). The best estimate for the age of this tuff is 377.3 ± 12 Ma taken from the intercept of the three-point regression line (Figure 68). The upper intercept on the concordia plot is at approximately 2.43 Ga, clearly indicating the presence of Precambrian inheritance. These zircons have experienced lead loss suggesting that the age of the tuff may be older (Appendix II).

The lower part of the Big Creek group is broadly correlative to the blue-grey, fissile shales of the Devono-Mississippian Earn Group in the Cassiar area. The Earn Group is also characterized by minor amounts of chert, quartz wackes and sandstones (black clastics) which are also a small component of the Big Creek group. The Earn Group is also noted for occurrences of stratiform lead-zinc-barite mineralization. The presence of stratiform barite in shales and argillites in the Munro Creek area suggests that they are part of the Big Creek group.

Correlative of the Big Creek group in the Cariboo-Barkerville area is the Upper Devonian and Lower Mississippian Guyet Formation (Struik, 1988a) which is predominantly a clastic sequence composed of conglomerate, sandstone and greywacke. These lithologies form a minor part of the Big Creek group.

Struik (1990) describes dark grey to black slate, argillite and minor limestone of Carboniferous (Tournaisian) age, east of the McLeod Lake fault. The characteristics of this package are very similar to those of the Big Creek group.

Devono-Mississippian felsic tuff is observed elsewhere in rocks of North American affinity in the Cordillera. Schiarizza and Preto (1987) describe bodies of Middle Devonian to upper Mississippian rhyolitic material within the Eagle Bay and Fennell successions in the Adams Plateau area. Eagle Bay rocks are part of North American stratigraphy and some are time correlatives to rocks of the Big Creek group.

Mafic volcanic rocks of possibly similar age are also found in the Black Stuart Group (Struik, 1988a). Agglomerate, tuff and pillow basalt make up the bulk of the Waverly Formation which Struik tentatively correlates with the Earn Group, a direct correlative of the Big Creek group.

Felsic volcanics are not recognized in the Devono-Mississippian Earn Group of the Cassiar area but are well documented in the Earn Group of the Selwyn Basin (Gordey *et al.*, 1991). They include tuff, breccia, flow rocks and their small intrusive equivalents.

The Mississippian to Permian upper section of the Big Creek group is in part correlative with Mississippian to Permian sediments in the northern part of the Cassiar Terrane (Nelson and Bradford, 1993). The sediments in the Midway area are characterized by varicoloured ribbon chert which is not found in the Big Creek group. Similar age sequences south of the map area are slates and carbonates of the Allex Allan Formation and succeeding Pennsylvanian carbonates of an unnamed unit (Struik, 1988a).

Struik (1989a, 1990) describes tuff and cherty tuff of Permian age in the McLeod Lake area. They sit above argillite, slate and limestone which are in part Carboniferous. This tuff and argillite has an overall similarity to rocks of the upper Big Creek group, though tuff in the latter is subordinate.

Permian sediments are uncommon in the Cassiar and Kootenay terranes, but Struik (1988a) described Permian crinoidal limestone (Sugar limestone) in the Barkerville area which is part of the Barkerville (Kootenay) Terrane.

Lithology

A sequence of shales and argillites is exposed near the headwaters of Big Creek and is assigned to the Big Creek group. This unit is 600 to 800 metres in thickness and characterized by blue-grey or dark grey shales, argillites, limestone, felsic tuff and sandstones. Typical Big Creek shales are confined to the northern parts of the map area, between Blue Lake and the Osilinka River. Occurrences of similar shales are found in the south, primarily along the Manson fault zone and south of Munro Creek. In these areas the unit is much thicker, due to faulting, and is probably tectonically interleaved with rocks of the Slate Creek succession.

The Big Creek group has been locally subdivided into two parts based primarily on the character of bedding within the argillites. Shales and argillites in the lower part of the Big Creek display highly planar bedding, in contrast to the wavy bedding in the shales and argillites of the upper part.

Lower Part: The lower shales are extremely fissile, forming large, thin, flexible sheets several millimetres thick, and have a characteristic blue-grey colour (Plate 16). Up-section these shales become interlayered with thicker bedded argillites and silty argillites. This sequence is approximately 400 to 500 metres thick.

Plate 16. Grey, extremely fissile shales of the Big Creek group, northwest of Echo Lake. This shale typically breaks into large, thin, flexible sheets which is characteristic of this unit.

Southwest of Mount Brown, approximately 30 metres of thickly bedded quartz-chert sandstones are found in the upper part of this sequence. These sandstones contain thin, discontinuous layers of dark grey to black argillite, very similar to lower Big Creek group. The sandstone is predominantly quartz (greater than 90%) with the remainder being chert (Plate 17). The grains are rounded and medium to coarse grained.

Limestone, though rare, is exposed in the upper parts of this succession. It is dark grey to black, argillaceous and only a few metres thick. Near Munro Creek the argillites and slates can be calcareous and approach an argillaceous limestone in composition. A buff-weathering, white to beige, recrystallized limestone is exposed near Munro Creek. It is upwards of 5 metres thick and contains thin to moderately thick beds of calcareous siltstone or phyllite. Its stratigraphic position is uncertain due to poor exposure and tectonic disruption near the Wolverine fault zone. This limestone may be part of the upper section of the Big Creek group.

Barite occurs in the slates and argillites of this sequence in the southeastern quarter of the map area.

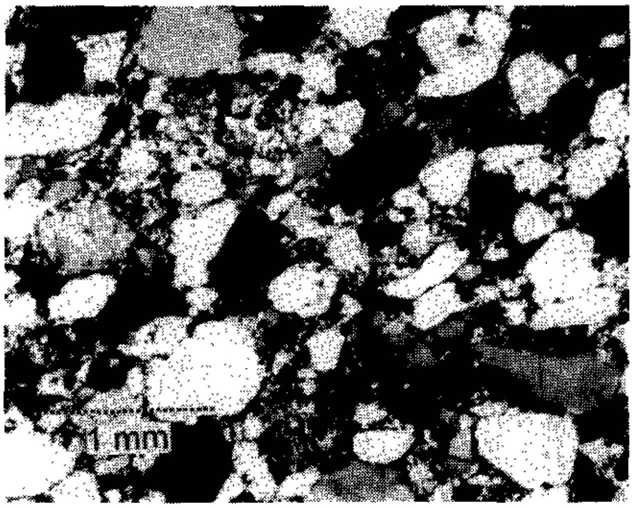

Plate 17. Photomicrograph of quartz-chert sandstone to wacke ("black clastic") in the upper part of the Big Creek group along the south side of Flegel Creek. This sandstone sequence is up to tens of metres thick.

Moderately bedded barite is exposed along a creek between Gaffney and Munro creeks (McCammon, 1975) in sections up to 7 metres thick (*see* also Table 6 and chapter on Economic Geology).

Gilliland Tuff: Light coloured felsic tuff outcrops at several localities within the lower Big Creek group. Tuffs form both thin, discontinuous layers less than a metre thick and large bodies up to several square kilometres in area.

A poorly exposed, northwest-trending body of dacitic tuff crops out on the north shore of the Omineca River, opposite Germansen Landing and is referred to as the Gilliland tuff. The best exposures are just below the bridge and on the north side of the road leading into the Gilliland Lodge. Approximately 5 kilometres southeast along strike, is another body of tuff. Its outline is tentative as it is based on only four outcrops.

This unit is surrounded by argillites of the Big Creek group and contact relationships are not seen. The rocks are grey to cream on fresh surface and grey to brown weathering. They are composed of up to 30% quartz clasts, 5 to 10% plagioclase and potassic feldspar crystal fragments, 1 to 2% muscovite and biotite and minor hornblende and zircon. The groundmass is recrystallized to sericite, carbonate, quartz and chlorite. The best-preserved quartz clasts exhibit resorption embayments and the mica is commonly bent. The tuffs display a penetrative foliation.

Similar tuff beds are found in the hydraulic pits along the Germansen River approximately 2 kilometres southwest of Germansen Landing. At this locality tuff beds, 20 centimetres to more than 2 metres thick, are in sharp contact or grade into the phyllites and argillites. They occasionally contain rip-up clasts of argillite and fill scour channels in the sediments. They are white to cream in colour, tan to rusty weathering and contain up to 80% coarse quartz and feldspar crystal fragments which are sometimes graded.

Upper Part: This unit can be easily confused with shales and argillites of the lower Big Creek group. Generally, the older shales are highly planar which is atypical of shales and argillites in the upper section.

The upper part of the Big Creek group is some 200 to 300 metres thick in the northwestern corner of the map area. Elsewhere it may be tectonically interleaved with other argillite packages and its thickness is unknown. It is composed predominantly of grey to dark grey or black, rusty weathering, thin-bedded, wavy to platy argillites (Plate 18). Of lesser importance are argillaceous limestone, quartz wacke and felsic tuff. Argillite may grade into slates or phyllites with cleavage becoming the dominant planar fabric. These slates and phyllites predominate in the southern half of the map area.

The upper part of this succession contains 5 to 10-metre sections of thickly bedded, interlayered buff-weathering limestone and silicified limestone (Plate 19). The siliceous limestone typically appears cherty and is the only cherty material within this sequence.

Lenses of dark grey to black, massive to poorly bedded chert-quartz wacke, 10 to 20 metres thick, are


Plate 18. Massive to weakly fissile argillites and shales of the upper part of the Big Creek group northwest of Mount Howell.

Plate 19. Interlayered limestone and silicified limestone immediately below (structurally) Nina Creek sediments northeast of Cooper Ridge. This sequence of carbonates yielded Permian conodonts suggesting a continuous stratigraphic sequence with underlying rocks of the Big Creek group.

sporadically exposed in the lower parts of this sequence. The clasts are fine to coarse grained, subangular to subrounded, predominantly chert, and make up less than 50% of the rock (Plate 20). These rocks are well exposed near Cooper Ridge.

In the far northwestern corner of the study area several metres of light grey to cream-coloured quartz-bearing felsic tuff are present within the succession. The tuff contains upwards of 20% medium-grained subhedral quartz crystals and crystal fragments which commonly

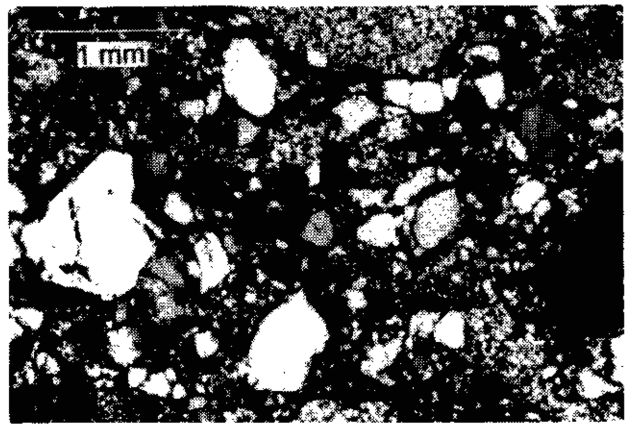

Plate 20. Photomicrograph of quartz-chert wacke (black clastic) from northeast of Cooper Ridge. These clastic rocks are a very minor component in the upper part of the Big Creek group and commonly contain a northwest-trending lineation produced by stretched clasts.

show resorbed margins. These rocks are similar to the Gilliland tuff but may be younger. Alternatively, they may be a fault repetition of Gilliland tuff from the lower part of the Big Creek group.

BLUE LAKE VOLCANICS (Informal, Eocene?)

Massive, dark grey, olivine-bearing basalts and volcanic breccia crop out near Blue Lake (A. D. Halleran, personal communication, 1989). Only a few scattered outcrops of basalt were observed during mapping and, based on aeromagnetic data, we believe that these basalts are restricted to within 1 kilometre of Blue Lake. These rocks lack the penetrative fabric seen in surrounding Paleozoic and Proterozoic sediments.

Several undeformed, mafic dikes cut rocks of the lower Swannell Formation near Munro Creek and in the lower Ingenika Group northwest of the Manson River. These intrusions have been included with the Blue Lake volcanics.

Age and Correlation

Extensive post-Jurassic mafic volcanics in the Fort St. James area were assigned to the Endako Group by Armstrong (1949). He suggested they are Oligocene or younger based on stratigraphic relationships. More recent work indicates that Endako Group volcanism is of Eocene age (Mathews, 1989; Souther, 1991).

INTERMONTANE SUPERTERRANE

In the map area the Intermontane Superterrane is represented by the Quesnel and Slide Mountain terranes and the Harper Ranch Subterrane. Arc-related sediments and volcanics of the Quesnel Terrane belong to the Middle Triassic to Lower Jurassic(?) Takla Group. The Harper Ranch subterrane is a subdivision of Quesnellia and is represented by the upper Paleozoic Lay Range assemblage, a sedimentary and volcanic arc sequence.

Harper Ranch rocks in southern British Columbia are unconformable below Mesozoic strata of Quesnellia (Monger *et al.*, 1991). The upper Paleozoic Slide Mountain Terrane comprises the Manson Lakes ultramafics, and oceanic volcanics, sediments and mafic igneous rocks of the Nina Creek group.

SLIDE MOUNTAIN TERRANE

NINA CREEK GROUP
(Informal, Mississippian to Permian)

In the Manson Creek and Germansen Landing areas rocks of the Nina Creek group were first described by Armstrong (1949) who placed them within the Manson Lakes belt of the Cache Creek Group, on the basis of the lithologic similarities between the two assemblages. He used the term "Nina Creek greenstones" to describe the thick sequence of volcanics in the upper part of the Nina Creek group. Monger (1973), Monger and Paterson (1974) and Gabrielse (1975) realized the distinct nature of these rocks, although they did not formally name them. Monger (1977a) described the most complete sequence of this package in the Nina Creek area and compared it with other Paleozoic volcanic assemblages along the belt. Ferri and Melville (1988, 1989, 1990a) termed these rocks the Slide Mountain Group based on their apparent similarities to rocks described in the Barkerville-Cariboo area to the south (Struik, 1988a).

They are now termed the Nina Creek group in accordance with early workers (Armstrong, 1949; Monger, 1977a) who made reference to Nina Creek in describing the package. It is felt that a local name will better differentiate them from similar rocks elsewhere along the belt.

In the northern part of the map area these rocks are beautifully exposed around the headwaters of Nina Creek. Here, a thickness of nearly 7 kilometres of basalt, argillite, gabbro, chert, siltstone, and minor sandstone make up the Pennsylvanian to Permian Nina Creek group. It has been subdivided into two informal units, the lower Mount Howell succession, which is composed of siliceous argillite, chert, gabbro and siltstone and the upper Pillow Ridge succession which is predominantly basalt. At Nina Creek these units form an apparently continuous southwest-dipping stratigraphic package, whereas to the south, the group has been dissected by the Manson fault zone and this apparent stratigraphic continuity is lost.

Basal sedimentary rocks of the Nina Creek group appear to rest conformably on sediments of the Big Creek group. Fossil data show that a major thrust fault separates these rocks from rocks of the Cassiar Terrane. These data also indicate the presence of a significant thrust between both successions of the Nina Creek group. The thrust faults delineated thus far also suggest that the internal geometry of each succession of the Nina Creek group may be an imbricate thrust stack.

The compositional similarity of gabbroic sills in the upper part of the Mount Howell succession with basalts of the Pillow Ridge succession suggests they are feeders to the basalts. Yet fossil data from both successions indicate a thrust fault separates the two along their eastern contact. Reconciliation of data leads us to assume that basalts which were fed by, and were immediately above the gabbroic bodies were thrust eastward and replaced by older and/or more westerly derived basaltic successions. Basalts above the fault slivers of Mount Howell sediments northwest of Nina Lake are assumed to rest conformably above these sediments as fossil data are lacking within basalts stratigraphically above this contact.

The similarity of Nina Creek sediments with Mississippian to Permian rocks of the Cassiar Terrane suggests a genetic relationship between them. However, feeders for the basalts of the Pillow Ridge succession are lacking in North American rocks, indicating that the basalts were formed in a setting different than Cassiar rocks. Data obtained by ourselves and others (Gabrielse, 1975), indicate that the Nina Creek group represents ocean-floor material. This, in conjunction with data from elsewhere along the belt, suggests that these rocks were formed in a basin near the western margin of North America and were thrust onto North American rocks during later compressional tectonism.

Age and Correlation

Fossil collections by the authors (*see* Appendix I) and others (Monger, 1977a; Gabrielse, 1975) indicate that the Nina Creek group spans the Mississippian to Permian periods. Fossil data also show that each succession within the Nina Creek group is roughly time equivalent (Figure 14). Thus, a major thrust fault must separate the two major packages within the group. This implies that volcanic rocks of the Pillow Ridge succession have been thrust eastward onto sediments of the Mount Howell succession which, in turn, have been placed on top of argillites of the Big Creek group. If this thrust stack follows normal relationships (Boyer and Elliot, 1982) this implies that the basalts of the Pillow Ridge succession represent more distal parts of the Nina Creek basin and that the Mount Howell succession was deposited closer to the North American craton. This is explained in more detail below.

The Nina Creek group is part of the Slide Mountain Terrane, a semicontinuous belt of oceanic rocks that can be traced along the entire length of the Canadian Cordillera (Figures 15 and 16). Rocks of the Slide Mountain Terrane have been described as an ophiolitic sequence (Monger, 1984) though all the elements of a classic ophiolite are not always present. Parts of the Nina Creek group are very similar to rocks seen within nearby correlatives such as the Sylvester allochthon to the north and the Slide Mountain Group to the south, (Figure 15). These similarities include the thick volcanic sequence, cherty sedimentary package and argillite sequence.

Correlations of Paleozoic oceanic rocks along the entire belt have been made in the past (Monger, 1977a) and have shown the similarities of the various units. A brief account of the various units within the Slide Mountain Terrane of the Canadian Cordillera is given below, to show how they correlate with the Nina Creek group.

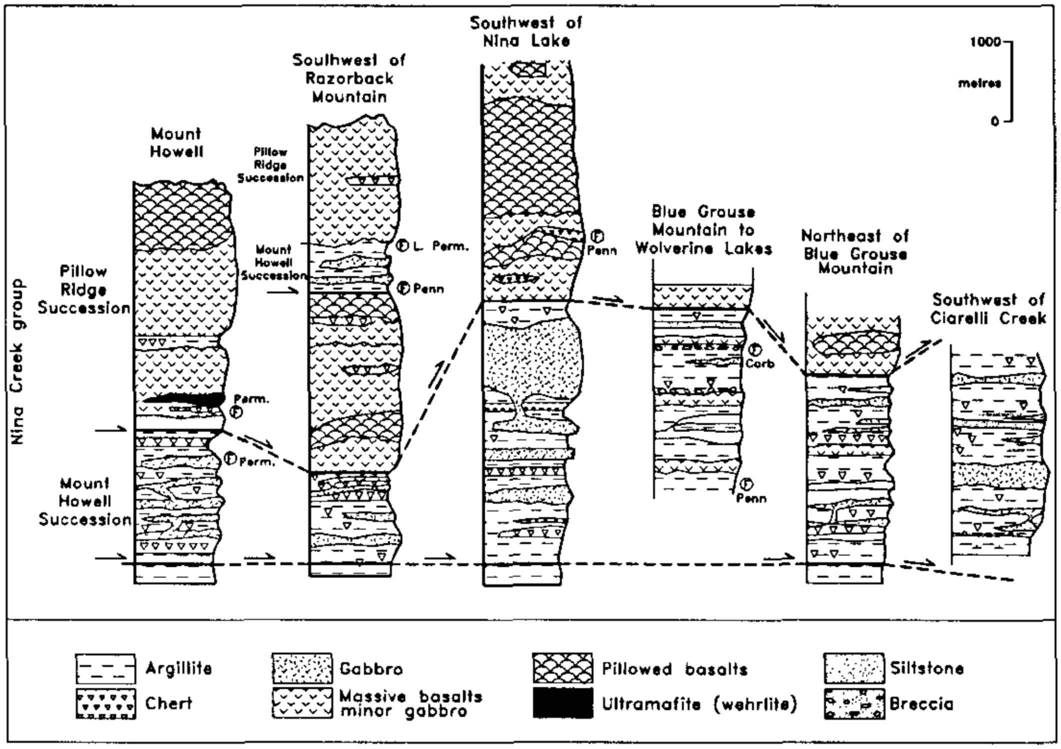

Figure 14. Schematic stratigraphic columns of Nina Creek Group within the map area.

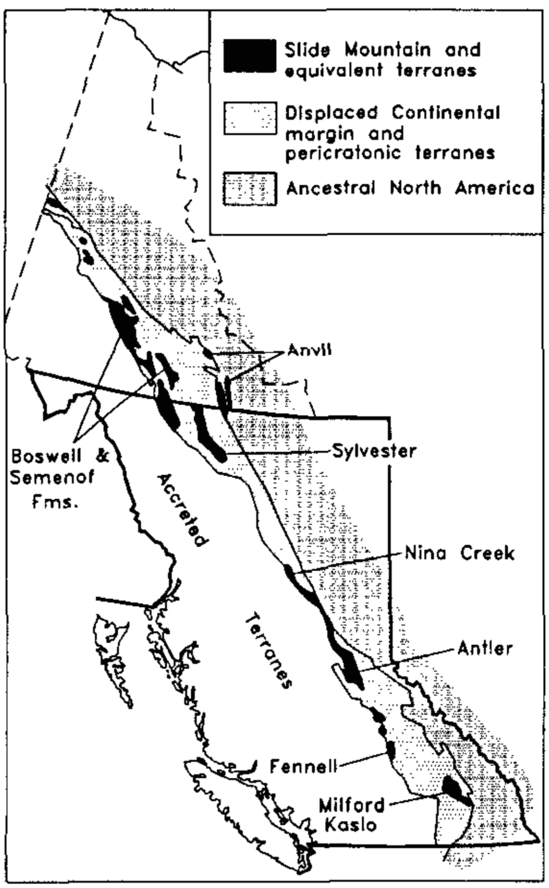

Figure 15. Distribution of the Slide Mountain assemblage throughout the Canadian Cordillera.

Rocks of the Sylvester allochthon represent highly dismembered ophiolitic and island arc suites. Workers in this region (Nelson and Bradford, 1987, 1993; Nelson *et al.*, 1988; Harms, 1984, 1985a, b, 1986) have subdivided this package into three divisions, all of which span the early Mississippian to Permian time period. Units within each division are in thrust contact with each other as indicated by older-over-younger conodont ages. This further emphasizes the highly imbricated nature of the allochthon. Divisions I and II represent rocks of oceanic (ophiolite) affinities whereas rocks of Division III have an island arc signature.

Division I consists predominantly of argillite, siliceous argillite, varicoloured chert, limestone, siltstone, sandstone and minor diabase sills and basalt. Cherty sediments and basalt form the younger or upper part of the sequence. These rocks are probable correlatives of the Mount Howell succession, though Division I contains sediments as old as early Mississippian. The oldest sediments yet recorded in the Mount Howell succession are early Pennsylvanian.

The structurally higher Division II is composed predominantly of basalt-diabase-sediment sequences and slivers of ultramafic rocks. This package has an overall similarity with rocks of the Pillow Ridge succession.

In the Nisutlin Plateau of the Yukon Territory, rocks of the Slide Mountain Terrane are represented by the Boswell and Semenof formations (Monger *et al.*, 1991). The lower to middle Pennsylvanian Boswell Formation appears correlative with the Mount Howell succession. This is based on the predominance of slate at its base which is followed by chert, greywacke, grit, greenstone

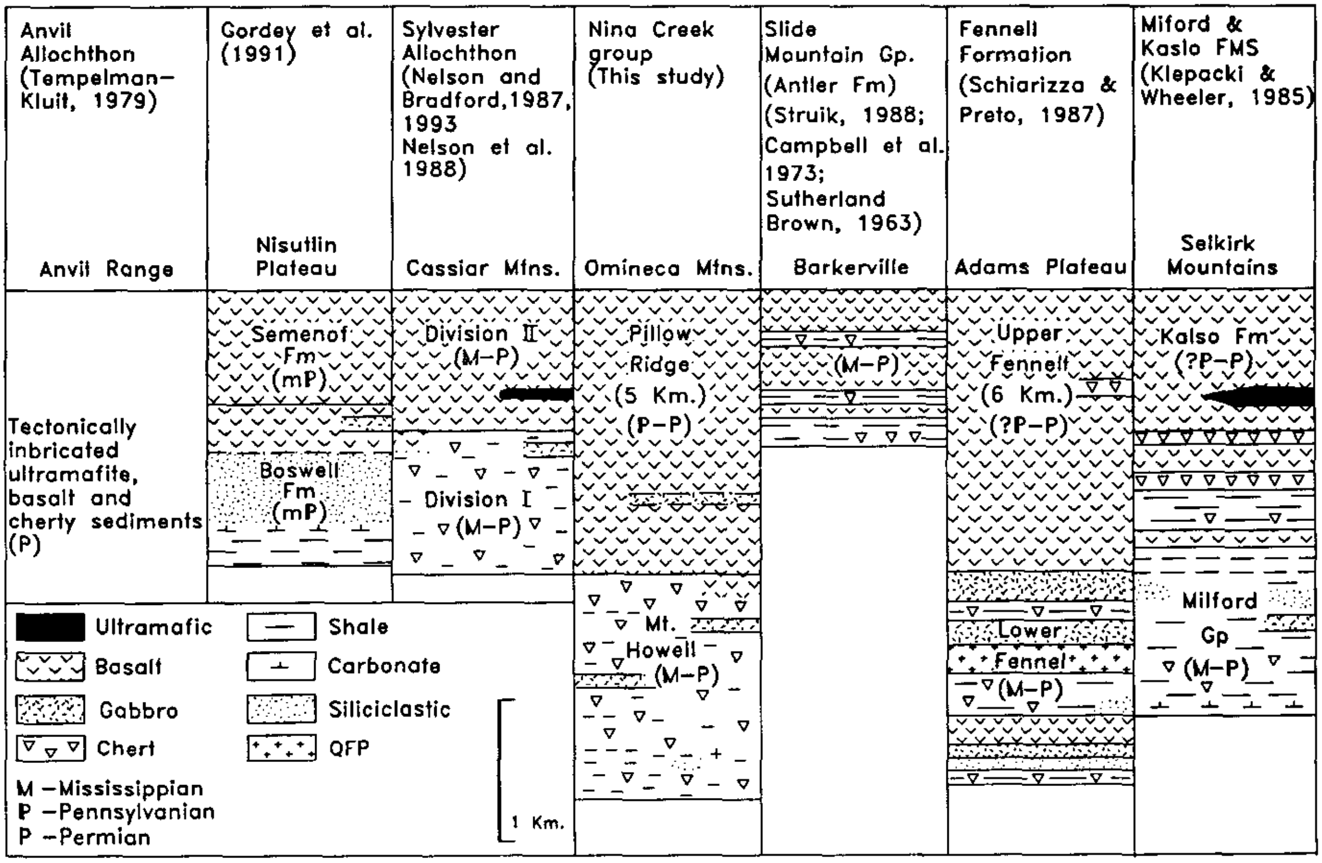

Figure 16. Stratigraphic correlation chart of the Nina Creek group and other formations of the Slide Mountain Terrane of the Cordillera (modified from Monger, 1977). along the length

sills and capping pillowed volcanics. The upper Pennsylvanian Semenof Formation with its massive basalt is directly correlative with the lower parts of the Pillow Ridge succession.

In the eastern part of the Yukon Territory, strongly dismembered rocks of the Anvil allochthon (Tempelman-Kluit, 1979) are most likely correlative with rocks of the Nina Creek group. In this region argillaceous and tuffaceous cherts of the Anvil Range Group (Gordey, 1983) are Early Permian in the upper part and are followed by massive to pillowed basalts. These may be equivalent to the Mount Howell and Pillow Ridge successions, respectively.

To the south, in the Cariboo-Barkerville area (Struik, 1988a, Campbell *et al.*, 1973, Sutherland Brown, 1963) and in the Prince George area (Tipper, 1961; Struik, 1985), the Slide Mountain Terrane is represented by the Slide Mountain Group. This package is predominantly basalt, chert, cherty argillite and diabase, with lesser agglomerate, greywacke, black slate and ultramafite. Struik (1988a) and Struik and Orchard (1985) describe conodont suites from the Slide Mountain Group which span the early Mississippian to Permian periods. Sutherland Brown (1963) reports that cherts and argillites are more abundant in the lower part of the Slide Mountain Group. This sequence of rocks is very similar in age and lithology to the Nina Creek group.

In the Adams Lake area, Schiarizza and Preto (1987) describe rocks belonging to the Mississippian to Permian Fennell Formation. In this region, the structurally lower division consists of chert, diabase, gabbro, sandstone, quartz feldspar porphyry and lesser basalt. These rocks are succeeded by the structurally higher division composed almost entirely of Permian and possibly Pennsylvanian basalt. These units are correlative with the Mount Howell and Pillow Ridge successions, respectively.

Farther south, basalts, cherts and ultramafites of the Pennsylvanian(?) to Permian Kaslo Group correlate with similar lithologies of the Pillow Ridge succession. The Mississippian to lower Pennsylvanian Milford Group, with its siliceous sediments, limestones and volcanics, appears grossly similar to the Mount Howell succession. This package unconformably overlies sedimentary rocks of North American affinity (Klepacki and Wheeler, 1985).

Mount Howell Succession (Informal, Mississippian To Permian)

This succession is named after Mount Howell where it is well exposed along a broad, northwest-trending syncline. In the type area the succession is upwards of 1 kilometre thick and in the central part of the study area it is estimated to be some 2.5 kilometres thick. In the southern part of the study area structural complexities and poor exposures do not allow even an approximate estimate of thickness.

This unit is well exposed along a series of ridges emanating from Cooper Ridge. Exposures are reasonably good around Echo Lake and Blue Grouse Mountain. South of the Omineca River, the succession is confined to the subalpine elevations and only small outcrops are exposed. In the southern part of the map area relatively good exposures are found southwest of Ciarelli Creek.

Lithology: In the Mount Howell area dark argillites of the Big Creek group are succeeded by thin to moderately bedded grey argillites, light grey to greenish siliceous argillites, light grey, green and maroon cherts and ribbon cherts of the Mount Howell succession. These rocks are intruded by gabbroic sills and dikes in the upper part of the succession. The maroon and salmon-coloured cherts only occur in the uppermost part of the section, either in association with the gabbro or immediately below the basalts. Cherts are massive to thickly bedded. Ribbon chert is rare and is composed of thin chert layers (1 to 5 centimetres) separated by thinner, cleaved siliceous argillite layers (Plate 21). Minor constituents are buff-weathering micritic limestone layers less than 0.5 metre thick, basaltic flows and a quartz-bearing tuff towards the base of the unit which is very similar to felsic tuff described in the Big Creek group.

Discontinuous sections of the Mount Howell succession occur northwest of Nina Lake. They are up to a kilometre in thickness and are carried on a thrust which disappears northwestward within monotonous basalts of the Pillow Ridge succession. These sediments and gabbroic rocks were originally thought to be intravolcanic sedimentary sequences by Ferri and Melville (1989). Fossil data now indicate an age inversion at the base of the section east of Nina Creek. This, in conjunction with tectonically disrupted rocks at the base of one package, indicates they are fault repetitions of the Mount Howell succession.

Gabbroic sills up to 1000 metres thick intrude the upper parts of the Mount Howell succession. These bodies are found at various stratigraphic levels and are traceable for several kilometres in some places. They are beautifully exposed along the ridges descending off Mount Howell (Plate 22). They are fine to coarsely crystalline, with subequal pyroxene and strongly altered (sericitized) plagioclase. The compositional similarity of these sills with basalts of the Mount Howell and Pillow Ridge successions (*see* under Chemical Analysis and Tectonic Setting of Nina Creek Basalts) suggest that they may be feeders to the basalts.

South of Nina Lake the composition of the Mount Howell succession is slightly different. Near Blue Grouse Mountain the upper cherts and siliceous argillites are interlayered with basalt flows. Basalt flows are also exposed near Jackfish Creek and along the ridge southwest of Ciarelli Creek. These massive flows can be up to 50

Plate 21. Ribboned cherts of the Mount Howell succession east of Gaffney Creek. Here 1 to 3-centimetre thick chert layers are separated by thinner cherty argillite beds.

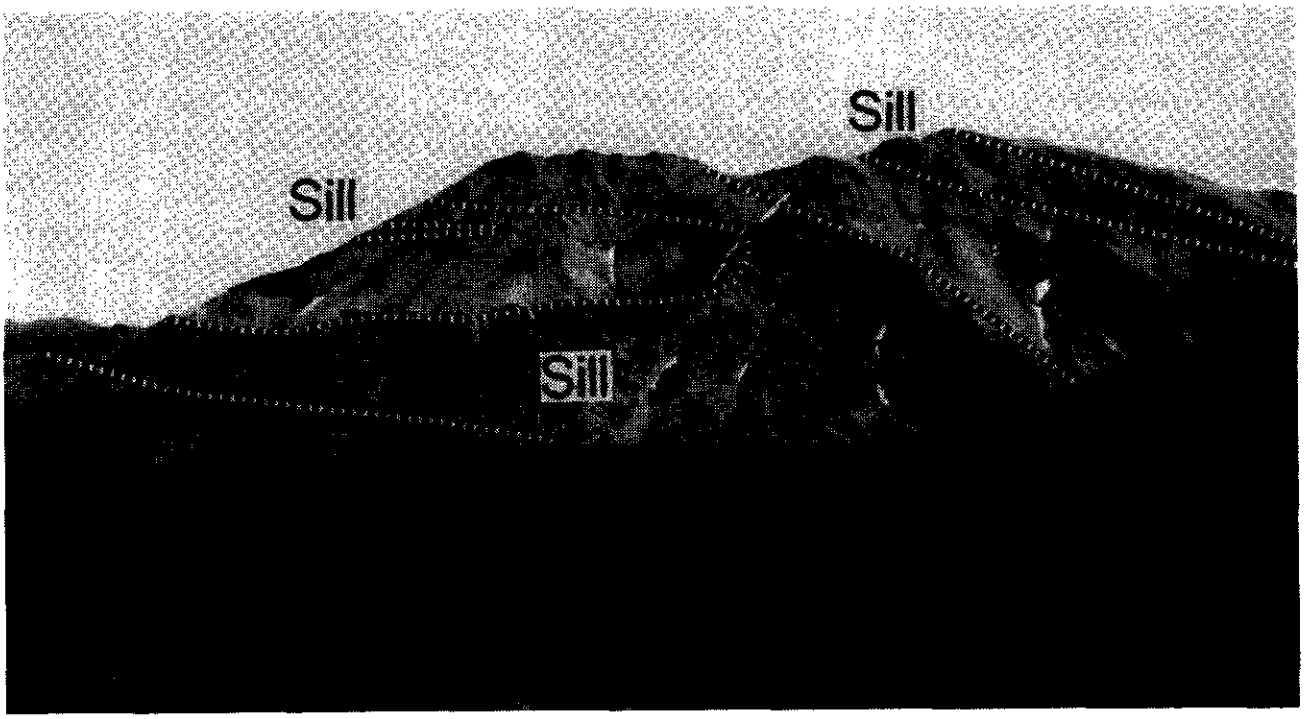

Plate 22. Gabbro sills within the Mount Howell succession as seen looking south from near Mount Howell. In this photograph up to four levels of sills can be seen in the background. The thickest is at the base and may feed into the higher ones.

metres thick and the upper parts contain tuffaceous breccia. Some of the thicker flows can be mistaken for finely crystalline, mafic intrusions. The basalts appear very similar to those of the Pillow Ridge succession (*see* following section).

Southeast of the Wolverine Lakes, the Mount Howell succession contains minor sequences of tuffaceous sediments. These are massive to thickly bedded, grey to greenish in colour and occur in sections up to 5 metres thick. These rocks grade into typical argillites of the Mount Howell succession. Coarser fractions contain crystal fragments such as feldspar and pyroxene. The tuffaceous sediments appear to become volumetrically important in the Ciarelli Creek and Munro Creek areas where they are interbedded with coarse quartzose sands. Some of these tuffaceous sequences bear similarities to the Lay Range assemblage tuffs suggesting either they are part of the Lay Range assemblage or represent a possible link between it and the Nina Creek group. These tuffs are found within sections typical of the Mount Howell succession precluding direct placement within the Lay Range assemblage.

Polymict sandstones, wackes and conglomerates are a rare component of the Mount Howell succession. They are interlayered with argillites and tuffaceous sediments, in sections up to 10 metres thick. They can be seen on Blue Grouse Mountain, south of Ciarelli Creek, near Cooper Ridge and approximately 1 kilometre south of the Manson River along the main road through the area (Gaffney Creek). These coarse clastic sediments are thin to moderately bedded, composed of subrounded to rounded clasts of chert, quartz, carbonate, argillite(?), feldspar-pyroxene-porphyritic volcanic, metamorphic rock fragments (as shown by undulose and sutured polycrystalline quartz grains) and rare, broken crystals of potassic and calcic feldspar. In the Gaffney Creek area the sandstones are quartz rich with the quartz crystals displaying a blue opalescence.

Age: Nine conodont suites were recovered from the Mount Howell succession, of which only five gave conclusive ages. These suites indicate this succession spans Mississippian to Permian time (Appendix I). North of Mount Howell, the lower part of the succession yielded Mississippian conodonts. Near Cooper Ridge, conodonts collected from a lens of chert within a gabbroic sill indicate a Permian age for the upper part of the succession. All localities are widely separated and the data do not rule out the possibility that thrust repetitions occur within this succession.

Pillow Ridge Succession (Informal, Early Pennsylvanian to Late Permian)

The Pillow Ridge succession is at least 5 kilometres thick northwest of Nina Lake and is composed of massive and pillow basalts and basaltic breccia, with lesser sediments, tuff and sills of gabbro. The best outcrops are near Pillow Ridge. This exposure continues southeastward, along several ridges, to Blue Grouse Mountain where thick sections of basalt are preserved in a faulted syncline. Only small areas of basalt are preserved as thin remnants at the top of the Mount Howell succession in the southern part of the map area. Southwest of Ciarelli Creek, basalts exposed at the top of the ridge have been included in the Mount Howell succession although they may actually be the base of the Pillow Ridge succession. Fault slices of basalt are also present within the Manson fault zone.

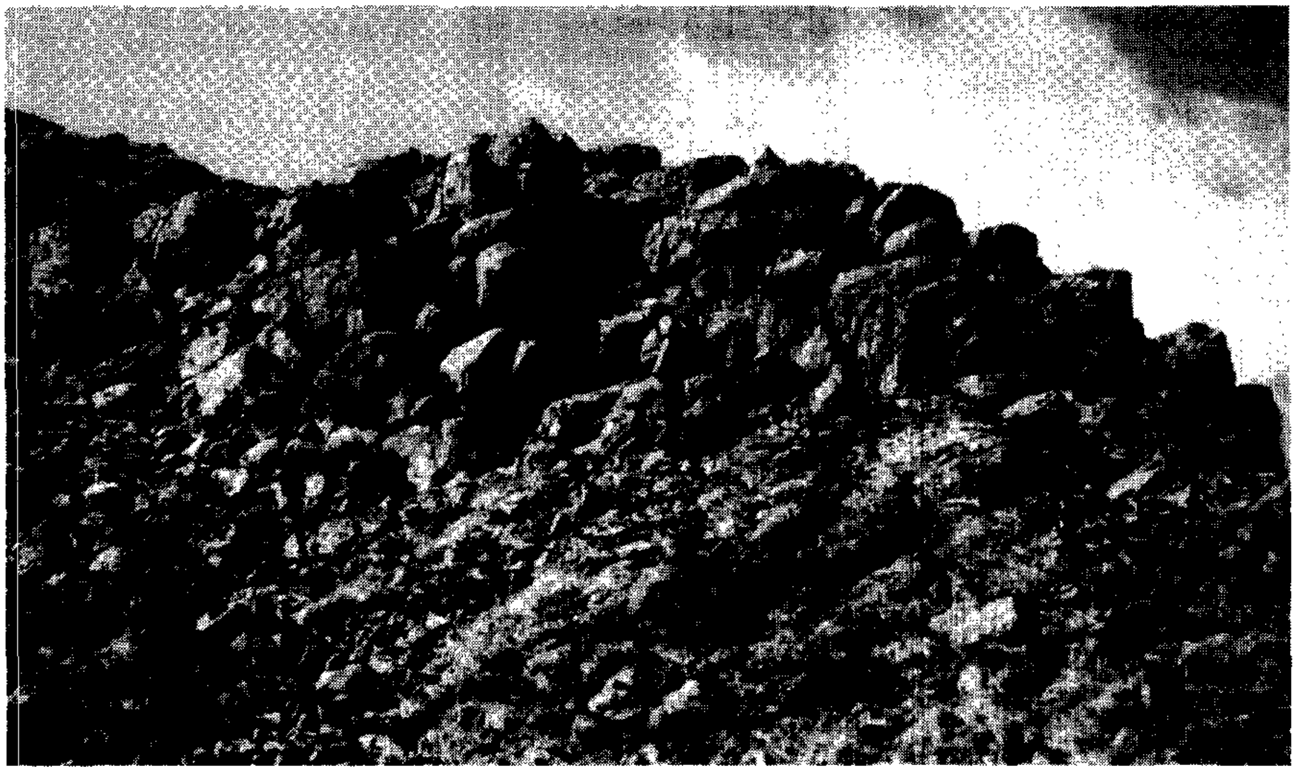

Plate 23. Pillowed basalts of the Pillow Ridge succession along Pillow Ridge.

Lithology: Over 95% of the Pillow Ridge succession is composed of dark green to greyish green, variolitic, pillowed (Plate 23) or massive basalt which contains irregular bodies of fine-grained gabbro. These gabbros may be the cores of very thick basaltic flows as it was often difficult to distinguish between mafic sills and thick basaltic flows. Massive and interpillow basaltic breccia is also common. Very fine to fine-grained phenocrysts of feldspar, pyroxene and olivine are found locally in the basalts. The groundmass is composed of titan augite, plagioclase and opaques of unknown composition. Alteration minerals are chlorite, epidote, clinozoisite, prehnite and pumpellyite, all of which occur as individual grains in the groundmass or as vein and vesicle fillings.

Sedimentary sections from 1 to 10 metres thick occur within the basalts and are composed of light to dark grey argillite and siliceous argillite, varicoloured cherts (cream, grey, green, salmon and maroon) and gabbro sills. These sedimentary rocks include lithologies very similar to those in the Mount Howell succession. Wavy argillites and ribboned chert are thin to moderately bedded. Cherts may also be thick to massively bedded. In many localities the cherts form large, shapeless masses up to 10 metres in diameter within the basalt.

Age: Fossils collected by ourselves and others (Monger, 1977a) indicate that the Pillow Ridge succession ranges in age from early Pennsylvanian to Late Permian (Appendix I). Immediately northwest of Blue Grouse Mountain, near the base of the succession, conodonts extracted from cherts yield an early to middle Pennsylvanian age. Northwest of Nina Lake, conodonts from a sedimentary sequence in the upper part of the succession give a Late Permian (Guadalupian) age. Individual conodont suites recovered elsewhere in this succession are Permian.

The base of the Mount Howell section, northwest of Nina Lake, is Pennsylvanian in age. Structurally below this point thin cherty sediments within the basaltic section contain conodonts which indicate a Pennsylvanian age and another suite contains Permian conodonts. Basalts above this sedimentary package, and others along strike with it, are assumed to be Late Permian. Alternatively, these upper basalts may be a thrust-sliver of the lower basaltic section. The fossil data do not permit resolution of these hypotheses.

Chemical Analysis and Tectonic Setting of the Nina Creek Basalts

Representative rock analyses were obtained for basalts and gabbros from the two successions of the Nina Creek group. In total, 16 basalts and 18 gabbros were analyzed. The results are presented in Appendices III and IV and the location of samples used in the following diagrams are shown in Figure 17. These samples were the least altered and as such would be the most representative. Most gabbro samples were taken from the Mount Howell succession, only two samples are from the Pillow Ridge succession.

All samples are lower greenschist to prehnite-pumpellyite metamorphic grade (*see* chapter on Metamorphism). As a consequence, major element mobility may have occurred during metamorphism and analytical results should be viewed with caution. The basalts and gabbros

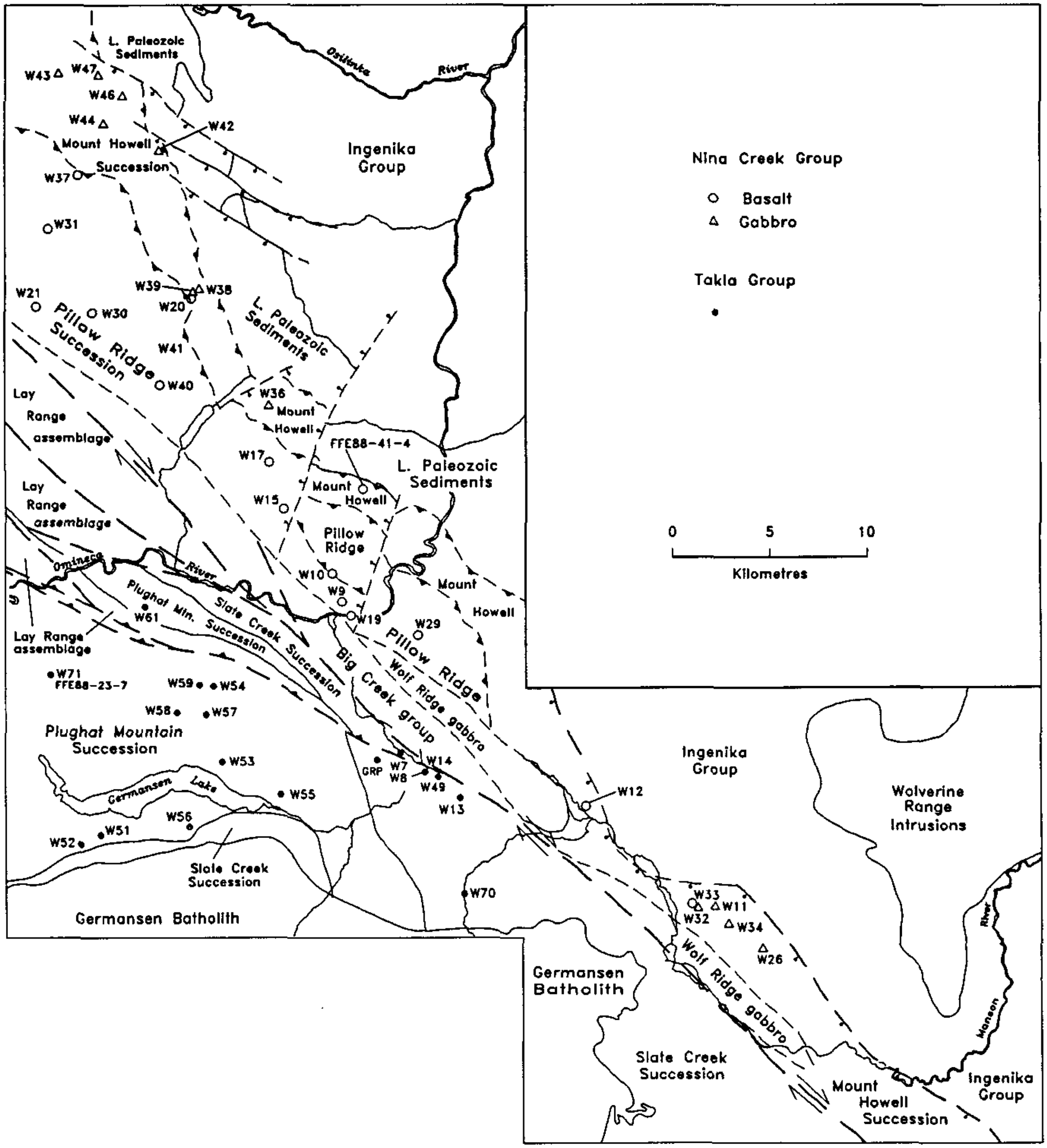

Figure 17. Location of Nina Creek basalts and gabbros and Takla Group basalts used in discrimination diagrams.

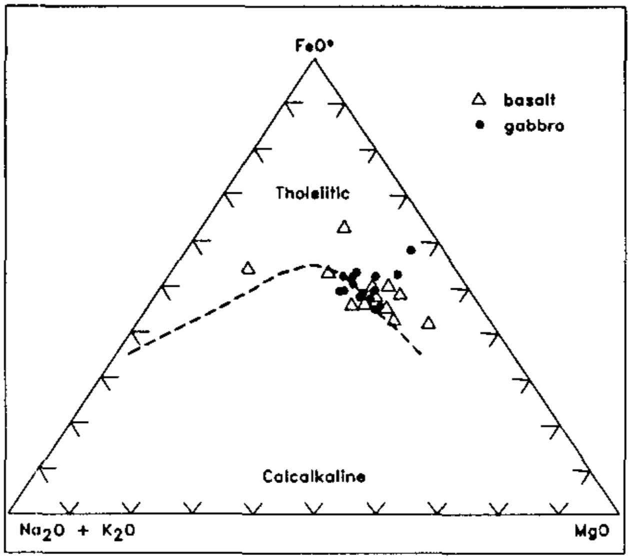

Figure 18. AFM plot of Nina Creek basalts and gabbros (after Irvine and Baragar, 1971).

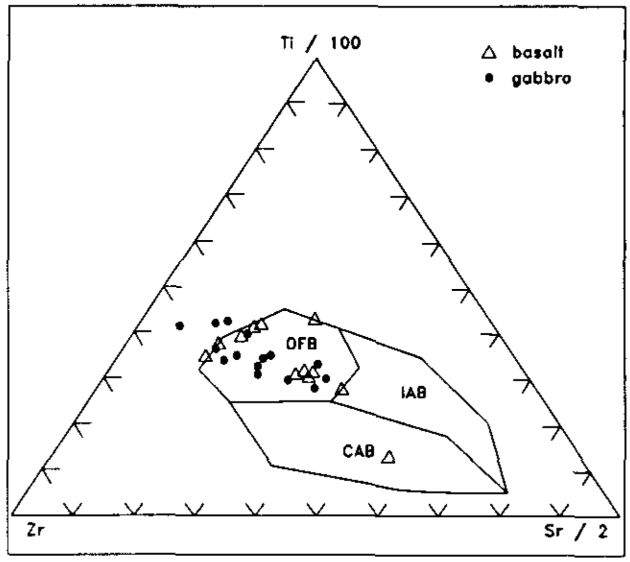

Figure 20. Ternary plot of Ti/100 - Zr - Sr/2 for Nina Creek basalts and gabbros. OFB=ocean-floor basalts; IAB=island-arc basalts; CAB=calcalkaline basalts (after Pearce and Cann, 1973).

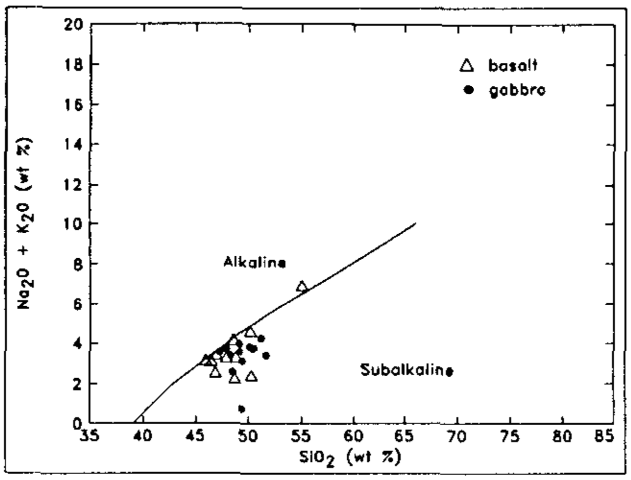

Figure 19. Plot of total alkali *versus* silica for Nina Creek basalts and gabbros (after Irvine and Baragar, 1971).

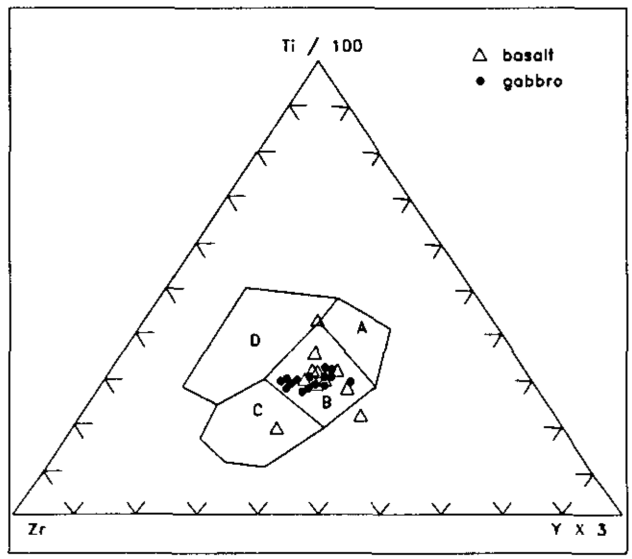

Figure 21. Ternary plot of Ti/100 - Zr - Yx3 for Nina Creek basalts and gabbros. A=ocean-floor basalts; A, B=low-potassium tholeiites; B, C=calcalkaline basalts; D=within-plate basalts (after Pearce and Cann, 1973).

are tholeiitic in composition, based on an AFM ternary plot (Figure 18). An alkali *versus* silica plot (Figure 19) shows the subalkaline nature of the basalts.

Several discrimination diagrams have been developed for basaltic rocks utilizing minor and trace elements, as they are relatively immobile during regional metamorphism (Pearce and Cann, 1973; Pearce, 1975; Floyd and Winchester, 1975). They are useful indicators of the chemical nature and original tectonic setting of these igneous rocks. Samples from the study area have been plotted on some of these diagrams (Figures 20, 21, 22, 23 and 24) and clearly indicate that these rocks are tholeiitic ocean-floor basalts. Their tholeiitic nature is clearly shown by the immobile elements which are independent of alkali content (Figures 23 and 24). The combination of Figures 20 and 21 illustrates the relatively tight cluster of data within the fields designated as ocean-floor basalts. Only strontium exhibits a slight spread of values due to its mobility during metamorphism. Figure 22 also defines these tholeiitic basalts as being of ocean-floor origin.

Extended trace element data for selected samples of Nina Creek basalts and gabbros have an overall flat signature and have normalized values close to unity, which is typical of mid-ocean ridge basalts (MORB; Pearce, 1982; Figure 25). The large scatter within the elements strontium through to barium is due to mobility of these elements during metamorphism. Average values for these elements are in agreement with typical MORB signatures.

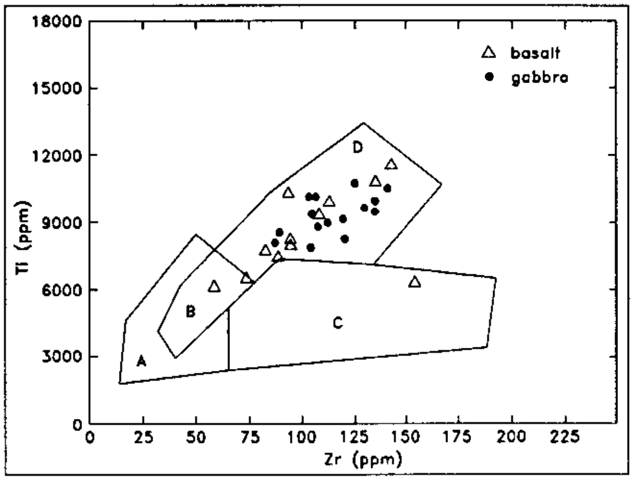

Figure 22. Plot of Ti *versus* Zr for Nina Creek basalts and gabbros. D, B=ocean-floor basalts; A, B=low-potassium tholeiites, A, C=calcalkaline basalts (after Pearce and Cann, 1973).

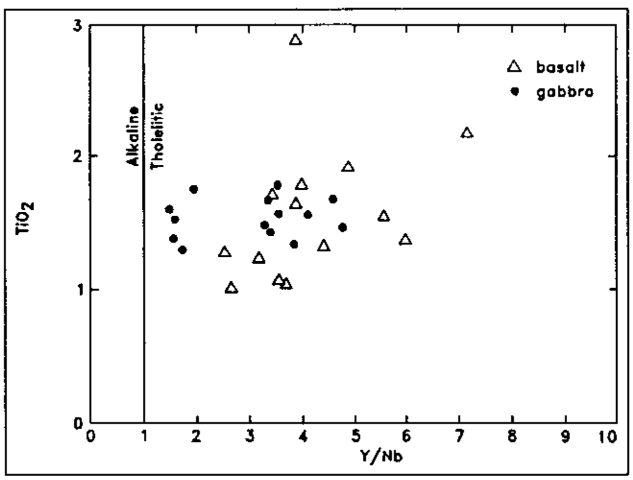

Figure 23. Plot of TiO_2 *versus* Y/Nb for Nina Creek basalts and gabbros (after Floyd and Winchester, 1975).

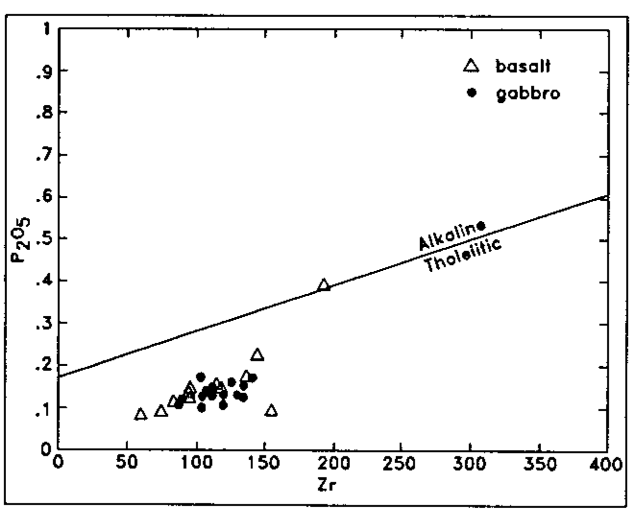

Figure 24. Plot of P_2O_5 *versus* Zr for Nina Creek basalts and gabbros (after Winchester and Floyd, 1976).

These data are similar to analyses reported by Rees (1987) on the Antler Formation from the Quesnel Lake area. He concluded that greenstones of the Antler Formation also represent ocean-floor basalts. Schiarizza and Preto (1987) present analyses for basalts of the Fennell Formation, a direct equivalent of the Nina Creek group. Using similar plots to those presented here, they too concluded that Fennell basalts are ocean-floor tholeiites.

The chemistry of the Nina Creek group basalts indicates that they were erupted in an ocean-floor setting, either along a mid-ocean ridge, or within a back-arc or marginal basin. Chemical data alone cannot differentiate these possibilities. These diagrams, when used in conjunction with other geological information, will suggest which of the settings is the most plausible.

Volcanic and sedimentary rocks of the Nina Creek group suggest a back-arc basin flanked by the ancestral North American margin. The bulk of the sedimentary rocks are argillites and cherts, indicative of quiet, deep water sedimentation. The basalts are pillowed or massive and typical of ocean-floor basalts. Although most of these rocks support formation in a deep, oceanic environment, parts of the Mount Howell succession contain minor, but important, sequences of polymict sandstones, wackes and conglomerates. The presence of these clastic rocks indicates a nearby high-energy source. Some of the wackes are very quartz rich and suggest a continental origin, presumably North America. Sandstones in the Blue Grouse Mountain area are rich in volcanic fragments and contain rare metamorphic clasts. These rocks could not have been derived from the east as the Precambrian basement was buried deep below the miogeocline during this period, and there are no thick successions of mafic volcanics within miogeoclinal strata capable of generating this material. This suggests a western source. Clast types indicate a source area rich in volcanic material. An island arc, possibly floored by continental material, would be an environment capable of producing such high-energy deposits.

Arc-type deposits contemporaneous with those of the Nina Creek group within Quesnel rocks of the map area are assigned to the Lay Range assemblage (Roots, 1954; Ross and Monger, 1978; Ferri *et al.*, 1992a,b, 1993a,b). Tuffaceous sequences within the Lay Range assemblage are similar to the volcaniclastic sequences in the Mount Howell succession. High-energy rocks of the Lay Range assemblage may represent material shed off an active arc to the west (back-arc sediments) which was covered by subsequent Triassic volcanism.

It is suggested that the Nina Creek group was deposited within a back-arc basin marginal to North America that resulted from back-arc spreading during formation of the arc. The regional tectonic implications of this interpretation are further discussed in a later chapter (Geological Synthesis).

MANSON LAKES ULTRAMAFICS (Informal, Mississippian to Permian?)

The Manson Lakes ultramafics were originally grouped with the Trembleur intrusions, a name proposed by Armstrong (1949) to describe a series of ultramafic

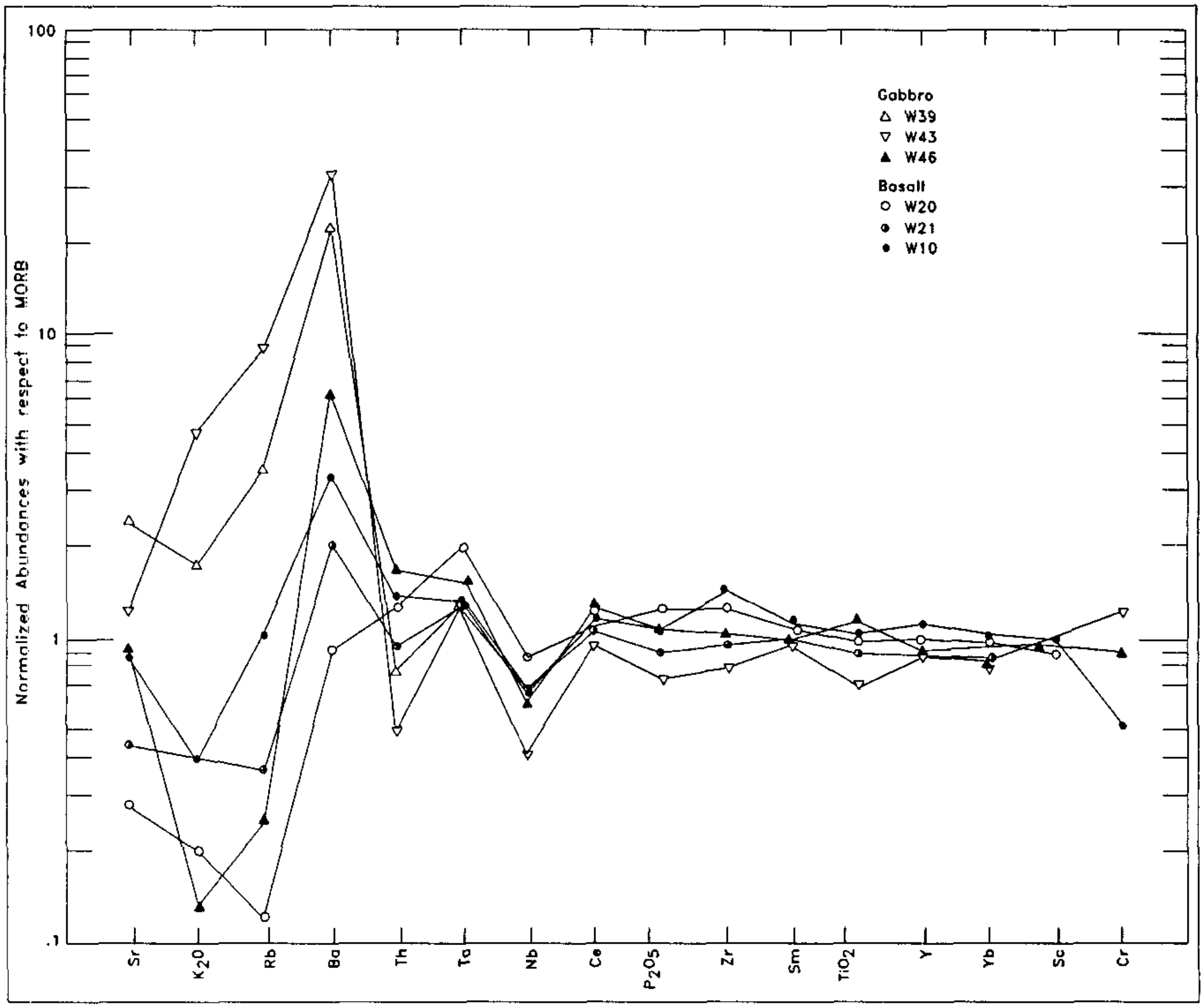

Figure 25. Extended trace element plot for Nina Creek basalts and gabbros. This flat signature is typical for mid-ocean ridge basalts, *see* text for details. These are normalized to mid-ocean ridge basalt using values from Pearce (1982); Sr=120 ppm; K_2O=0.15%; Rb=2 ppm; Ba=20 ppm; Th=0.2 ppm; Ta=0.18 ppm; Nb=3.5 ppm; Ce=10 ppm; P_2O_5=0.12%; Zr=90 ppm; Sm=3.3 ppm; TiO_2=1.5%; Y=30 ppm; Yb=3.4 ppm; Sc=40.0 ppm Cr=250 ppm.

bodies exposed within the Cache Creek Group. These bodies are now known to be slivers of oceanic crust within the Cache Creek Group (Monger, 1984; Ash and Arksey, 1990; Ash and MacDonald 1993) and not intrusive bodies. Alaskan-type ultramafic intrusions, such as the large Polaris body (Nixon *et al.*, 1990) and a small body northwest of Uslika Lake (Roots, 1954), are exposed to the northwest, along strike with the Manson Lake ultramafics. Elsewhere in the Slide Mountain Terrane ultramafic rocks have been interpreted as part of a dismembered ophiolitic suite (Crooked amphibolite, Antler Formation, Montgomery, 1978, Struik, 1988a, Rees, 1987; Anvil allochthon, Tempelman-Kluit, 1979). The Manson Lakes ultramafic bodies are not grouped directly with the Nina Creek group as no relationship can be demonstrated between the two suites except that they are both involved in the Manson fault zone. The ultramafic rocks have been included within the Slide Mountain Terrane on the basis of relationships seen elsewhere. Due to their highly dismembered and altered state within the fault zone it is uncertain whether these rocks represent oceanic crust or Alaskan-type intrusions.

Contacts, where exposed, are tectonized. Steep, brittle fault zones are seen within the Manson fault zone (Plates 34 and 36). One body of ultramafite is separated from underlying Boulder Creek sediments by a subhorizontal fault which contains kinematic indicators suggesting motion to the east (Plate 29).

Age and Correlation

The Manson Lakes ultramafic bodies maybe correlated with the Crooked amphibolite of the Slide Mountain Group (Struik, 1985, 1988a; Rees, 1987). Lenses of the ultramafite crop out along the western margin of the Boulder Creek group which is inferred to be related to the

Snowshoe Group (*see* Boulder Creek group). There is a similar structural relationship to the south between the Crooked amphibolite and the Snowshoe Group. The Crooked amphibolite is equated with the Antler Formation of the Slide Mountain Group, suggesting a genetic relationship between the Nina Creek group and the Manson Lake ultramafites.

The age of these ultramafic bodies is unknown but K-Ar dating of mariposite has yielded an age of 134 Ma (Appendix II). There are no other metamorphic or igneous events of the same age in the map area.

Lithology

A series of poorly exposed lenticular bodies of ultramafite are exposed along the Manson fault zone. These bodies are small, with the largest being only a few square kilometres in area, and occur intermittently from the southeastern corner of the map area, northwestward to the Germansen River. Three types of ultramafite have been recognized: serpentinite, talc-serpentine bodies and talc-ankerite-serpentine schists or listwanites.

Serpentinite bodies are the most abundant; they are essentially pure serpentine with minor amounts of disseminated talc, ankerite and epidote which may accompany quartz-calcite veining. Serpentinites are generally magnetic and may contain veinlets of chrysotile. These rocks are well exposed immediately south of the Farrell showing on the north side of the Germansen River and at the south end of a ridge approximately 8 kilometres west of Gaffney Creek.

The talc-serpentine bodies are up to 50% talc which occurs as either disseminated grains, fine-grained masses 0.5 to 1 centimetre in size, or as radiating crystal masses a few centimetres in diameter. A weak foliation is present in the more talc-rich bodies. Examples of these are seen around Boulder Creek.

The second most abundant ultramafite type is talc-ankerite-serpentine schist. These rocks commonly carry mariposite, magnetite and quartz as accessories but are composed essentially of talc and ankerite. They are grey-green to brownish weathering and commonly coarsely crystalline with large (up to 1 centimetre) porphyroblasts of ankerite. Magnetite is present as finely disseminated crystals which may comprise up to 2% of the rock. Bodies of these schists are well exposed along a creek in the southern part of the map area, along the north shore of the Lower Manson Lake, north of Boulder Creek and at the big bend in the Germansen River.

QUESNEL TERRANE

LAY RANGE ASSEMBLAGE (Mississippian? to Permian)

The name Lay Range assemblage was first used by Ross and Monger (1978) for a succession of upper Paleozoic volcanic and sedimentary rocks which are well exposed along the high ridges in the Lay Range. These rocks were first described by Roots (1954) who traced them as far south as Uslika Lake. Ross and Monger (*ibid.*) extended this package into the Nina Lake area and included rocks of the Nina Creek group. Wheeler and McFeely (1991) grouped these rocks with the Harper Ranch Subterrane which is considered to be the basement of Quesnellia. Ferri and Melville (1988, 1989) and Ferri *et al.* (1988, 1989) postulated the presence of Harper Ranch rocks in the Germansen Landing area based on lithology and on early fossil identifications. More recently Ferri *et al.* (1992a, b), working in the adjacent Uslika Lake map sheet to the northwest, described Lay Range assemblage volcanic and sedimentary rocks sitting above rocks of the Cassiar Terrane. Lay Range rocks in the Uslika Lake area were mapped southward into the Discovery Creek valley by Ferri *et al.* (1992a, b) where Nelson *et al.* (1993a, b) traced them southeastward to the Omineca River. This mapping suggests that all volcanic rocks southwest of the Manson fault zone and north of the Omineca River are part of the Lay Range assemblage.

Superficially these rocks appear very similar to the Takla Group. This led Armstrong (1949), as well as Ferri and Melville (1988, 1989) and Ferri *et al.* (1988, 1989), to place them within the Takla Group. Differences between lithologies of the Lay Range assemblage and the Takla Group can be subtle. Rocks of the Lay Range assemblage are commonly characterized by a more penetrative deformation and greater induration. Tuffs are commonly a blue-green colour which is more intense and somewhat different than the grey to grey-green and maroons of the Takla Group. Compositionally, volcaniclastic, rocks can sometimes be distinguished from those of the Takla Group by the presence of quartz and chert clasts. Lay Range agglomerate and lapilli tuffs, by themselves, are typically indistinguishable from those of the Takla Group.

The overall character of Lay Range rocks is very similar to the Takla Group suggesting a volcanic arc setting. The presence of quartz clasts within the sequence suggests a more evolved volcanic centre or a continent as possible sources for some of the material.

Lay Range assemblage rocks form a fault-bounded package north of the Omineca River and southwest of Nina Lake. Numerous other faults dissect this sequence (along Wendy and Cook creeks) precluding a detailed understanding of the internal stratigraphy. Generally, a coarse volcaniclastic section (unit MPlr2) appears to lie stratigraphically above a package of fine tuffs and argillites (unit MPlr1). The combined thickness of these units is difficult to determine though a minimum thickness of approximately 2000 metres is estimated.

Age and Correlation

No fossils were recovered from rocks of the Lay Range assemblage in the map area. Permian conodonts were collected by J.W.H. Monger from the Lay Range assemblage in the Uslika Lake area (M.J. Orchard, personal communication, 1991; Ferri *et al.*, 1992a). Roots (1954) collected macrofossils in the Lay Range which suggested a late Paleozoic age. Some of Roots' fossil assemblages indicate possible Mississippian lower age limits. Ross and Monger (1978) recovered middle Pennsylvanian fusulinids from limestones in the Lay Range.

The assemblage appears to be confined to the upper Paleozoic and spans the Mississippian? to Permian periods.

Assignment of the Lay Range assemblage to the Harper Ranch Subterrane is questionable (Monger *et al.*, 1991). The fine clastics, carbonates and cherts have some similarities to the Upper Devonian to Upper Permian Harper Ranch assemblage in southern British Columbia (Monger *et al.*, 1991), but the Harper Ranch assemblage lacks the voluminous coarse volcaniclastics which typify Lay Range assemblage lithologies. Smith (1974) concluded that the fine sediments of the Harper Ranch assemblage in the Kamloops area were derived from a distal volcanic arc. Lay Range assemblage rocks in the Germansen Landing area strongly indicate a volcanic arc setting suggesting that the Harper Ranch assemblage may represent more distal facies equivalents.

Harper Ranch rocks locally unconformably underlie Mesozoic rocks of Quesnellia in southern British Columbia (Monger *et al.*, 1991; Read and Okulitch, 1977). Lay Range rocks appear to lie structurally against rocks of the Takla Group and Nina Creek group in the map area.

Coarse volcaniclastic and flow rocks of late Paleozoic age within Quesnellia north of the map area are absent or poorly exposed. Possible correlatives may be present within the Sylvester allochthon in the Cassiar Mountains. The uppermost part of the allochthon (Division III) is a volcanic arc sequence (Nelson and Bradford, 1987, 1989, 1993; Nelson *et al.*, 1988) which contains mafic to felsic volcaniclastics and flows, chert, limestone, argillite, sandstone and tonalite of Mississippian to Permian age. The mafic volcanics and epiclastic sequences bear some gross similarities to the Lay Range assemblage. The intermediate to felsic volcanism evident in Division III is not recognized in the Lay Range assemblage and, if the two are related, Division III must represent a more evolved arc.

Unit MPlr1

This unit is characterized by blue-grey to grey-green tuff to volcanic sandstone or conglomerate together with tuffaceous siltstone, dark grey to greenish argillite and silty argillite, siltstone and minor lapilli tuff and grey-brown to brown chert to cherty argillite. Volcanic sandstone and conglomerate are characterized by clasts of basalt (sometimes augite-plagioclase phyric), argillite, chert and quartz. Lapilli tuff contains a predominance of augite plagioclase porphyry clasts with rare chert and argillite clasts. Locally one finds small bodies of green, fine to medium-grained gabbro.

The Nina Creek and Goat Creek valleys are underlain by a fault-bounded package of this unit which is dominated by dark grey to grey sheared argillites, grey-green siltstones and cherty beds. Minor lithologies include tuff and lapilli tuff. These rocks can be traced southeastward to the Omineca River and are assumed to be faulted against the Gilliland tuff, though a stratigraphic contact is not ruled out.

Fine to coarse volcaniclastics and tuffaceous siltstones, together with minor argillaceous rocks and quartz-bearing volcaniclastics, are exposed along Evans Creek. Pillowed basalts occur in the sequence along Evans Creek and on a ridge southwest of the creek. The pillows may contain 1 to 5% augite phenocrysts up to several millimetres in size. The basalt is associated with green tuffaceous rocks in the upper plate of the Evans Creek thrust fault. These rocks may be separated from the Evans Creek limestone (*see* below) by a splay of the Evans Creek thrust (*see* Structure chapter).

Southwest of Nina Creek, unit MPlr1 contains coarser tuffs and lacks an abundance of argillite and cherty horizons. It also appears to lie stratigraphically below coarser volcaniclastics of unit MPlr2.

Unit MPlr2

Unit MPlr2 is best exposed along the ridges between Wendy and Cook creeks. This unit is characterized by blue-grey to grey-green or maroon augite-plagioclase-phyric agglomerate to lapilli tuff with lesser amounts of tuff, tuffaceous siltstone, siltstone and argillite. The coarser volcaniclastics of this unit exhibit the greatest similarities to coarse volcaniclastics of the Takla Group. Small bodies of green to grey, fine to medium-grained gabbro are also found within this unit.

EVANS CREEK LIMESTONE (Permo-Triassic)

The Evans Creek limestone outcrops on the ridge north of Evans Creek and extends northwestward across the Omineca River where it is truncated by faults and sandwiched between rocks of the Lay Range assemblage. It is some 500 metres thick and present only in the north-central part of the map area where it is uplifted on a southwest-verging thrust fault. The limestone is generally a massive, cliff-forming unit although bedding can sometimes be seen as faint platy partings. It is grey to light grey on fresh surfaces and dark grey to grey-brown weathering. It is finely recrystallized and has a slightly fetid odor when broken. Commonly it is cut by numerous quartz-calcite veins of various orientations.

Age and Correlation

Several conodont collections were recovered from north and south of the Omineca River. The age range suggested by all suites is Middle Permian to Late Triassic (Carnian *see* Appendix I). Some of the individual samples indicate a definite Permian age (fossil locality 34) whereas others are Middle to Late Triassic (fossil localities 32, 35, 37, 38). Several samples have a mixed faunal assemblage. Locality 33 has both Middle to Late Permian and Middle Triassic suites (M. J. Orchard, personal communication, 1993). Sample 31 contains Middle Permian and Early Triassic fossils, and almost all conodonts from locality 36 indicate a Carnian age except for one which is Early Triassic.

The mixed faunal assemblages suggest several possibilities:

- reworking of older conodont-bearing limestone and incorporation into younger carbonate,

- sampling across a highly condensed sequence which encompasses the Permo-Triassic boundary and/or a disconformity at this boundary.

Conodont morphology does not indicate reworking (M. J. Orchard, personal communication, 1993) which suggests sampling along a condensed sequence containing the Permo-Triassic boundary. The nature of this boundary is not known. Sampling south of the Omineca River was near the stratigraphic top of the unit but there appeared to be no variation in lithology reflecting the age change suggested by some of the mixed faunal assemblages. If this unit contains the Permo-Triassic boundary then the assignment of this limestone to either the Lay Range assemblage or the Takla Group becomes problematic. Because of the ambiguous fossil control, we suggest that this limestone remain as a separate unit until definite stratigraphic relationships are determined.

Thick, massive Permo-Triassic limestones are rare within the Quesnel Terrane. Early to Late Permian limestone, several hundred metres thick, is found in the Harper Ranch Group in southern British Columbia (Orchard and Forster, 1988; Nelson and Nelson, 1985). Nelson and Bradford (1993) describe slivers of Early, middle and Late Permian limestones in Division III of the Sylvester allochthon. Although these rocks are part of the Slide Mountain Terrane, elements of Division III are quite similar to those of the Harper Ranch Subterrane.

TAKLA GROUP
(Middle Triassic to Lower Jurassic(?))

Armstrong (1949) named the Takla Group after its extensive exposure in the Takla Lake area. He applied the name to two belts of mafic volcaniclastic rocks and related sediments exposed on either side of the Cache Creek Group in the Fort St. James area. The type locality is west of the Pinchi fault and is thus part of the Stikine Terrane.

Takla rocks within the Manson Creek and Germansen Landing area are part of the Quesnel Terrane. These rocks represent an island arc which spans the Middle Triassic to Early Jurassic time periods (Souther, 1991). This belt of volcanics and related sedimentary rocks extends the length of the Canadian Cordillera and includes the Slocan Group, Rossland Group (in part) and Nicola Group to the south, and the Shonektaw and Nazcha formations north of the study area.

The Takla Group in the map area has been subdivided into two successions; the lower Slate Creek succession composed of phyllite, argillite, limestone and lesser tuffs, mafic volcanics and coarser, volcanically derived epiclastics; and the upper Plughat Mountain succession which is a thick sequence of augite-bearing, mafic and intermediate(?) calcalkaline to alkaline pyroclastic rocks, massive flows and lesser epiclastic rocks (Figure 26). The total thickness is at least 5 kilometres in the southwestern half of the map area.

The Takla Group is in fault contact with the Nina Creek group.

Age and Correlation

Conodont collections from the Takla Group indicate a Middle to Late (Carnian) Triassic age for the Slate Creek succession. The succeeding mafic volcanics of the Plughat Mountain succession are assumed to be Middle to Late Triassic in age as are similar rocks along the Quesnel belt (Armstrong, 1949; Bailey, 1978, 1988, 1989; Struik, 1988b; Panteleyev, 1988). Lower Jurassic volcaniclastics and sediments are found within the Takla Group in the Quesnel Lake area (Bailey, *ibid*). These heterolithic feldspar-rich and analcite-bearing volcanics are unlike the volcaniclastics in the Germansen Landing area. Lower Jurassic volcanic sequences have also been recognized within the Takla Group in the area (Armstrong, 1949; Roots, 1954; Nelson *et al.*, 1991, 1993a) suggesting that the Plughat Mountain succession includes Lower Jurassic strata. Lower Jurassic lithologies in the area are dominated by heterolithic volcanic breccias rich in feldspar which, again, is not typical of the Takla Group in the map area.

In the Germansen Landing area, two broad facies belts have been recognized within the Takla Group, corresponding to the Plughat Mountain and Slate Creek successions. To the east, fine-grained clastic rocks of the Slate Creek succession give way westward and become interfingered with coarser clastics and volcaniclastics of the Plughat Mountain succession (Figure 27). This relationship indicates that the Slate Creek and Plughat Mountain successions are essentially the same age. In the Germansen Lake area, coarse volcaniclastics and flows of the Plughat Mountain succession rest in sharp contact on argillites of the Slate Creek succession. This relationship indicates that the local volcanic centre probably lay to the west. Very similar facies relationships have been demonstrated within the Takla and Nicola Groups south of the map area (Nelson *et al.*, 1991; Struik, 1988b; Rees, 1987; Monger *et al.*, 1991).

Argillites similar to the basal Slate Creek succession extend from the study area southeastward to southern British Columbia (Table 4). Immediately to the south, Nelson *et al.* (1991) report basal slates, argillites and minor volcanically derived sediments which they call the Rainbow Creek formation. These include quartzose sands of possible cratonic origin and appear similar to the lower parts of the Slate Creek succession. Argillites, tuffaceous sediments and coarser volcaniclastics of the inferred younger Inzana Lake formation correlate with the upper Slate Creek succession.

The Slate Creek succession is equivalent to the Middle to Late Triassic black phyllite in the Quesnel Lake area (Rees, 1987; Bloodgood, 1987, 1988, 1990; Struik, 1988b). The black phyllite unit has similar lithologies, age and facies relationships with the western Takla Group volcanics and also contains mafic flows as seen in the Manson Creek area (Rees, 1987; A. Panteleyev, 1990, personal communication).

South of Quesnel the Slate Creek succession is probably equivalent to Carnian to Norian phyllites, limestones and minor sandstones of the Slocan Group (Klepacki and Wheeler, 1985).

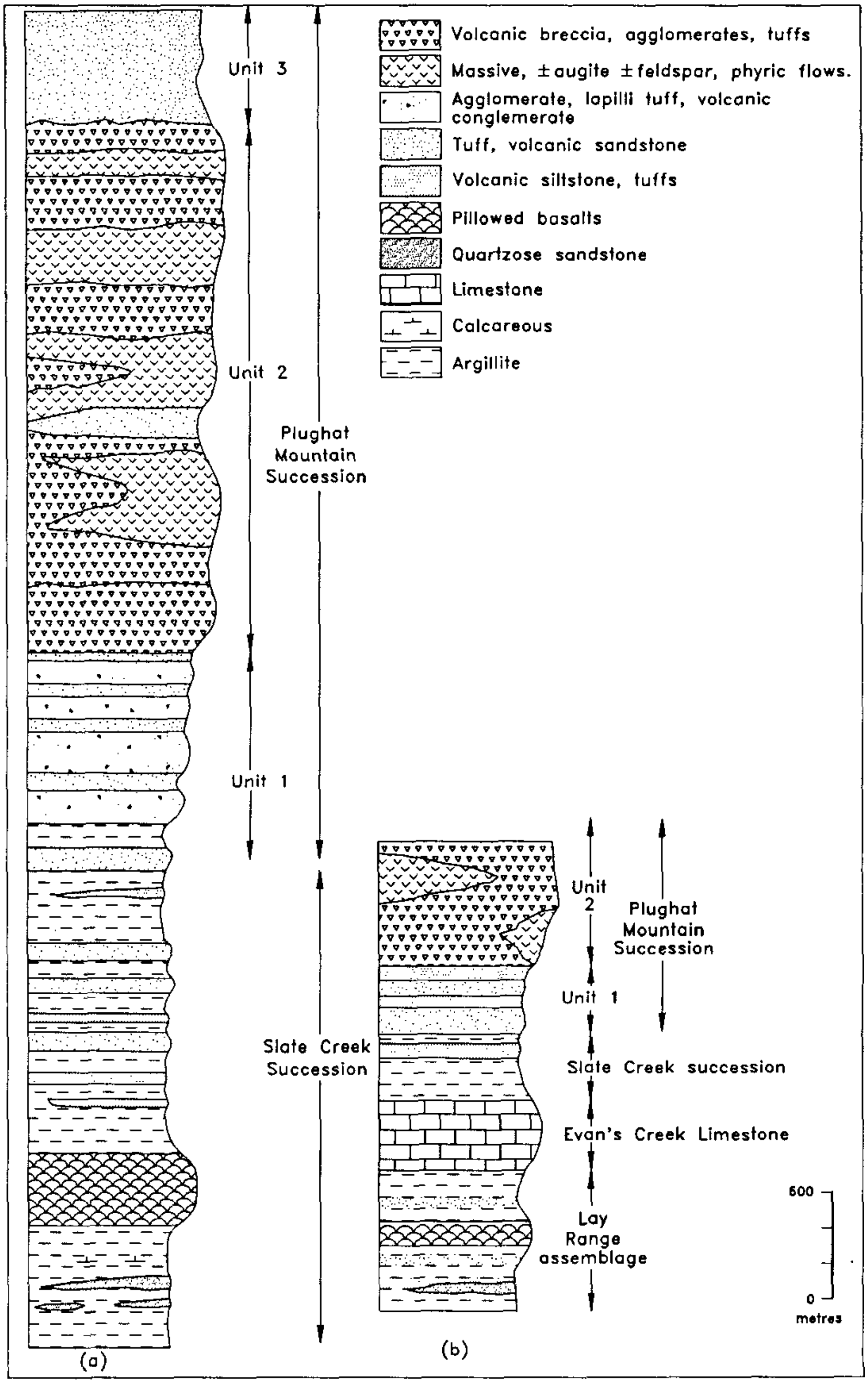

Figure 26. Schematic stratigraphic columns of the Takla Group and Evans Creek limestone within the study area. (a) Composite stratigraphic diagram involving outcrops east and southeast of Plughat Mountain where unit 1 of the Plughat Mountain succession is present. (b) Schematic stratigraphic column in the Evans Creek area showing position of the Evans Creek limestone.

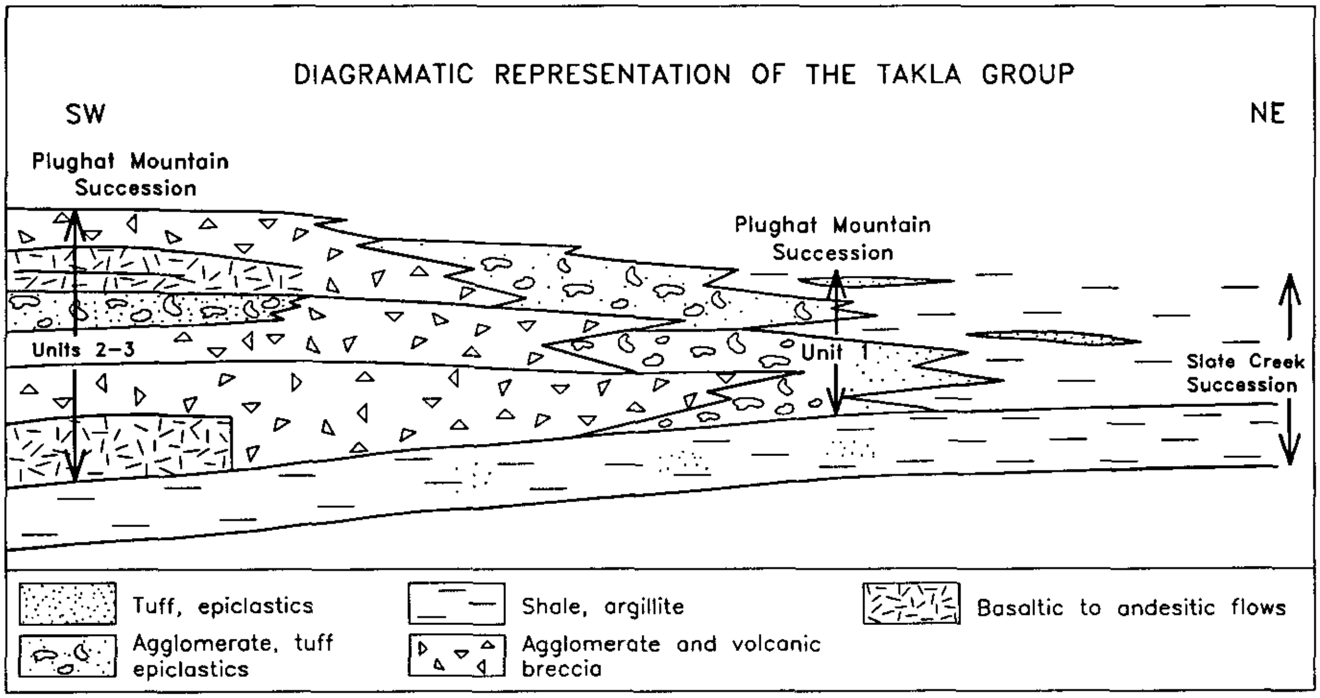

Figure 27. Diagram showing facies relationships between various units of the Takla Group within the study area.

TABLE 4
CORRELATION CHART OF TAKLA GROUP ROCKS WITHIN THE STUDY AREA AND SIMILAR ROCKS TO THE SOUTH.

	OMINECA MOUNTAINS *(This Study)*	NATION RIVER *(Nelson et al., 1991)*	QUESNEL LAKE *(Panteleyev, 1987, 88; Bailey, 1987-89; Bloodgood, 1988)*	QUESNEL LAKE *(Struik, 1988b)*	
Norian	Plughat Mountain succession	Witch Lake formation	Lower Takla Group	Takla volcanics	Black phyllite
		Inzana Lake formation			
Carnian	Slate Creek succession	Rainbow Creek formation ?	Black phyllite		
Ladininan					
Anisian					

The black phyllite and Slocan Group both rest unconformably on volcanic and ultramafic rocks equivalent to the Nina Creek group (Klepacki and Wheeler, 1985; McMullin *et al.*, 1990). This relationship was not observed in the map area.

Augite-bearing mafic, calcalkaline to alkaline volcanic rocks of the Plughat Mountain succession are typical of the most volumetrically important lithologies of the Quesnel Terrane. They are equivalent to the Shonektaw and Nazcha formations north of the study area (Gabrielse, 1968). Immediately south of the map area, recent mapping by Nelson *et al.*, (1991) has delineated a mafic to intermediate volcanic and volcaniclastic sequence called the Witch Lake formation which is also equivalent to the Plughat Mountain succession (Table 4). Unit 1 volcanic sediments and tuffs of the Plughat Mountain succession are equivalent to Inzana Lake formation epiclastics.

In the Quesnel area, the Plughat Mountain succession is equivalent to the lower mafic and intermediate volcanics of the Takla Group which are of Norian age (Panteleyev, 1987, 1988, Panteleyev and Hancock, 1989, Bailey, 1988, 1989).

In southern British Columbia, Upper Triassic to Lower Jurassic volcanic rocks of Quesnellia are represented by the Nicola Group. It is subdivided into three belts; a western belt composed of basic to felsic pyroclastic and volcaniclastic rocks, a central belt of porhyritic augite basalt, and andesite flows and breccias and an eastern belt composed of central belt volcanics which interfinger with sedimentary facies to the east (Preto, 1977; Mortimer, 1987). The Plughat Mountain succession is equivalent to rocks of the central and eastern belts.

Slate Creek Succession (Informal, Middle to Upper Triassic)

Lithology: The Slate Creek succession comprises argillite, slate, siliceous argillite, limestone, lithic tuff, mafic volcanics and volcanic siltstone with lesser chert, volcanic wacke, volcanic sandstone, volcanic conglomerate to breccia and rare quartz-rich siltstone to sandstone. It typically crops out on the eastern side of the Takla Group and can be traced from the Gaffney Creek area northwestward toward Nina Creek. It is the dominant unit of the Takla Group in the southern part of the map area but thins to the northwest. The succession is 500 to 1000 metres thick northwest of the Germansen River and at least several kilometres thick southeast of Mount Gillis. It is involved in the Manson fault zone and occurs as sequences of crumpled slates and argillites which are well exposed along Slate Creek. The argillites usually contain a spaced cleavage (from a few millimetres to several centimetres) which often becomes penetrative within the Manson fault zone. The upper part of the unit is interlayered with lithologies of the Plughat Mountain succession in the eastern and northeastern parts of the Takla Group but is believed to be in sharp contact with the volcanics of the overlying Plughat Mountain succession in the Mount Germansen area.

The argillites are thin to moderately bedded, cream to rusty weathering and typically grey on fresh surfaces. They are sometimes graphitic and contain abundant, finely disseminated pyrite. The argillites are sometimes quite siliceous and are interlayered with dark grey to grey graphitic siliceous argillite or chert. Minor limestone sequences (less than 1 metre) or beds 1 to 30 centimetres thick are sometimes present.

Thin layers (less than 30 centimetres) of quartz wacke and quartz-rich siltstone to very fine grained sandstone were observed within the argillites. They are grey to light brown weathering and contain no internal sedimentary structures. These quartz-rich clastics occur within the Manson fault zone.

Buff-weathering, dark grey, massive limestone up to 5 metres thick is found along Slate Creek and on Connaghan Creek. This limestone is typically finely crystalline although patches are coarsely recrystallized.

A northwest-trending band of mafic volcanic rocks is mapped within the succession north of Mount Gillis. It terminates to the northwest against the Germansen batholith and can be traced to the southeast for approximately 5 kilometres. A continuation of these volcanics may be present to the northwest, along the Manson River, where several outcrops of hornfelsed, pillowed volcanics are exposed. Thin mafic volcanics flows within slates along the south side of the Germansen River are also believed to be part of this sequence.

At Mount Gillis the volcanics are up to 400 metres thick and massive to pillowed (Plate 24). They commonly contain a weak to moderate flattening fabric which parallels the boundary of the unit. Pillows are stretched parallel to this fabric. These rocks become hornfelsed within 2 to 3 kilometres of the Germansen batholith and contain biotite, actinolite, chlorite, plagioclase, quartz, epidote and opaques. Epidote and calcite veining is not uncommon. Mafic minerals are randomly distributed to partially aligned. This weak fabric is a recrystallization of an earlier fabric.

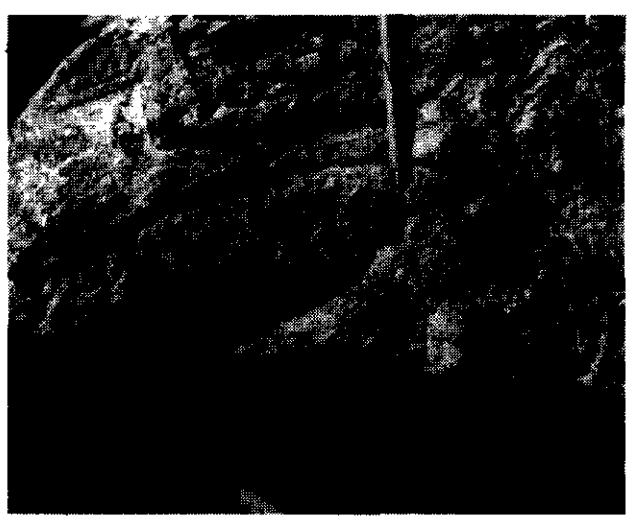

Plate 24. Pillowed basalt of the Slate Creek succession near Mount Gillis. This unit can be traced for approximately 10 kilometres in the southeastern part of the study area.

Several kilometres along strike to the southeast, similar greenstones are associated with weakly to moderately foliated, coarsely crystalline gabbro and were seen in several outcrops. They are composed of coarse actinolite and plagioclase with traces of quartz.

Tuffs beds in the Slate Creek succession are cream to beige in colour, thin to moderately bedded and fairly siliceous. They occur both interbedded with the argillites and in sections 1 to 10 metres thick. The coarser tuffs have discernible clasts of feldspar, feldspar porphyry, and rarely, argillite and quartz.

Thin to thickly bedded volcanic sandstone, conglomerate and some volcanic breccia are exposed in the upper part of the succession. The sandstone clasts are subangular and composed of feldspar crystal fragments, feldspar and augite feldspar porphyries, augite crystal fragments and rare quartz and argillite. Clasts in the conglomerates and breccias are predominantly feldspar augite porphyries, aphanitic volcanics and minor argillite.

Discussion: Basalts within lowermost argillite and siltstone of the Slate Creek succession are thought to represent submarine flows within the Slate Creek basin and not tectonically emplaced slivers of Nina Creek basalts.

It is tempting to correlate these mafic volcanics with sheared volcanics, amphibolite and ultramafite of the Crooked amphibolite (Slide Mountain Group) to the south. This unit is found intermittently at the base of the black phyllite unit in the Quesnel Lake area, and is in structural contact with it and rocks of the Barkerville Terrane (Struik, 1985, 1988a; Rees, 1987). However, in the map area, these mafic rocks are bounded on both sides by sediments of the Slate Creek succession which is not a typical structural relationship for the Crooked amphibolite. Furthermore, internal primary structures are lacking in the Crooked amphibolite in the Barkerville area and the fabric is better developed than that observed in volcanics of the study area.

Age: Conodonts recovered from limestones in the Slate Creek succession indicate a Middle (Ladinian) to Late (Carnian) Triassic age.

Plughat Mountain Succession (Informal, Upper Triassic)

Rocks of the Plughat Mountain succession represent the bulk of the Takla Group in the map area. They are predominantly mafic pyroclastic rocks, mafic flows and epiclastic rocks of volcanic origin. The succession is some 4 kilometres thick and has been subdivided into four units. The first three units appear to comprise a crude stratigraphy and are represented by: a lower unit composed primarily of distal tuffs mixed with volcanic sandstone, conglomerate and breccia, siltstone (tuffaceous) and argillite; a middle unit of coarse pyroclastics (agglomerates, tuffaceous breccias and lapillistones) and mafic flows with subordinate tuffs; and an upper unit made up of volcanic sandstone and conglomerate. Unit 4 is composed of maroon flows and volcaniclastics with minor but characteristic quartz and chert clasts. The relationship of this unit to other units of the Plughat Mountain succession is not known.

The preceding section on the Lay Range assemblage outlines the similarities between lithologies of the Takla Group and Lay Range assemblage. It is sometimes impossible to distinguish between the two successions when distinctive characteristics are lacking. The recognition of Lay Range rocks geographically between Takla and Nina Creek lithologies in the northwestern part of the map area has led to a re-evaluation of similar sequences in the region west of Manson Creek. Some areas of coarser tuffs and epiclastics have characteristics similar to Lay Range lithologies but for the most part these rocks share more similarities with the Takla Group. Deformation and alteration within the Manson fault zone has made this distinction somewhat more difficult.

Unit 1: Unit 1 is characterized by tuff to volcanic sandstone and conglomerate, tuffaceous siltstone and argillite. The best exposures are on small knolls north and south of the confluence of the Germansen and South Germansen rivers. The unit is over 1 kilometre thick in the eastern part of the map area but pinches out westward, toward Germansen Lake where there is an abrupt facies transition.

Tuff is intermixed with epiclastic or more reworked volcaniclastics. These rocks are grey to dark grey-green, massive, poorly sorted and typically coarse grained with isolated lapillis or cobbles. The majority of the clasts are pyroxene feldspar porphyries of various types, although hornblende feldspar and feldspar-phyric clasts are also present. Pyroxene, feldspar and hornblende crystal fragments are abundant. All clasts are angular, subangular to subrounded and the lithic clasts are typical of Takla Group lithologies farther west. The matrix is typically finely crystalline chlorite although some fractures contain prehnite/pumpellyite infills.

Massive to poorly sorted volcanic conglomerates and breccias are typically matrix supported, with the matrix being a volcanic sandstone as described above. These coarse volcaniclastic rocks grade into lapilli tuffs. Clasts range from 0.5 to 30 centimetres across and can be polymict. They are composed of vesicular to amygdaloidal basalts, pyroxene and hornblende feldspar porphyries, feldspar porphyries and rare chert and argillite. The volcanic clasts are identical to Takla volcanic lithologies farther west. These conglomerates are locally penetratively deformed as indicated by the presence of flattened clasts.

The lower parts of the unit contain sections of argillite and tuffaceous beds similar to those described in the Slate Creek succession. These finer grained lithologies contain a spaced cleavage which is not well developed in the conglomerates.

The coarser epiclastics bear some similarities to Lay Range assemblage lithologies, particularly the presence of rare chert and argillite clasts. This does not exclude them from the Takla Group, as it contains some quartz-bearing tuffs (Unit 4), but a cautionary note is needed here.

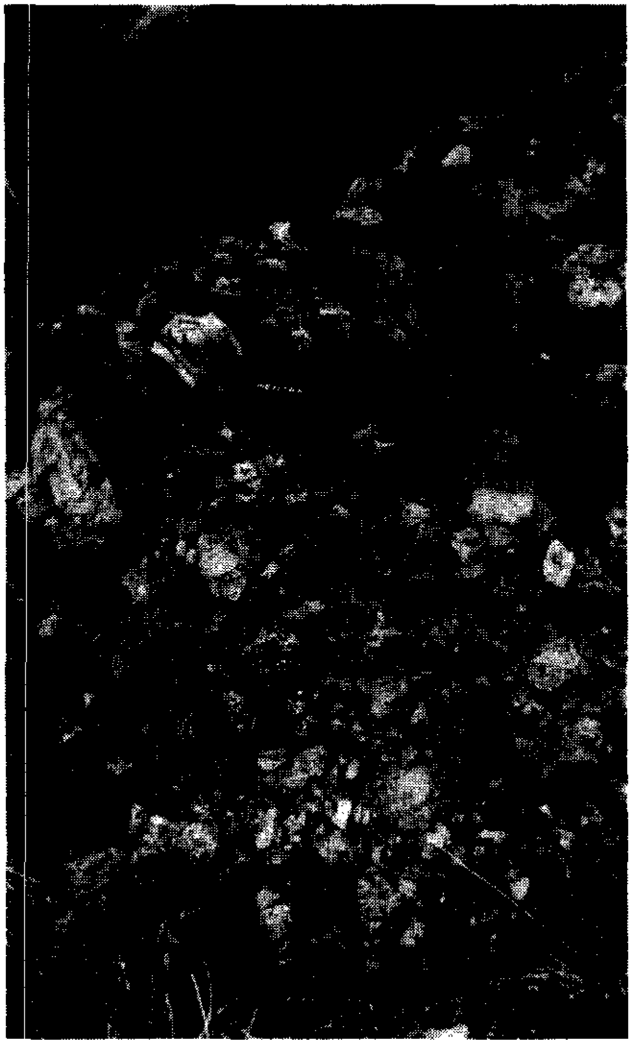

Plate 25. Augite and plagioclase-phyric agglomerate of the Plughat Mountain succession, north of Plughat Mountain.

Characteristics resembling the Lay Range assemblage are best seen in sections immediately northeast of the confluence of the Germansen and South Germansen rivers and in the area around the QCM showing. South of the Germansen River the same unit appears quite Takla-like and seems to grade eastward into finer tuffs and epiclastics of the Slate Creek succession which has yielded an Upper Triassic conodont. If these rocks are, in part, Lay Range assemblage it is difficult to separate them.

Unit 2: Unit 2 is composed predominantly of augite *and feldspar-phyric basalt to basaltic andesite.* These volcanics are dominated by coarse pyroclastics (Plate 25) with lesser massive flows and finer tuffs. The best exposures are north and south of Germansen Lake, although it extends into the central part of the map area, south of the Omineca River. The thickness of the unit varies from 2 to 3 kilometres. Its contact with unit 1 is generally gradational. East of Plughat Mountain, tuffaceous breccias of this unit give way eastward, over a broad interval, to tuffs, lapilli tuffs and epiclastics of unit 1 In contrast, its contact with the Slate Creek succession south of Germansen Lake is very sharp. Unit 2 has been subdivided into four broad subunits: (2a) is composed predominantly of pyroclastics – agglomerates, tuffaceous breccias, lapillistones and volcanic sediments with lesser massive flows, (2b) comprises predominantly flows and coarse pyroclastics with lesser fine tuffs, (2c) is represented by well-bedded tuffs to lapilli tuffs and (2d) characterized by maroon bladed-feldspar flows. Subunits 2a and 2b are volumetrically the most abundant.

Augite-bearing, massive basalts are more abundant in the lower, more easterly exposures of this unit whereas in the upper, more westerly parts, feldspar-phyric flows of a more intermediate composition are common. Faint outlines of pillows were observed in massive augite-phyric basalts along the ridge northeast of Evans Creek.

The volcanics of unit 2 are commonly augite phyric with lesser augite or hornblende feldspar porphyries which may contain serpentinized phenocrysts of olivine. They tend to be green, grey-green or grey to brown. The more mafic volcanic rocks are slightly magnetic. Individual flows and agglomerates vary from a few metres to tens of metres thick. Pyroxene phenocrysts form up to 30% of the rock and are up to a centimetre in length.

Maroon to brown, aphanitic, amygdaloidal (calcite-filled) basalts are also present within this unit. They are well exposed on a ridge 2 kilometres south of Plughat Mountain. Flows tens of metres thick are capped by flow-top breccia which may be infilled by micritic limestone.

In the vicinity of the Germansen batholith, biotite and actinolite are developed within the volcanics. These volcanics generally do not display a penetrative fabric but rather a weak foliation or cleavage, produced by the subparallel alignment of actinolite and biotite crystals.

Tuffaceous siltstones and argillites with lesser lapilli tuffs are found approximately 3 kilometres west of Plughat Mountain, between Paquette and Evans creeks. These rocks are part of a sequence several hundred metres thick but do not extend along strike, indicating a facies transition or fault.

Approximately 8 kilometres west of Plughat Mountain is a sequence of coarsely bladed, maroon feldspar-porphyry flows and agglomerates (2d) which are distinct from the other porphyritic volcanics in the Takla Group. The feldspars are up to a centimetre long, are generally sericitized and comprise up to 20% of the rock. Only a few exposures of this rock type were seen and the extent of this unit is uncertain.

Grey, finely crystalline limestone in the upper part of this unit crops out on the northeastern shore of Germansen Lake. It is up to 25 metres thick and has been traced discontinuously for several kilometres. It is generally massive but in some localities bedding is apparent in thin discontinuous, darker grey and coarser grained layers.

Thin (less than 1 metre) hornblende porphyry dikes were mapped cutting the volcanics of unit 2 at several localities. They are dark green to grey-green in colour with up to 20% acicular hornblende crystals which may approach 1 centimetre in length. Thin dikes or irregular bodies of diorite intrude the volcanics of unit 3. These bodies are only 5 or 10 metres in diameter and are composed of subequal, fine to medium-grained plagioclase and pyroxene. They are also exposed in a few other localities such as south of Germansen Lake. Their relationship to the volcanics of unit 2 is not known.

Unit 3: Unit 3 is a poorly exposed sequence of massive to thickly bedded, dark grey to grey, volcanic sandstone, conglomerate and tuff exposed in a synclinal core centred on Germansen Lake. The conglomerates are matrix supported with the clasts consisting of porphyries similar to those in unit 2. The thickness of the unit, based on structural cross-sections, is estimated to be upwards of 1 kilometre.

Unit 4: Unit 4 is exposed south of the Omineca River, along the western margin of the map area. It has many similarities to the other units of the Plughat Mountain succession but is distinguished by the presence of well-bedded tuffs with rare quartz clasts. It has been subdivided into two sequences, an apparently lower succession dominated by coarse volcaniclastics and flows of basaltic composition (4a) and an upper package of finer, well-bedded tuffs, tuffaceous siltstones and agglomerate.

Coarse volcaniclastics and flows are maroon to dark grey to green and may be vesicular to amygdaloidal. These volcanics are typically aphanitic to slightly porphyritic with 1 to 10% phenocrysts. Typically augite is subordinate with feldspar being the dominant phenocryst.

Tuffs, lapilli tuffs and tuffaceous siltstones are maroon to grey-green in colour, well bedded and in sections up to 150 metres thick. Tuff layers can be up to several metres thick and display gradational bedding. Coarse agglomeratic horizons can be found within these tuffaceous sequences. The well-bedded tuff sections are also locally characterized by the presence of angular to subangular clasts of quartz which can comprise up to 1 or 2% of the rock.

The relationship of unit 4 to other units of the Plughat Mountain succession is not certain. It shares many characteristics with the maroon porphyritic basalts of unit 2 but a direct correlation is not possible. This unit is separated from the unit 2 by an assumed fault.

Age: There is no fossil control on the age of the Plughat Mountain succession in the map area. Limestone sequences within it appear very similar to Carnian carbonates in the Slate Creek succession. Armstrong (1949) collected macrofossils from several localities along the Quesnel belt indicating a Late Triassic to Early Jurassic age for rocks equivalent to the Plughat Mountain succession. It is postulated to be Norian based on its similarity to Norian volcanics south of the map area (Panteleyev and Hancock, 1989; Bailey, 1988; *see also* introductory section on the Takla Group).

Chemical Composition and Tectonic Significance of Takla Basalts

Major and trace element analyses were obtained from 17 samples of Takla Group basalts within the map area. Samples were collected from massive or brecciated flows of unit 2 and their locations are shown in Figure 17. Care was taken to sample massive flows, but thin sections indicate that even massive-appearing samples are fragmental in nature. All samples are of prehnite-pumpellyite or lower metamorphic grade. Some samples are strongly altered and were not plotted on the diagrams. Numerous major and trace element discrimination diagrams were produced from these data (Figures 28 to 37). Most of them are similar to those used to describe Nina Creek basalts and the reader can easily contrast the chemistry of the two suites of rocks.

Based on silica content the Takla volcanic rocks are basaltic to basaltic andesite in composition and alkaline to subalkaline in character. A plot of total alkali *versus* silica (Figure 28) shows the alkaline bias of these rocks which is typical of the entire belt. Another characteristic is their slight potassium enrichment. The subalkaline basalts are dominantly calcalkaline (Figure 29). Figures 28 and 29,

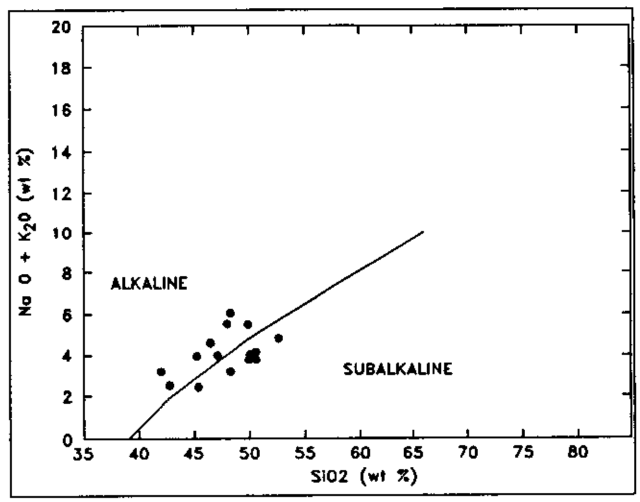

Figure 28. Plot of total alkali *versus* silica for Takla Group basalts (after Irvine and Baragar, 1971).

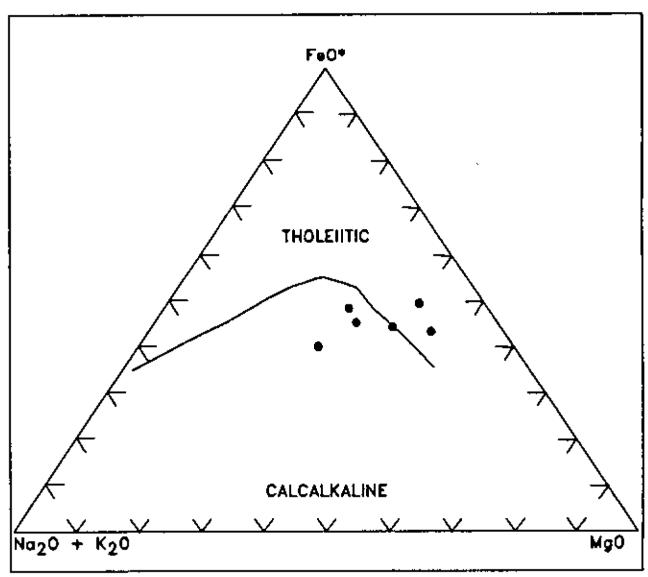

Figure 29. AFM plot of subalkaline Takla Group basalts (after Irvine and Baragar, 1971).

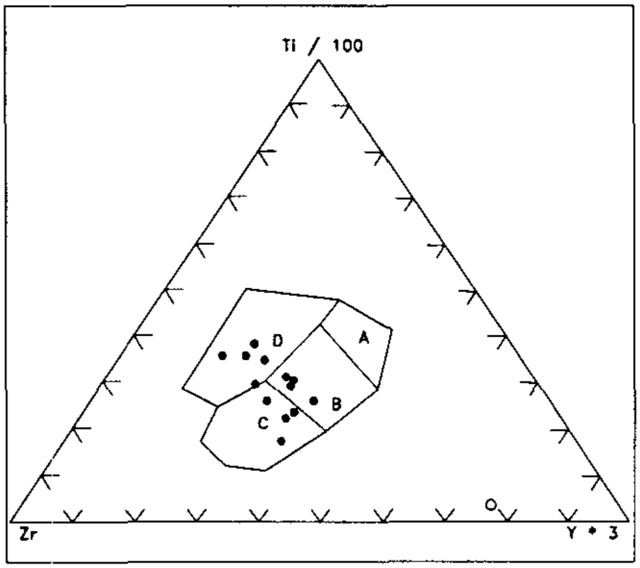

Figure 30. Ternary plot of Ti/100 - Zr - Yx3 for Takla Group basalts. B=ocean-floor basalts; A, B=low-potassium tholeiites; B, C=calcalkaline basalts; D=within-plate basalts (after Pearce and Cann, 1973).

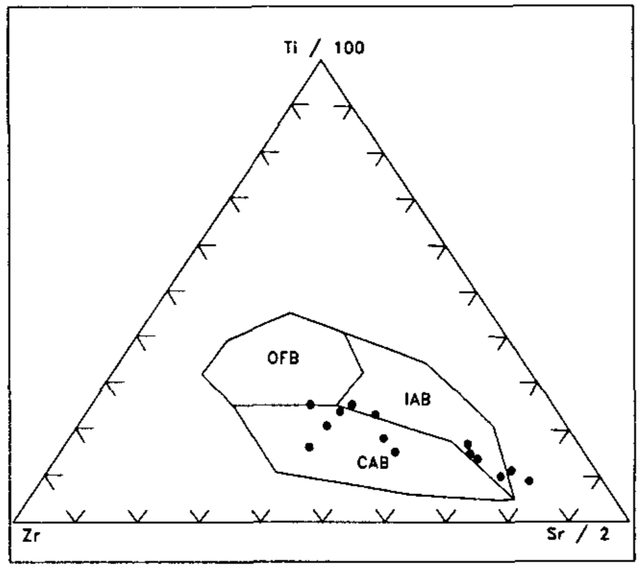

Figure 31. Ternary plot of Ti/100 - Zr - Sr/2 for Takla Group basalts. The linear trend of data from the strontium apex is probably a result of alteration. OFB=ocean-floor basalts; IAB=island-arc basalts; CAB=calcalkaline basalts (after Pearce and Cann, 1973).

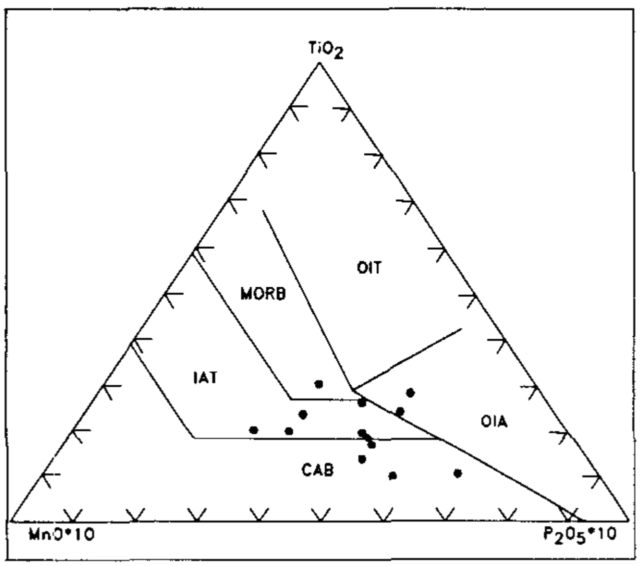

Figure 32. Ternary plot of TiO_2 - MnOx10 - P_2O_5x10 for Takla Group basalts. OIT=ocean-island tholeiites; MORB=mid-ocean ridge basalts; IAT=island-arc tholeiite; OIA=ocean-island alkaline basalt; CAB=calcalkaline basalt (after Mullen, 1983).

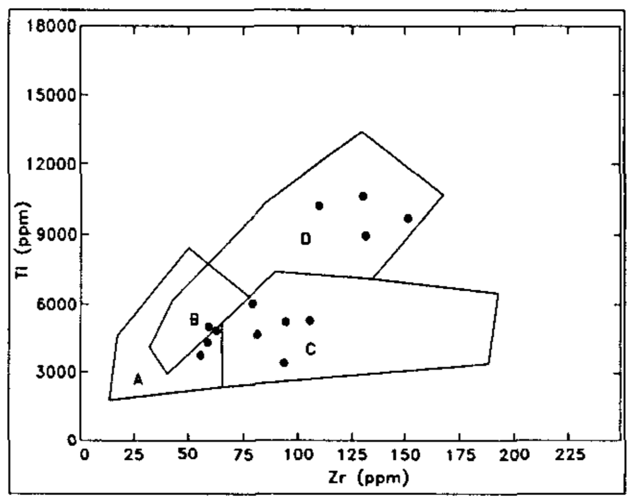

Figure 33. Plot of Ti *versus* Zr for Takla Group basalts. D, B=ocean-floor basalt; A, B=low-potassium tholeiite; A, C=calcalkaline basalt (after Pearce and Cann, 1973).

together with other major element diagrams not shown here, display a significant amount of scatter, indicating major element remobilization during regional metamorphism or weathering. Other minor and trace element plots were utilized in an attempt to overcome this problem. As can be seen in the succeeding diagrams the amount of scatter is as great, or greater than in the major element plots. This probably reflects the variable nature of the Takla Group (*i.e.*, island arc to back-arc basin) and possibly the composition of the basement.

Plots of TiO_2 *versus* Y/Nb and P_2O_5 *versus* Zr (Figures 35 and 36) also show the alkaline nature of these basaltic rocks. On Figure 35, the discrimination of alkalic from tholeiitic basalts is based on the yttrium/niobium ratio, which is less that 1 for alkalic rocks. Approximately half the samples plot on or below this line.

Tectonic discrimination diagrams of Pearce and Cann (1973) and Pearce (1980) utilize the elements titanium, zirconium yttrium and strontium (Figures 30, 31, 33 and 34). These diagrams, when taken together, favour an arc setting for the Takla volcanics. Data points on Figure 31 are relatively scattered (due to the mobility of strontium

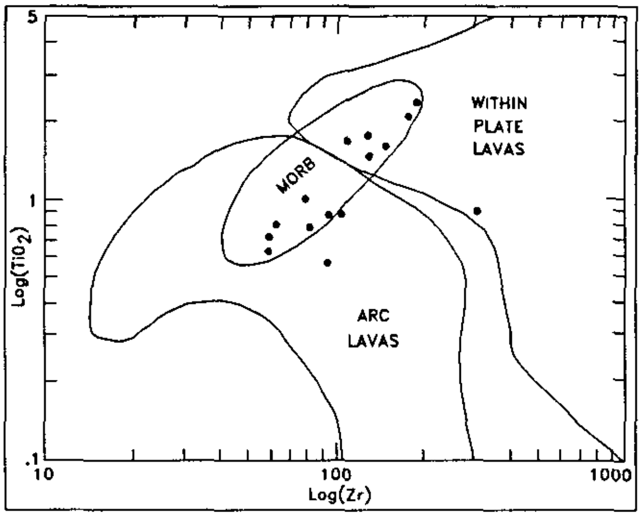

Figure 34. Plot of log(TiO_2) *versus* log(Zr) for Takla Group basalts. MORB=mid-ocean-ridge basalts (after Pearce, 1980).

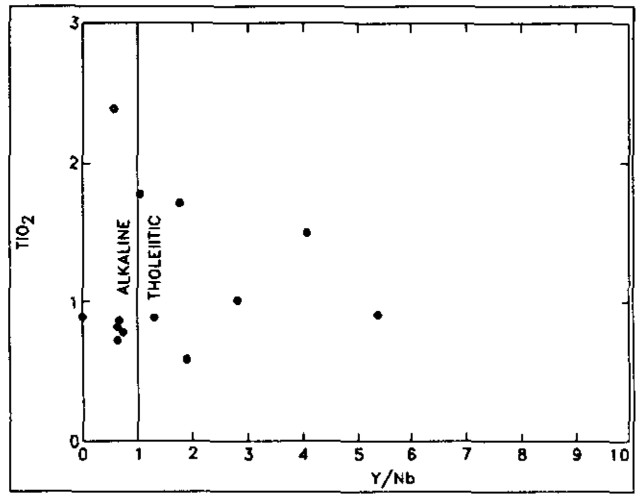

Figure 35. Plot of TiO_2 *versus* Y/Nb for Takla Group basalts (after Floyd and Winchester, 1975).

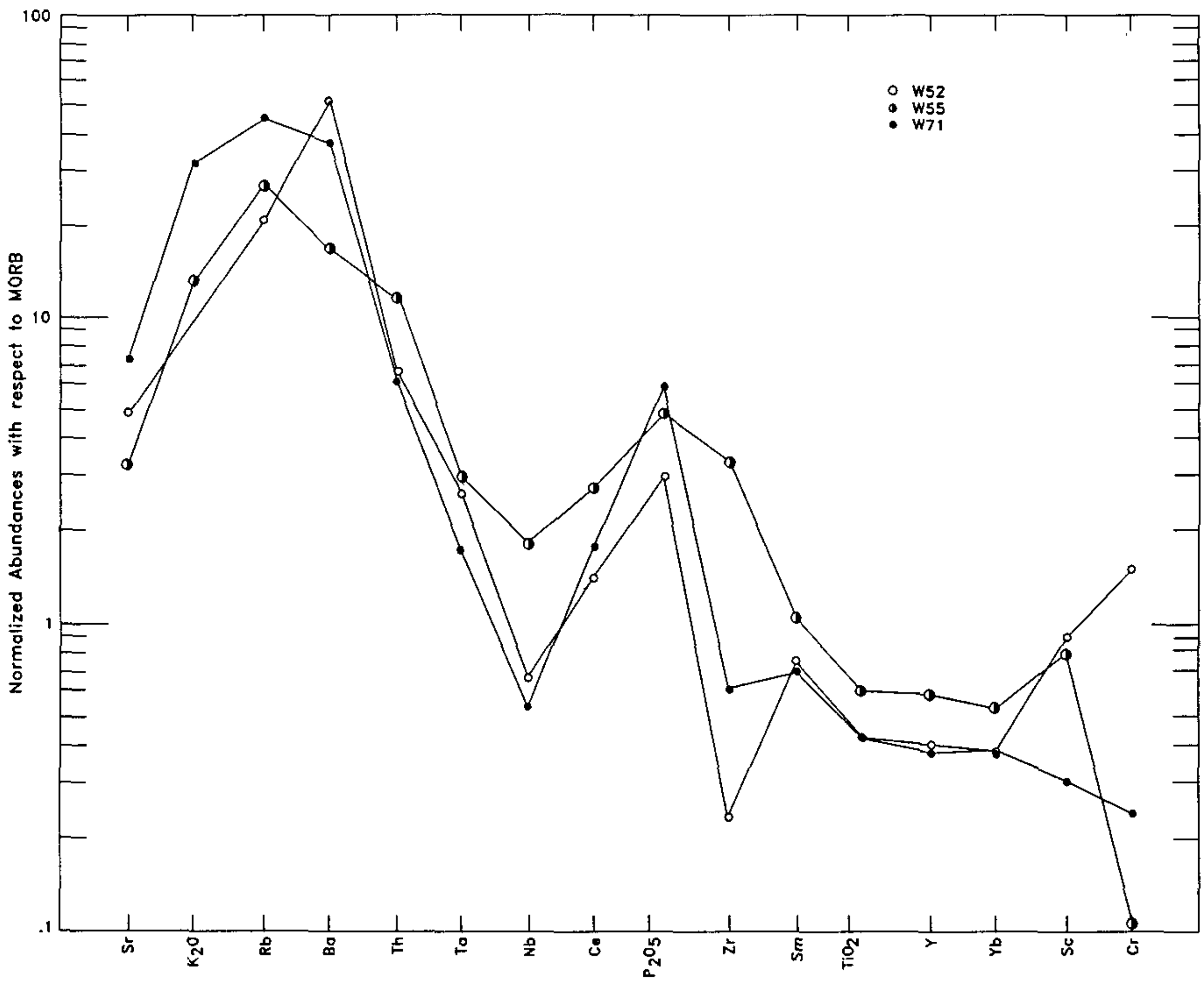

Figure 37. Extended trace element plot for Takla Group basalts and basaltic andesites of the study area. This pattern is indicative of basalts erupted within island-arcs. Normalized against mid-ocean ridge basalts using values from Pearce (1982); Sr=120 ppm; K_2O=0.15%; Rb=2 ppm; Ba=20 ppm; Th=0.2 ppm; Ta=0.18 ppm; Nb=3.5 ppm; Ce=10 ppm; P_2O_5=0.12%; Zr=90 ppm; Sm=3.3 ppm; TiO_2=1.5%; Y=30 ppm; Yb=3.4 ppm; Sc=40.0 ppm Cr=250 ppm.

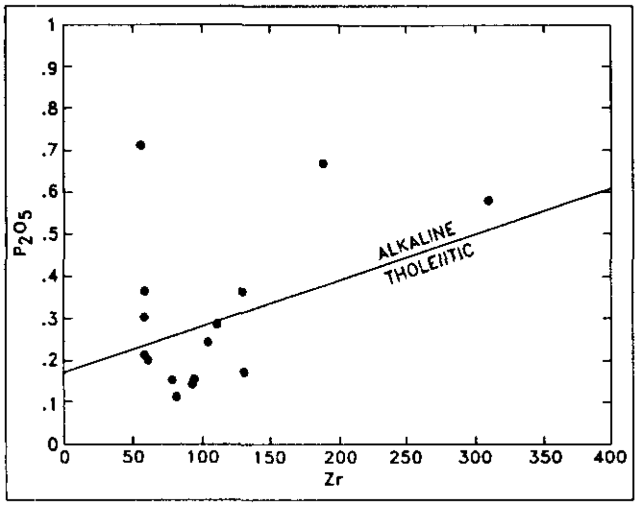

Figure 36. Plot of P_2O_5 *versus* Zr for Takla Group basalts (after Winchester and Floyd, 1976).

during low grade metamorphism), but fall within the fields defined as calcalkaline basalts to island-arc basalts. Figure 33 (Zr *vs* Ti) also indicates the calcalkaline nature of these basalts but the spread of data also falls within the field designating ocean-floor basalts. Figures 30 and 34 show the calcalkaline arc nature of these rocks and also their trend toward within-plate basalts (*i.e.*, alkalic oceanic-island basalts). This latter trend led some geologists working in the southern Quesnel belt to favour a rift environment (Morton, 1976; Preto, 1977).

The titanium content of island arcs tends to be low, less than 0.7% TiO_2 (Perfit *et al.*, 1980), a characteristic displayed by some of the data plotted on Figure 35. Mullen (1983) uses this trend in a ternary plot of TiO_2-P_2O_5-MnO (Figure 32) and these data show the calcalkaline island-arc nature of these volcanics. Takla basalts with anomalous TiO_2 values are clearly seen on Figures 30, 33 and 34 where they produce distinct clusters separate from the other basalts. These basalts originate from the Plughat Mountain region and may represent localized, anomalous magmatism with within-plate characteristics.

Finally, extended trace element data were obtained for selected samples of the Takla Group. These data are shown on Figure 37. The relatively flat slope that is characteristic of MORB composition is lacking. Instead the pattern is typical of island-arc volcanics. The elements strontium through to thorium and phosphorous show an enrichment relative to tantalum and niobium which is typical of island-arc basalts (Pearce, 1982). Another feature of island-arc basalts is the low abundance (below unity) of zirconium through to scandium relative to MORB values.

These basalts also show an overall enrichment of strontium to samarium relative to true island-arc tholeiites (*see* Figure 1 of Pearce, 1982). Such a pattern can be produced by anomalous volcanic-arc basalts. This anomalous character may result from a mantle source which records either two periods of enrichment (as opposed to one for classic island-arc tholeiites) or mixing of magmas from two separate sources. Pearce (1983) indicates that continental lithosphere contamination of arc lavas (*i.e.*, arcs deposited on continental crust) can cause a similar, and more dramatic, enrichment in these elements. Pearce (*ibid.*) also presents a diagram which discriminates between arcs developed on continental or oceanic lithosphere on the basis of zirconium and yttrium ratios (Figure 38). Data for Takla rocks from the study area clearly plot within the continental-arc field. This suggests that the Takla arc may be built on continental lithosphere. There is no evidence for this within the map area but indirect evidence exists in the Lay Range, immediately to the northwest (*see* under Nina Creek group and chapter on Metamorphism).

Chemical trends documented here are in very good agreement with those previously reported in southern British Columbia (Morton, 1976; Preto, 1977; Fox, 1977; Mortimer, 1986, 1987; Bailey, 1978; Lu, 1989) and in the study area (Meade, 1977).

Many of the trace element and rare earth plots indicate calcalkaline magmatism related to arc volcanism, however, other diagrams suggest within-plate signatures (*i.e.*, ocean-island basalts or rift volcanism). The latter trend may suggest a more complex origin for these volcanic rocks. Mortimer (1987) obtained similar variations for Nicola volcanics in southern British Columbia. He shows that volcanics having within-plate characteristics have affinities with volcanics that are distinctly calcalkaline and arc related. He points out that the two groups are interbedded (as seen in the study area) and rules out the possibility that arc volcanism may have been periodically interrupted by rifting as suggested by the within-plate basalts. These lavas indicate a transition between arc and within-plate volcanism which may be related to back-arc spreading. Furthermore, Mortimer states that the chemical trend of volcanics from western to eastern belts suggests eastward subduction.

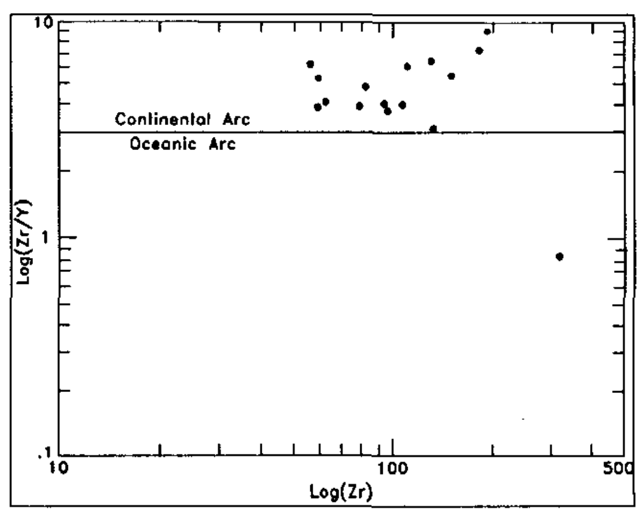

Figure 38. Plot of log (Zr/Y) versus log Zr (from Pearce, 1983). This diagram distinguishes between arc volcanics erupted on oceanic crust and those erupted on continental crust. Almost all the data for the Takla Group fall within the continental-arc field.

Chemical data, in conjunction with the overall characteristics of the Takla Group volcanics and sediments, suggests they formed in an island arc.

INTRUSIVE ROCKS

CARBONATITES (Late Devonian to Early Mississippian)

Carbonatite and syenite intrude the Ingenika Group at Granite Creek and approximately 5 kilometres northeast of the Wolverine Lakes. These bodies are small; the Granite Creek exposure is only 50 metres wide and 500 metres long. They contain significant concentrations of rare earth elements, particularly niobium. They have been dated by Pell (1987), using uranium/lead ratios, as Late Devonian to early Mississippian. For a more detailed account of these rocks see chapter on Economic Geology and Pell (1987).

WOLF RIDGE GABBRO (Informal, Late Paleozoic to Earliest Mesozoic?)

Lenticular bodies of gabbro, the largest of which is some 15 kilometres long and 3 kilometres wide, are found within the Manson fault zone. They extend, en echelon, from immediately southeast of Germansen Landing to southeast of Lower Manson Lake. The best exposures are on Wolf Ridge, directly north of Manson Creek.

The margins of these bodies are not well exposed. Typically, highly strained or brittly deformed rocks occur close to gabbro contacts, as near the Fairview showing, 1 kilometre northwest of Manson Creek, and on the north shore of Lower Manson Lake. On Wolf Ridge, there is a decrease in grain size toward the edge of the gabbro (towards the southwest) which may represent a chilled margin. However, the lenticular shape of these bodies, their presence within the Manson fault zone, and the fault zones near their margins, all suggest that their contacts are probably faulted and that the gabbros preserved along the Manson fault are slivers of an originally larger intrusive body.

The gabbro is green to dark green and light brown to rusty brown weathering. It ranges in composition from 40 to 60% completely sericitized plagioclase with the remainder of the rock being pyroxene, minor hornblende and biotite. It is typically fine to medium grained, although pegmatitic phases are present on the crest of Wolf Ridge.

Almost all exposures of this unit exhibit a weak to moderate mineral lineation with an accompanying, very weak planar fabric. This weak fabric may grade into zones of mylonite a few metres across but the deformation is not uniform throughout any outcrop. The highly strained zones are generally found toward the edge of the gabbro bodies.

Age: Preliminary U-Pb radiometric dating of the Wolf Ridge gabbro is ambiguous due to: the limited number of zircon fractions analyzed, their low uranium and lead contents, and low measured $^{206}Pb/^{204}Pb$ ratios (Appendix II, Figure 69). An approximate minimum age of 245.4 ± 0.7 Ma (2σ) is given by the near concordant coarse fraction. The present limited data precludes confident dating any closer than late Paleozoic.

The lenticular bodies of gabbro occur within phyllites and argillites of the Slate Creek succession and Big Creek group. If their contacts are intrusive then this makes these rocks no older that Late Triassic. This conclusion run contrary to the approximate late Paleozoic age for the Wolf Ridge gabbro. This suggests that either the contacts are not intrusive or that the argillites assigned to the Slate Creek succession are older. This latter inference is quite possible considering the abundance of similar, variously aged argillite packages in the map area. The mafic composition of these bodies and their proximity to the Manson Lakes ultramafics and associated rocks of the Nina Creek group, suggests a genetic relationship. The Wolf Ridge gabbro, together with the Manson Lakes ultramafics and the Nina Creek group, may represent fragments of a dismembered ophiolite. The Crooked amphibolite, which is correlative with the Manson Lakes ultramafics, contains gabbroic lithologies (Rees, 1987) which further suggests a link between the Wolf Ridge gabbro and the Manson Lakes ultramafics. The present data do not permit resolution of this problem.

WEHRLITE (Triassic to Jurassic)

In the northwest part of the map area, the basal part of the Pillow Ridge succession contains lenticular bodies of wehrlite up to 200 metres thick. These occur at several horizons and are associated with gabbro sills and siliceous sediments of the Pillow Ridge and Mount Howell successions. They are composed of clinopyroxene, olivine, serpentine (after olivine) and magnetite. The contacts with the surrounding rocks are not tectonically disturbed, indicating they are intrusive.

This group of intrusions may be related to the Polaris Complex and related Alaskan-type ultramafic bodies which intrude rocks of similar age in the Uslika Lake area and in the Lay Range (Nixon *et al.*, 1990; Roots, 1954).

GABBRO (Jurassic or Younger)

A small body of gabbro intrudes the lower part of the Takla Group, 1 kilometre south of the mouth of Nina Creek. It is grey, massive, medium to coarsely crystalline and contains a very weak foliation which trends northwesterly. It is composed of plagioclase (50%), pyroxene (30%), sphene(?) (10%) and hornblende, sericite and calcite. Similar gabbro intrudes Takla rocks at the extreme western margin of the map area, immediately north of the Omineca River. It does not resemble the Wolf Ridge gabbro and its exact age and relationship to other intrusive rocks is not known.

GERMANSEN BATHOLITH AND RELATED ROCKS (Cretaceous and Tertiary)

The southern part of the map area is intruded by the Germansen batholith. It is exposed on the alpine slopes near Mount Gillis and extends northwestward to the area around Mount Germansen, immediately south of Germansen Lake. The batholith is a multiphase intrusion composed of granodiorite, two-mica granite, related pegmatitic phases and aplite dikes.

Granite is characteristic of the Mount Gillis area, but granodiorite and diorite border phases were mapped at the southeastern contact. The granite is white to grey in colour and weathers beige to pink. It is commonly coarsely crystalline and occasionally phenocrysts of potassic feldspar up to a few centimetres in length are present. Accessories are primarily biotite and muscovite with lesser amounts of hornblende and, in some areas, chlorite after biotite. Granite pegmatite and aplite dikes, up to a metre in thickness, cut the batholith. The pegmatites are similar in composition to the intrusion but commonly contain garnet and occasionally apatite.

Near Mount Germansen, the batholith is a weakly to moderately foliated hornblende biotite granodiorite composed of 40 to 50% plagioclase, 20 to 25% quartz, 15 to 20% potassic feldspar and 10 to 15% biotite and hornblende. Accessory minerals include apatite, zircon and magnetite(?). It is medium to coarsely crystalline and commonly contains large (up to 5 centimetres long) phenocrysts of potassic feldspar aligned along the foliation. The foliation generally parallels the intrusive contact and is associated with a steep mineral lineation indicating that this fabric is related to batholith emplacement.

Rocks in the southeastern parts of the intrusion are similar in composition to the granodiorite in the Mount Germansen area but are finer grained, lack phenocrysts and are only weakly foliated.

Age: Several radiometric dates have been obtained from the batholith in the study area. Garnett (1978) obtained K-Ar ages of 106 and 86 Ma on hornblende and biotite respectively from the granodiorite below Mount Germansen. The 20 Ma difference between the cooling ages probably reflects resetting of the biotite K-Ar systematics by local Tertiary monzonite intrusions as opposed to simple cooling of the magma. This study obtained a K-Ar date of 107 Ma on biotite from two-mica granite in the Mount Gillis area (Appendix II). These data suggest that both phases of the Germansen batholith were closely spaced in time.

MONZONITE TO QUARTZ MONZONITE AND RELATED VOLCANICS (Early Tertiary)

Small irregular stocks (less than 1 square kilometre) and dikes of andesite or related monzonite or quartz monzonite porphyry intrude rocks of the Takla Group, Nina Creek group, Germansen batholith and Ingenika Group in the southern part of the map area. They are locally vesicular, indicating a possible extrusive or subvolcanic origin. The dikes trend predominantly north-northwest and are commonly recessive, producing gullies.

The monzonites are beige to pinkish in colour and are plagioclase, potassic feldspar and quartz phyric (quartz monzonites) with the quartz displaying resorbed margins. The matrix is composed of fine-grained plagioclase, potassic feldspar and muscovite. Phenocrysts are muscovite, biotite and hornblende

Abundant monzonite to quartz monzonite intrudes the Germansen batholith around Mount Germansen, and segments of the Olsen Creek fault. These rocks form dikes up to 15 metres wide and irregular bodies over 20 metres in diameter. Only a few dikes were observed in the Mount Gillis area. This unit lacks the penetrative fabric of the Germansen batholith.

Extensive subvolcanic or extrusive examples of these rocks can be seen along West Dog and Dog creeks west of Germansen Lake. Smaller extrusive centres are found west of Lower Manson Lakes within the Boulder Creek group and along Connaghan Creek. These volcanics(?) are quite calcareous along Dog Creek and are associated with copper and zinc mineralization (Table 6). The wide distribution of outcrops of this type in the area west of Germansen Lake suggests this area is entirely underlain by these rocks.

Age and Correlation: A specimen of subvolcanic andesite from immediately east of Connaghan Creek, in the southern part of the map area, returned a biotite K-Ar age of 48.6 Ma (Appendix II). These rocks appear very similar to small porphyry bodies which intrude the Germansen batholith and its margin. Monzonite from the Germansen batholith has yielded a K-Ar age of 45 Ma on biotite (*see* Appendix II). Mineralogically and geochronologically, these two groups of rocks are similar which further suggests they are genetically related.

Subvolcanic and volcanic rocks of this suite near Connaghan Creek were originally included with the Endako Group by Armstrong (1949). Armstrong also noted that these rocks have greater affinities with younger Eocene or Oligocene felsic volcanics than with the predominantly mafic volcanics of the Endako Group. Eocene felsic volcanism within the central Intermontane Belt is represented by the Ootsa Lake Group (Souther, 1991). Monzonite and their extrusive equivalents in the map area are correlated with Eocene Ootsa Lake Group volcanics and related intrusive rocks

MONZONITE TO SYENITE (Cretaceous or Tertiary)

In the southeastern part of the map area, approximately 2 kilometres east of the Manson River, bodies of monzonite, monzodiorite and syenite intrude schists and gneisses of the Ingenika Group (Halleran, 1988). They form small stocks or dike-like bodies and are important in that they carry significant amounts of rare earth elements (*see* Economic Geology). They contain accessory aegerine-augite which is commonly altered to epidote.

There is no age on the rare earth rich syenites east of the Manson River. They lack a penetrative fabric typical of the Devono-Mississippian carbonatites, suggesting they are much younger. These rocks are found within the Wolverine Range and are spatially related to the Late Cretaceous to Tertiary(?) Wolverine Range intrusions, suggesting a genetic link. The abundance of Tertiary intrusive and volcanic activity in the area does not preclude these intrusions from being younger than Cretaceous.

WOLVERINE RANGE INTRUSIONS (Informal, Late Cretaceous to Tertiary? or Older?)

A series of dikes and sills of pegmatite and related granodioritic stocks intrudes the strongly metamorphosed rocks of the Ingenika Group in the Wolverine Range. These intrusive rocks are volumetrically important as they constitute over 50% of the exposed lithologies in the lower parts of the Ingenika Group within the Wolverine Range.

Pegmatite typically occurs as dikes and sills up to 5 metres thick and large irregular outcrops of pegmatite up to 250 metres in diameter are common. These bodies are grey to white in colour and are made up of garnet, muscovite, biotite, quartz, potassium feldspar and plagioclase. Garnet comprises up to 10% of the rock; it is often concentrated toward the contacts of the sill or dike. Micas constitute up to 20% of the pegmatites and large crystals of mica, up to 10 centimetres across, are commonly present within some of the larger pegmatite bodies.

Granodiorite is grey to beige in colour, medium to very coarsely crystalline and occurs as small stocks up to 50 square kilometres in area. Their composition is similar to that of the pegmatite dikes and sills, with garnet being a very important accessory. These rocks are very uniform in composition throughout the complex. North and west of Chamberland Creek, granodiorite and pegmatite underlie an area of some 60 square kilometres. The granodiorites display a weak to moderate foliation which is steeply dipping and trends northeasterly.

Age: Preliminary U-Pb data from zircon analyses indicate a Late Cretaceous age for the granodiorites within the Wolverine Range (Appendix II, Figure 70). Three fractions were analyzed including two monozite. A minimum age of 71.0 $\pm$ 0.6 Ma (2σ) is obtained using points b and c (Figure 70). The $^{207}Pb/^{235}U$ ratio provides the most dependable date for monozite analyses which in this case is 72.8 $\pm$ 0.2 Ma (2σ). The age of inherited lead is 1.8 $\pm$ 0.1 Ga based on upper intercepts through points b and c (Figure 70).

Many of the larger pegmatite sills and dikes commonly contain a poorly developed, widely spaced cleavage or foliation at their contacts which parallels the foliation in the metasediments. This indicates that these rocks may have intruded near the end of the D_1 deformation which is of Jurassic age (*see* Structure chapter). Many of the thinner pegmatite sills and dikes are strongly boudinaged, sometimes to the point of complete dislocation. However, the large bodies of granodiorite contain a weak, northeast-trending foliation not related to any of the main deformational events, indicating that they may be much younger (as shown above) than the bulk of the pegmatitic material.

Deville and Struik (1990) have shown that in the southern part of the Wolverine Complex fabric found within post-D_1 granitic rocks is probably Tertiary in age and is related to extensional and strike-slip tectonics. The age of this fabric is based on the interpreted Tertiary age of these granitic rocks. Furthermore, this fabric is shown to be parallel to the D_1 foliation in the surrounding metasediments. These observations suggests that the fabric affecting pegmatites and related granodiorite within the Wolverine Range is entirely Tertiary and not related to the older D_1 deformation. This fabric is probably related to uplift of the metamorphic complex along the Wolverine and related fault zones.

STRUCTURE

INTRODUCTION

Many structural styles are evident within the map area, which reflects its position along the boundary between two major tectonostratigraphic provinces of the Canadian Cordillera. The northeastern quadrant of the area is dominated by polydeformed and strongly metamorphosed rocks of the Omineca Belt. These rocks become less metamorphosed and deformed to the southwest, such that at the upper levels of this package only one or two phases of deformation are evident. The Intermontane Belt is characterized by low-grade metamorphism and broad, high-level structural features similar to those in the upper levels of the Omineca Belt. These two structural and stratigraphic provinces are separated by the dextral Manson fault zone, one of several, major structural elements in the area. The other important structural feature is the Wolverine fault zone, a brittle-ductile fault located on the west side of the Wolverine Complex.

Four penetrative phases of deformation (D_1 to D_4) have been identified within metamorphic rocks of the map area. They have been recognized on the basis of interference and crosscutting relationships, structural styles and their connection to metamorphism.

A chart indicating timing of major deformational and metamorphic events is shown in Figure 39. Structural elements within the map area will be described with respect to the two tectonostratigraphic provinces (*i.e.*, Omineca and Intermontane belts) due to the distinct structural styles and deformational histories found within each region.

The following discussion will make reference to specific deformational "events" and related structures (D_1, D_2, S_1, S_2, F1, F_2, *etc.*). These "events" have been invoked solely for descriptive purposes and do not necessarily represent distinct episodes of deformation. In fact, some or all of them may be part of one extended period of deformation.

OMINECA BELT

The Omineca Belt contains strongly metamorphosed and polydeformed rocks that culminate within metamorphic core complexes which record an extended period of contractional deformation spanning the Jura-Cretaceous boundary. Subsequently these rocks were uplifted and cooled during the Late Cretaceous to Early Tertiary (Parrish *et al.*, 1988; Carr *et al.*, 1987, Brown and Carr, 1990). As a consequence, the core complexes are flanked by less deformed and metamorphosed rocks representing higher structural levels.

Rocks of the Cassiar, Kootenay and Slide Mountain terranes are included within the Omineca Belt. Even though they may have been formed in regions far removed from each other, the structures present within each reflect the processes that brought them to their present configuration.

Rocks of the Omineca Belt within the study area typify the structural and metamorphic style of the belt. Gneiss and schist underlying the Wolverine Range were rapidly uplifted during the Early Tertiary, following several episodes of deformation that began in mid-Jurassic time. Uplift occurred along the east-side-up Wolverine fault zone. This fault marks the boundary between polydeformed and strongly metamorphosed rocks of the Wolverine Metamorphic Complex (Domain 1, Figure 40) and less metamorphosed strata in the hangingwall, which in this area are represented by the upper parts of the Proterozoic Ingenika Group, lower Paleozoic succession and the Nina Creek group (Domain 2). Deformation within the Wolverine Metamorphic Complex reflects the highly ductile, deeper structural and stratigraphic level of the orogen (*i.e.;* infrastructure) whereas the flanking rocks represent more brittle, upper level regions (superstructure). Omineca rocks of the study area have been divided into three large domains reflecting these differences (Figure 40). This has been done primarily for ease of discus-

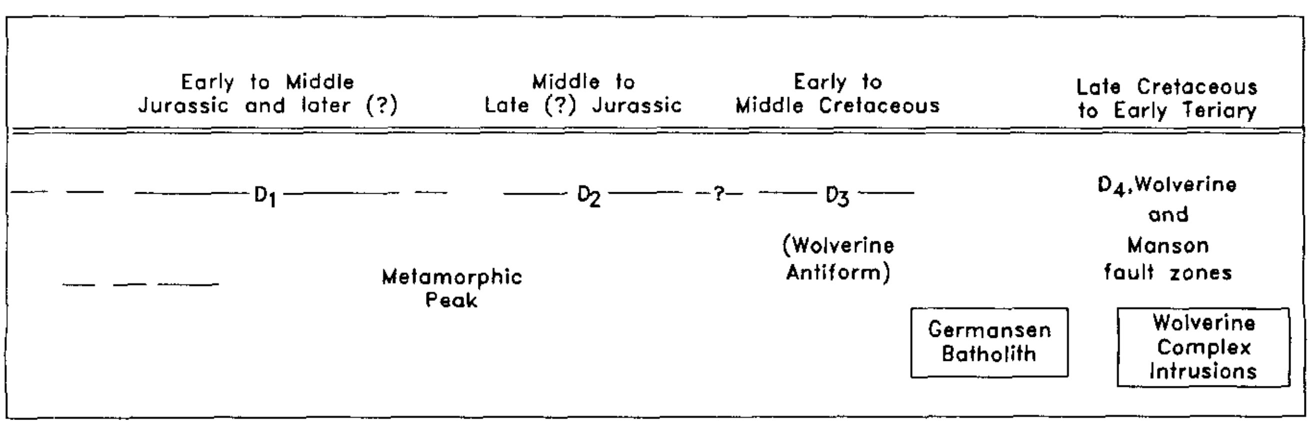

Figure 39. Relative timing of main deformational, metamorphic and intrusive events in the study area.

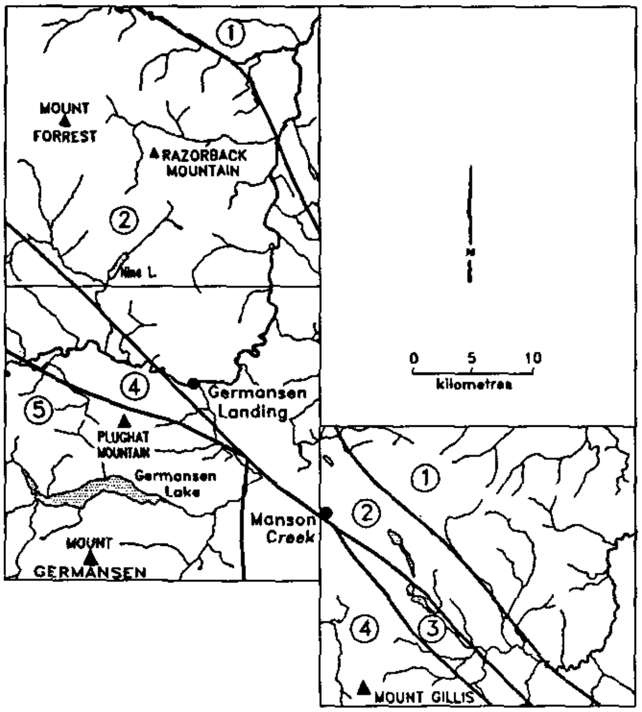

Figure 40. Structural domains used in discussion of structural trends.

sion and to contrast the structural styles in each domain which reflect the different metamorphic grades at each level.

Domain 1 is located east of the Wolverine fault zone and essentially follows the trend of the Wolverine Range. It is composed of high-grade metamorphic rocks of the Ingenika Group. Rocks of Domain 1 were at considerably higher grade (garnet to sillimanite) during the progressive deformation and remained relatively hot until Early Tertiary time.

Domain 2 lies between the Wolverine and Manson fault zones and occupies a much broader area. Due to the variable attitude of the Wolverine fault zone, this domain is considerably wider at its northwestern end. In the Manson Lakes area it is some 5 kilometres wide, whereas in the north it is over 20 kilometres in width. This domain includes rocks of the Swannell to Tsaydiz formations, the lower to middle Paleozoic succession and oceanic rocks of the Nina Creek group. Most of the strata of Domain 2 were below garnet grade metamorphism during deformation and cooled in Middle Jurassic time. It also contains a series of excellent marker units (Atan Group and Espee Formation) which are useful in outlining megascopic structures. Fossiliferous units within the domain permit the documentation of numerous cryptic thrust faults.

Domain 3 lies within the Manson fault zone. Rocks of Domain 3 are dominated by the Boulder Creek group, thought to be part of the Kootenay Terrane and stratigraphically linked to rocks of the Cassiar Terrane. They contain polyphase structures and metamorphic assemblages (garnet-staurolite) typical of Cassiar rocks within Domains 1 and 2. The present configuration of these rocks is a consequence of movement along the Late Cretaceous to Tertiary Manson and Wolverine fault systems. Domain 3 is a narrow region which is open to the southeast and tapers to a single fault plane in the northwest where the two bounding fault strands come together. No marker horizons are recognized within the monotonous Boulder Creek sequence, and as a result, the internal geometry is unknown.

The eastern part of the Omineca Belt (Domain 1) is characterized by the Wolverine antiform, a broad, kilometre-scale D_3 structure. Except for fold hinges, foliation is everywhere layer parallel. There are no marker horizons within the lower Ingenika Group and so detailed megascopic structures could not be delineated. Only upright, kilometre-scale F_2 folds could be mapped by the reversal of bedding attitudes. As a consequence, the detailed internal geometry of this region is unknown.

Rocks west of the Wolverine fault zone (Domain 2) define a southwest-dipping homoclinal succession representing the west flank of the Wolverine antiform. Strata in the Porter Creek area swing eastward and delineate the top of another large, subsidiary antiform. Outcrop in the Porter Creek area is very limited and does not preclude the presence of thrust faulting as a possible mechanism for the production of this pattern. The homoclinal succession of Domain 2 is modified by large subsidiary folds in the northern part of the map area and is cut by a series of late, normal faults.

In Domain 1, metamorphic mineral assemblages indicate garnet to sillimanite grade or higher. These rocks behaved quite plastically during D_1 deformation leading to the production of a strong, ubiquitous layer-parallel fabric. Most of the rocks in Domain 2 are at chlorite grade or lower. As a consequence these rocks were relatively less ductile during D_1 deformation and movement was concentrated along comparatively incompetent horizons or fault zones. Only a small area of Domain 2 (on the northeast flank of Breeze Peak) is between biotite and garnet grade, and contains similar fabrics to those in Domain 1.

The four phases of deformation are most clearly developed within the strongly metamorphosed rocks in the eastern part of the belt. Only one or two of these phases of deformation are clearly evident in the western part of this region. The following discussion examines the structural elements of each phase of deformation.

PHASE 1

The most dominant structural element of the D_1 deformation is the ubiquitous, layer-parallel foliation (S_1). It was produced by the preferential alignment and subsequent growth of phyllosilicate minerals parallel to bedding. This fabric is most pronounced in rocks above the biotite isograd.

Throughout most of Domain 2, this S_1 fabric is most prominently developed within interlayered siltstone and shale or sandstone and shale sequences with the fabric being most prominent within the shaly layers. Typically muscovite and chlorite porphyroblasts have grown parallel to compositional layering in shaly horizons.

In Domain 3 (Boulder Creek group) the first phase of deformation also resulted in a layer parallel foliation (S_1).

Its vergence is unknown as no minor structures were observed. Deformation and metamorphism were contemporaneous with metamorphism, outlasting deformation (*see* chapter on Metamorphism).

Within the strongly metamorphosed rocks of Domain 1, D_1 structures are characterized by tight to isoclinal, northeast-verging folds with an axial planar foliation (S_1) defined by the preferred growth of micaceous minerals (Plate 26). F_1 folds are relatively rare as can be seen from the relatively few measurements plotted on Figures 41 and 42. They exhibit a similar type fold style (Ramsay, 1967) which is common in rocks deformed at high temperatures. The presence of micas at a high angle to bedding within the hinge zones of F_1 folds indicates that compositional layering has been transposed parallel to foliation during folding.

In the northern part of Domain 1, F_1 fold axes, together with metamorphic mineral lineations (Figure 43), trend southeasterly. These fold axes are subhorizontal to slightly southeast plunging. Some of the fold axes plotted on Figure 41 plunge southwest or vertically. This may be the result of motion along the ductile segment of the Wolverine fault zone which has rotated the fold axes into the transport direction. Alternatively, these attitudes may be the result of northeast transport during compressional deformation.

Mesoscopic F_1 folds are very rare in most of Domain 2 and may simply reflect the lower ductility of these rocks. In the Big Creek group, tight, northeast-verging chevron folds were mapped near the Otter Lakes (Plate 27). Their axial planes are subparallel with compositional layering and their fold axes trend northwesterly. Similar folds were mapped in carbonate rocks of the upper Big Creek group.

One outcrop of quartz-chert wacke in the Big Creek group contains a very strong lineation produced by stretched quartz and chert clasts. It plunges gently to the northwest, appears parallel to bedding and is believed to be related to this phase of deformation.

Plate 26. F_1 fold in schists of the lower Swannell Formation north of Edmunds Creek. These folds are very difficult to distinguish within the rather monotonous clastic sequence of the Swannell Formation. They commonly display a similar fold style and are tight to isoclinal.

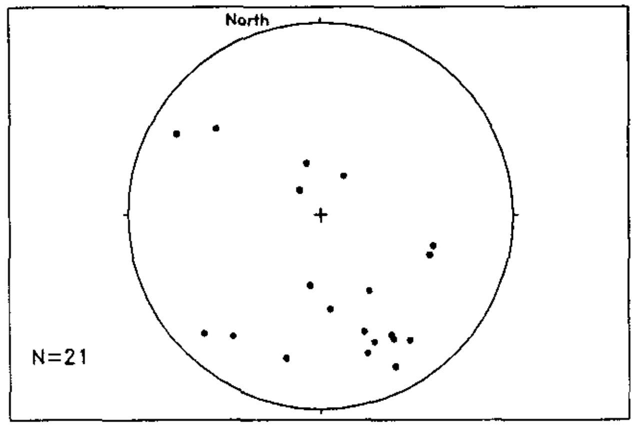

Figure 41. Equal-area projection of F_1 fold axes, southern part of Domain 1. These trend southeasterly for the most part.

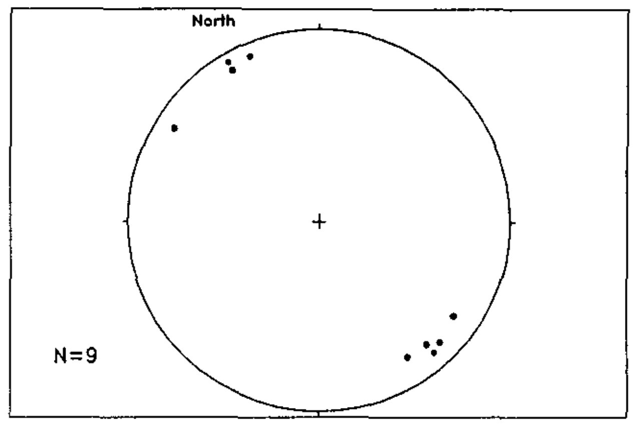

Figure 42. Equal-area projection of F_1 fold axes in the northern part of Domain 1.

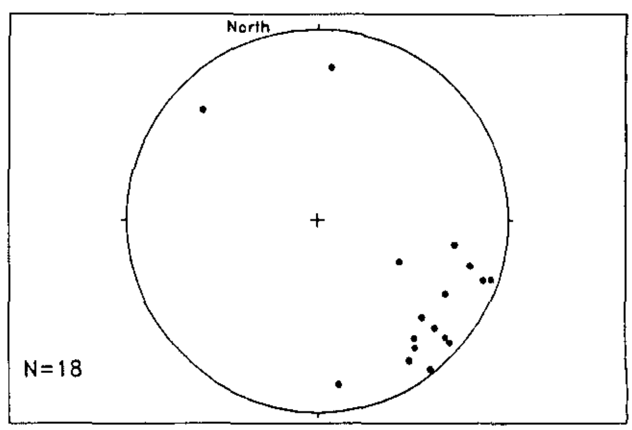

Figure 43. Equal-area projection of mineral lineations in the northern part of Domain 1.

Plate 27. Tight chevron fold in Big Creek shales (immediately to the left of the pencil), near Otter Lakes. These northeast-verging folds may be related to D_1 deformation.

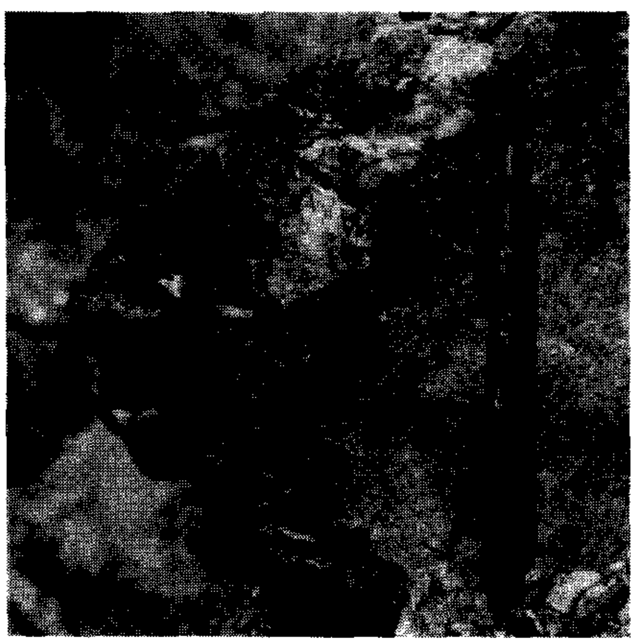

Plate 28. Flat-lying late-F_1 fold near the mouth of Edmunds Creek. S_1 foliation is axial planar to these folds, but as seen here, this foliation is crenulated within these fold hinges suggesting these folds are late in D_1 deformation. *See* text for details.

Small, 1 to 2-centimetre wavelength, northeast-verging folds were observed in thinly layered carbonates of the Atan and Echo Lake groups. Similar fold styles outlined by quartzitic layers of the Atan Group, have been noted in a float boulder.

A crenulated S_1 foliation was observed in the hinge regions of mesoscopic folds in Domain 1 and in the high-grade areas of Domain 2 (Plate 28). These folds are northeast-verging, tight to isoclinal and have axial planes parallel to compositional layering and S_1 foliation. They are extremely rare in the map area and, we believe, do not warrant a separate classification. They clearly postdate metamorphism as evidenced by the lack of mica growth in their hinges; yet these folds have the same vergence, morphology and attitude as F_1 folds. It seems possible that late in D_1 deformation, S_1 foliation was refolded in discrete areas due to local perturbations in the flow regime.

The age of D_1 deformation must be Middle Jurassic. This is deduced from cooling K-Ar ages of syn-metamorphic minerals in the hangingwall of the Wolverine fault zone which are dated at 171 Ma (*see* chapter on Metamorphism). Rocks in the footwall of the Wolverine fault zone (Domain 1) either remained hot until the Early Tertiary or were reheated in the Early Tertiary. The latter interpretation assumes that the primary fabric seen in the Wolverine Range was produced during D_1 deformation and that it is the same as the D_1 fabric in the hangingwall of the Wolverine fault zone. It is only along the Wolverine fault zone that earlier D_1 foliation is overprinted by fabric produced during motion on the fault zone.

PHASE 2

In the monotonous, metamorphosed sequence of the Swannell Formation, compositional layering, together with the S_1 fabric, are folded into kilometre-scale, upright folds which we believe to be F_2 structures. These megascopic folds have been delineated primarily by dip reversals on the earlier planar elements. The folds are associated with similarly oriented and commonly observed fold crenulations which have a wavelength of 1 to 2 centimetres. In the southern part of Domain 1, in areas above the sillimanite isograd, subsidiary megascopic F_2 folds were not observed and only rarely were F_2 crenulations noted. These folds are most dominant above the garnet isograd (in Domain 2) and may indicate a depth dependency for D_2 deformation. The simplest interpretation based on structural data suggests that F_2 folds are related to the Wolverine antiform due to their post-peak metamorphic nature and similar orientations. However, mica growth parallel to S_2 cleavage planes in the Boulder Creek group, indicates that these kilometre-scale folds may be older than the antiform as this anticlinorium folds metamorphic isograds of the region. This mica growth suggests that D_2 deformation occurred near the end of regional metamorphism. In the Ingenika Range these are post-peak metamorphic structures which are clearly older than the Swannell antiform (a structure equivalent to the Wolverine antiform; Bellefontaine, 1990).

The attitude of the crenulations in the northern part of Domain 1 is illustrated in Figure 44. Note the vertical to steep northeast dip of the axial planes indicating that F_2 folds, if axial planar to these crenulations, are inclined to the southwest. In the northern part of the map area, the few crenulation fold axes observed within homogenous layers are subhorizontal.

The region occupied by Domain 2 contains a series of excellent markers which delineate several megascopic D_2 folds within the southwest-dipping panel of strata. These folds are upright to slightly inclined to the northeast (Figure 45). Cross-sections (Figure 7) indicate that these structures are probably northeast verging.

Megascopic folds are most prominent in the northern part of this domain. Near Mount Howell, the Mount Howell succession outlines several broad, southwest-plunging folds with wavelengths in the order of 5 kilometres. This succession also outlines a very wide, faulted syncline near Blue Grouse Mountain. Segments of this structure have been rotated by the northeast-trending faults such that its plunge is in the order of 30° to the southeast (Figure 46).

The basal beds of the Mount Brown quartzite outline an open, upright and north-west plunging fold pair below Mount Brown (Figure 47) which becomes much narrower to the southeast where it is outlined by the Espee Formation. The Espee Formation delineates a series of tight folds in the Mount Dewar area and traces a broad anticline in the Granite Creek area.

The wavelengths of megascopic folds in the northern part of Domain 2 become shorter with stratigraphic (and structural) depth. Typically folds outlined by the Nina Creek group are up to 10 kilometres in wavelength. This decreases to a few kilometres in the Atan Group and less than a kilometre in the Espee Formation. This may be the result of the increase in ductility of these rocks with depth.

Macroscopic folds were only rarely observed in rocks of Domain 2. One example is from the Mount Kison limestone south of Henschel Creek where 100-metre wavelength, northeast-verging, similar-style folds can be seen. Chevron folds were occasionally observed in ribboned chert or siliceous argillite sequences of the Nina Creek group. They are tight to open with wavelengths in the order of 1 to 2 metres.

In the northern part of Domain 2, bedding-cleavage intersection lineations (Figure 48) consistently indicate a gentle northwest plunge for large structures. This changes to a southeast plunge toward the southern part of the domain (Figure 46).

On a microscopic scale, D_2 is expressed as a penetrative, slaty to crenulation cleavage. Crenulations are common in regions above biotite grade metamorphism where micaceous minerals have produced a strong anisotropy. The character of these crenulations was described in an earlier section.

In Domain 3 second-phase crenulations are only found in a few localities, near Skeleton Mountain and south of Boulder Lake. They have a wavelength of 0.5 to 1 centimetre and generally do not exhibit pressure solution

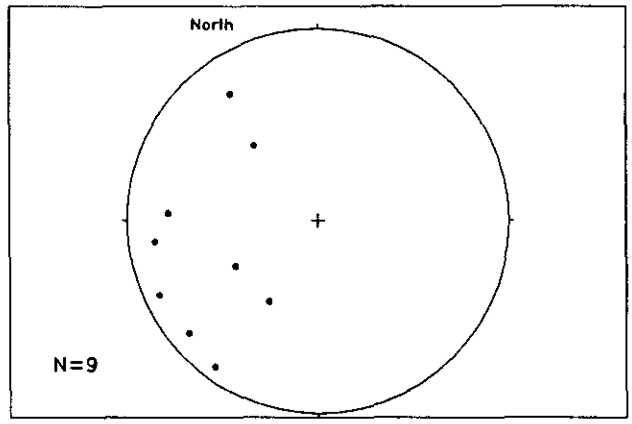

Figure 44. Equal-area projection of poles to F_2 crenulation planes, northern parts of Domain 1.

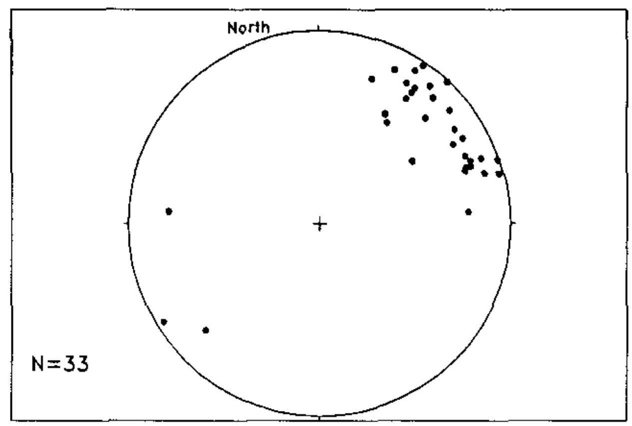

Figure 45. Equal-area projection of poles to S_2 cleavage in northern part of Domain 2 showing the steep southwest dip of this cleavage set.

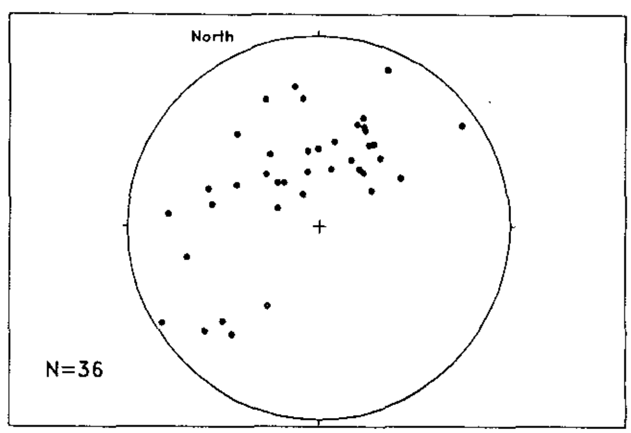

Figure 46. Equal-area projection of poles to bedding within the Mount Howell succession, near Blue Grouse Mountain, Domain 2.

The figures' text labels are given below each image reference.

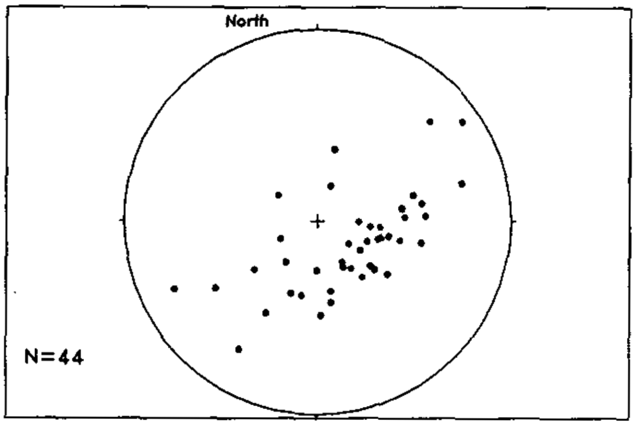

Figure 47. Equal-area projection of poles to bedding within a fold pair delineated by the Mount Brown quartzite, near Mount Brown, northwestern end of Domain 2. This diagram shows the gentle northwest plunge of these structures.

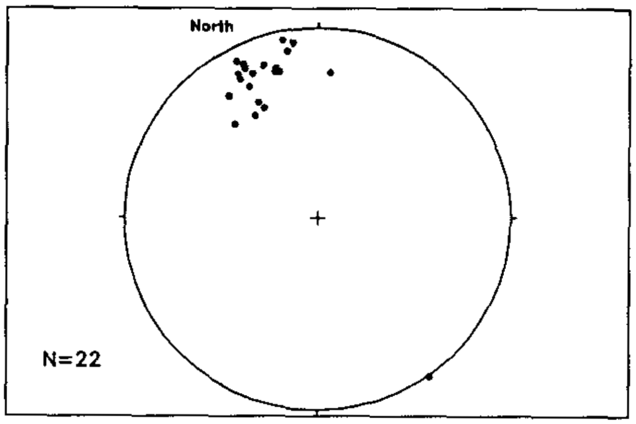

Figure 48. Equal-area projection of bedding-cleavage intersection lineations within Proterozoic and Paleozoic sediments, northwestern part of Domain 2. The northwest plunge is in agreement with data in Figure 47.

on the limbs. They postdate peak metamorphism (as seen by their deflection around staurolite porphyroblasts, *see* also chapter on Metamorphism) but biotite porphyroblasts have grown parallel to the crenulations. It appears that the timing relationships between deformation and metamorphism in Domain 3 are slightly different from those in Domains 1 and 2.

Elsewhere, in rocks below the biotite isograd, S_2 is typically a pressure-solution cleavage which may be associated with a crenulation in shaly rocks that have a strong S_1 fabric. In silty rocks the cleavage is manifest as pressure solution and micaceous seams around clasts. A spaced pressure-solution cleavage is commonly found within the calcareous units of this subdomain. The presence and spacing of the cleavage reflect the argillaceous content of the carbonate. The ragged morphology of phyllosilicates on cleavage planes indicates that they have been rotated during dissolution of the enclosing rock. No phyllosilicates have grown along these cleavage planes. Where porphyroblasts, such as chloritoid, are present the cleavage planes are deflected by the porphyroblasts, indicating that this deformation is postmetamorphic.

The S_2 cleavage generally dips to the southwest (Figure 45), but in the northern part of Domain 2, near Mount Brown, cleavage dips steeply to the northeast. The anomalous attitude may result from cleavage fanning along the northeast limb of the fold pair below Mount Brown. Cleavage refraction is sometimes observed in interlayered slate-siltstone sequences in the upper Ingenika Group or lower Atan Group.

In Domain 3 bedding and the early S_1 foliation are folded into a broad, subhorizontal anticline attributed to D_2. Its vergence is unknown.

The age of D_2 deformation is bracketed between Middle Jurassic and Cretaceous. This corresponds to post-D_1 deformation and the onset of D_3 anticlinoria (Evenchick, 1988). Growth of metamorphic micas parallel to S_2 cleavage planes within the Boulder Creek group indicates that this deformation began in Middle Jurassic time. This deformation appears to postdate metamorphism elsewhere in the study area, suggesting that D_2 deformation outlasted metamorphism. This argument assumes that the S_2 cleavage seen in the various domains of the map sheet are of the same age.

PHASE 3

This is the most prominent phase of deformation in the Omineca Belt. It is represented by the broad, north to northwest-trending Wolverine antiform which dominates Domain 1. This large fold is one of many anticlinoria within metamorphic rocks of the northern Omineca Belt (Gabrielse, 1975). Plots of foliation along its length (Figures 49, 50 and 51) indicate the curving nature of its fold crest. In the Manson River area (Figure 49), this antiform plunges northwestward whereas in the Bison Mountain area (Figure 50) the plunge is to the southeast. Near the Osilinka River (Figure 51) the structure is subhorizontal. In the northwest, the core of the antiform has been cut by the Wolverine fault zone along the Osilinka River. Its trace is lost north of the river.

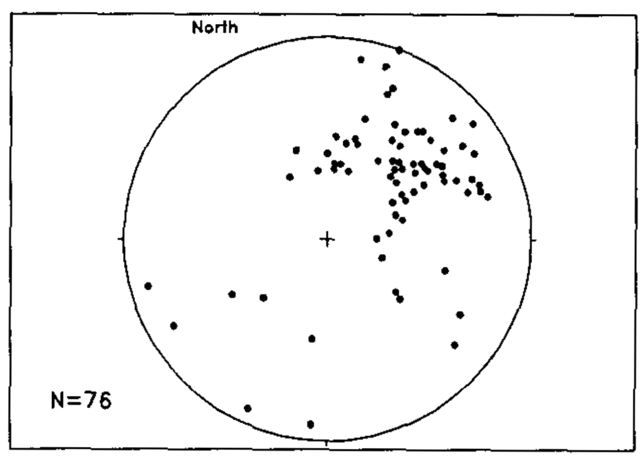

Figure 49. Equal-area projection of poles to compositional layering, southeastern part of Wolverine antiform, Domain 1. These points delineate a very poor girdle with its pole plunging gently to the northeast.

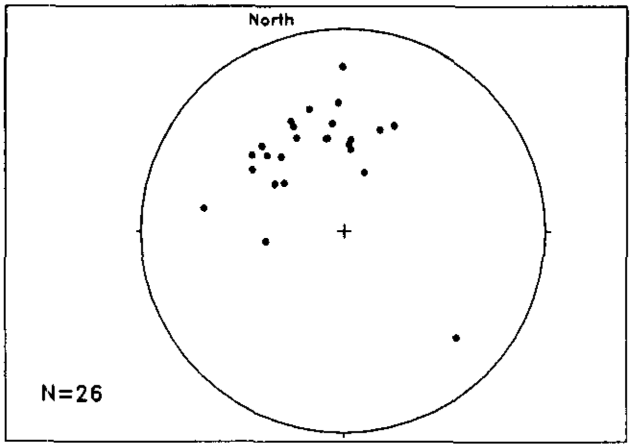

Figure 50. Equal-area projection of poles to compositional layering along the Wolverine antiform, Mount Bison area, Domain 1. These points define a girdle with its pole plunging to the southeast in conjunction with F_1 fold axes and mineral lineations.

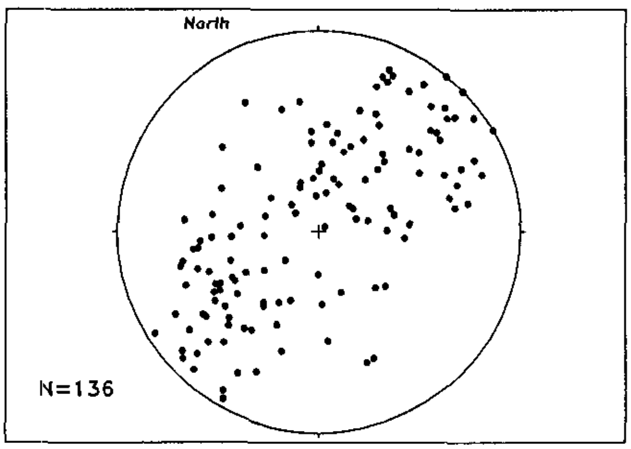

Figure 51. Equal-area projection of poles to compositional layering, northwestern part of Wolverine antiform, Domain 1. These points clearly display the subhorizontal attitude of D_2 structures (Wolverine antiform fold axis).

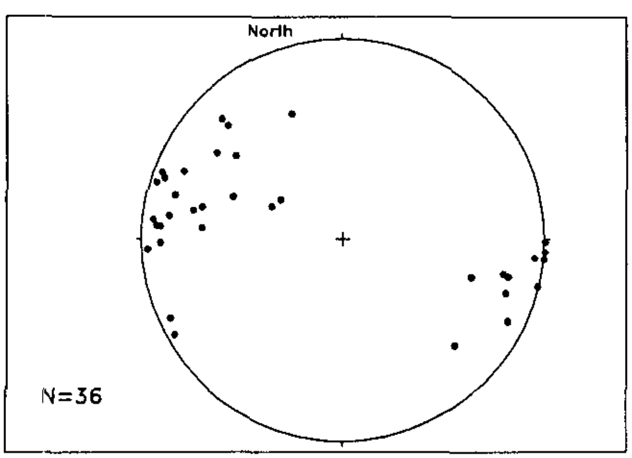

Figure 52. Equal-area projection of poles to S_4 cleavage in granodiorites of the Wolverine Range.

The age of this structure, and others like it, is most likely Early to Middle Cretaceous. Evenchick (1988), notes that in the northern Cordillera, anticlinoria like the Sifton and Swannell antiforms, have significantly younger K-Ar metamorphic cooling ages in their cores than on their limbs. These ages range from 90 to 140 Ma. Evenchick suggests that these variable ages reflect gradual uplift and cooling of these rocks during the production of these large D_3 structures.

PHASE 4(?)

A fourth phase of deformation is postulated for this area. It is expressed by the presence of a weak, steeply dipping, northeast-trending foliation in the granodioritic bodies that intrude highly metamorphosed rocks in the Wolverine Range. The attitude of this foliation (Figure 52) is unrelated to any other structures except rarely observed crenulations in metasedimentary rocks of the complex.

D_4 deformation is found within Late Cretaceous or possibly Early Tertiary granitic bodies (*see* chapter on Lithologic Units). This implies that it is Late Cretaceous or younger.

FAULTS

Faulting is only observed within the superstructure where excellent marker horizons are present. Thrust faults, in highly monotonous sequences are demonstrated mainly on the basis of age reversals apparent from fossil data.

THRUST FAULTS

Significant thrust faults are present within, and at the base of, the Nina Creek group. They are layer parallel and are mapped primarily on the basis of conodont age determinations. These fossil data indicate the presence of thrust faults between the Pillow Ridge and Mount Howell successions, and the Mount Howell succession and Big Creek group. Thrust repetition of the Mount Howell and Pillow Ridge successions is also demonstrated in the northwestern part of the map area. There is little or no observed evidence (such as shear zones) for the existence of these thrust faults. These faults also suggest that the monotonous sequences of the Mount Howell and Pillow Ridge successions contain numerous thrust faults which could not be delineated given the sparse fossil data available. Numerous thrust imbrications have been demonstrated within Slide Mountain rocks elsewhere along the Cordillera (Gordey, 1983; Struik and Orchard, 1985; Harms, 1985a, b, 1986; Klepacki and Wheeler, 1985; Schiarizza and Preto, 1987; Nelson and Bradford, 1993).

Interleaving of the Mount Howell and Pillow Ridge lithologies is evident north of Pillow Ridge. Mapping to the west and northwest by Ferri *et al.* (1992a, b) and Nelson *et al.* (1993a, b) clearly demonstrated the emplacement of a wedge of Mount Howell sediments between Pillow Ridge basalts. The fault panel of Mount Howell rocks pinches out southwestward into the present map area, with the two bounding faults apparently joining and following the Goat Creek valley. A similar thrust fault repeats Mount Howell and Pillow Ridge rocks immediately to the northeast. The stratigraphic level at which this fault occurs varies along its trace, as indicated by the uneven distribution of Mount Howell sediments.

Fossil data indicate a thrust fault of unknown displacement between Nina Creek rocks and those of North American affinity. This structural relationship between the Cassiar and Slide Mountain terranes is the same as documented north and south of the study area (Nelson and Bradford, 1993; Struik and Orchard, 1985; Schiarizza and Preto, 1987; Rees, 1987; Struik, 1980; Harms, 1986; Klepacki 1983).

These thrust faults are most likely east verging as there is no eastern source for rocks of the Nina Creek group in the miogeocline. There is clear evidence that these rocks represent obducted pieces of an ocean floor that formed west of the continental margin (Monger, 1984).

Age constraints for these thrust faults can only be broadly defined. They are post-Permian but must predate D_2 deformation which is believed to be Cretaceous in age. The only other major deformational event in the Omineca Belt of this magnitude and with the same sense of vergence is D_1 deformation. It is suggested here that the thrust emplacement of the Nina Creek group is part of D_1 deformation and is Middle Jurassic in age.

Bodies of ultramafite occur within Domain 3 north of Boulder Creek. Along Boulder Creek, approximately 2 kilometres upstream from its mouth, strongly altered ultramafite is in fault contact with metasediments of the Boulder Creek group. The fault zone is flat lying to slightly southwest dipping and strongly sheared (Plate 29). Kinematic indicators are consistent with a top-to-the-northeast emplacement of the ultramafite. Contact relationships seen at this locality suggest that the other ultramafite bodies immediately to the north and northwest are also bounded by flat-lying thrust(?) faults and that they are part of an imbricate thrust package including the enclosing metasediments. The emplacement of these ultramafite bodies is believed to have occurred in the Middle Jurassic. This is based on correlation of these ultramafites with the Nina Creek group.

The southwest margin of the Boulder Creek group (Domain 3) is interpreted as a splay of the Manson fault zone, based on its subparallelism with the fault zone and the presence of numerous ultramafite bodies along its trace. Ultramafite bodies are an important characteristic of the Manson fault zone in the map area. Due to poor exposure, actual contact relationships between the ultramafite bodies and surrounding rocks of the Boulder Creek group and Slate Creek succession were not seen. Surrounding rocks provide no indication of major shearing related to thrust emplacement as occurs in the Boulder Creek area or as described in similar rocks farther south (Rees, 1987, Struik, 1985). This lack of evidence does not preclude the possibility that an obscure thrust relationship

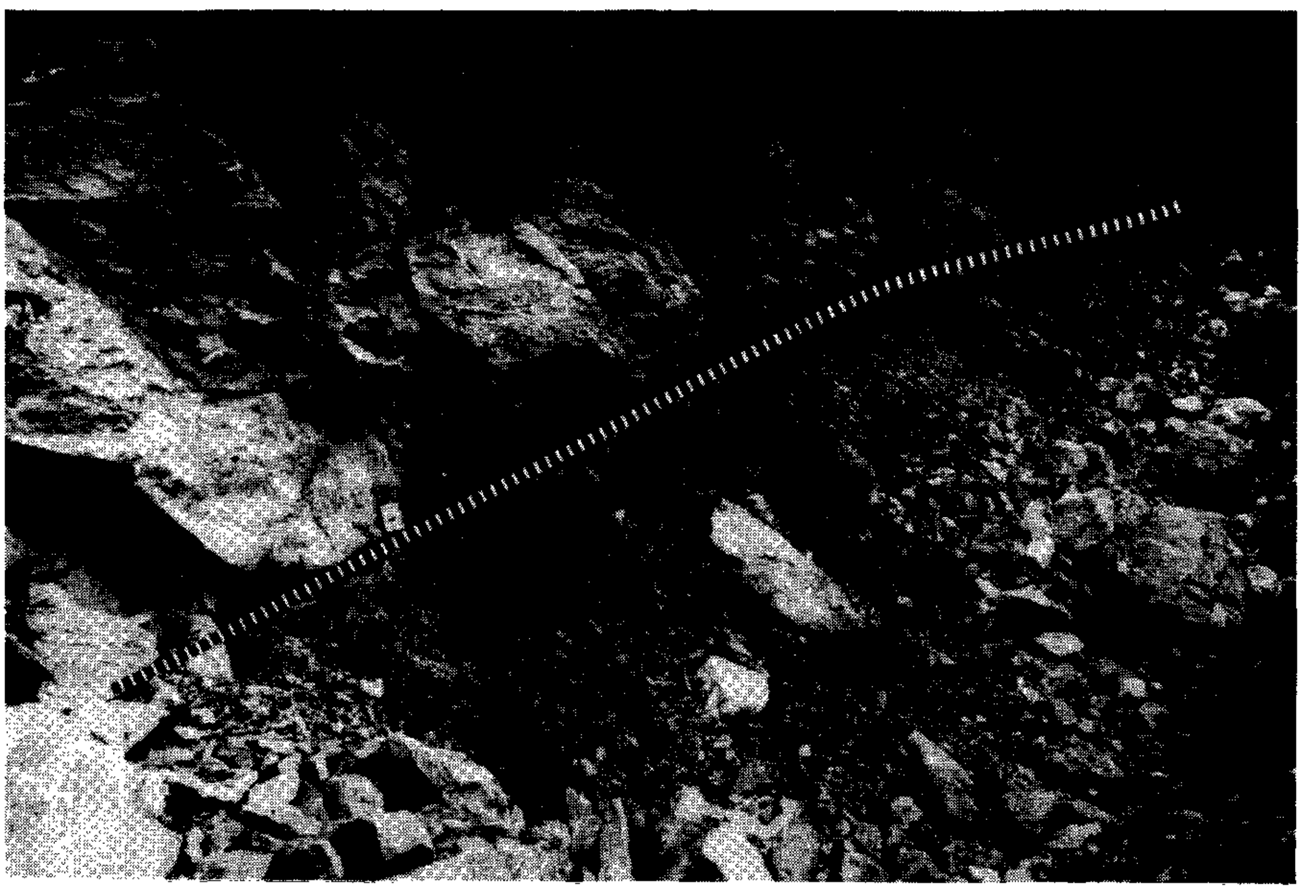

Plate 29. Flat-lying thrust fault between Manson Lakes ultramafics (above) and Boulder Creek sediments (below) as exposed along the north side of Boulder Creek. Kinematic indicators suggest eastward motion of the Manson Lakes ultramafics.

may be somewhere preserved. Alternatively, an original thrust relationship between these rock units may have been overprinted by later fault motion along the Manson fault zone.

Demonstrable thrust faulting is rare within the remaining parts of the Omineca Belt. Just south of Granite Creek, a repetition of the Espee Formation is interpreted as a thrust fault. This interpretation is different from the offset anticline proposed by Ferri *et al.* (1988).

A thrust fault is interpreted to repeat Razorback and Echo Lake strata in the northern part of the map area. Shales and argillites along the Osilinka River, to the north, contain Ordovician graptolites and may be part of the Razorback group (Ferri *et al.*, 1993a, b). This thrust fault would help explain the increased thickness of the Echo Lake group in the northern part of the map area. Its age is uncertain but it is most likely related to either D_1 or D_2 deformation. Alternatively, these shales may be part of the Echo Lake group (*see* Razorback group) in which case there would be no need to invoke this thrust fault.

NORMAL FAULTS

Two sets of normal faults affect the superstructure in the study area, one trending northeast and the other northwest. Northwest-trending normal faults are concentrated in the northwest portion of Domain 2, where they cut the upper parts of the Ingenika Group, the lower Paleozoic sequence and lower parts of the Nina Creek group (Figure 7). The most significant of these faults have been named (from northeast to south) Flegel Creek, Big Creek, Razorback Mountain and Mount Forrest. All, except the last, are northeast-side-up normal faults. Their traces indicate that they dip steeply southwest. Maximum displacement on any one of these faults is in the order of 2 kilometres.

Northeast-side-up normal faults are parallel to the trace of the Wolverine fault zone along the Osilinka River. The similar orientation and sense of displacement of the two fault systems suggest they are genetically related. The concentration of these faults within rocks of the upper Ingenika Group and Paleozoic units may simply reflect the presence of useful marker horizons at these levels which allows the delineation of these normal faults. Some faults may continue much further into the Swannell Formation but due to the monotonous nature of these rocks, fault displacements are not readily apparent. These faults are probably a result of Tertiary extension and uplift of the Wolverine Metamorphic Complex.

Immediately south of Granite Creek, a northwest-trending northeast-side-up normal fault places the middle part of the Nina Creek group against rocks of the Stelkuz Formation. Thus, its stratigraphic displacement is in the order of 3.5 kilometres. This fault terminates to the west against the Manson fault zone and to the east against the Wolverine fault zone. It is believed to be part of the Wolverine fault system which places higher level Domain 2 rocks against uplifted, high-grade metamorphic rocks of Domain 1.

Northeast-trending faults have been recognized in the northern part of the map area. The most important are the Henschel, Blue Grouse Mountain, Nina Creek and Echo Creek fault systems. The Henschel fault is a northwest-side-down structure and is the largest of these, with a displacement upwards of 2.5 kilometres. It has been traced from northeast of Echo Lake, southwestward to 3 Mile Creek (Figures 7 and 8) where it is cut by the Manson fault zone. This fault involves rocks of the Nina Creek group, lower Paleozoic succession and the Ingenika Group. The large syncline outlined by the Mount Howell succession in the Blue Grouse Mountain area, is lost north of Henschel fault. Blue Grouse Mountain fault cuts this large syncline and has rotated segments of it to the southeast.

Northwest of Nina Creek, packages of siliceous sediments occur within the basalts of the Pillow Ridge succession. These sediments do not continue along strike to the southeast, indicating a fault along this valley. Similar arguments indicate the presence of a fault along the Nina Lake–Echo Creek valley. Northwest of Nina Lake, a succession of siliceous sediments disappears abruptly southeast of the valley, and, in conjunction with displacement on the lower Pillow Ridge contact, indicates a southeast-side-down fault. The valley containing this fault is a conspicuous, straight, northeast-trending feature essentially parallel to the Henschel fault.

Near Echo Creek, a series of normal faults forms several small graben-like structures. These faults are prominent on the ridge northwest of Mount Kison where they offset the basal beds of the Mount Brown quartzite. They have been projected to the southwest to explain the outcrop pattern of limestone and shale in the upper part of the Paleozoic succession.

Northeast-trending normal faults appear to be regionally important. Straight, northeast-trending valleys are present throughout the Omineca and Intermontane belts northwest of the study area (Wasi and Uslika lakes).

The inferred age of fault motion is based on their crosscutting relationships with other fault systems. They cut thrust faults within the Nina Creek group, indicating they are post Early to Middle Jurassic. They are apparently cut by the Manson fault zone which would fix an upper age limit of Late Cretaceous to Early Tertiary. Alternatively these faults may be contemporaneous with the Manson fault zone (*see* under on Manson Fault Zone).

WOLVERINE FAULT ZONE

The Wolverine fault zone separates the two principal domains of the Omineca Belt in the map area . Armstrong (1949) first postulated the presence of this fault to explain the discordance of strata on either side of it. It also explains the changes in structural trends and metamorphic grade across it. Its trace marks the boundary between metamorphic rocks with early Tertiary K-Ar ages east of the fault and those with older ages west of the fault. It is a brittle, moderate(?) to steep, northeast-side-up normal fault (Plate 30). It cuts, or is parallel to, a ductile shear zone along most of its trace and the two are believed to be genetically related.

The Wolverine fault can be traced from the Munro Creek area northwestward to Granite Creek, where it

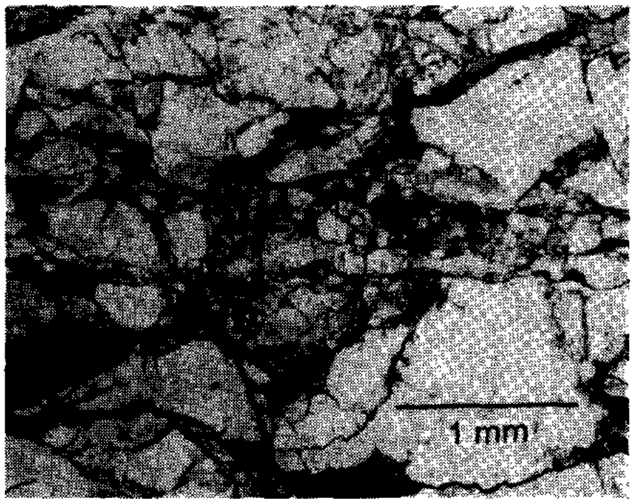

Plate 30. Photomicrograph of fault breccia within the Wolverine fault zone on the south side of Munro Creek. This brittle deformation overprints a ductile fabric found in the footwall of the fault zone.

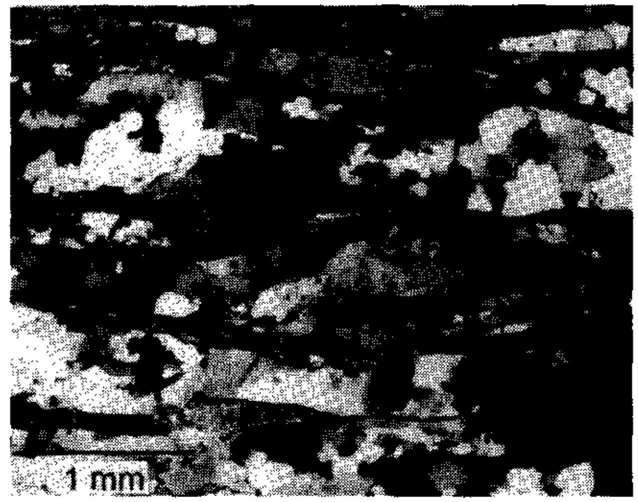

Plate 31. Photomicrograph of quartz ribbons and fish-scale micas within a ductile portion of the Wolverine fault zone. These strained quartz and mica grains are in sharp contrast to annealed textures within the core of the Wolverine Metamorphic Complex (*see* Plate 41).

splays into several smaller, westerly trending faults. The main fault can be traced past Granite Creek, where it swings to a more northerly trend and follows the foot of the steep western face of the Wolverine Range. It leaves the map area north of the Wolverine Lakes and reappears east of Porter Creek. We interpret it to be composed of two faults at this point (Figure 7). The fault zone cannot be traced across the Osilinka River and we believe it veers westward along the Osilinka valley.

A fault along the Osilinka River can be inferred from the juxtaposition of higher grade and lower grade metamorphic rocks on either side of it. Across the river, north of Dwyer Creek, the metamorphic grade increases sharply from biotite to garnet. The trace and relative motion of the inferred fault are parallel to northeast-trending faults to the southwest and with a fault mapped by Roots (1954) in the western part of the Fort Grahame sheet.

The Wolverine fault zone is assumed to dip steeply to the southwest and may be parallel to a related, moderately dipping, ductile shear in its footwall.

Displacement on this fault is variable along its trace. In the Munro Creek area, sillimanite-grade paragneisses of the Ingenika Group are in contact with chlorite-grade rocks of the Nina Creek group, indicating displacement of tens of kilometres. In the Granite Creek area, the relatively short distance between the biotite and sillimanite isograds (approximately 2 kilometres) is an artifact of displacement on the Wolverine fault zone. In the northern part of the map area, near the Osilinka River, the fault zone is within rocks of the Swannell Formation and displacement has decreased substantially. Just south of the Osilinka River the fault is located within a broad, straight, north to northeast-trending, valley. Here rocks on either side of the fault are of similar metamorphic grade but differ in metamorphic cooling ages. The position of the fault is based on the change in metamorphic ages across it.

A layer-parallel, southwest-dipping ductile shear zone is found in the footwall of the southwest-dipping Wolverine fault zone in the southern part of the map area. Indications of its presence were first noted by Ferri and Melville (1988a) who remarked that the west flank of the metamorphic belt contained a layer-parallel, post-metamorphic fabric not seen in the core of the complex. This shear zone can be up to 1 kilometre wide. It is typically manifested by flattened quartz grains in moderately deformed areas to highly strained, ribboned quartz and kinked and fish-scale textured micas (Plate 31). Lineations produced by deformed grains and elongate minerals in this zone plunge moderately to the south or southwest (Figure 53), although other mineral lineations, such as sillimanite in the Munro Creek area, plunge gently to the northwest. Several oriented samples were collected from the shear zone near the mouth of Ciarelli Creek. One of these clearly indicates southwest-side-down motion (Plate 32).

This ductile shear zone is most likely a deeper level manifestation of the brittle Wolverine fault zone. This is based on their proximity to each other and on the similar sense of motion. It is assumed here that uplift along this fault zone has exposed its deeper, more ductile portions and juxtaposed these against higher level, more brittle segments of the fault zone.

AGE AND TECTONIC IMPLICATIONS

The Wolverine fault zone separates high-grade metamorphic rocks of the lower Ingenika Group (Wolverine Metamorphic Complex) from less metamorphosed rocks of the upper Ingenika Group, lower Paleozoic succession and Nina Creek group. It also marks the boundary between metamorphic rocks with consistent Early Tertiary metamorphic ages and metamorphic rocks dated as old as Middle Jurassic.

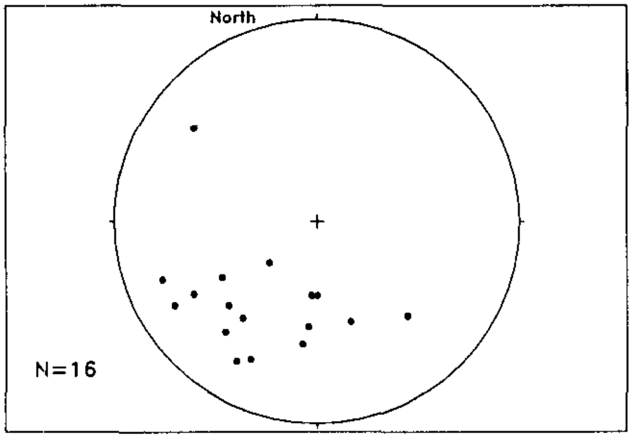

Figure 53. Equal-area projection of mineral lineations in the southern part of the Wolverine fault zone.

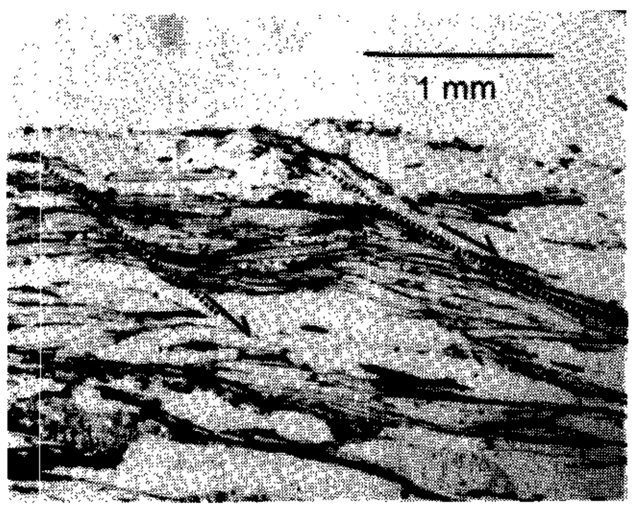

Plate 32. Shear-bands within ductile portion of the Wolverine fault zone, north of Ciarelli Creek. This is a view to the southeast and the shear bands indicate tops-to-the-southwest motion for the upper plate.

Metamorphic ages in the Wolverine Metamorphic Complex indicate that these rocks were uplifted and cooled in earliest Tertiary times. This Tertiary uplift is further substantiated by clasts of gneiss and schist in the nearby Tertiary Sifton Formation (Roots, 1954, Gabrielse, 1975) indicating that the Wolverine Complex was unroofed in early Tertiary time. Isotopic and structural data indicate that the uplift and unroofing of the complex occurred along the Wolverine fault zone.

Most mineral lineations within the fault zone, dip to the southwest indicating dip-slip motion. This is based on the assumption that most of the mineral lineations and deformed crystal grains represent the long axis of the finite strain ellipse which is parallel to the transport direction. It should be pointed out that not all mineral lineations indicate dip-slip movements; some are subhorizontal and trend northwesterly, which suggests a component of subhorizontal motion.

The rheological nature of the fault zone was depth dependent. In the higher level, cooler parts of the crust, uplift was facilitated by movement on steep, brittle faults whereas in deeper, ductile regions movement was concentrated along moderately dipping ductile shear zones.

These preliminary data are in agreement with detailed studies of core complexes in the southern Canadian Cordillera (Carr *et al.*, 1987; Brown and Carr, 1990). Evenchick (1988), working north of the study area in the Sifton Ranges, clearly demonstrates that uplift of the metamorphic rocks is the result of northward thrusting related to strike-slip motion. This possibility cannot be ruled out in the study area. A southeast extension of the Wolverine fault zone appears to feed into the McLeod Lake – northern Rocky Mountain Trench right-lateral fault systems. Dip-slip motion on the Wolverine fault zone, in the study area, may somehow be related to strike-slip motion farther south.

DISCUSSION

The deformational history of the map area is, for the most part, consistent with that reported by other workers throughout the Omineca Belt. It begins with east-verging, synmetamorphic D_1 structures and ends with the formation of postmetamorphic anticlinoria and subsequent uplift. Perhaps the most striking structural observation is the apparent lack of southwest-verging structures which have been reported by many workers to the north (Bellefontaine, 1989, 1990; Gabrielse, 1971, 1972, 1975; Gabrielse *et al.*, 1991; Mansy, 1972, 1974; Mansy and Dodds, 1976) and to the south (Murphy, 1987; Struik, 1988a; Rees, 1987).

Southwest-verging structures in the Ingenika Range (Bellefontaine, 1990) have been explained using a model of tectonic wedging and delamination originally proposed by Price (1986). In this process a panel of rock is thrust eastward and wedged below a roughly correlative panel (Figure 54). The wedge is bounded above and below by thrust faults. The overlying panel is transported to the southwest, relative to the wedge, along a northeast-dipping detachment at the top of the wedge. As a consequence, the upper panel is characterized by southwest-verging structures whereas structural elements in the wedge are dominated by northeast vergence. The vergence reversal is accentuated if the zone of detachment between the upper panel and the wedge behaves ductily before faulting. Furthermore, early northeast-verging elements in the upper panel are overprinted by southwest-verging structures whereas in the lower panel no overprinting relationship is seen. This model may explain structures observed in and around the study area. Cross-sections of Roots (1954), just to the northwest, show southwesterly directed thrust faults that separate regions of definite southwest-verging structures from those that appear upright to northeast verging. These thrusts may represent the upper detachment fault above an underthrust wedge. These cross-sections also show areas with upright to northeast-verging structures. Similar structures were mapped by Gabrielse (1975) immediately east of the Aiken Lake map sheet. Two of Gabrielse's cross-sections, which join along strike (sec-

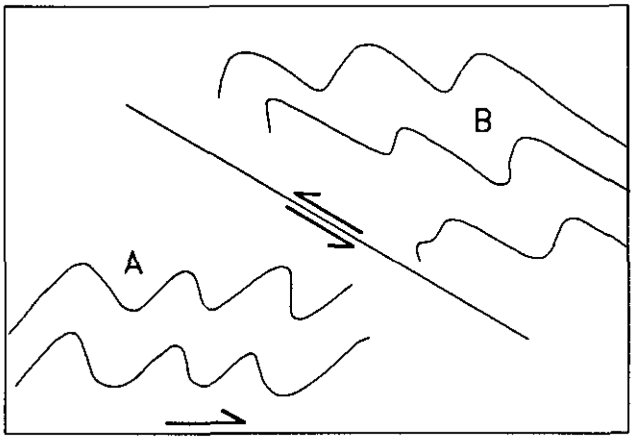

Figure 54. Modified tectonic wedging model of Price (1986). In this diagram the lower block (a) forms the wedge bounded above and below by detachment faults. The wedge contains eastward-verging to upright structures whereas structures in the over-riding block are west verging.

tions E-F and C-D), show large-scale structures with opposite senses of vergence, northeast and southwest.

The lack of southwest-verging structures in the study area can be explained in two ways. Apparent southwest-verging structures near the study area suggest tectonic wedging and delamination as a mechanism. If this is so, then the lack of southwest-directed structures in the Manson Creek area can be explained by the area's position within the indenting wedge. Alternatively, tectonic wedging, delamination and southwest-verging structures may not have occurred in the map area.

INTERMONTANE BELT

Rocks of the Intermontane Belt occupy the area south of the Manson fault zone and are characterized by broad, open structures attributed to D_2 deformation and movement along the Manson fault zone. This large region is subdivided into two domains (Domains 4 and 5, Figure 40). Domain 4 is bounded to the northeast by the Manson fault zone and to the southwest by the Evans Creek thrust fault and the South Germansen River. Domain 5 occupies the area south of the Evans Creek thrust and west of the South Germansen River.

Except for basal shales and argillites of the Slate Creek succession these rocks lack the strong layer-parallel fabric typical of rocks in the Omineca Belt.

PHASE 1

A weak layer-parallel fabric (S_1?) is sometimes developed in the lowermost shales of the Slate Creek succession and may be related to D_1 deformation in the Omineca Belt. No other structures were seen that could be attributed to this phase of deformation.

PHASE 2

Phase 2 deformation is characterized by megascopic, northwest-trending folds. Axial traces of these folds are based on bedding reversals as extensive marker horizons are lacking. Wavelengths of these upright, northwest-trending folds vary from 1 kilometre to over 5 kilometres. The folds are believed to be related to similarly oriented F_2 folds of the Omineca Belt. In some localities a northwest-trending, vertical to southwest-dipping, spaced to penetrative slaty cleavage is axial planar to F_2 megascopic folds and is believed to be genetically related.

A very prominent structure is the syncline, cored by Plughat Mountain augite porphyries, between Evans Creek and the Omineca River. It is over 10 kilometres long and can be traced from the western border of the map sheet southeastward into the Manson fault zone. Its attitude is similar to other F_2 folds in the map area but its presence in the hangingwall of the Evans Creek thrust indicates that it may be related to motion on the Manson fault zone.

F_2 anticlines are older than the Germansen batholith as they are cut by it in Domain 4. This is further substantiated by the lack of a penetrative, northwest-trending cleavage in the batholith within Domain 4. This makes F_2 structures no younger than 106 Ma (Middle Cretaceous) and is in accordance with estimates from the Omineca Belt in the map area.

EAST-TRENDING STRUCTURES SOUTH OF THE EVANS CREEK FAULT

Domain 5 is characterized by the east-west trend of structural elements which is completely discordant with trends in other domains. Structures related to the deformational events described previously are not seen here, and no overprinting relationships were observed between the two structural trends. It is believed that these structures formed during a phase of deformation unrelated to the D_1 and D_2 structures in the rest of the map area. Near Mount Germansen, structures follow the trend of the contact of the Germansen batholith, suggesting that they formed during emplacement of the batholith.

The east-trending structures in the Plughat Mountain area are most likely a consequence of right-lateral motion on the Manson fault zone. Regional strain patterns related to such movement would result in bulk shortening roughly parallel to compression indicated by megascopic structures within Domain 5 (Figure 55).

A penetrative fabric is uncommon in the rocks of the Takla Group. In contrast, the Germansen batholith, in the vicinity of Mount Germansen, contains a weak to moderate penetrative foliation (Plate 33). The trend of this foliation follows the contact of the batholith, indicating that it is related to its intrusion. This is further substantiated by the presence of a very steep (up to 80°) mineral lineation within the plane of the foliation.

Takla Group volcanics and sediments locally contain a weak to moderate, steeply dipping, east to northeast-trending foliation in the vicinity of the Germansen batholith. Granoblastic textures of metamorphic minerals indicate that deformation ended prior to cooling of the batholith. We believe this foliation is related to intrusion of the batholith and is a result of increased ductility of country rocks in response to heating during intrusion.

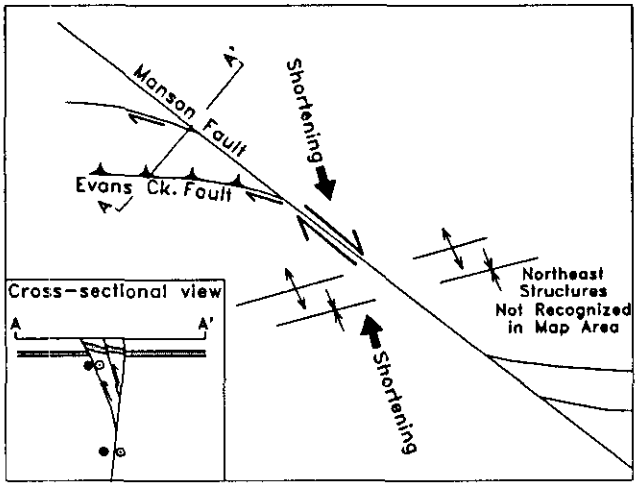

Figure 55. Diagram showing fold and fault structures related to right-lateral strike-slip motion and their possible counterparts within the map area (modified from Sylvester, 1988; Woodcock and Fischer, 1986). The inset shows a cross-sectional view of a positive flower structure which is theorized to be controlling the Evans Creek thrust fault. East-trending fold structures within Domain 4 are part of the shortening related to right-lateral motion on the Manson fault zone.

FAULTS

EVANS CREEK FAULT

The Evans Creek thrust fault separates Domains 4 and 5 of the Intermontane Belt in the northern part of the study area. This southwest-verging, steeply dipping thrust is required along this valley to explain the abrupt disappearance of the thick Permo-Triassic carbonate south of Evans Creek. Evidence for the thrust is provided in outcrop by strongly brecciated limestones and shales of the Slate Creek succession exposed along Plughat Creek.

The Evans Creek fault merges with the Manson fault zone in the southern part of its trace. The attitude and motion of this fault are compatible with it being a splay of the Manson fault. It may be the bounding fault of a contractional duplex or positive flower structure (Woodcock and Fischer, 1986; Sylvester, 1988). Such a structure develops from the wedging of a large fault lozenge at restraining bends in the fault complex (*see* inset Figure 55). Several subsidiary faults with similar motion are inferred in this area and may have emplaced Lay Range rocks southwestward against Takla rocks. The Wendy Creek valley may mark the trace of such structure with its motion obscured by the relatively monotonous Lay Range succession. A thrust fault, in conjunction with a normal fault, must cut the Evans Creek limestone north of the Omineca River and wedge it between rocks of the Lay Range assemblage.

THRUST FAULTS

Thrust faults were rarely recognized in rocks of the Intermontane Belt due to lack of adequate marker horizons. However, a thrust fault which repeats Slate Creek argillites above basal volcaniclastics of the Plughat Mountain succession is tenuously interpreted in the Germansen River area. Such a pattern may also reflect facies variations in the Takla Group. The age of this fault is unknown although it is likely related to D_1 or D_2 deformation.

NORMAL FAULTS

Normal faulting has affected the Olsen Creek area where a northeast-trending, northwest-side-down normal fault cuts units of the Slate Creek and Plughat Mountain

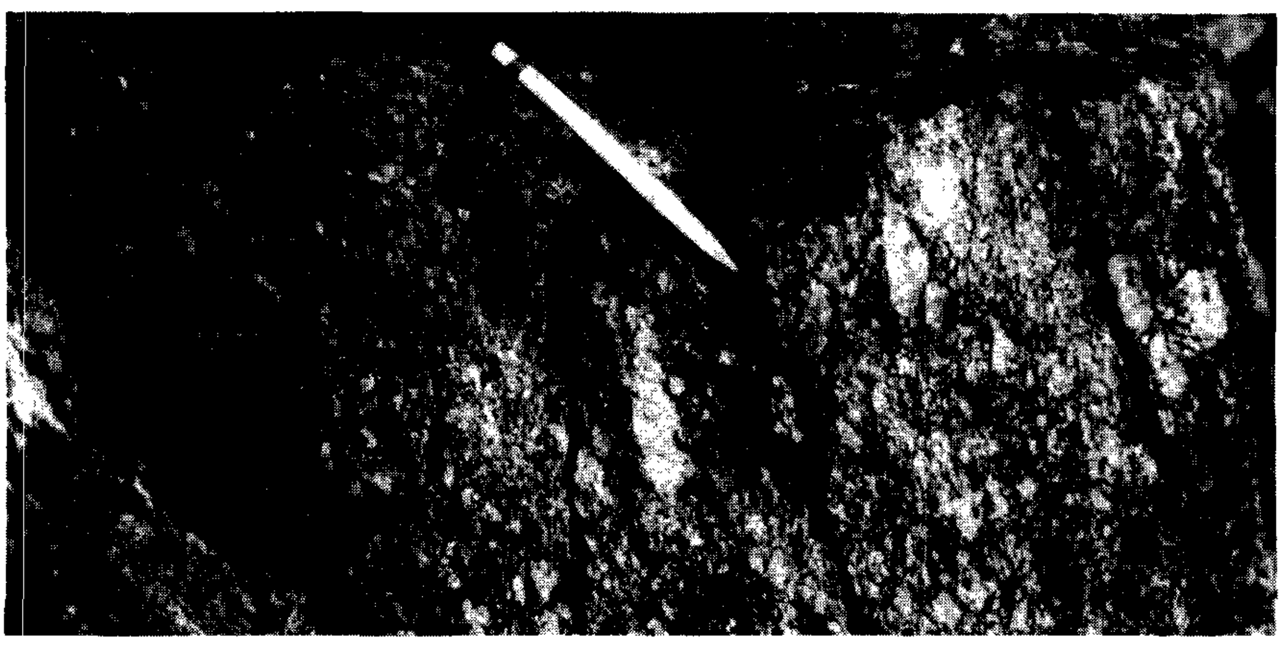

Plate 33. Steep foliation within granodiorite of the Germansen batholith, several kilometres north of Germansen Mountain.

successions (Meade, 1977). It is intruded by small bodies of quartz monzonite at various points (Figure 7) and its trend and attitude suggest formation during emplacement of the Germansen batholith.

Normal faults probably separate unit 4 of the Takla Group from other Takla units northwest of Plughat Mountain. The relative motion on these faults is not known as the stratigraphic relationship of unit 4 to other Takla units is not understood.

MANSON FAULT ZONE

The Manson fault zone is the most significant structural feature in the map area. This structural break separates rocks of the Quesnel Terrane from those of the Slide Mountain and Cassiar terranes. It is a vertical, transcurrent fault on which the most recent fabrics (*e.g.*, slickensides, deformed clasts, Figure 56) indicate strike-slip displacement. Right-lateral sense of motion is given by slickensides along several segments of the fault zone. This zone was first named by Armstrong (1949) who noted its relationship to gold occurrences in the region. It can be traced from Gaffney Creek in the southwest part of the map area, northwestward along the Manson Lakes drainage system, along the Germansen River, and into the Nina Creek valley. The fault zone is made up of a series of anastomosing faults extending over a width of 1 to 5 kilometres.

The Manson fault is exposed along the main road on the west side of Gaffney Creek where fractured and altered rocks of the Nina Creek group crop out over a distance of approximately 1 kilometre. Strongly altered and fractured ultramafite bodies, in vertical fault contact with crumpled slates of the Slate Creek succession are exposed along Lower Manson Lake. Contacts of Wolf Ridge gabbro bodies along the north shore of Lower Manson Lake are faulted and these fault zones contain strongly fractured and altered slivers of gabbro, ultramafite and slate (Plate 34). Outcrops on a small island in the centre of Lower Manson Lake expose fault breccia containing subhorizontal, elongate clasts of Boulder Creek lithologies stretched parallel to the fault trace (Plate 35). Near Manson Creek, small ultramafite bodies are in vertical fault contact with deformed slates of the Slate Creek succession (Plate 36). Fault-bounded ultramafite bodies are also exposed along the Germansen River. Folded and deformed Big Creek argillites and tuffs, lying within the fault zone, are exposed in the old placer pits south of Germansen Landing. At this locality, rip-up clasts are stretched parallel to the trace of the fault. Altered and fractured Lay Range assemblage rocks crop out along the road leading to Nina Lake.

Only a few lineation measurements were made along the fault zone and these consistently indicate southwest-trending, subhorizontal motion (Figure 56). An exception are lineations within bodies of Wolf Ridge gabbro which generally plunge gently south. Depending upon the composition of the rocks involved, both ductile and brittle

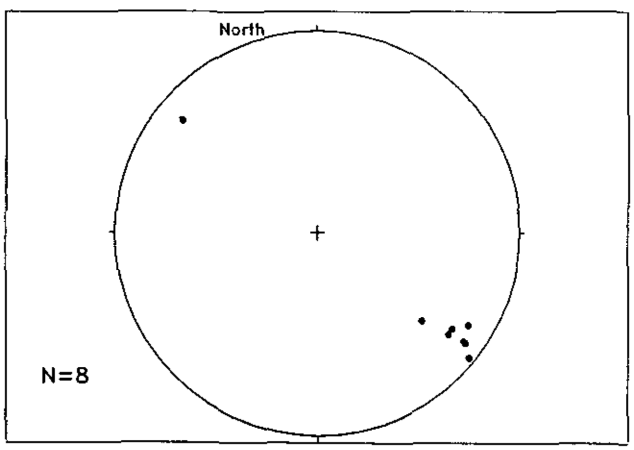

Figure 56. Equal-area projection of mineral lineations, deformed clasts and slickensides along the Manson fault zone. Note the subhorizontal attitude.

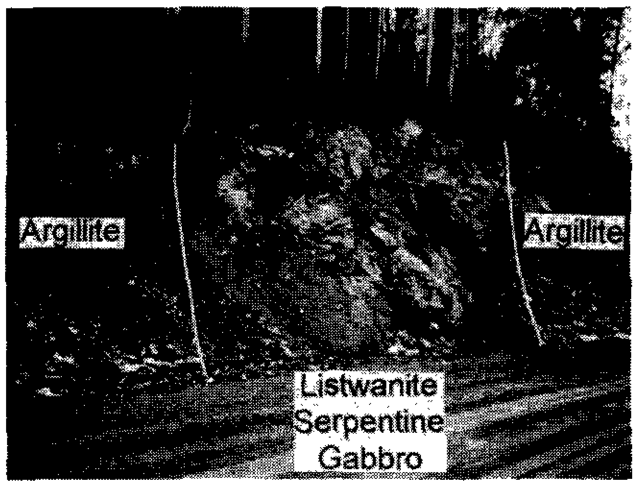

Plate 34. Brecciated rocks within the Manson fault zone exposed along the road along the north end of Lower Manson Lake. This section contains lenses of Wolf Ridge gabbro, listwanites and serpentine of the Manson Lakes ultramafics and Big Creek or Slate Creek argillites.

Plate 35. Fault breccia of Boulder Creek group within the Manson fault zone on a small island in the middle of Lower Manson Lake. Many of these clasts are elongated subhorizontally and parallel to the trace of the fault zone.

processes have accommodated motion on the Manson fault zone.

Ultramafite bodies commonly occur as slivers within the fault zone. Ultramafite contacts within the zone are steep and strongly fractured. The presence of these bodies was used to delineate the zone. They typically have a linear trend and occur at contacts between contrasting lithologies (for example, the southwestern margin of the Boulder Creek group).

The southwestern margin of the Boulder Creek group is interpreted to be a splay of the Manson fault zone. Supporting evidence includes: ultramafite pods along this contact, and apparent truncation of metamorphic isograds at this boundary (*see* chapter on Metamorphism).

As already discussed, the contacts of several elongate bodies of Wolf Ridge gabbro are faulted. It seems probable that their shape is, in part, the result of movement within the Manson fault zone.

TIMING OF MOVEMENT

The timing of movement on the Manson fault zone must postdate compression and imbrication of the Quesnel, Slide Mountain and Cassiar terranes in Early to Middle Jurassic time. Further refinement of the lower age limit of movement is provided by a 134 Ma K-Ar age determination on mariposite from an altered ultramafite body in the fault zone. Quartz-carbonate-mariposite alteration of the ultramafite probably reflects movement on the fault zone, but does not rule out alteration related to an earlier compressional event.

An upper limit on the age of faulting can be postulated from crosscutting relationships in the Boulder Creek area. Here, the southwestern margin of the Boulder Creek block is thought to be bounded by a splay of the Manson fault zone. The 107 Ma (K-Ar, biotite) Germansen batholith intrudes the splay in the Boulder Creek area. This places an upper age limit on the splay, and by inference, on the main part of the Manson fault zone.

Regional-scale deformation resulted from movement on transcurrent faults in the northern part of the Cordillera between Middle Cretaceous and earliest Tertiary time (Gabrielse, 1985). The southern extension of the Manson fault zone ultimately feeds into the McLeod Lake - Northern Rocky Mountain Trench right-lateral fault systems which appear to have been active in Early Tertiary time.

Northwest of the map area, the Manson fault zone extends into the Conglomerate Mountain area which is underlain by Late Cretaceous to Early Tertiary sediments of the Uslika Formation (Eisbacher, 1974). A pull-apart basin related to movement on the Manson fault zone is a possible depositional setting for these conglomerates. If this is true, movement is in part Late Cretaceous to Early Tertiary. This interpretation is consistent with the evidence provided by other small basins of Cretaceous and Tertiary sediments found throughout the northern Cordillera.

Plate 36. Steep fault contact between Slate Creek argillites (left) and Manson Lakes ultramafics (right) along the Manson fault zone, immediately southwest of Manson Creek.

EXTENSIONS OUTSIDE THE MAP AREA

South of the map area, the Manson fault zone can be projected into a major fault mapped by Struik and Northcote (1991) in the southwestern quadrant of the Pine Pass sheet. This structure connects with a major fault system in the McLeod Lake map area and ultimately into the McLeod Lake fault system (Struik, 1989b).

Northern projection of the fault zone is less straightforward. Northwest of the map area, it can be traced into the Conglomerate Mountain area, but there are no major lineaments that may be a topographic expressions of the fault. The only possibility is in the upper part of the Osilinka River, although Roots (1954) did not mention the presence of a major fault zone within the underlying rocks of the Hogem batholith. This evidence suggests that the Manson fault zone is losing expression to the north.

Roots (1954) mapped a series of faults or fault zones northwest of Conglomerate Mountain, along the lower part of Vega Creek, along sections of Tenakihi Creek, and along the Tutizika River. These zones form a northwest-trending belt and can be extended into a major fault along the Lay Creek valley which separates Takla rocks from those of the Lay Range assemblage. The fault lineament along these creeks is en echelon with the Manson fault zone. It is postulated that motion on the Manson fault zone is transferred to an en echelon fault along the Vega-Tenakihi-Lay Creek valleys and that this displacement feeds into the Finlay and Ingenika fault systems to the northwest.

This northwestward extension of the Manson fault zone has been supported by recent mapping in the area by Ferri *et al.* (1992a, b and 1993a, b) and Nelson *et al.* (1993a, b) who have demonstrated the presence of a large northwest trending strike-slip fault.

RELATIONSHIP TO WOLVERINE FAULT ZONE

The relationship of the Wolverine fault zone to regional strike-slip motion was addressed earlier. Gabrielse (1985) first postulated the relationship between strike-slip motion and uplift of metamorphic core complexes. Some workers, such as Evenchick (1988) in the Sifton Ranges and H. Plint (personal communication, 1991) in the Horseranch Range, have demonstrated a relationship between core complex uplift and regional strike-slip motion. Movement along the western bounding fault (Wolverine fault zone) of the Wolverine Metamorphic Complex has been accommodated by dip-slip motion. Its eastern boundary is marked by the right-lateral Northern Rocky Mountain Trench fault. Thus some type of relationship between uplift and strike-slip motion is inferred in the study area.

The moderately to steeply dipping Wolverine fault zone must be cut or joined at depth by the near vertical Manson fault zone. Crosscutting relationships between the fault systems are unknown. Timing of fault motion on both fault systems is similar and regionally the Wolverine fault zone appears to feed into the McLeod Lake – Northern Rocky Mountain dextral fault systems: a situation exemplified by the Manson fault zone as it merges with the Wolverine fault zone at depth.

INTRODUCTION

Rocks in the map area were variably metamorphosed during the Mesozoic and Cenozoic. Regional metamorphism is, for the most part, chlorite grade or lower within the Intermontane Belt and is probably of Mesozoic age. In the Omineca Belt rocks reach sillimanite grade and record Middle Jurassic and Early Tertiary thermal events. This variability reflects the different tectonic histories of the two belts. Rocks of the Intermontane Belt were deformed at a much higher structural level than those of the Omineca Belt.

INTERMONTANE BELT

Regional metamorphism in the Intermontane Belt attained chlorite grade. Biotite and garnet grade assemblages are seen locally, but represent contact metamorphism related to the Germansen batholith.

Generally, metamorphic grade increases to the east. In western exposures, mafic volcanics of the Takla Group contain prehnite and pumpellyite in association with chlorite, epidote, calcite and muscovite. These minerals are found as vein and vesicle fillings and as alteration of matrix material. To the east, prehnite and pumpellyite are absent and Takla and Lay Range volcanics contain chlorite, muscovite, epidote and calcite, indicating a slightly higher metamorphic grade.

Pelitic rocks contain chlorite, muscovite and quartz; whereas epidote is common in the more tuffaceous sediments. Close to the Manson fault zone, silvery muscovite-rich slates may contain significant amounts of iron-rich carbonate which locally form large porphyroblasts (Plate 37). The presence of carbonate porphyroblasts in these sediments usually corresponds with the nearby occurrence of strongly altered ultramafic bodies (listwanites) in the Manson fault zone (*see* chapter on Economic Geology). It is possible that there is an unconformity between the Slate Creek succession and the Manson Lakes ultramafics (evidence discussed in Geological Synthesis chapter) and that the abundance of iron in Slate Creek sediments may, in part, be due to erosion of material from the ultramafics.

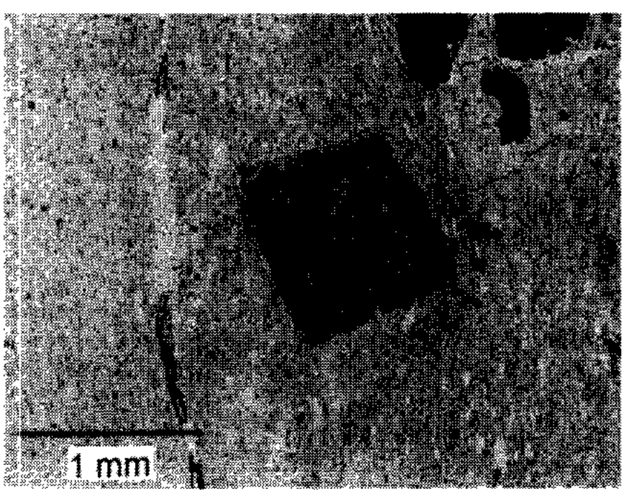

Plate 37. Photomicrograph of idiomorphic ankerite porphyroblasts in Slate Creek argillites near the Motherlode showing. Also seen in this picture is a xenomorphic ankerite porphyroblast.

Actinolite, biotite and garnet are widespread within the contact aureole of the Germansen batholith. The aureole extends up to 2 kilometres into the sediments and volcanics of the Takla and Boulder Creek groups. Northeast of Mount Gillis, Takla mafic volcanic rocks contain actinolite which commonly forms radiating masses centred on augite or hornblende phenocrysts; biotite (stilpnomelane?) is concentrated in the volcanic matrix. Tiny porphyroblasts of garnet are found within interbedded argillites and calcareous argillites of the Slate Creek succession near Mount Gillis. North of Mount Germansen, nematoblastic actinolite and biotite form a foliation in conjunction with flattened volcanic clasts.

OMINECA BELT

A characteristic of the Omineca Belt is the presence of dynamothermal metamorphism which culminates within regional-scale sillimanite-grade core complexes. Rocks of the Omineca Belt represent the infrastructure of the orogen in the eastern part of the Cordillera.

The metamorphic grade of the Omineca Belt within the map area ranges from chlorite grade in its western part to sillimanite grade in the east. Metamorphic grade gradually increases to the northeast with an abrupt increase across the Wolverine fault zone. North of the Osilinka River, metamorphic grade increases east and west of the headwaters of Edmunds Creek, as indicated by the appearance of staurolite to the east and the coarser schistose nature of the rocks to the west. Sillimanite-grade rocks form a northwest-trending belt confined to the lower parts of the Ingenika Group in the Wolverine Range.

Displacement on the Wolverine fault zone has juxtaposed sillimanite grade rocks against rocks of garnet and lower grade. Apparent displacement on the Wolverine fault decreases to the north resulting in the limited appearance of staurolite and kyanite just northwest of the confluence of the Omineca and Osilinka rivers. The lack of outcrop and the poor development of kyanite and staurolite have prevented the delineation of offset isograds. However, isograds are definitely truncated by the Wolverine fault; whereas, elsewhere they roughly parallel the dominant structural trends.

There is a general concordance between metamorphic grade and stratigraphic level, with chlorite-grade metamorphism persisting down to the upper part of the Swannell Formation and increasing below this level. In the western part of the area the biotite isograd consistently occurs below the Espee Formation whereas, in the east, a thick carbonate believed to be the Espee Formation, is at staurolite grade. The Wolverine antiform has broadly warped these isograds into domal surfaces.

Metamorphism reaches staurolite grade within the Boulder Creek group where tentative garnet and staurolite isograds have been mapped (Figure 7). Metamorphic grade increases to the southwest within the Boulder Creek group and peaks southwest of Lower Manson Lake in an area of limited outcrop where staurolite and garnet-grade assemblages appear to terminate against the southwestern boundary of the group. The presence of greenschist grade metamorphic rocks in the Takla Group southwest of the Boulder Creek group indicates a faulted boundary between the two units.

MINERAL ISOGRADS

Progressive metamorphism of these rocks is illustrated by mineral isograds defined by the presence of porphyroblasts (Figure 57). These isograds (in ascending grade) mark the appearance of chloritoid, biotite, garnet, staurolite, kyanite and sillimanite. Some of these diagnostic minerals occur only locally and an isograd cannot be mapped (*e.g.*, chloritoid, staurolite and kyanite). A brief description of each metamorphic facies, with reference to various structural elements, follows.

CHLORITOID

Chloritoid porphyroblasts up to several millimetres in length are found in the upper parts of the chlorite zone (Plate 38). This mineral is only locally developed; consequently, it has not been possible to define a chloritoid isograd. Its presence and textural relationships define the relative age of foliations.

Chloritoid appears to be confined to pelitic rocks of the Ingenika Group where it persists into garnet-grade rocks. It occurs as single porphyroblasts that are subidioblastic to xenoblastic and are parallel to subparallel to the dominant foliation. They can also be poikiloblastic and may exhibit an hourglass structure. The chloritoids commonly contain oriented inclusions of the groundmass material aligned parallel to the fabric in the groundmass. They do not overgrow a later pressure-solution crenulation cleavage (S_2, Plate 38).

At one locality a chloritoid crystal has grown at a high angle to the layer-parallel foliation (S_1). This foliation appears to be slightly "bowed" or flattened around the porphyroblast (Plates 38, 39). In this sample most chloritoid porphyroblasts are oriented subparallel to S_1 foliation, though many are also at a high angle to S_1 foliation. This, in conjunction with the slight flattening of S_1 foliation around some of these porphyroblasts, indicates that they grew late during D_1 deformation.

Very small crystals of chloritoid were observed in schists of the Boulder Creek group. They are idioblastic to xenoblastic and have grown parallel or subparallel to the dominant foliation.

TOURMALINE

Porphyroblasts of tourmaline are seen at all metamorphic grades above the biotite isograd. Relatively unmetamorphosed Ingenika Group sediments contain abundant detrital grains of tourmaline and it seems probable that the porphyroblasts were produced by the recrystallization of this material. This is substantiated by the outlines of detrital grains within idioblastic crystals of tourmaline.

Tiny, idioblastic tourmaline porphyroblasts occur at several localities east of the garnet isograd (biotite zone). In contrast, near Edmunds Creek (staurolite zone), tourmaline occurs as large porphyroblasts up to 2 centimetres long. In thin section these porphyroblasts are poikiloblastic with straight inclusion trails (Plate 40).

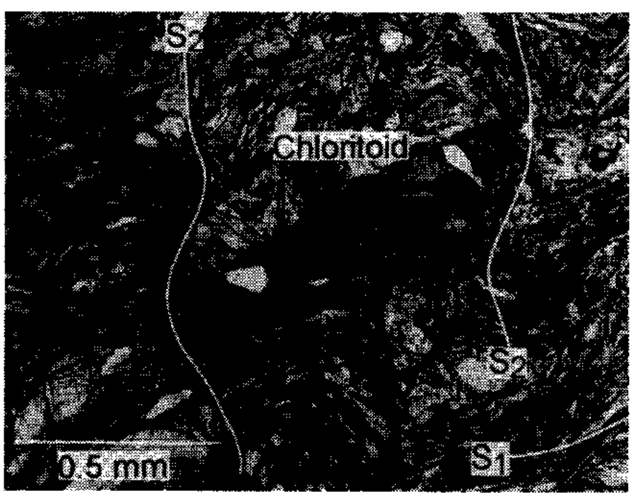

Plate 38. Photomicrograph of a chloritoid porphyroblast in phyllites of the Ingenika Group. The chloritoid overgrows and makes a high angle with the S_1 foliation. S_1 is also slightly bowed around this chloritoid crystal, indicating that the crystal grew late during D_1 deformation.

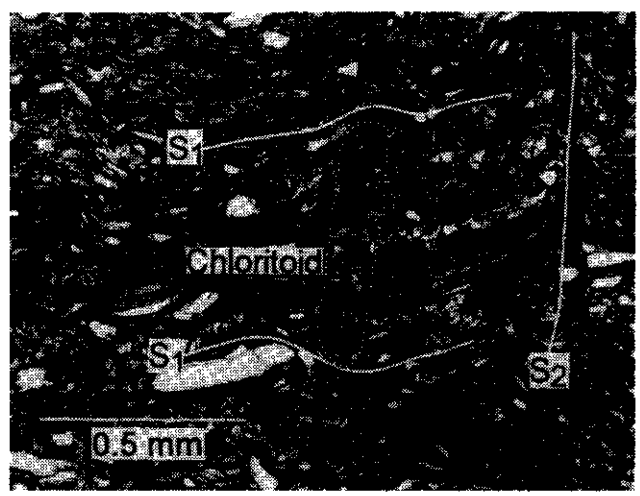

Plate 39. Photomicrograph of chloritoid porphyroblasts in schists of the Ingenika Group. This chloritoid overgrows the S_1 foliation but it is pre-S_2 as seen by the deflection of S_2 cleavage planes around its edges.

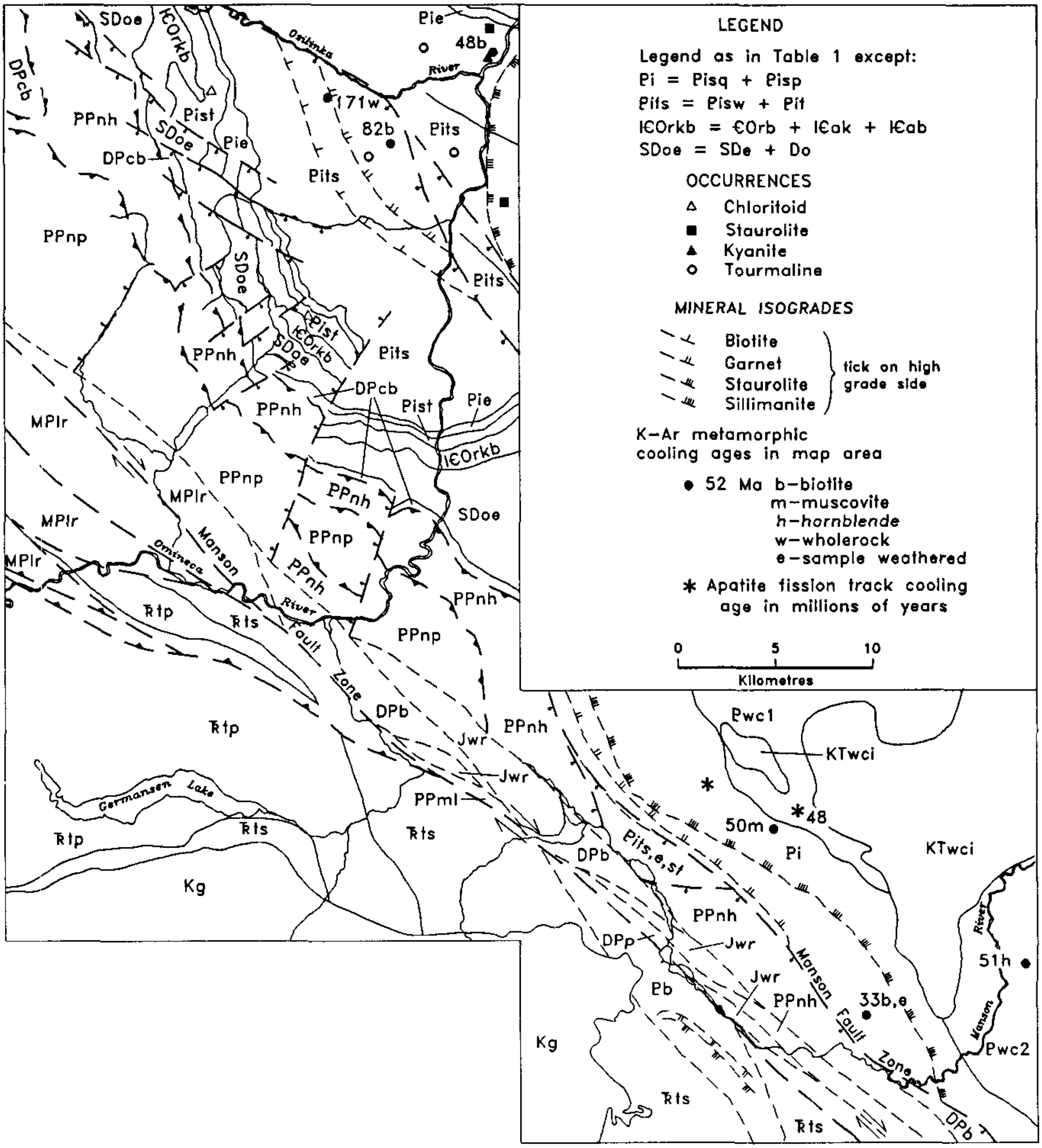

Figure 57. General geology of the map area showing the location of isograds and occurrences of chloritoid, tourmaline, staurolite and kyanite. Also shown is the geochronology of the high-grade metamorphic rocks. m=muscovite, b=biotite, h=hornblende, w=whole rock.

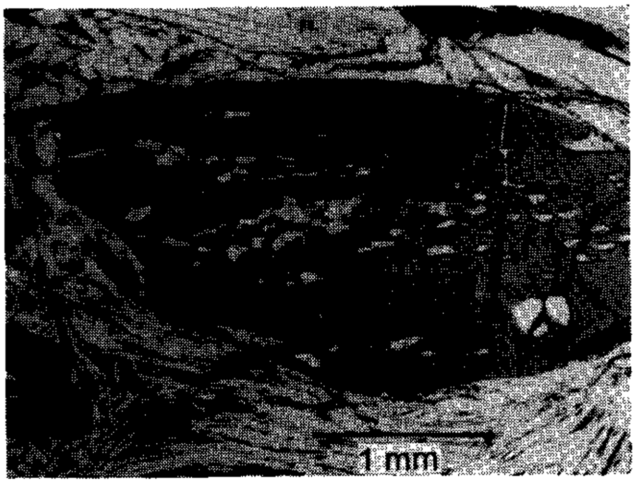

Plate 40. Photomicrograph of tourmaline porphyroblast in schists of the Ingenika Group.

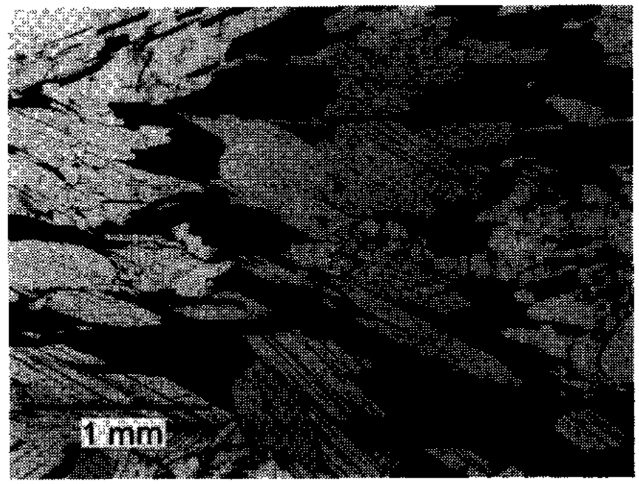

Plate 41. Photomicrograph of recrystallized (annealed) biotite and muscovite crystals in the central or high-grade regions of the Wolverine Metamorphic Complex. Compare this with the fabric within the ductile portion of the Wolverine fault zone (Plate 31).

BIOTITE

The biotite isograd was mapped continuously through rocks of the Ingenika Group. The first occurrence of this mineral typically corresponds with the lower levels of the Tsaydiz Formation or upper parts of the Swannell Formation. This isograd can be mapped from the Osilinka River southeastward towards the Wolverine Range, where it terminates against the Wolverine fault zone. To the south it is restricted to small fault blocks of upper Ingenika Group rocks in the vicinity of Granite Creek.

The first biotite porphyroblasts seen in the Ingenika Group occur as tiny crystals oriented parallel or subparallel to S_1 foliation. Biotite porphyroblasts, up to several centimetres across, may occur at higher metamorphic grades. They may be poikiloblastic and the inclusions are often randomly oriented. These porphyroblasts are typically xenoblastic and the S_1 foliation commonly wraps around them. Above the sillimanite isograd, biotite and other phyllosilicates are recrystallized as shown in Plate 41. Here, biotite and muscovite crystals are recrystallized around F_1 fold hinges and show little internal strain.

Biotite in the lower grade metamorphic rocks is commonly chloritized. Typically chloritization is incomplete and remnants of the original biotite can be seen in thin section. Recrystallization resulting in large, single crystals of chlorite is not evident.

Two generations of biotite are observed in samples from the Boulder Creek group. One is represented by tiny xenoblastic porphyroblasts growing parallel to subparallel to the main foliation. These increase in size with the grade of metamorphism. The second group are subidioblastic and grow at an angle to the dominant foliation. In some sections these discordant porphyroblasts are poikiloblastic and have inclusion trails parallel to the exterior foliation. There is no post-growth flattening of the S_1 foliation. Many of these biotite crystals are oriented parallel to a late crenulation but some appear to be randomly oriented.

GARNET

The trace of the garnet isograd closely mimics that of the biotite isograd. Its trace within the Boulder Creek block is tentative due to the sporadic occurrence of garnet. Garnet is extensively developed in the southeastern portion of the map sheet where a well-defined isograd follows the trend of the Wolverine fault zone.

Garnet porphyroblasts are red to pinkish red in colour and up to 2 centimetres in diameter. They are almost always equant and vary from xenoblastic to idioblastic, though the latter are uncommon (Plate 42). Poikiloblastic textures are common, and in some cases inclusions form a crude layering within the porphyroblast which is always at an angle to the dominant foliation in the rock. Garnets with helicitic inclusion trails are very rare (Plate 43). Locally poikiloblastic porphyroblasts form very irregularly shaped, "ragged" crystals (Plate 44). These frequently contain a rim rich in quartz and feldspar inclusions. The larger, more equant, idioblastic porphyroblasts are usually found in the most pelitic rocks, whereas ragged

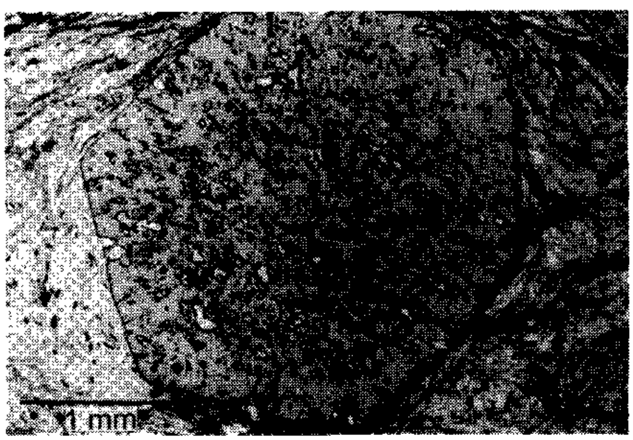

Plate 42. Photomicrograph of idioblastic garnet porphyroblast in schists of the Ingenika Group.

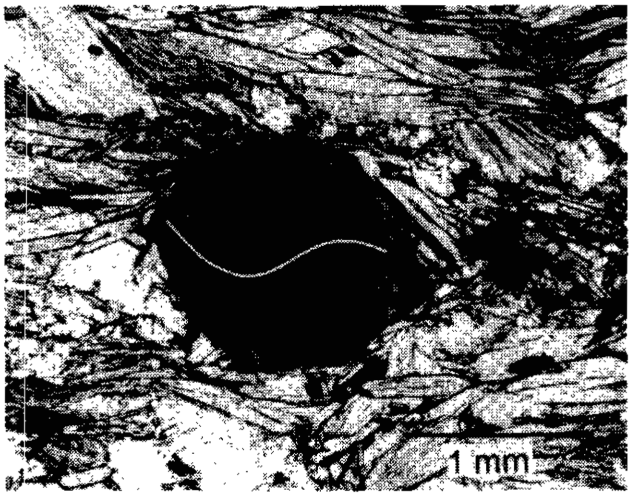

Plate 43. Photomicrograph of garnet porphyroblast with helicitic inclusion trails which indicates that metamorphism was occurring during D_1 deformation.

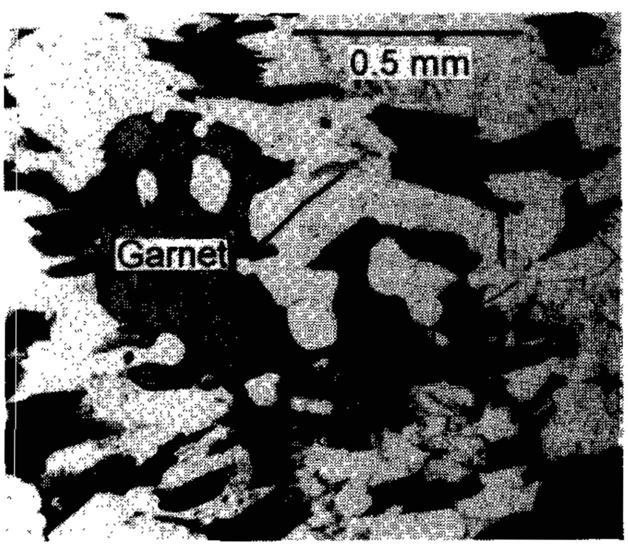

Plate 44. Photomicrograph of irregularly shaped garnet porphyroblast within schists of the Ingenika Group.

porphyroblasts are more typical of quartz and feldspar-rich lithologies.

The S_1 foliation commonly wraps around garnet porphyroblasts (Plate 45) though in some samples S_1 foliation is relatively unaffected (Plate 42). F_2 crenulations are deflected (Plate 45) by garnet porphyroblasts.

In the lower amphibolite facies, garnet is often retrogressively altered to chlorite, muscovite and quartz (Plate 45). The original nature of these pseudomorphs is often difficult to distinguish in the field.

Garnet was only observed in a few localities in the Boulder Creek group where it usually occurs as small, red to brown idiomorphic porphyroblasts up to 0.5 centimetre in diameter. In thin section it displays the same textural relationships as staurolite with the other fabric elements (*see* section below on relationships of metamorphism to deformation).

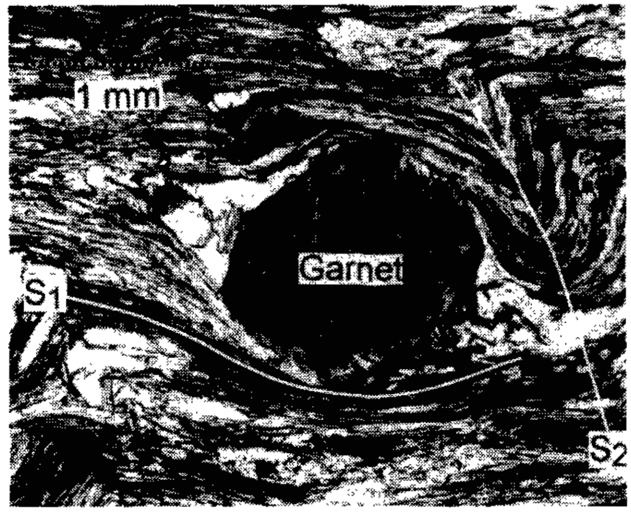

Plate 45. Photomicrograph of retrogressed garnet porphyroblast within schists of the Ingenika Group. In this picture S_1 foliation is flattened around the garnet indicating that deformation outlasted the peak of metamorphism (if the peak of metamorphism corresponds to porphyroblast growth). Also seen in this photo are S_2 crenulations which cut across S_1.

STAUROLITE

Staurolite is only recognized in a few localities; in the far northeastern corner of the map area and within the Boulder Creek group (Figure 57). In the northeast, near Edmunds Creek, staurolite occurs as large porphyroblasts up to 2 centimetres long. They may be idioblastic, though commonly only a few crystal faces are well formed (Plate 46). They are poikiloblastic with the inclusions forming a crude layering parallel to the long axis of the porphyroblasts (Plate 47). These inclusion trails (and the long axis of the staurolite crystals) are often at an angle to the dominant foliation which wraps around the porphyroblasts.

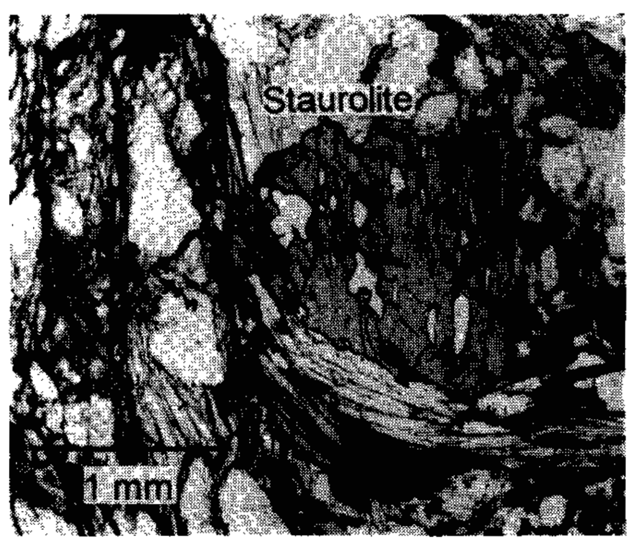

Plate 46. Photomicrograph of subidiomorphic staurolite porphyroblast in Ingenika Group schists showing poikiloblastic texture. These inclusion trails make a high angle with the surrounding foliation which suggests post-growth deformation.

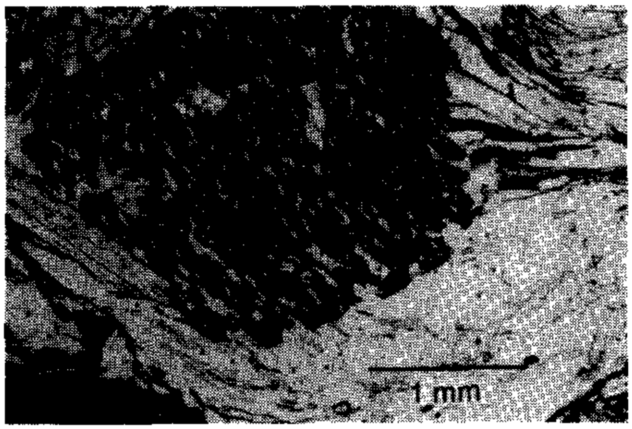

Plate 47. Photomicrograph of staurolite porphyroblast showing layered inclusion trails at a high angle to foliation. These trails are also slightly curved. This indicates synmetamorphic D_1 deformation with deformation outlasting metamorphism.

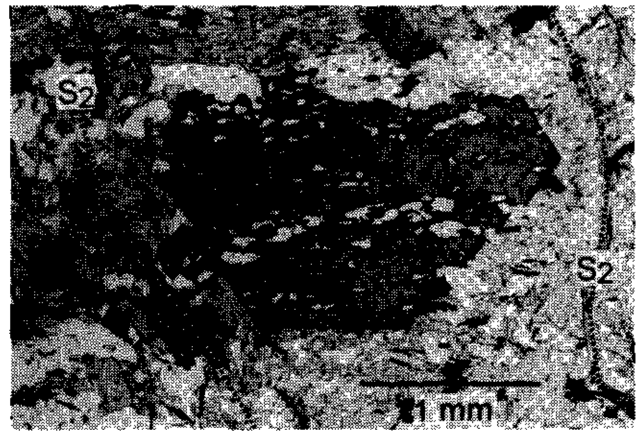

Plate 48. Photomicrograph of subidiomorphic staurolite porphyroblast from within the Boulder Creek block showing straight inclusion trails and deflected crenulation cleavage. This photo also shows biotite porphyroblasts growing within the S_2 cleavage planes.

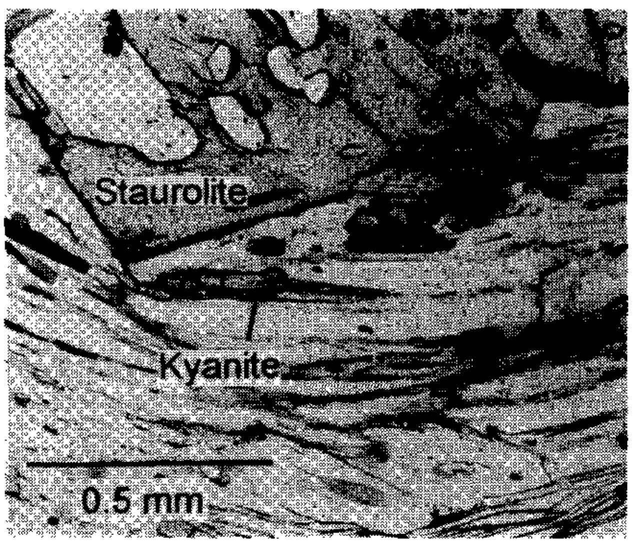

Plate 49. Photomicrograph of kyanite porphyroblast at the edge of a staurolite porphyroblast in Ingenika schists.

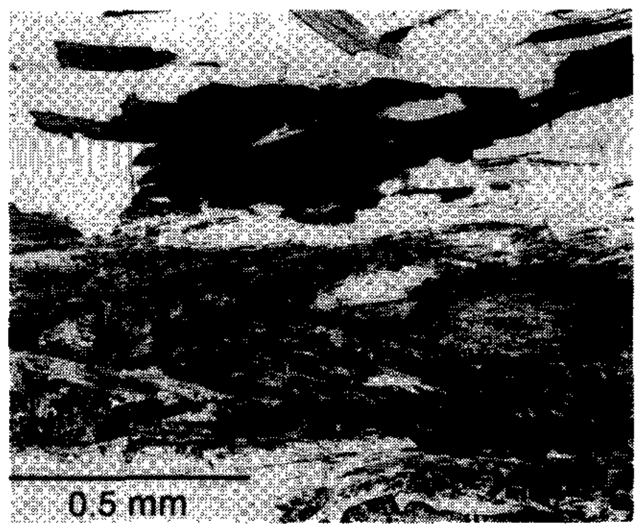

Plate 50. Photomicrograph of sillimanite needles (fibrolite) nucleated on mica grains in Ingenika schists.

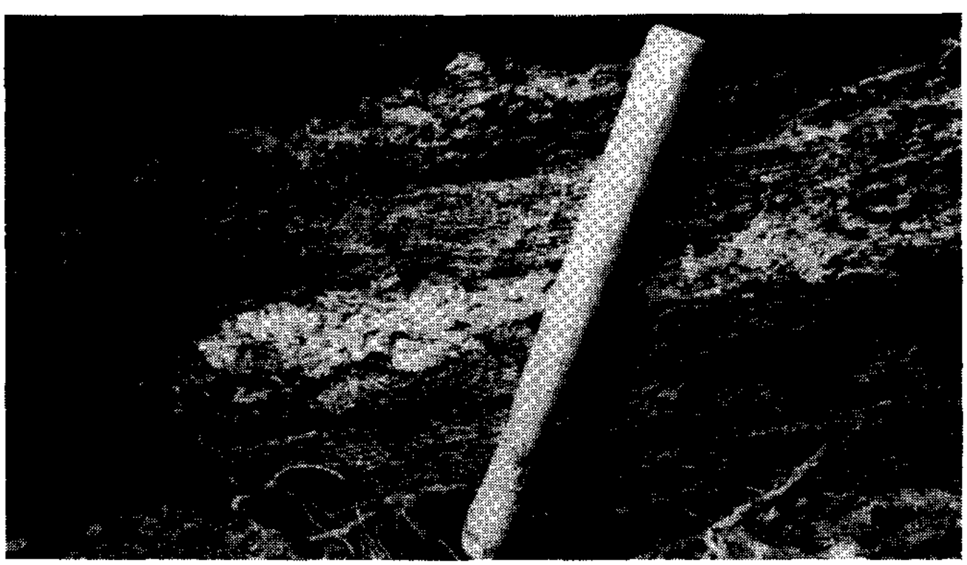

Plate 51. Migmatite (?) in amphibolite gneiss of unit Pipi north of Munro Creek.

Staurolite forms porphyroblasts up to 0.5 centimetre long within the Boulder Creek group. They are idioblastic and poikiloblastic, with the inclusion trails parallel to the dominant foliation (S_1, Plate 48). The long axes of the crystals also parallel the S_1 foliation and there is no post-growth flattening of the S_1 foliation. A late crenulation cleavage is deflected by the staurolite porphyroblasts.

KYANITE

Kyanite is found in only two samples in the Edmunds Creek area where it is associated with staurolite. It forms tiny (less than 0.5 millimetre) subidioblastic crystals (Plate 49) growing parallel to the dominant foliation.

SILLIMANITE

Sillimanite is present throughout the Wolverine Ranges (Figure 57). It is difficult to identify at the outcrop, but is typically seen in thin section in the form of fibrolite (Plate 50). In the Munro Creek area sillimanite forms large crystal masses up to several centimetres long. These porphyroblasts have formed at the expense of garnet and define a south to southeast-trending subhorizontal lineation.

In thin section sillimanite is observed replacing phyllosilicates (Plate 50). These porphyroblasts are either needle-like crystals within the cores of muscovite and biotite grains or fibrous mats along the edges of micas.

MUSCOVITE-OUT (?)

High-grade metasediments containing only biotite are found in the northeastern part of the Wolverine Range within unit Pipi . The mineral assemblage in these rocks is biotite, quartz, potassium feldspar, plagioclase and occasionally garnet. This assemblage may reflect the disappearance of muscovite and indicate a higher grade of metamorphism in the northeast but it should be noted that these rocks did not contain sillimanite and many of the reactions which consume muscovite have sillimanite as a product (Winkler, 1979). Thus the lack of muscovite may reflect the bulk composition of the rocks rather than very high metamorphic rank.

MIGMATITE (?)

Quartzofeldspathic layer-parallel lenses up to several decimetres long and 10 centimetres wide occur rarely within the amphibolite gneisses north of Munro Creek (Plate 51). The presence of this migmatite-like material is probably related to increasing metamorphic grade to the southeast in the Wolverine Range. These migmatitic bodies suggest partial melting of the metasediments.

Alternatively the quartzofeldspathic lenses may represent highly dismembered pegmatitic material. In high-grade rocks north of the Manson River, pegmatites are foliated and boudinaged within the main foliation to produce thin bodies similar in appearance to the migmatites. In these pegmatites there is a gradation from relatively undeformed to boudinaged sections. No such gradation or internal fabric was observed in the quartzofeldspathic lenses in the Munro Creek area.

RETROGRADE METAMORPHISM

Retrograde metamorphism or alteration variably affects metamorphic minerals in the map area. It is most pronounced in the garnet and biotite zones and rarely observed at higher metamorphic grades. Retrogression is most evident along the west flank of the metamorphic complex and is very apparent near the Wolverine fault zone. It is believed that the Wolverine fault zone may have localized this retrogression. The brittle and ductile parts of the fault zone must have had a greater permeability than the surrounding rocks. The fault zone may have acted as a conduit for magmatic, meteoric and/or metamorphic fluids which produced retrograde assemblages within adjacent higher level rocks.

RELATIONSHIP OF METAMORPHISM TO DEFORMATION

Rocks of the Omineca Belt display clear textural relationships that are readily interpreted within the context of a regional deformational-metamorphic history. Figure 39 shows the timing relationships between deformation and metamorphism within the Omineca Belt. Relationships in the Omineca Belt are directly applicable to rocks of the Intermontane Belt as the processes (*i.e.*, tectonic events) which brought these belts together, and subsequently deformed them, produced similarly aged structures and metamorphism within each belt. However, the character of these structures and metamorphic events is manifested differently within each belt; the Omineca Belt generally records deeper, more ductile processes and the Intermontane Belt contains higher and more brittle features.

INGENIKA GROUP (CASSIAR TERRANE)

Relationships between porphyroblasts, fabrics and regional-scale structural elements appear to be consistent within the Ingenika Group. Straight inclusion trails in chloritoid, garnet and staurolite porphyroblasts (Plates 38, 39, 43, 45 and 47) indicate that the S_1 schistosity predates main-stage metamorphism. Helicitic textures in some porphyroblasts (Plates 43, 47) indicate that the peak of metamorphism occurred during D_1 deformation. Furthermore, semi-randomly oriented porphyroblasts (Plates 38, 39) and little or no flattening of S_1 foliation around some porphyroblasts (Plate 42) suggest the peak of metamorphism was (very) late during D_1, probably towards its close.

In all samples above greenschist grade metamorphism, the dominant schistosity is flattened around larger porphyroblasts (Plates 47, 52). If garnets grew at the peak of metamorphism, clearly deformation extended beyond the metamorphic peak. Straight to slightly helicitic inclusion trails in garnet, tourmaline and staurolite are preserved at a high angle to the main schistosity. This again suggests that the first deformation outlasted the peak of metamorphism.

East of the Wolverine fault zone, minerals within rocks at predominantly sillimanite grade show little or no internal strain. The same holds true for schistose rocks north and east of the Osilinka River. All phyllosilicates

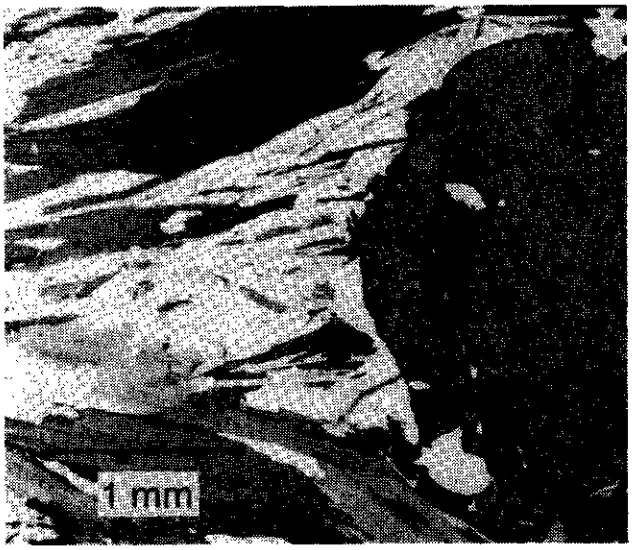

Plate 52. Photomicrograph showing foliation wrapping around garnet in schists of the Ingenika Group.

and quartz show annealed textures indicating that metamorphism outlasted deformation (D_1 and D_2). The annealed textures imply that temperatures remained high enough to remove any acquired strain. We suggest that these rocks remained relatively deep and above the blocking temperature of metamorphic minerals until Early Tertiary time when the complex was rapidly uplifted.

West of the Wolverine fault zone, micas and quartz show little evidence of annealing. The mineral grains exhibit undulose extinction and polygonization indicating post-peak metamorphic strain, probably related to D_2 deformation.

BOULDER CREEK GROUP (KOOTENAY TERRANE)

The peak of metamorphism in the Boulder Creek block is post-D_1 and pre-D_2, although S_2 mica growth suggests that metamorphism may have continued at least to the onset of D_2 deformation. This is also suggested by staurolite porphyroblasts that contain straight inclusion trails aligned parallel to the layer-parallel fabric in the enclosing rocks which is not flattened around the porphyroblasts. Crenulation cleavage planes (S_2) are deflected around these staurolite porphyroblasts.

Biotite crystals are locally developed parallel to S_2 cleavage planes and also at angles to S_1 and S_2 indicating that metamorphism may have outlasted both D_1 and D_2 deformations. Timing relationships between metamorphism and deformation within Boulder Creek strata are somewhat different from the relationships seen in the most of the Omineca Belt in the map area. In the Boulder Creek group the peak of metamorphism is clearly post-D_1 and may be synchronous with the onset of D_2 deformation whereas in the Ingenika Group the peak of metamorphism coincides with D_1 and clearly pre-dates D_2 deformation.

GEOTHERMOMETRY

Garnet-biotite geothermometry has been conducted on two samples (FFe87-35-7 and DMe87-33-7; *see* Figure 57 for locations) of sillimanite grade rocks from the Ingenika Group. A total of 43 microprobe analyses were conducted using the ARL microprobe at the University of Calgary; 26 on garnet and 17 on biotite. Mineral stoichiometries were calculated using microcomputer programs written by G. Poirier at McGill University. Garnet analyses are normalized to eight cations and all iron is assumed to be ferrous. Biotite stoichiometries are based on fourteen cation sites using the method of Dymek (1983). Microprobe analyses and mineral stoichiometries are presented in Appendix V.

Garnets in these samples are manganese-rich almandine with MnO contents ranging from 3.4 to 8.5%. Biotite has a relatively constant composition. Chemical zoning is not apparent in either of these porphyroblastic minerals.

Temperatures have been calculated on averaged mineral analyses using the methods of both Ferry and Spear (1978) and Hodges and Spear (1982). Ferry and Spear's application is limited to systems that do not contain significant amounts of calcium, manganese, and titanium; that is only if $(Ca+Mn)/(Ca+Mn+Fe+Mg)=0.20$ for garnet and $(Alvi+Ti)/(Alvi+Ti+Fe+Mg)=0.15$ for biotite. For minerals that do not meet these chemical specifications the methods of Hodges and Spear should be used.

Temperature results calculated using both geothermometers are presented in Table 5. Due to the chemical restrictions listed above, the results for sample FFe87-35-7 may be better estimated using Hodges and Spear's methods, whereas sample DMe87-33-7 may be better approximated using Ferry and Spear's techniques. Both samples produce results which are virtually indistinguishable within the error estimates of the calibrations (±50°C).

Temperatures calculated using rim analyses yield results similar to those obtained from the cores of minerals, with the exception of sample DMe87-33-7. The extremely high temperature obtained for the garnet-biotite rim pair in sample DMe87-33-7 may indicate disequilibrium in the sample. Overall, temperatures are assumed to represent peak metamorphic conditions. The results

TABLE 5
GEOTHERMOMETRY RESULTS FOR SAMPLES FFe87-35-7 AND DMe-87-33-7.

GEOTHERMOMETRY RESULTS

SAMPLE FFE 35-7	FERRY AND SPEAR	HODGES AND SPEAR
Garnet core - Biotite rim	630°C	650°C
Garnet middle - Biotite rim	625°C	640°C
Garnet rim - Biotite rim	625°C	640°C
*Garnet rim - Biotite rim	600°C	620°C

SAMPLE DME 33-7	FERRY AND SPEAR	HODGES AND SPEAR
Garnet core - Biotite rim	650°C	670°C
Garnet middle - Biotite rim	630°C	650°C
Garnet rim - Biotite rim	915°C	950°C

*Analysis pair from a biotite inclusion in garnet.

range from 620° to 650°C for the preferred calibrations and are consistent with expected temperatures for rocks of sillimanite grade.

GEOCHRONOLOGY AND TECTONIC IMPLICATIONS

Metamorphic cooling ages were determined for seven samples from high-grade metamorphic rocks of the Ingenika Group (Figure 57, Appendix II). Rocks east of the Wolverine fault zone returned Early Tertiary ages (33-59 Ma) whereas a sample from the hangingwall of the fault produced a Middle Jurassic age (171 Ma). A specimen in or near the fault zone yielded a Late Cretaceous age (82 Ma). These data are consistent with peak metamorphism in Middle Jurassic time, but with rocks east of the Wolverine fault zone reset in the Early Tertiary. The 82 Ma sample may record Middle Jurassic metamorphism that is only partially reset.

Early Tertiary dates are quite common in metamorphic rocks around the study area (Figure 58) and in core complexes of the southern Omineca Belt (Parrish, 1979; Parrish *et al*, 1988). Recent work in core complexes of the southern Canadian Cordillera has shown that they are bounded by moderate to steeply dipping normal faults or shear zones (Parrish *et al.*, 1988; Carr *et al.* 1987). High-grade rocks of the core consistently return Early Tertiary metamorphic cooling ages whereas Cretaceous

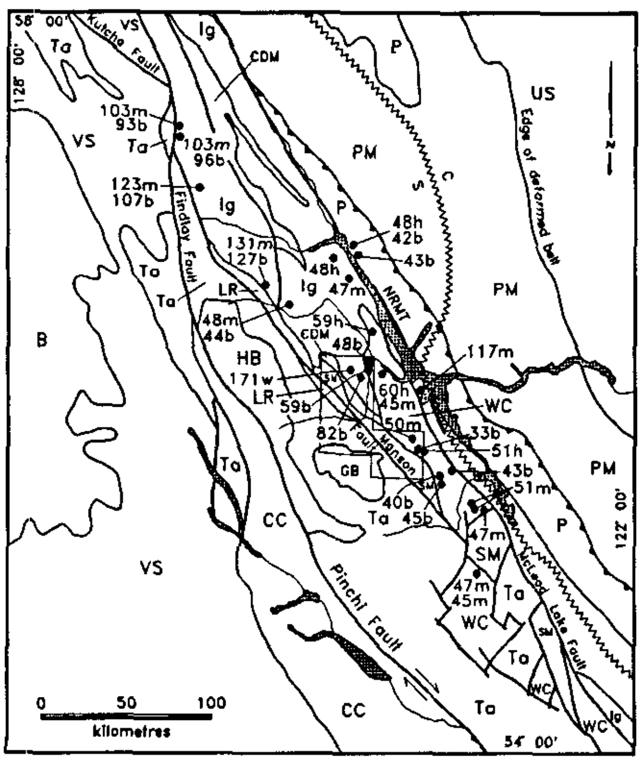

Figure 58. Regional geology map with K-Ar dates along the Omineca Belt and parts of the Rocky Mountains. Data from this study, Parrish (1979), Gabrielse (1975) and Wanless *et al.* (1979). m=muscovite, b=biotite, h=hornblende, w=whole rock.

and older ages are obtained for rocks in the hangingwalls of the bounding faults. Such evidence indicates that the shear zones were active in Early Tertiary times and that the K-Ar ages of metamorphic rocks in these complexes represent cooling due to rapid uplift in the Tertiary and do not represent a thermal reset of earlier metamorphism (Brown and Carr, 1990).

According to this theory, strata of the Omineca Belt were thickened and metamorphosed in the Early to Middle Jurassic. Rocks in the upper parts of the deformed crust were uplifted just after Middle Jurassic deformation. Rocks in the deeper parts of the continental crust (core complexes) remained above the K-Ar blocking temperatures of metamorphic minerals until Late Cretaceous to Early Tertiary time, when they were quickly uplifted along extensional shear zones.

Structural and metamorphic data within the map area are consistent with this hypothesis. Early Tertiary metamorphic ages in high-grade rocks within the Wolverine Range are separated from older metamorphic ages by the west-side-down Wolverine fault zone. Exposed metamorphic mineral assemblages in the Wolverine Range require uplift in the order of 20 to 30 kilometres of which a large portion may have been accommodated by motion on the Wolverine fault zone. Rocks in the hangingwall of the Wolverine fault zone represent upper crustal regions that were cooled through normal denudation processes following their deformation and metamorphism.

Uplift of the Wolverine Complex appears to have been very rapid as gauged by apatite fission-track analysis of two samples. The more reliable of these samples shows the complex cooled below 100°C at approximately 48 Ma (Figure 57). Taken in conjunction with K-Ar blocking temperatures and ages of metamorphic minerals, this indicates cooling from approximately 500°C to 100°C in a few million years, implying rapid uplift of these rocks in the Early Tertiary. Evidence for unroofing of the complex immediately following annealing and cooling of apatite grains is provided by the presence of metamorphic detritus in the Early Tertiary Sifton Formation exposed in the northern Rocky Mountain Trench (Gabrielse, 1975).

An 82 Ma K-Ar date from near the fault zone also points to uplift and cooling of rocks in Late Cretaceous time. Cretaceous uplift is further substantiated by the occurrence of metamorphic clasts in the Late Cretaceous to Early Tertiary Uslika Formation immediately northwest of the map area (Roots, 1954). However, most metamorphic cooling ages are Early Tertiary indicating that Cretaceous dates record the onset of a mainly Tertiary uplift event.

Middle Jurassic dates on prograde metamorphic minerals from the Omineca Belt are well documented in the southern Canadian Cordillera (Greenwood *et al.*, 1991), but are poorly represented in the Omineca Mountains. In the Chase Mountain region, immediately north of the map area, Parrish (1979) obtained a date of 166 Ma from Rb/Sr ratios on muscovite from a schist. This led him to postulate that metamorphism was of Middle Jurassic age with thermal overprinting or uplift in the Early Tertiary. A similar age obtained in the map area further corroborates Parrish's Chase Mountain data as well as detailed studies to the south.

Metamorphism in the southern part of the Omineca Mountains appears to be more or less synchronous with metamorphism in the southern Omineca Belt. Such widespread synchronous deformation ultimately reflects hinterland accretion of allochthonous terranes. Docking of these terranes probably occurred at about the same time along the length of the Cordillera.

The Wolverine Metamorphic Complex appears to terminate at the northern end of the Wolverine Range but Tertiary extension northwest of the map area is expressed by other metamorphic culminations. One such area is the southern part of the Butler Range which has consistently yielded Tertiary metamorphic cooling ages (Gabrielse, 1975). The Butler Range is bounded on each side by steep slopes which fall off into straight valleys oriented parallel to the Wolverine fault zone. It seems probable that the Butler Range represents another uplift that is en chelon with the Wolverine Metamorphic Complex.

The cause for uplift of these complexes is not known. Brown and Carr (1990) suggest that it was the result of isostatic instability in the highly thickened crust immediately after the cessation of contractional deformation. Alternatively, Evenchick (1988) clearly demonstrated the relationship between strike-slip motion and the uplift of high-grade Tertiary rocks in the Sifton Ranges. A similar relationship exists for uplifted metamorphic rocks of the Horseranch Range (Plint *et al.*, 1992).

The Wolverine Metamorphic Complex is bounded on its northeast side by the dextral northern Rocky Mountain Trench fault system. The southern extension of the Wolverine fault zone joins the McLeod Lake fault system which is a major right-lateral fault. Furthermore, other complexes in the region (such as the Butler Range complex) are bounded by faults which are part of strike-slip fault systems. Uplift of the Wolverine and related complexes is believed to be linked to transcurrent motion along the Northern Rocky Mountain Trench and related dextral faults (Gabrielse, 1985; Struik, 1988c; Parrish *et al.*, 1988; Evenchick, 1988; Plint *et al.*, 1992).

The Manson Creek and Germansen Landing areas have a long exploration history dating back to the late 1800s when placer gold was first discovered. Hardrock exploration has been fairly sporadic since the late 1800s but has led to the discovery of 45 mineral occurrences within the confines of the map area (Figure 59, Table 6). Of these 45 occurrences, three were discovered in the course of this project (the Dog Creek, Dave and Whistler occurrences).

Mineral showings in the map area can be grouped into twelve occurrence types. Most of the occurrences (21) are related to vein mineralization and there are only one or two examples of the remaining groups. This variation of occurrence types reflects the presence of four diverse terranes within the map area. The following descriptions and accompanying table of mineral occurrences (Table 6) broadly outlines distinctive characteristics of each occurrence type (Figure 60).

Appendices to this report include a series of lithogeochemical analyses of mineralized and unmineralized rocks (Appendix VI) and the geochemistry of standard and bulk stream-sediments, and moss-mat samples (Appendices VII to IX). The locations of these samples are shown on Figure 8.

POLYMETALLIC VEINS

Twenty-one polymetallic vein occurrences have been documented in the area. Based on the sulphide mineralogy, lack of epithermal minerals and vein textures (no colloform, banded, crustiform, vuggy or drusy textures), these veins are classified as mesothermal.

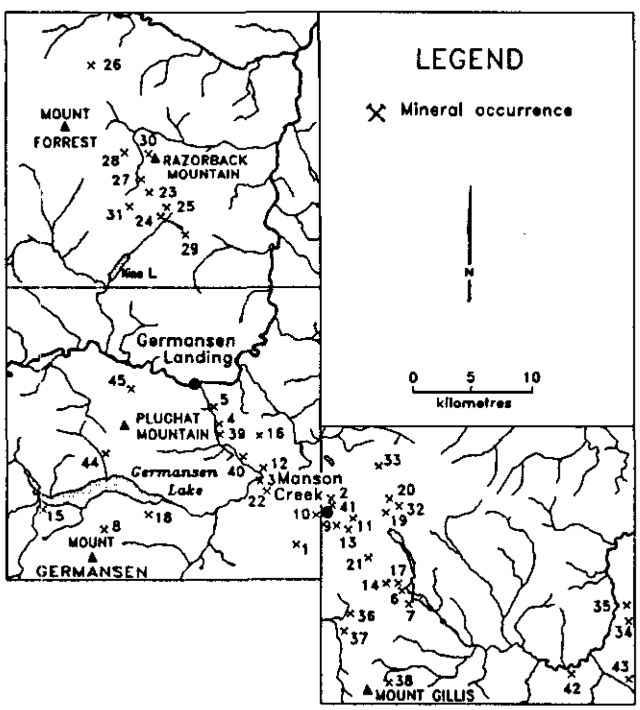

Figure 59. Mineral occurrence location map of the project area (numbers correspond to map numbers in Table 6).

The veins can be divided into three main groups (I, II and III) based on their proximity to the Germansen batholith and the Manson fault zone. Type I veins are associated with the Germansen batholith. Type II veins occur along the Manson fault zone and can be subdivided on the basis of wallrock alteration, vein mineralogy and host formation. The three subgroups are: IIa) veins having low copper values and carbonate wallrock alteration predominant over silicification; IIb) veins containing tetrahedrite and with silicification predominant over carbonate alteration in the wallrocks; and IIc) veins found primarily in sedimentary rocks and only silica alteration in the wallrocks.

This division is similar to both Lay's (1939) and Armstrong and Thurber's (1945) who classified the veins only on the basis of observed mineralization.

I - BATHOLITH-RELATED VEIN SYSTEMS

Polymetallic veins near the Germansen batholith are hosted by Takla Group metasediments. They are close to the batholith (between 0.5 and 2 kilometres) and wallrocks exhibit only silica alteration. They characteristically contain galena, sphalerite, pyrite and minor pyrrhotite; molybdenite is conspicuously absent. Chalcopyrite may also occur with the lead and zinc sulphides. The veins carry variable amounts of silver and little or no gold. They are of varying thicknesses and generally strike in a radiating pattern outwards from the batholith.

The Blackhawk prospect (MINFILE 093N 022), located approximately 5 kilometres south of Manson Creek, is typical of these occurrences. The following details are summarized from a report by Campbell (1989). Its history dates back to the 1930s. A short adit has been driven along one of the larger veins and the prospect was drilled by Noranda Exploration Company, Limited in 1989

This occurrence comprises at least nine quartz veins ranging between 0.3 to 3 metres wide (Armstrong and Thurber, 1945; Lay, 1939; Campbell, 1989). The veins strike north to northeasterly (approximately perpendicular to the batholith contact) and dip steeply to the west. The 30-metre zone containing the veins is intensely silicified and, in places, stockworks of small quartz veinlets have formed.

The hostrocks are hornfelsed Takla siltstones, calcareous shales, argillites and minor argillaceous limestones. Purple to dark green, silicified and fine-grained metasiltstones predominate. Where observed, bedding is contorted or masked by small quartz veinlets. Pervasive silicification obliterates most of the original sedimentary structures.

Both massive and disseminated sulphides, including argentiferous galena, sphalerite, pyrrhotite, pyrite and minor amounts of chalcopyrite are present in the milky

TABLE 6

KNOWN MINERAL OCCURRENCES WITHIN THE STUDY AREA.

(These have been categorized as in Figure 59 and as described in text)

Deposit Type	Map No.	MINFILE Number	UTM Easting	UTM Northing	Property Name(s)	Metals or Commodity	Dominant Sulphides/ Commodity Form	Character	Hostrocks	Country Rock Alteration	Last Year of Work Reported and Type
POLYMETALLIC VEINS											
Type I	1	093N 022	402930	6167090	Blackhawk	Ag, Pb, Zn, Au	sphalerite, galena, pyrite chalcopyrite, pyrrhotite	quartz veins	Hornfelsed Takla Group siltstone, calcareous shale, argillite and minor argillaceous limestone	silica	1989 - drilling, soil geochemistry
IIb	2	093N 023	405879	6170831	Fairview	Au, Ag, Cu, (Sb)	Native gold, tetrahedrite, chalcopyrite, malachite	quartz veins	Nina Creek group argillite, serpentinite, and mafic volcanics in the Manson fault zone	silica, carbonate	1988 - trenching, rock geochemistry
IIb	3	093N 024	399510	6173910	Motherlode, Flagstaff, Vidl	Au, Ag, Cu, Pb	native gold, tetrahedrite,	quartz veins	Takla Group phyllite	silica, carbonate	1982 - mapping, rock geochemistry
IIb	4	093N 025	395470	6179040	Farrell, P.E.M.	Au, Ag, Cu	native gold, tetrahedrite, chalcopyrite, pyrite	quartz veins	Nina Creek group phyllite	silica, carbonate	1984 - drilled 304.8 m
IIc	5	093N 026	394830	6181090	Sunset	Cu, (Ag)	chalcopyrite, pyrite, malachite	quartz veins	Big Creek group phyllite within the Manson fault zone	silica	showing reported in 1938
IIa	6	093N 027	413850	6162150	ASP, A.G., Boulder Creek	Pb, Ag (Mo, Au, Zn, Cu)	galena, pyrite	quartz veins	Boulder Creek group chlorite schist within the Manson fault zone	silica, carbonate	1982 - geological mapping, sampling
IIa	7	093N 028	414230	6161575	Berthold, Elsie	Pb, Ag	galena, pyrite	quartz veins	Boulder Creek group chlorite schists within the Manson fault zone	silica, carbonate	1979 - percussion drilling
IIc	8	093N 029	383250	6169300	Erickson	Cu, (Au, Ag)	chalcopyrite, pyrite	quartz veins	Sheared Takla Group argillite in close proximity of the Germansen batholith	silica	showing reported in 1949
IIa	9	093N 030	407210	6168750	Kathy, Glo, Troy, Joy	Pb, W, Cu, Zn, Ag	galena, pyrite, scheelite, sphalerite, chalcopyrite	carbonate/ quartz veins	Nina Creek group phyllite, arenaceous limestone and ultramafite	carbonate, slight silica	1981 - soil, rock geochem, geophysics
IIc	10	093N 063	404950	6169605	Discovery Bar	Ag, Pb, Zn	galena, sphalerite, pyrite	quartz veins	Takla Group argillites within the Manson fault zone	silica	showing reported in 1949
IIc	11	093N 117	406330	6169450	Lost Creek	Pb, Ag	galena, pyrite	quartz veins	Takla Group black argillite and limestone within the Manson fault zone	silica	pre 1940 - adit
IIc	12	093N 130	399650	6174520	JEA	Cu, Au, Ag	tetrahedrite	quartz veins	Big Creek group argillite and altered ultramafite near the Manson fault zone	silica, carbonate	showing reported in 1941
IIc	13	093N 136	407725	6168800	AJM	Pb (Ag, Au)	galena, pyrite	quartz veins	Takla Group argillite (?) within the Manson fault zone	silica	showing reported in 1941
IIa	14	093N 137	412650	6162950	Bold 1, Stroh, Spaner	Pb, Zn, Ag, Ba, Au, Cu, Mo	galena, pyrite, sphalerite, chalcopyrite, molybdenite	carbonate/ quartz veins	Boulder Creek group limestone and schist	carbonate, silica	1982 - soil geochem, geological mapping
I(?)	15	093N 145	377545	6171439	Dog Creek	Cu, Ag, Zn, (Sb)	chalcopyrite, sphalerite, argentiferous tetrahedrite	oxidized shear zone, quartz veins	Takla Group sediments and volcanics	silica	reported 1989
IIb(?)	16	093N 144	399408	6178021	Dave	Cu, Ag, (Sb)	friebergite, argentiferous tetrahedrite, pyrite	quartz veins	Nina Creek group sediments and gabbro	silica, late stage carbonate	reported 1989
IIa	17	093N 197	413250	6162620	Bold 2, Boulder Creek	Pb, Zn, Mo, Ag, Au	galena, sphalerite, molybdenite, pyrite	carbonate/ quartz veins	Boulder Creek group arenite and carbonate near the Manson fault zone	carbonate, silica	1982 - geological mapping, trenching
I	18	093N 202	388075	6170450	Cat	Zn, Pb, Cu	sphalerite, galena, chalcopyrite, pyrite	quartz veins	Takla Group shale, siltstone and sandstone near the Germansen batholith	silica	1984 -geological mapping, geochemistry
PRECIOUS METAL QUARTZ VEINS	19	093N 134	411945	6176890	GAM	Au, Ag	pyrite	quartz veins	Ingenika Group rocks (Stelkuz Formation) near the Manson fault zone	silica	showing reported in 1945
	20	093N 132	412875	6171390	SEM	(Au, Ag)	pyrite	quartz veins	Ingenika Group rocks (Stelkuz Formation)	silica	showing reported in 1942
VEINS (?)	21	093N 148	409850	6165500	Blackjack Mountain	Pb	galena (?)	vein (?)	Boulder Creek group phyllite and argillite	?	showing reported in 1946
DISSEMINATED PRECIOUS METALS	22	093N 198	399950	6172450	QCM	Au	pyrite, gold	disseminated	Takla Group altered volcanic siltstone, sandstone and conglomerate	carbonate, silica, sericite	1989 - geological mapping, geophysics

STRATABOUND BASE METALS	23	093N 010	389130	6202600	Jemima, B, B.V.D. 1-4	Zn, Pb, (Ba)	sphalerite, galena, (barite)	podiform to disseminated	Otter Lakes group dolomite and arenaceous dolomite	carbonate	1989 - geophysics
	24	093N 075	390250	6200150	W. Vernon, B.V.D. 32	Zn, Pb, Ag, (Ba)	sphalerite, galena, (barite)	disseminated to massive	Otter Lakes group dolomite and arenaceous dolomite, massive in shear zones	carbonate	1988 - rock geochem, petrology
	25	093N 076	390750	6200850	Vernon, Zone E, B.V.D 33	Zn, Pb, Ag, (Ba)	sphalerite, galena, (barite)	disseminated to massive	Otter Lakes group dolomite and dolomitic breccia	slight silica	1989 - geophysics
	26	094C 096	384050	6214870	Whistler, FF	Zn, Pb, (Ba)	sphalerite, galena, (barite, pyrite, dolomite)	podiform to disseminated	Otter Lakes group dolomite, megacrystic dolomite occurs as replacement	carbonate	showing reported in 1969
	27	093N 114	388550	6203750	Biddy, Rae	Zn, Pb, Ge, Ag	sphalerite, galena	replacement, fracture filling	Otter Lakes group arenaceous dolomite and dolomite	slight silica	1989 - geophysics
	28	093N 158	387020	6207070	Crin, Cry	Pb, Zn	galena, sphalerite	podiform to disseminated	Otter Lakes group dolomite	carbonate	1976 - trenching
	29	093N 172	392750	6198645	Sheila, Echo	Zn, Pb, Ag, (Ba)	sphalerite, galena, (barite, pyrite)	breccia filling, disseminated	Otter Lakes group dolomitic breccia	carbonate	1974 - soil geochem, geological mapping
STOCKWORK BASE METALS	30	093N 170	389560	6206760	Osi	Pb, Zn, Ag	galena, sphalerite (hematite, siderite)	stockwork	Echo Lake group carbonates	carbonate	1974 - soil geochem, geological mapping
SILICIFIED SHEAR ZONE	31	093N 011	387120	6201100	Nina	Au, Ag, Cu, (Zn)	chalcopyrite, pyrite, (sphalerite)	shear zone	Nina Creek group sheared gabbro and lesser argillaceous chert	silica, epidote	1988 - diamond drilled
CARBONATITES	32	093N 012	413125	6171150	Lonnie, Granite Creek	Nb, Zr, Ti, U, Th	pyrochlore, columbite, zircon	alkali syenite	Biotite sovite, syenite, aegerine sovite intruding Ingenika Group rocks	alkali metasomatism	1979 - diamond drilled
	33	093N 174	411200	6174950	Virgil, Brent, Wolverine	Nb, Zr, REE, U, Ti	columbite, pyrochlore, zircon	alkali syenite	Biotite sovite, syenite intruding Ingenika Group metasediments	alkali metasomatism	1982 - soil geochem, geophysics
LAYERED REE (ALKALIC GNEISSES)	34	093N 201	436649	6158900	Will, Will 2	Th, REE, La, Ce, Nd, Y, Ta, Cu	monazite, chalcopyrite	layered, disseminated	Aergerine-augite syenite, monzonite, monzodiorite in the Ingenika Group.	alkali metasomatism	1988 - geology, soil and rock geochem
SULPHIDE BEARING AMPHIBOLITE GNEISS	35	093N 180	435805	6160257	Manson River East, MC	Cu	chalcopyrite, pyrite	disseminated	Ingenika Group plagioclase-biotite-amphibole gneiss (metamorphosed sediment)	none observed	showing reported in 1987
PORPHYRY/VEIN Mo	36	093N 118	407050	6160050	Blackjack East	Mo (Cu)	molybdenite (chalcopyrite)	quartz veinlets	Hornfelsed sediments within the Germansen batholith	Biotite, silica	1984 - geophysics
	37	093N 119	407075	6158250	Blackjack central & south	Mo (Cu)	molybdenite (chalcopyrite)	quartz veins	biotite, hornblende? hornfels Takla Group pendant within the Germansen batholith	Biotite, silica	1970 - soil geochem, geological mapping
	38	093N 133	411451	6153252	Jordi	Mo	molybdenite	quartz veins	biotite monzonite of the Germansen batholith	Biotite, silica	1981 - geochem, geophysics, mapping
ULTRAMAFIC ASBESTOS	39	093N 115	395360	6178550	Germansen River	asbestos	chrysotile	fibrous veins	Low to medium grade metamorphosed ultramafic rocks within the Manson fault zone	serpentine	showing reported in 1945
ULTRAMAFIC NICKEL	40	093N 116	397410	6178210	Ah Hoo Creek	Ni	pyrrhotite, pentlandite	disseminated	Low to medium grade metamorphosed ultramafic rocks within the Manson fault zone	serpentine	1989 - prospected
ULTRAMAFIC CHROMITE	41	093N 135	406100	6170350	NRS	Cr	chromite	disseminated	Low to medium grade metamorphosed ultramafic rocks within the Manson fault zone	serpentine	showing reported in 1942
STRATIFORM BARITE	42	093N 087	430500	6153620	Omineca Queen	Ba	barite	stratiform, layered	Stratiform layers within Big Creek group slate and argillite	slight silica	1970 - soil geochemistry
SEDIMENTARY METAMORPHIC	43	093N 203	436500	6152400	Mon	C	graphite	disseminated	Upper amphibolite grade Ingenika Group marble, calc-silicate and biotite schist	none observed	1985 - rock geochem, geological mapping
DISSEMINATED SULPHIDES	44	093N 153	384150	6176150	Gem	Cu	chalcopyrite, pyrite	disseminated	Takla Group volcanics (fragmental basalt and andesitic basalt)	none observed	1972 - geological mapping, soil geochem
	45	093N 147	385150	6182300	RLA	Cu	chalcopyrite?, pyrite?	?	Takla Group argillite and siltstone	?	poorly known showing reported in 1945

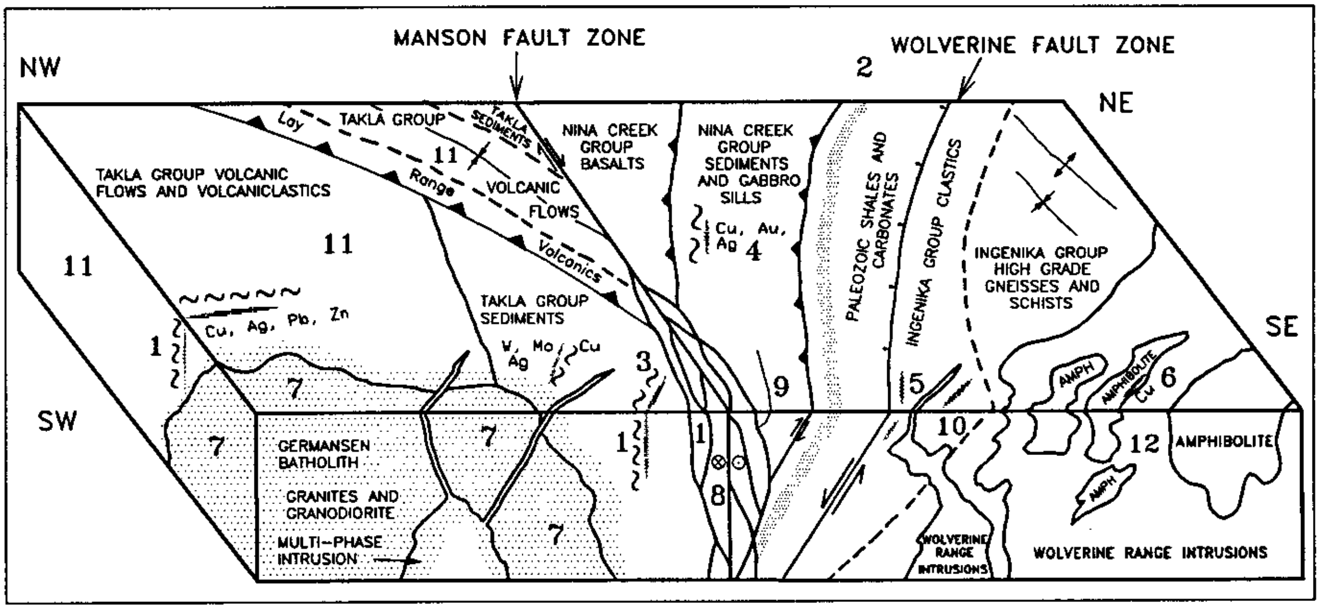

Figure 60. Schematic block diagram illustrating the relationship between general geology and mineral occurrence types. Numbers represent occurrence types. 1) polymetallic vein deposits; 2) stratabound base metal deposits; 3) disseminated gold deposits; 4) silicified shear zone deposits; 5) carbonatites; 6) sulphide-rich amphibolite gneiss deposits; 7) porphyry molybdenum (copper) deposits, 8) ultramafic-related deposits; 9) stratiform barite deposits; 10) sedimentary metamorphic (graphite) deposits; 11) disseminated sulphide deposits; 12) Rare earth rich alkalic intrusives.

quartz veins. Where massive, the most abundant sulphide is pyrrhotite with some sphalerite. A sample across 1.5 metres returned assays of 1399 grams per tonne (40.8 oz/ton) silver, 3% lead and 3% zinc (Lay, 1939). A 3-metre chip sample along the extension of the main vein returned values of 2.14% lead and 416 grams per tonne (12.13 oz/ton) silver. Two drillholes intercepted this vein system at depth. The largest vein intersection was 1 metre wide and contained 15% galena, 15% pyrrhotite and 5 to 10% pyrite. No further work was done on the showing as it was felt the veins and vein system narrowed at depth (Campbell, 1989).

II – VEIN SYSTEMS RELATED TO THE MANSON FAULT ZONE

Polymetallic veins in and near the Manson fault zone are hosted by ultramafite, carbonates, arenaceous sediments and fine-grained argillites. Within the fault zone, these rocks (fault-bounded slivers) belong to either the Nina Creek, Takla or Boulder Creek groups. Although the genesis of all veins is probably related to the same event(s) and they are similar to each other, these vein systems exhibit subtle differences and can be divided into three subgroups, based upon the hostrock alteration assemblages and to some extent, the nature of the mineralization.

TYPE IIA VEINS

Type IIa veins contain a wide range of metals including lead, zinc, copper, silver and gold in a carbonate or quartz gangue. Molybdenum and tungsten also occur, possibly indicating a genetic link to the Germansen batholith. The veins are typically less than a metre to several metres wide.

The hostrocks are a mix of carbonatized and silicified ultramafite and sediments. The altered ultramafic rocks (listwanites) are talc-ankerite-mariposite schist. The carbonatization is so intense that the sediments commonly contain ankeritic porphyroblasts. The alteration halo varies in width and typically terminates abruptly.

The Bold 2 occurrence (MINFILE 093N 197) is located west of the Manson Lakes, just north of Boulder Creek and shows most of the Type IIa characteristics. It was discovered in 1982 while exploring the Bold 1 (MINFILE 093N 137) showing lower on the slope.

This occurrence is referred to as the "main showing" by Melnyk (1982) and is described as contorted quartz veins carrying pyrite, galena and sphalerite with minor chalcopyrite and finely disseminated molybdenite flakes. A grab sample collected by the authors returned analyses of 90 grams per tonne silver, 9.5% lead, 127 ppm copper and 111 ppm zinc. Gold was undetectable in this sample and molybdenum was not analyzed.

The veins are predominantly quartz with the carbonate wallrock alteration being associated with carbonate veinlets. Mineralized veins strike easterly (80-120°) and dip fairly steeply (70-80°) to the north. The width of the veins ranges from 0.5 to 3 metres and the mineralization is "clumpy" galena, forming 1 to 10-centimetre patches scattered irregularly across the vein. Disseminated pyrite, minor chalcopyrite, and calcite are also present in the veins.

The wallrocks are quartz muscovite schist of the Boulder Creek group in close proximity to intensely sheared and altered Manson Lakes ultramafics. These ultramafic rocks are structurally interleaved with rocks of the Boulder Creek group along flat-lying thrusts which have been cut by the Manson fault zone.

TYPE IIB VEINS

Type IIb veins always carry tetrahedrite and are associated with ultramafic rocks. The hostrocks are silicified and carbonatized. The veins are always contained within the Manson fault zone and generally follow its northwest trend. Both stockwork zones and discrete veins tens to hundreds of centimetres wide are present. The typical metals are copper, gold and silver. Copper sulphides are typically altered to malachite and azurite.

Wallrock alteration is somewhat similar to Subgroup IIa in that it can be quite pervasive and end abruptly. Most hostrocks are less altered than in Subgroup IIa (*i.e.*, serpentinite rather than talc-ankerite schists), although in some occurrences (*e.g.*, Fairview) carbonate alteration is very intense in narrow zones around and within the vein systems.

The Fairview occurrence (MINFILE 093N 023) is located 0.5 kilometre northwest of Manson Creek and has been known since the early 1900s (Lay, 1939). It has been trenched several times during its history. The main vein averages 1 to 3 metres in width with a known strike length of 48 metres. It has been recently examined by BP Resources Limited (McAllister, 1986; McAllister and Sandberg, 1988) and the following descriptions are taken from assessment reports.

The occurrence is within the Manson fault zone, strikes southeast (155°) and has a vertical dip. It is composed of massive white quartz, massive ankerite with patchy silicification (grading into the massive quartz), ankerite breccias with a quartz matrix, and ankerite within quartz stockwork.

The massive quartz contains blebs of pyrite, chalcopyrite and argentiferous tetrahedrite-tennanite with related malachite and azurite staining. Visible gold has been reported. The most mineralized samples returned gold values up to 18 grams per tonne (the same sample returned 6.6 ppm silver and 152 ppm copper). Silver values range up to 85.73 grams per tonne.

The veins are hosted by mafic volcanics (and possibly the Wolf Ridge gabbro). They are strongly silicified, carbonatized and sheared. Large porphyroblasts of ankerite are found in the wallrocks and mariposite is also present. These rocks contain anomalous gold and silver values.

Other nearby veins containing pyrite and tetrahedrite are hosted in serpentinites, gabbros and argillites of the Nina Creek group.

TYPE IIC VEINS

Type IIc veins are characterized by the absence of carbonate alteration in the hostrocks. They are hosted by Takla and Nina Creek group sediments which are generally argillites and are found within or near the Manson fault zone. The occurrences representing this subgroup are known only from early reports by Lay (1939) and Armstrong and Thurber (1945). The lack of recent exploration for these veins reflects their low levels of precious metals. The typical minerals are galena, sphalerite and chalcopyrite with little or no gold and silver.

ALTERATION

Carbonatization, in association with silicification, is the most significant and widespread alteration type associated with vein and disseminated gold mineralization along the Manson fault zone.

This alteration is typified by large porphyroblasts of iron carbonate (ankerite) which, when weathered, give the rock a rusty brown appearance. Typically mafic and ultramafic rocks exhibit the most intense alteration resulting in a rock composed of variable amounts of talc, ankerite, mariposite, quartz, sericite and chlorite and commonly referred to as a listwanite. Alteration zones vary in width and it is not uncommon to find tens of square metres of listwanized rock (north shore of lower Manson Lake). They may be weakly to moderate foliated but in many instances no fabric is present. These zones are fault controlled and they commonly end abruptly against relatively unaltered rocks. The alteration can be so intense that it is often impossible to recognize the original lithology.

Ankeritic sediments are typically silicified and exhibit a phyllitic to schistose sheen. They contain fine sericite, albite and calcite in addition to large porphyroblasts of ankerite (Plate 37). These altered sediments are usually close to listwanized ultramafics. Examples of altered sediments can be seen near the Motherlode showing (MINFILE 093N 024) and the QCM occurrence (MINFILE 093N 198).

An excellent example of increasing carbonate and silica alteration of mafic volcanic rocks can be found in a 15-metre-wide outcrop along the old portion of the

Plate 53. Outcrop of listwanitized augite-porphyritic Takla basalt between Manson Creek and Germansen Landing. The left side of the outcrop is strongly altered and contains a strong foliation; this alteration quickly disappears to the right. Samples GRP 6, 7 and 8 (of Figure 62) were taken in the area marked 'highly altered' with the remaining samples collected from the area to the right. Sample GRP 8 was taken from the far left of the altered zone and sample GRP 1 from the far right (*see* Figure 62 for data).

Omineca mining road between Manson Creek and Germansen Landing (*see* Figure 17 for location; Plate 53; samples GRP 1 to 8 in Appendix III). This outcrop of augite porphyry basalt contains an alteration gradient which displays the textural, mineralogical and chemical changes which occurred during the progressive alteration of these rocks. The intensity of this alteration increases to the west where it is abruptly terminated by a fault. As the alteration increases, the rock takes on a more schistose appearance such that, at the western and most intensely altered part of the outcrop, a moderate to strong foliation is present and it is impossible to determine the volcanic protolith. This outcrop displays many of the common characteristics of carbonate alteration in the map area.

The least altered part of the outcrop is strongly chloritized and displays a very weak penetrative foliation. Relic textures within the volcanic protolith are still discernible. The most intensely altered section of the outcrop has a moderate to strong foliation and exhibits the brown-weathering iron stain typical of listwanites. It is composed entirely of quartz, sericite, ankerite and mariposite, and the original rock type is indistinguishable. Ankerite is either found interstitially or as distinctive porphyroblasts. Iron-magnesium silicates (dominated by chlorite) are increasingly replaced by iron carbonate and sericite as the alteration increases within the transition zone.

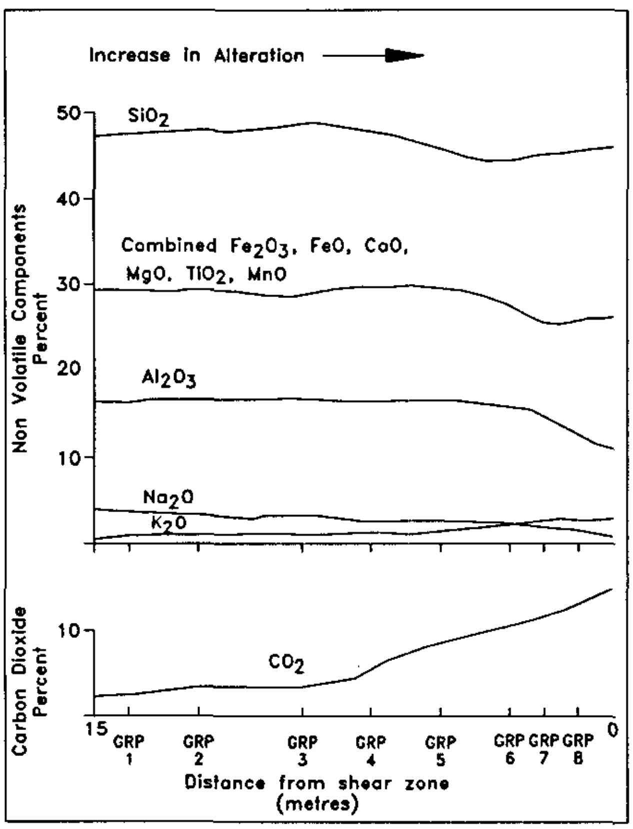

Figure 61. Chemical changes produced by the carbonate alteration of a basaltic andesite near the Manson fault zone. See text for details and Plate 53.

A chemical profile of this alteration was obtained through whole-rock analyses (major and minor oxides, and trace elements, Appendix III) of eight samples collectedacross the outcrop. The combined oxides shown a general depletion (Figure 61); MnO and CaO show erratic values across the zone and increase slightly near the strongest alteration. Copper concentrations decrease continuously across the zone whereas zinc is not mobile until the alteration becomes very intense. The trends described here and portrayed in Figure 61 are typical of listwanized mafic and ultramafic rocks found within greenstone belts of the Precambrain shield (Boyle, 1979).

PRECIOUS METAL QUARTZ VEINS

Only two precious metal vein occurrences are known in the study area. These showings were reported by Lang (1941, 1942). They are quartz-pyrite veins with low(?) values of silver and gold found in metasediments of the Ingenika Group along Granite Creek (MINFILE 093N 132 and 134).

DISSEMINATED GOLD

The only reported occurrence of disseminated gold is the QCM prospect (MINFILE 093N 198). Anomalous gold, silver, copper and zinc values in soil and rock samples were first reported in this area in 1972 (Rodgers, 1972). This early soil geochemistry outlined two large anomalous trends; the Flag zone and the Central zone (Figure 62). Since 1972, this area has undergone extensive geological, geochemical and geophysical investigation which led to reverse circulation drilling in 1983 (Riccio, 1983).

Rocks in the anomalous area are poorly exposed but are believed to belong to the Takla Group. Recent mapping in the Uslika Lake area by Ferri *et al.* (1992a, b), and Nelson *et al.* (1993a, b) in the Discovery Creek area suggests that volcaniclastics immediately southwest of the Manson fault zone may belong to the Lay Range assemblage (*see* chapter on Lithologic Units). They are composed of volcaniclastics (tuffs and lapilli tuffs), lesser volcanically derived sediments and argillites, aphanitic to pyroxene-phyric flows and lesser cherts. The argillites are thin to moderately bedded, cream to rusty weathering and grey on fresh surfaces. They are interbedded with cream to beige, thin to moderately bedded tuffs to tuffaceous siltstones in sequences 1 to 10 metres thick. Less abundant are thin to thickly bedded tuffs and lapilli tuffs with lesser volcanic sandstones, conglomerate and wackes. Clasts within these volcaniclastics are subangular feldspar and augite crystal fragments, feldspar augite porphyries, aphanitic volcanics and minor argillite. The basalts are green to dark green, amygdaloidal mafic flows with small phenocrysts of pyroxene and plagioclase and commonly containing a penetrative cleavage (Ferri, 1989).

All of these rock types have been affected, to varying degrees, by carbonate alteration with the main alteration minerals being ankerite and pyrite. Riccio *et al.*, (1982) distinguished two types of carbonate alteration, the first characterized by large porphyroblasts which have poikiloblastic cores containing quartz, feldspar, hematite

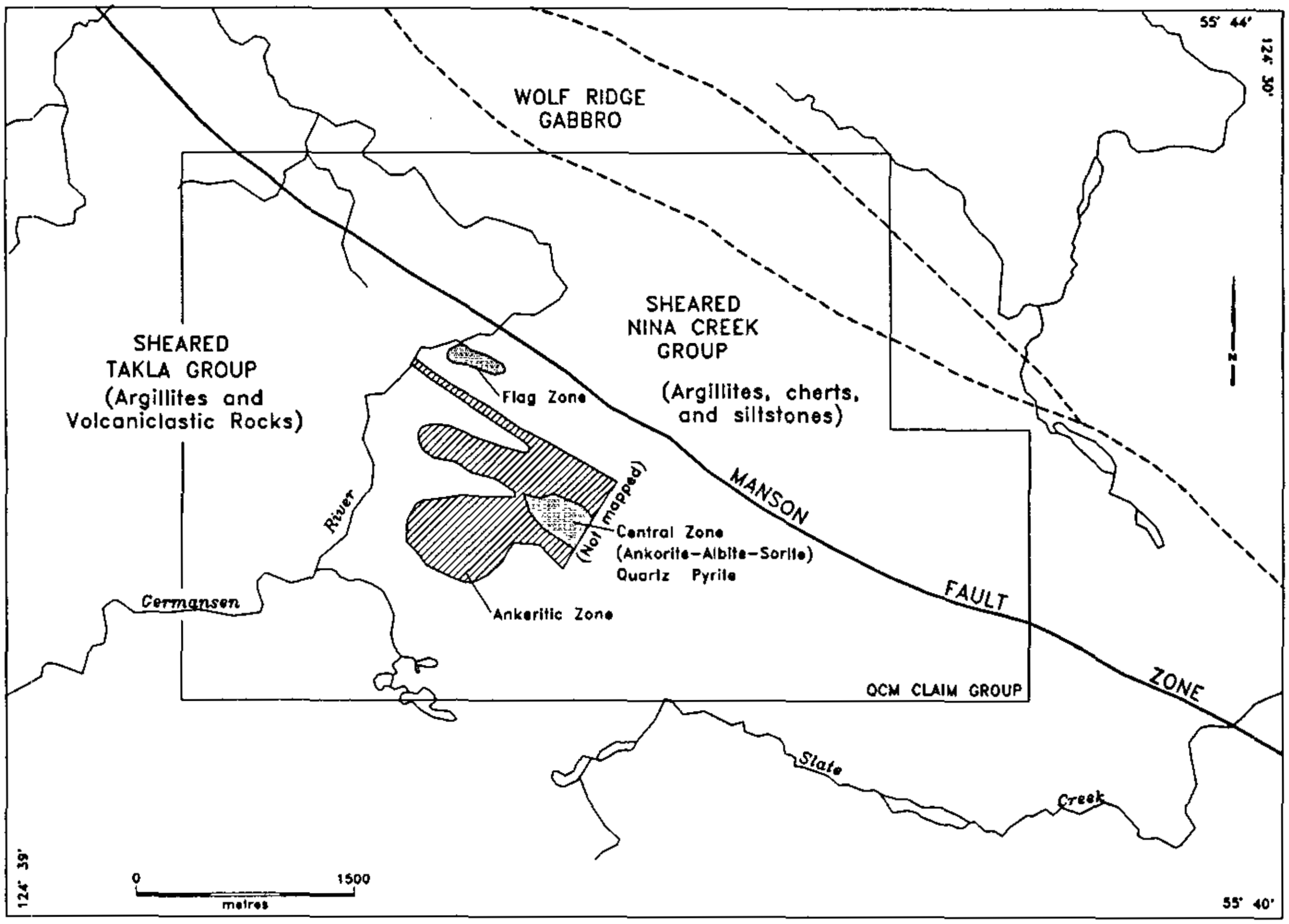

Figure 62. Simplified geology of the QCM claim group (modified from Ferri, 1989; Riccio *et al.*, 1982).

and other opaques, and the second by idioblastic, iron-poor porphyroblasts which may be related to the inclusion-free rims of the porphyroblasts of the first type. The only sulphide recognized in these altered zones is pyrite which forms up to 10% of the rock and is generally fine grained and idioblastic.

Alteration assemblages are varied and dependent upon lithology. In the mafic and intermediate volcanics the alteration assemblage is typically ankerite-albite-sericite$\pm$quartz$\pm$mariposite$\pm$pyrite and the volcaniclastic rocks typically contain ankerite, sericite, albite and quartz with or without pyrite. The most intensely altered zones are cut by abundant quartz veins of varying widths.

The Central zone is some 200 by 300 metres in area and is hosted by volcaniclastic rocks of the Takla Group. The volcanics are bleached to a whitish or cream-coloured rock composed primarily of sericite, quartz, iron carbonates, pyrite (5%) and albite, but with very little quartz veining. The original clastic nature of these rocks is barely discernible.

The above rock types occupy northwest-trending belts separated from each other by steeply dipping faults related to the Manson fault zone (Ferri, 1989). As in areas to the southeast, numerous splays of the Manson fault zone control the quartz-carbonate-sericite (listwanite) alteration.

Surface lithogeochemical sampling on this zone returned gold values as high as 3.7 grams per tonne from 1-metre chip samples (Riccio *et al.*, 1982). The zone was tested by four reverse-circulation drill holes which averaged 100 metres in length. They all cut strongly altered volcanic sediments, as seen on surface. Median gold values range from 0.17 gram per tonne in Hole 1 to 0.13 gram per tonne in Hole 4. In Hole 2 a 5-metre section averaged 1.8 grams per tonne gold with a 1-metre section of 3.2 grams per tonne. Several 1-metre sections returned over 1 gram per tonne gold.

Riccio *et al.*, (1982) point to a positive correlation between anomalous gold values and pyrite content, suggesting that the gold is within the pyrite. They also indicate that the intensely altered zones are quartz veined and so the possibility that fine, free gold may be a vein constituent cannot be ruled out. However, they also note that gold has not been reported from these veins and very little veining is present in this area which suggests that the gold may be disseminated in the altered volcanics.

STRATABOUND BASE METAL OCCURRENCES

Stratabound sulphide mineralization is confined within a specific stratigraphic interval which ranges from the Big Creek – Otter Lakes contact downwards to the uppermost sandy dolomites of the Echo Lake group (sandy dolomite unit). These are carbonate-hosted sulphide deposits with the typical sulphide assemblage being yellow to red-brown sphalerite, argentiferous galena, barite and minor pyrite (Melville, 1990; Ferri and Melville, 1990a). The sulphides occur as semimassive irregular pods in collapse breccias, massive lenses localized in shear zones, or as disseminated blebs in arenaceous dolomites. Germanium may be associated with the sphalerite.

Brecciated dolomites (collapse breccias) host semimassive sphalerite and galena together with megacrystic barite. Typical grades average 3 to 4% sphalerite (Leighton, 1988) with variable galena (usually less than sphalerite); grades of greater than 15% combined lead-zinc have been recorded (Ferri and Melville, 1990a). The sulphides also occur as clasts in a calcite-barite matrix; as matrix with carbonate clasts; or as a combination of both (Melville, 1990).

Tectonic breccias are similar to the dolomitic breccias in terms of variable galena, zinc and barite mineralization. The sulphides occur either as semimassive irregular pods (Leighton, 1988) or as the matrix of fault breccia (Sonnendrucker, 1975).

Mineralization within the lower Otter Lakes and upper Echo Lake groups is generally restricted to disseminated sphalerite in arenaceous dolomites, fine-grained dolomites, and rarely, sandstones. The sphalerite occurs with minor amounts of galena and pyrite and may reach grades of 4% zinc (Sonnendrucker, 1975).

At the Biddy occurrence (MINFILE 093N 114), the trace element germanium is reportedly present in amounts averaging 0.05% of the sphalerite mineralization (Leighton, 1988). Germanium values in excess of 220 ppm have been reported in material assaying 14.7% zinc (Melville, 1990).

Mineralized dolomitic breccias occur just below the Big Creek shales and no stratabound lead-zinc mineralization has been found above this stratigraphic interval. This suggests that the shales acted as an impermeable barrier, channeling the movement of mineralizing fluids through the Otter Lakes carbonates.

These occurrences share some similarities with the Midway Camp as they are found in the same stratigraphic interval, are not structurally complex, and occur as combinations of matrix and clast replacement suggesting several phases of mineral deposition. However, in the Cassiar area, larger deposits like Midway are mantos with a characteristically complex sulphide suite (*i.e.*, pyrite, sphalerite, galena, pyrrhotite, friebergite, arsenopyrite, pyargyrite, and tin and lead sulphosalts; Nelson, 1990) and appear to be related to granitic intrusions of Cretaceous age.

Occurrences in the Germansen Landing – End Lake area, have much simpler sulphide mineralogy (primarily galena and sphalerite) and the lead has a Cambrian shale curve model age (C. I. Godwin; personal communication, 1990). These characteristics are similar to sediment and carbonate-hosted showings in the Cassiar area referred to as "old" by Bradford (1988). These deposits are hosted in

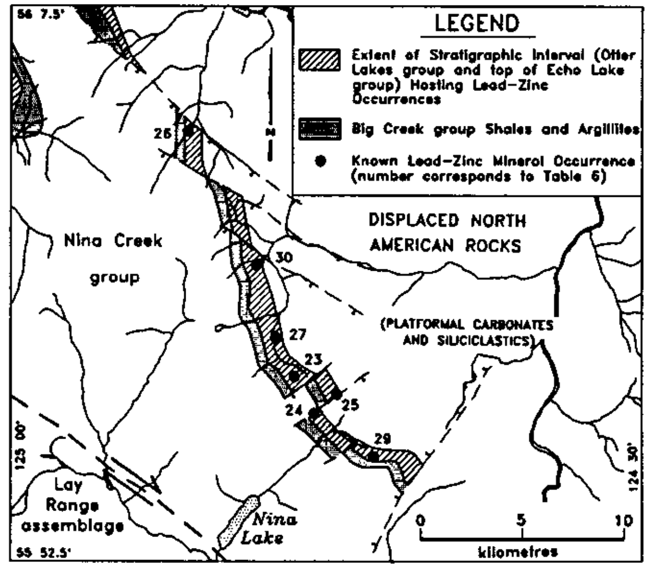

Figure 63. Regional extent of favourable hostrocks for stratabound base metal (carbonate replacement) deposits (modified from Melville, 1990).

lower Mississippian shales and Lower Cambrian carbonates and contain lead with Early Cambrian or older shale curve model ages. Bradford (1988) believes that the lead in these deposits was remobilized along faults from lower crustal regions during Devono-Mississippian rifting. A similar process is theorized to have produced the occurrences in the map area.

Figure 63 shows the regional extent of favourable hostrocks, the local crosscutting faults and the known mineral occurrences. Mineralization is well documented along the southern exposure of the hostrocks. Detailed prospecting along this stratigraphic horizon elsewhere in the map area, will undoubtedly expose more occurrences.

SILICIFIED SHEAR ZONE (VOLCANOGENIC MASSIVE SULPHIDE?)

The Nina occurrence (MINFILE 093N 011, Figure 64) is the only example of this deposit type found in the map area and has been known since the 1940s (Armstrong and Thurber, 1945). Since that time it has been examined sporadically and was drilled in 1988. It is located approximately 4.5 kilometres north of Nina Lake and occurs within rocks of the Nina Creek group. It is characterized by a relatively simple mineral suite within a silicified shear zone. The shear zone is characterized by strong oxidation and appears red-brown within the green to grey-green sediments and volcanics. Its relationship to other structures in the map area is uncertain. Mineralization includes copper and silver sulphides, and gold in association with pyrite. It has been suggested by Watkins and Atkinson (1985) that this prospect may be a sheared volcanogenic massive sulphide deposit.

The hostrocks are grey-green, fine-grained, pyroxene-porphyritic basalts intercalated with laminated,

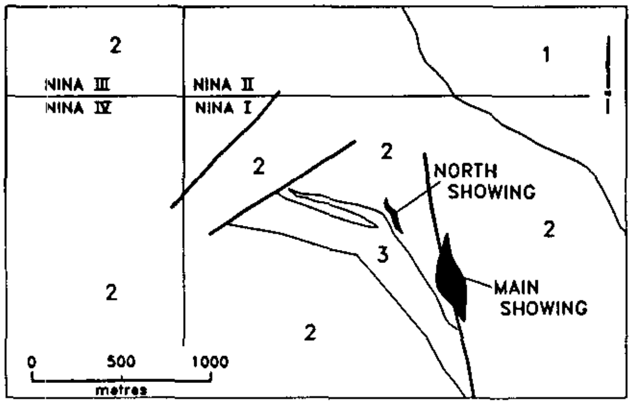

Figure 64. Geology of the Nina claim group (modified from Cope, 1988). 1 – Siliceous argillite, varicoloured chert and gabbro. 2 – Massive basalt and basaltic breccia. 3 – Tuffaceous argillite and banded chert. Black areas are mineralized zones.

cherty, pale green tuffs, dark grey argillites and gabbro sills. The sedimentary units are of variable thickness and strike northwesterly with moderate dips to the south.

The main shear zone (Figure 64) is 2 to 20 metres wide and strikes northerly, dipping steeply to the west. Lenses of massive sulphides and silicified fault breccia are localized within it. The country rocks contain disseminated pyrite (Cope, 1988). Epidote alteration is associated with the silicification (although not as pervasive).

The sulphides consist primarily of massive pyrite, variable chalcopyrite and minor sphalerite (Watkins and Atkinson, 1985). Gold and silver concentrations vary; the silver is in argentiferous tennanite and argentiferous tetrahedrite. One grab sample from the property returned an assay of 0.60 gram per tonne gold, 20.2 grams per tonne silver and 14.91% copper and another, 6.90 grams per tonne gold and 146.5 grams per tonne silver (Cope, 1988).

CARBONATITES

Carbonatites are represented in the project area by two elliptical, northwest-trending, sill-like bodies (Lonnie and Virgil; MINFILE 093N 012 and 174). They are exposed in the southern part of the map area and are on strike from one another, along the ductile portion of the Wolverine fault zone. The country rocks, like the carbonatites, have been metamorphosed to amphibolite grade and are quartzites to garnet-biotite-muscovite schists of the Proterozoic Ingenika Group.

Both carbonatite complexes are comprised of various intrusive rocks which include biotite sovites, aegerine sovites, and syenites of possible Late Devonian to early

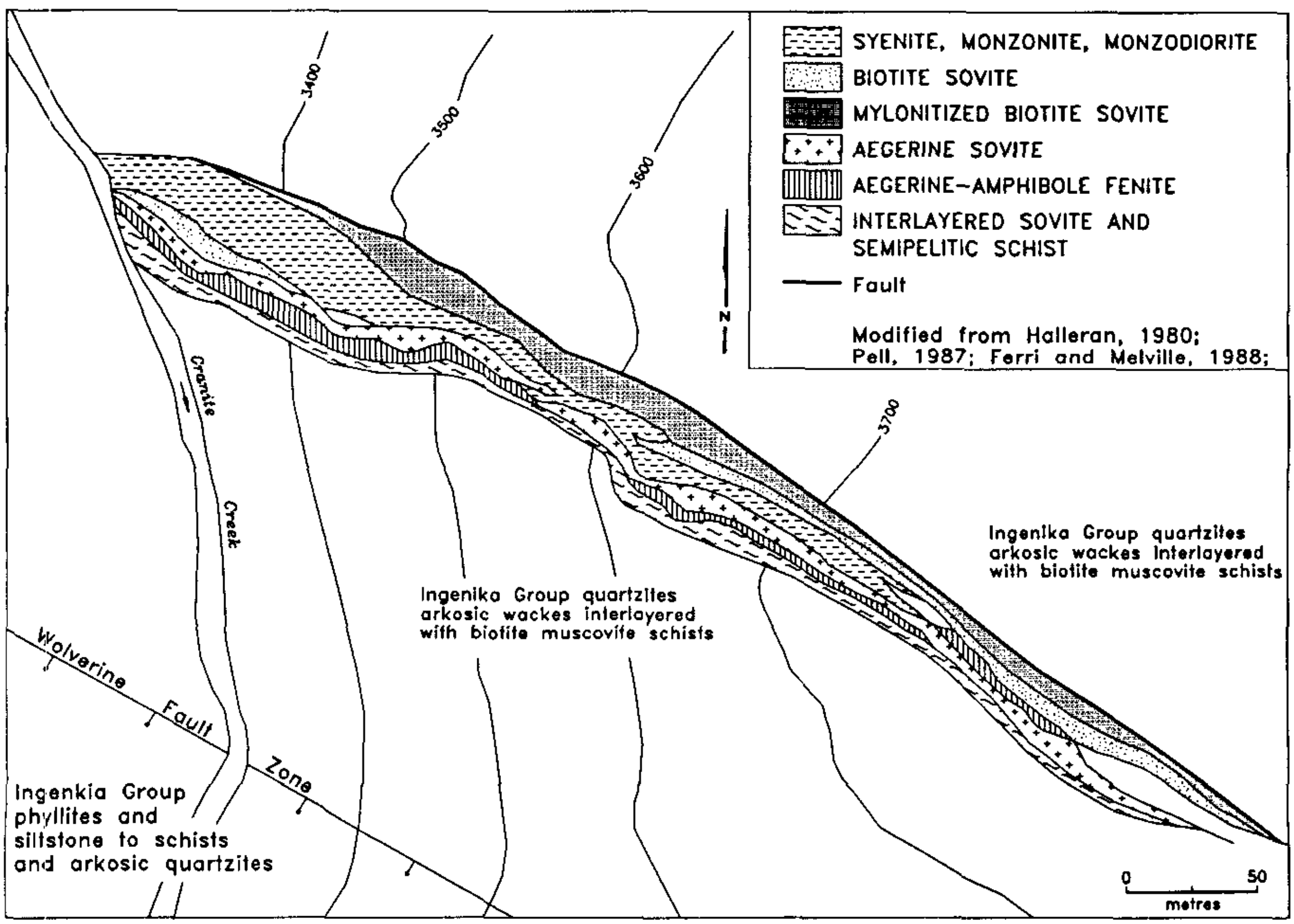

Figure 65. Geology of the Lonnie carbonatite complex (modified from Halleran, 1980; Pell, 1987; Ferri and Melville, 1988).

Mississippian age. There is a pervasive aureole of alkali metasomatism (fenetization) in the surrounding rocks which is typical of calcite carbonatites (Pell, 1987; Halleran, 1980).

The Lonnie occurrence was discovered by prospecting in 1953 and staked in 1954. It has subsequently been mapped, trenched and drilled.

The Lonnie carbonatite is approximately 50 metres wide and 460 metres long (Halleran, 1980). The complex follows a northwesterly trend paralleling the Wolverine fault zone, and is comprised of numerous interfingering intrusive rock types (Figure 65).

Two varieties of carbonatite are described by Pell (1987); an aegirine sovite composed primarily of calcite, microcline, perthite and aegirine, and a biotite sovite containing calcite, biotite and usually plagioclase. The aegirine sovite occurs along the southwestern margin of the complex and the biotite sovite along the northeast margin. These rocks are associated with syenite, monzonite and monzodiorite. All intrusive types contain a pervasive penetration foliation parallel to that of the country rock. The biotite sovite is mylonitized and faulted against the micaceous country rocks.

Rare earth geochemistry on a sample of aegirine sovite yielded anomalous strontium (11 547 ppm), niobium (4578 ppm), zirconium (739 ppm), titanium (2811 ppm), and yttrium (119 ppm) and reflects the mineralogy which includes zircon, pyrochlore and columbite as primary minerals, and pyrite, pyrrhotite and ilmenorutile as accessory minerals. The strontium most likely occurs as a form of strontium carbonate. Niobium pentoxide values on the Lonnie prospect have been reported as high as 0.3% over 7.5 metres for a length of 240 metres (Vaillancourt and Payne, 1979).

RARE EARTH RICH ALKALIC INTRUSIVES

High-grade metamorphic rocks of the Ingenika Group contain a series of rare earth element (REE) bearing monzonites to syenites in the southeastern part of the study area (Will; MINFILE 093N 201). They are found about 2 kilometres east of the Manson River, approximately 5 kilometres northeast of the mouth of Munro Creek. These intrusions are covered by the large Visa claim block centred to the southeast, within NTS 093O/012 (Halleran, 1988). These REE-rich intrusions were first discovered in 1986 during detailed work around the Mon graphite occurrence.

These bodies are differentiated from the carbonatites because they are considerably younger, probably Early Tertiary, and by their lack of abundant sovite. They intrude paragneisses and schist of unit Pia of the Ingenika Group. Rare earth concentrations are localized in small bodies of aegerine-augite monzonite and monzodiorite which may show banding. They are associated with aegerine-augite syenite dikes and alkalic feldspar - aegerine-augite syenite dikes (Halleran, 1988). The monzonite is also related to numerous quartz-feldspar, aegerine-feldspar-quartz and quartz pegmatites. The monzonites and monzodiorites lack the strong gneissosity present in the country rocks and the banding present in parts of these bodies may represent relic structures due to metasomatization of the country rocks (A. Halleran, personal communication, 1991). A sample of aegerine-augite monzodiorite contained 0.27% cesium; 013% lanthanum; 0.1% neodymium and 0.13% thorium (Halleran, 1988). These rocks also contain significant amounts of zirconium and yttrium. Some dikes contain minor amounts of chalcopyrite, malachite and magnetite.

SULPHIDE-RICH AMPHIBOLITE GNEISSES

There is a single occurrence of sulphide-rich amphibolite gneiss located within high-grade metamorphic rocks of the Ingenika Group in the southeastern edge of the study area. The Manson River East occurrence (MINFILE 093N 180) was discovered during the 1987 field season in the course of work on this project.

Visible mineralization consists of disseminated chalcopyrite and pyrite hosted by amphibolite gneisses layered 10 to 30 centimetres thick. These gneisses are interlayered with hornblende-bearing granitic gneisses and cut by pegmatites. A grab sample returned an analysis of 0.12% copper and 3 ppm silver; gold was not detected.

These mineralized amphibolite gneisses may represent evidence of mafic volcanism resulting from a Proterozoic rifting event in the lowermost Ingenika Group (T. Höy, personal communication, 1990). Similar amphibolite gneisses are reported by Evenchick (1988) in the Sifton Range to the north. There, they sit upon 1.85 Ga basement gneisses and are believed to represent mafic volcanics related to rifting.

Areomagnetic maps indicate that these mafic gneisses continue to the southeast of the map area, suggesting that this area has potential for other similar occurrences.

PORPHYRY/VEIN MOLYBDENUM OCCURRENCES

Porphyry occurrences in the map area are concentrated in the northeastern part of the Cretaceous Germansen batholith and its surrounding metamorphic aureole. The hostrocks are granites, granodiorites and hornfelsed Takla sediments.

Mineralization occurs as disseminations, fracture fillings or in veins. Disseminated flakes of molybdenite occur in rocks near the intrusive contact. At the Blackjack East occurrence (MINFILE 093N 118), easterly striking fracture fillings, quartz veins and veinlets carrying small rosettes of molybdenite are found in both hornfels and intrusive rocks (Sinclair, 1969). Typical sulphide assemblages include pyrite, molybdenite, minor chalcopyrite, and rarely, pyrrhotite.

The Jordi occurrence (MINFILE 093N 133) is located on a steep north-facing slope approximately 2 kilometres northeast of Mount Gillis. The molybdenite is found in feldspar-quartz$\pm$muscovite veins cutting biotite monzonites and granodiorites of the Germansen batholith (Helsen, 1981).

ULTRAMAFIC MINERALIZATION

Numerous slivers of serpentinized ultramafic rocks occur within the Manson fault zone. These bodies host *chromite, pentlandite(?), and chrysotile occurrences.* Placer concentrates from the immediate area sometimes contain platinum (Davies, 1983).

The NRS prospect (MINFILE 093N 135) predates regional metamorphism; disseminated chromite is found in serpentinized zones (Lang, 1941).

Serpentinized ultramafics from the Ah Hoo Creek occurrence (MINFILE 093N 116) are reported to carry up to 0.18% nickel occurring in pentlandite (Lay, 1936). Samples collected from various serpentine bodies within the Manson fault zone during the course of the project returned nickel values between 0.12 and 0.17% which probably represent the original nickel content of serpentinized olivines.

The Germansen River occurrence (MINFILE 093N 115) is a low-grade chrysotile asbestos showing (Armstrong and Thurber, 1945).

STRATIFORM BARITE OCCURRENCES (SEDIMENTARY EXHALATIVES)

Stratiform barite occurs in slates and argillites of the Big Creek group at the Omineca Queen occurrence (MINFILE 093N 087). The sections of barite reach thicknesses of 3 to 7 metres and their lateral extent is limited due to faulting. They are characteristically fine grained and contain a dark striping parallel to the foliation in the slates. The layering is due to opaque impurities of unknown origin. Although these barite bands appear to replace quartz-rich layers, they also indicate that the deposit may have formed as a sedimentary exhalate (McCammon, 1975).

The Big Creek group is equivalent to the Earn Group which, in the northern Cordillera, hosts several large lead-zinc-barite sedimentary exhalative deposits (Tom, Jason, Stronsay (Cirque) suggesting the potential for similar occurrences in the area.

SEDIMENTARY-METAMORPHIC (GRAPHITE) OCCURRENCES

Metamorphism of organic rich (carbonaceous) Proterozoic sediments of the lowermost Ingenika Group, produced graphite concentrations in upper amphibolite grade rocks in the Wolverine Range. These rocks include marbles, calcsilicate gneisses and biotite schists.

The only documented graphite showing is the Mon occurrence (MINFILE 093N 203) located northeast of Munro Creek. Graphite occurs as discrete flakes or as thin layers. The graphite flakes are 1 to 5 millimetres in length and reach concentrations as high as 4.7% (Halleran, 1985).

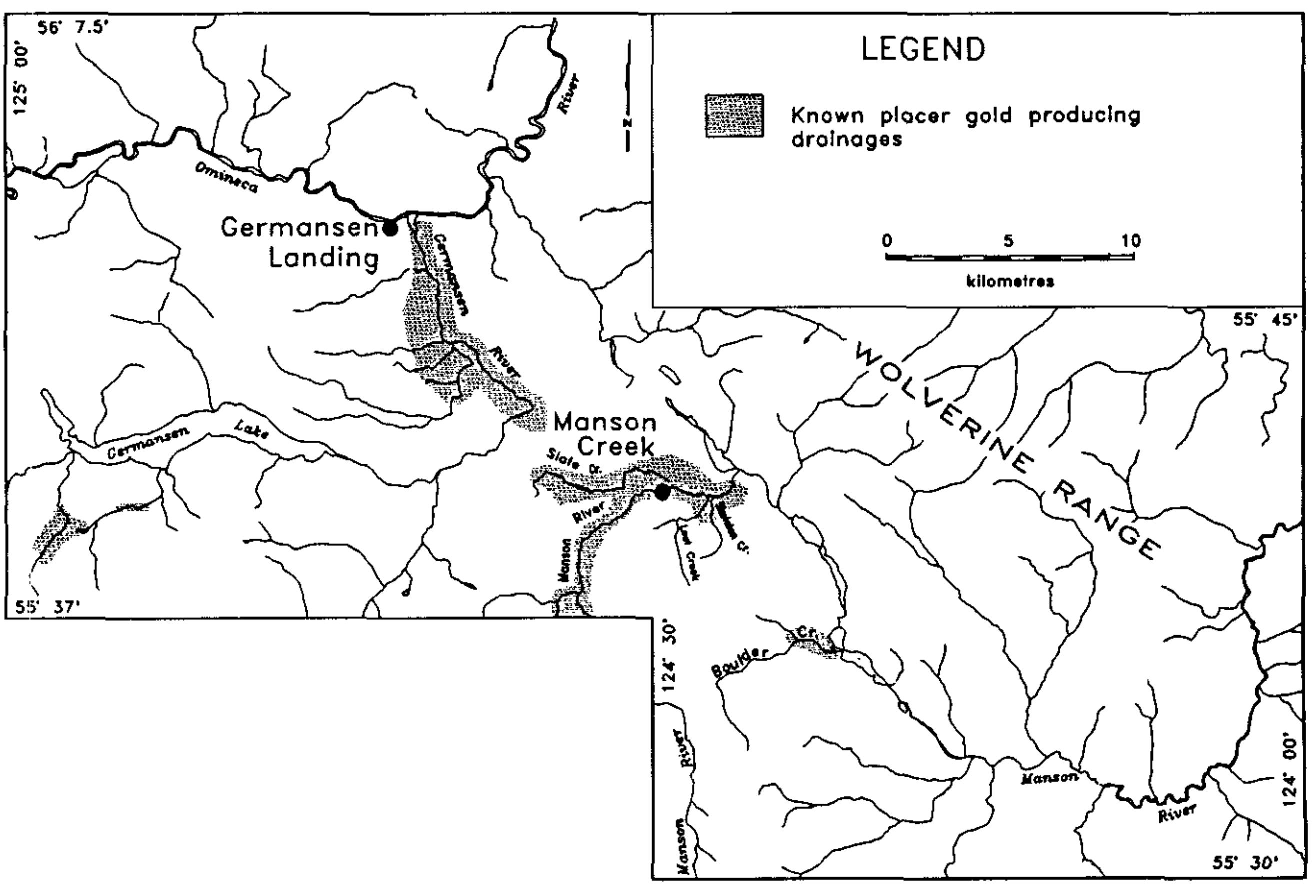

Figure 66. Placer gold producing drainages within the project area.

The graphite layers can be as thick as 6 centimetres and are hosted by calcsilicate gneisses.

DISSEMINATED SULPHIDES (PORPHYRIES?)

Two poorly documented showings of disseminated sulphide mineralization occur within Takla Group volcanics (MINFILE 093N 147 and 153). Minor chalcopyrite and pyrite occur in massive to fragmental augite-phyric basalts and basaltic andesites (Armstrong and Thurber, 1945; Geology, Exploration and Mining in British Columbia, 1972)

PLACER DEPOSITS

Placer gold was discovered on the Germansen River in 1870 and on the Manson River in 1871 (Kerr, 1934; Holland, 1950) and gave rise to the Manson Creek placer gold camp. The earliest exploration concentrated on the gold-rich gravels along these two rivers and then moved on to their tributary creeks. Evidence of early placer work abounds, including kilometre-long flumes and large open cuts in gravel beds produced by hydraulic mining (Plate 2).

Total gold production from this area is unknown. Holland (1950) reports gold production prior to 1950 for the Germansen River at 515 845 grams (16 585 ounces); the Manson River, 358 025 grams (11 511 ounces); Lost Creek, 11 385 grams (366 ounces), and Slate Creek, 100 340 grams (3226 ounces).

Current placer gold mining activity consists mainly of small operations on the past-producing streams (Figure 66). A large operation on the Germansen River, near the old Germansen town site, operated round the clock during the 1988 season.

TECTONIC MODEL

Stratified and igneous rocks of the Manson Creek – Germansen Landing area record a geological history that spans the latest Precambrian to the present. These rocks form part of four separate tectonostratigraphic terranes which represent rocks of oceanic affinity to the west (Intermontane Superterrane) and continental rocks of the Omineca Belt to the east (Figure 5; Monger, 1984). Most rocks within the map area are older than Jurassic and were deformed by crustal shortening beginning in the Early Jurassic, although there is evidence for similar deformation of Permian age (Klepacki and Wheeler, 1985, Harms, 1986). The geologic sequence of the Omineca Belt records long periods of stable shelf development, punctuated by several rifting events prior to compressional deformation. Rifting episodes led to the formation of the oceanic Nina Creek group (or Slide Mountain Terrane) and the oceanward development of an arc complex (Lay Range assemblage, Harper Ranch Subterrane). This was followed by collapse of the Nina Creek basin and subsequent development of the Quesnel arc. Deformation and eastward transport of Slide Mountain, Lay Range and Quesnel rocks led to their present configuration. Mineralizing episodes during this long history are restricted to periods of deformation and arc construction.

The following discussion is by no means entirely original. It evolved from absorbing ideas from Rees (1987), Struik (1987; 1988a,c), Schiarizza (1989), Evenchick, (1988), Nelson and Bradford (1993) and of course countless articles on Cordilleran evolution which are too numerous to mention here. What follows is an attempt to integrate data from the present map area with that from other studies of the Intermontane-Omineca Belt boundary in hopes of producing a refined model that is applicable along the length of the Canadian Cordillera.

PROTEROZOIC

A major Proterozoic extensional event affecting the length of the western edge of the ancestral craton resulted in widespread deposition of continental terrace sediments of the Windermere Supergroup (Figure 67a, Evenchick, 1988; Mansy and Gabrielse, 1978). Basal amphibolite gneiss and quartzite of the Ingenika Group in the Sifton Ranges (and Misinchinka Group in the Deserters Ranges) may represent latest Proterozoic igneous activity and subsequent deposition of basal clastics related to initiation of Windermere sedimentation over 1.85 Ga granitic basement (Evenchick, 1988). Lower feldspathic and quartz wackes of the Ingenika Group are probably high-energy deposits shed from highlands composed predominantly of horst blocks of Precambrian basement. The oldest rocks in the map area belong to the Upper Proterozoic Ingenika Group, the lower parts of which have been strongly metamorphosed and in part form the Wolverine Metamorphic Complex.

Thick successions of amphibolite gneiss and paragneiss unique to unit Pia (*see* Table 1) may be situated near the base of the Ingenika Group in the map area. No other amphibolite is seen in higher Ingenika strata. Tens of kilometres of deformed strata have been removed by erosion during uplift on the Wolverine fault zone in the Manson River area. This has resulted in the exposure of the lowermost parts of the Ingenika stratigraphy. Mafic gneisses of unit Pia may represent metamorphosed flows or sills emplaced during rifting of the pre-Windermere basement. Thick sequences of metaquartzite at the base of the Ingenika Group in the Sifton Ranges (Evenchick, 1988) are lacking in the basal parts of unit Pia, implying stratigraphy slightly younger than the basal quartzite and amphibolites in the Sifton Ranges, but old enough to have recorded rift-related igneous activity.

Coarse clastics of the middle Swannell Formation are succeeded by finer clastics and carbonates of the upper Swannell, Tsaydiz, Espee and Stelkuz formations. Thus, erosion of the highlands and production of lower coarse clastic units was succeeded by shallow water deposition of carbonate strata (Mansy and Gabrielse, 1978).

Some authors suggest that Windermere rifting did not lead to continental break-up (Bond *et al.*, 1985; Devlin and Bond, 1988; Struik, 1987; Roots, 1987). They propose that episodic rifting produced a large intracratonic basin which persisted until latest Proterozoic or earliest Cambrian times (Devlin and Bond, 1988).

Mineralization related to rifting and intracratonic basin sedimentation occurs within the map area. Copper-bearing amphibolite gneiss of unit Pia may represent sulphide mineralization associated with Proterozoic rift-related volcanism. Graphite-rich calcsilicate bands, interlayered within unit Pia, represent highly metamorphosed, organic-rich limestones and may be potential hosts for carbonate-replacement, massive-sulphide mineralization.

EARLY PALEOZOIC

Early Paleozoic miogeoclinal sedimentation was initiated with deposition of Lower Cambrian basal orthoquartzites of the Atan Group which are succeeded by finer clastics and carbonates of the upper Atan Group. Carbonate deposition predominated until the end of the Middle Devonian (Otter Lakes group) forming a miogeoclinal wedge characteristic of passive, continental margins (Figure 67b).

Early Paleozoic sedimentation presumably occurred in response to extensional tectonism and subsequent thermal subsidence following continental break-up in earliest Cambrian times (Devlin and Bond, 1988). Alternatively, Struik (1987) suggests that episodic rifting occurred within the intracratonic Windermere basin until final breakup in the Late Devonian. Although the culmination of rifting was undoubtedly a diachronous event, an earliest Paleozoic breakup is most consistent with the geology of the Manson Creek area and areas to the north.

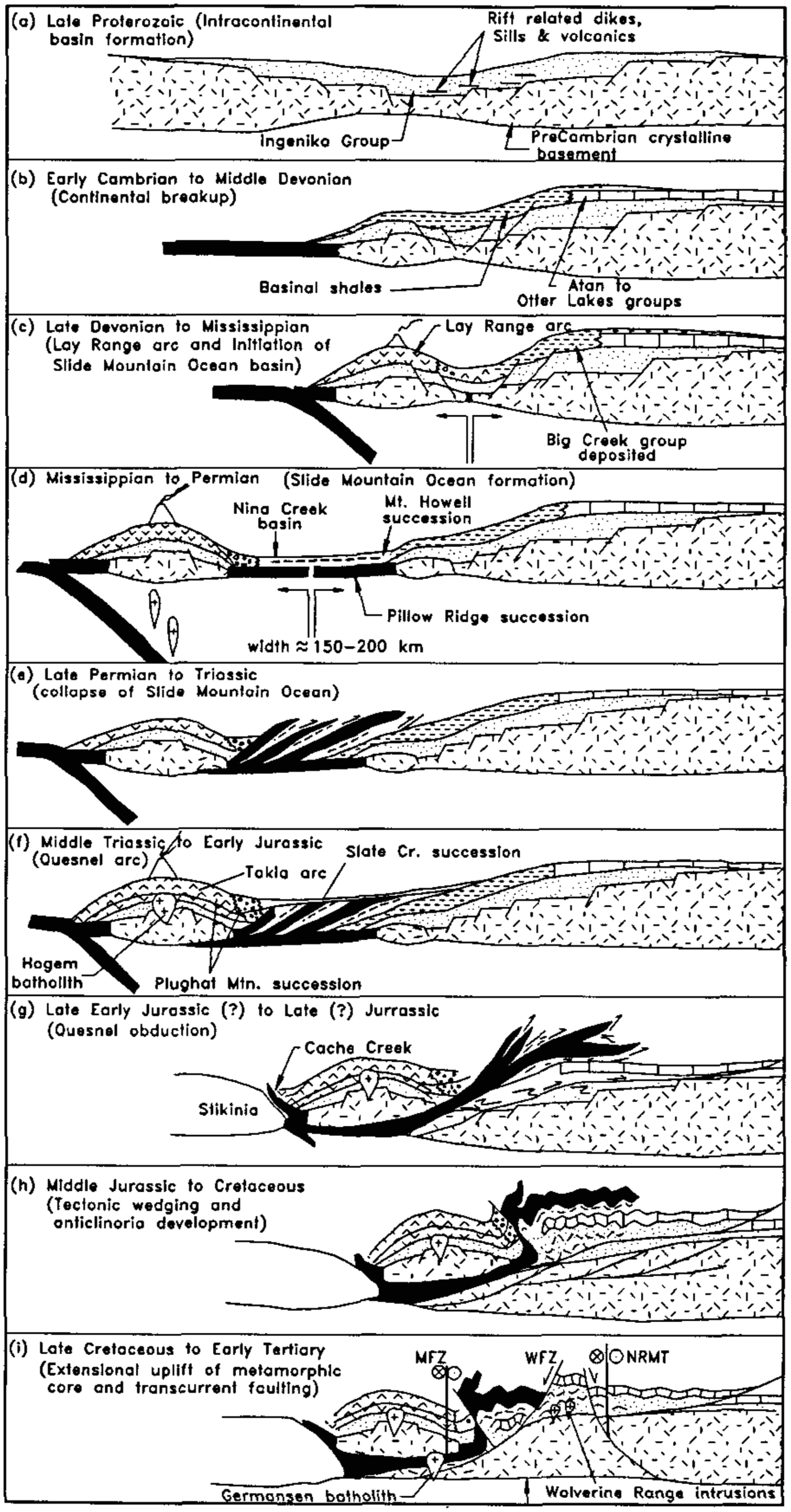

Figure 67. Schematic diagram depicting evolution of the study area from Late Proterozoic to present. *See* text for details. MFZ=Manson fault zone; NRMT=Northern Rocky Mountain Trench; WFZ=Wolverine Fault Zone.

An unconformity separates Proterozoic and Lower Cambrian rocks in many parts of the Cordillera, but evidence for a sub-Cambrian unconformity is lacking in the map area. Instead, deposition of Lower Cambrian orthoquartzite was preceded by coarsening-upwards impure quartzites of the upper Stelkuz Formation that probably represent initial immature sediments shed from uplifted blocks. As the blocks continued to be eroded, water depth decreased and a possible concurrent eastward transgression led to the deposition of the mature quartz sands of the Lower Cambrian (Devlin and Bond, 1988). Post-rifting subsidence following continental breakup led to stable miogeoclinal development and re-established deposition of thick carbonate sequences. Carbonate deposition was not dominant everywhere; fine to coarse clastics were deposited in deeper environments such as the Ospika embayment to the northeast (Thompson, 1989) and in the Cariboo area to the south (Struik, 1988a).

Carbonate deposition ended by latest Devonian time, and was succeeded by thick accumulation of Big Creek shales and argillites. Shale deposition occurred in response to another widespread rifting event along the western edge of the miogeocline (Gordey *et al.*, 1987). This blanket of shale reached far to the east within the miogeocline (Thompson, 1989). In the map area, deep water deposition of predominantly fine clastics continued until Permian time, punctuated briefly to the east of the map area by carbonate of the Carboniferous Prophet Formation (Thompson, 1989). In far northern British Columbia, the Earn Group (Big Creek group equivalent) contains sequences of clastic material which may have formed from the erosion of uplifted blocks produced during rifting (Gordey *et al.*, 1987). Devono-Mississippian argillite and shale of the map area contains minor coarse to fine clastics (quartz-chert wackes to sandstones of the Big Creek group) and felsic volcanics (Gilliland tuff) related to this event. Similar sequences of this age are reported by workers all along the belt (Nelson and Bradford, 1993; Struik, 1988a; Schiarizza and Preto, 1987). Furthermore, Devonian to Mississippian alkaline intrusions in the map area (Lonnie and Virgil bodies) are typically produced in areas undergoing extensional tectonism. Similar bodies also occur along the length of the Cordillera (Pell, 1987).

Rocks of the Boulder Creek group, and other sequences within the pericratonic Kootenay Terrane comprise Windermere stratigraphy which is overlain by lower Paleozoic deeper water clastics (Struik, 1987, 1988a). They are assumed to represent distal, highly attenuated pieces of the North American landmass produced during Cambrian and Devonian continental break-up.

Several styles of mineralization in the Manson Creek area can be related to this period of extension. Alkaline intrusions contain significant amounts of rare earth elements (Pell, 1987). Carbonate-hosted sulphide occurrances in the Otter Lakes group (Vernon, Biddy, *etc.*) may have formed during rifting. Lead/lead isotope studies of several of these deposits indicate lead of Cambrian age (C. J. Godwin, personal communication, 1990). This old lead must have a lower crustal source and may have been remobilized along normal faults related to extensional tectonism. Big Creek shales contain stratiform barite (Omineca Queen) and basal shales overlying the Vernon showing contain disseminated sulphides; both are related to exhalative, extension-related processes active during basin formation. Sedimentary exhalative mineralization is quite common in Upper Devonian to lower Mississippian shale sequences in the northern Cordillera.

LATE PALEOZOIC

The oldest rocks of oceanic affinity within the map area are the Pennsylvanian to Permian Nina Creek group of the Slide Mountain Terrane. Elsewhere in the Cordillera fossils as old as early Mississippian (Nelson and Bradford, 1993; Roots, 1954; Struik, 1988a; Schiarizza and Preto, 1987) provide a maximum age for the Slide Mountain (Nina Creek) ocean basin. Furthermore, initiation of rifting along the continental margin roughly corresponds to the oldest volcanics within the Slide Mountain Terrane (early Mississippian) implying that this rifting led to the formation of the Slide Mountain basin.

We argue that rifting resulted from back-arc spreading in late Devonian time (Figure 67c and d). Arc, and subsequent back-arc basin development, was initiated at the continental edge, perhaps over a distal piece of North American crust produced during early Paleozoic continental break-up. The Lay Range assemblage may represent the western arc. Evidence for this arc can be found elsewhere in the Cordillera (Nelson and Bradford, 1993; Smith, 1974; Roots, 1954; Monger *et al.*, 1991; Ferri *et al.* 1992a, 1993a). Parts of this arc are exposed within the Quesnel Terrane, but in our model, most of the arc is buried by the products of subsequent Late Triassic to Jurassic arc volcanism (Figure 67f).

In the Lay Range, immediately north of the map area, Roots (1954), Monger (1977a) and Ferri *et al.* (1992a, b; 1993a, b) describe tuffaceous sediments, mafic to intermediate flows and volcaniclastics, conglomerate and limestone of Mississippian(?) to Permian age. These rocks are time equivalents of the Nina Creek group and appear to occupy the same structural position. Such lithologies are not typical of the Nina Creek group and reflect higher energy sedimentary deposition and explosive volcanism associated with an arc. They may be proximal back-arc sediments; that is, material being shed off an active arc to the west. Nina Creek rocks represent deeper, more distal parts of the basin where low-energy sedimentation prevailed. Volcanism in the mature Nina Creek basin was by extrusion of typical mid-ocean-ridge basalts. Initial back-arc, basinal volcanism may have had an arc or transitional signature but as spreading continued and the basin widened, effects of this arc on basin volcanism diminished.

Rare polymict sandstones in the Mount Howell succession are most likely distal tongues of turbidic sediment from the western Lay Range arc. Clast composition is very similar to feldspathic sands and conglomerates of the Lay Range assemblage.

Farther north, in the Cassiar area, Division III of the Sylvester allochthon contains many indications of an arc built on the western margin of the Slide Mountain basin.

Division III, as a whole, represents pieces of an obducted island arc. It occupies the highest structural position within the allochthon indicating that it originated from a more westerly position than the underlying ocean-floor basalts of Division II. Division III contains fragmental basalts, intermediate volcanics, shallow water limestones with chert beds and gabbroic to granodioritic intrusions (Nelson and Bradford, 1993). Interspersed with the fragmental basalts are thick sections (100 metres) of volcanic sandstone. Trace and rare-earth element plots for basalts within this section have an island-arc signature (Nelson and Bradford, 1993).

In the southern part of the Quesnel Terrane, late Paleozoic arc-related volcanism may be manifest within rocks of the Upper Devonian to Permian Harper Ranch Group. These predominantly fine-grained sedimentary rocks contain notable sequences of fragmental volcanics and massive flows (Monger *et al.*, 1991). Smith (1974) studied Harper Ranch sediments in detail and concluded that they were derived from an active arc to the west.

Basement to the Lay Range - Harper Ranch - Sylvester Division III arc systems is believed to be continental in origin (as suggested in Figure 67c and d). Evidence for continental basement below these arc systems comes from several localities. Conglomerate lenses within the sedimentary and volcanic sequences in the Lay Range contain clasts of igneous and metamorphic composition (*see* also Roots, 1954; Ferri *et al.*, 1993a). The only eastern source for these conglomerates would have been rocks of the Canadian Shield which, at its western edges, was buried below some 3 to 4 kilometres of miogeoclinal sediments. The high-energy nature of these sediments precludes distally exposed shield rocks as a source. There is no evidence for uplift and erosion of shield material in the Omineca or Foreland belts prior to Tertiary time. This material must, therefore, be derived from western uplifted and eroded blocks of the arc core. Farther north, detrital zircons recovered from Division III sediments yield Precambrian ages, suggesting a continental source (J.L. Nelson, personal communication, 1993).

Rare-earth element signatures from Takla Group basalts in the study area suggest the existence of continental material below the Takla arc. Ratios of yttrium against zirconium suggest crustal contamination or assimilation resulting from eruption on top of continental lithosphere (*see* under Takla Group, Figure 38). However, the Takla arc is believed to have developed above the Lay Range arc (Figure 67f). This does not negate the existence of the Lay Range arc, it simply suggests both arc systems are floored by a fragment of continental crust. Although not analyzed, basaltic Y/Zr ratios of the Lay Range volcanics are expected to be similar to those of the Takla Group.

The original width of the Slide Mountain basin is unknown. The breadth of this back-arc basin would be dependent on the length of time subduction was active and on plate geometries at that time. Rees (1987) estimated a basin several hundred kilometres wide, based on structural reconstructions in the Quesnel Lake area. Struik (1987) assumed a width of approximately 150 kilometres.

Sedimentary evidence along the length of the Cordillera suggests that the Slide Mountain basin was marginal to the continent. In the map area, rocks of the Nina Creek group represent deposition in the centre of the basin, with little influence from the western arc system or North American continent to the east. This is not only reflected in the sedimentary record, but also in the geochemistry of the volcanic rocks where rare-earth element plots indicate typical MORB signatures with no contamination from continental material or from arc volcanism. But, as recorded by the Mount Howell succession, Nina Creek rocks were still close enough to a continental source (*i.e.*, North America) to receive influxes of quartz-rich sand.

North of the map area, the Slide Mountain Terrane preserves both western and eastern margins of the basin (Lay Range assemblage, Sylvester allochthon). In the Sylvester allochthon, Nelson and Bradford (1993) found quartz-rich sands within Divisions I and II and concluded that these rocks were derived from the nearby North American continent. As previously discussed, the structurally highest Division II comprises pieces of the western arc.

In the Adams Lake area, Schiarizza and Preto (1987) describe thick sandstones within the lower Fennell Formation, indicating proximity to a continental source. Schiarizza (1989) also concluded that the lower Fennell Formation was deposited along the North American margin.

Klepacki and Wheeler (1985) have demonstrated the equivalency of the Kaslo and Milford groups; the latter rests unconformably on North American rocks. This clearly shows the marginal nature of the Kaslo Group sediments and volcanics.

PERMIAN TO TRIASSIC

In the map area, as in the rest of the Cordillera, an exceedingly widespread unconformity encompasses the Upper Permian to Middle Triassic internal (Read and Okulitch, 1977). In the Quesnel and Slide Mountain terranes, sedimentation resumed in the Middle Triassic with the deposition of basinal shales.

The basal contact of the Middle to Upper Triassic Slate Creek succession is not apparent in the map area because is has been cut off by the Manson fault zone. In Quesnellia, basal Triassic slates commonly lie with angular unconformity over upper Paleozoic rocks with possible Slide Mountain affinities (Monger *et al.*, 1991; Read and Okulitch, 1977; Little, 1983). Exposures in the southern part of Quesnellia indicate an angular unconformity between units of the Slide Mountain assemblage and the overlying Slate Creek equivalents. Klepacki and Wheeler (1985) have shown the Lower Permian (to Middle Triassic, Gordey *et al.*, 1991) Marten conglomerate rests with angular unconformity on greenstones of the Kaslo Group (Nina Creek group equivalent). The Upper Triassic Slocan Group (equivalent to the Slate Creek succession) rests disconformably on the Marten conglomerate. This relationship requires uplift, tilting and erosion of the Kaslo Group during Permian or Early Triassic time. In the Quesnel area, McMullin *et al.* (1990) report conglomerates (Wingdam conglomerate) possibly within the Middle to Upper Triassic black phyllite, which contain metamorphic, sedimentary and ultramafic clasts presumably derived from the underlying Crooked amphibolite (Slide Mountain assemblage) and Snowshoe Group. This conglomerate may be of Jurassic age and unrelated to the Permo-Triassic unconformity (McMullin *et al.*, 1990; Struik, personal communication, 1993). If it is Triassic in age then it also implies uplift and erosion of the Slide Mountain assemblage in Late Permian to Early Triassic time, prior to deposition of the black phyllite. In the Cassiar area, the basal contact of the Upper Triassic Table Mountain Formation sediments is believed to represent a faulted unconformity above sedimentary and volcanic rocks of the Sylvester allochthon (Nelson and Bradford, 1993).

Direct evidence for this uplift is not seen in the map area but has been documented elsewhere in the Cordillera. In the Kaslo area, Klepacki and Wheeler (1985) report thrusting (Whitewater thrust) which is plugged by a Permian pluton. An analogous relationship is described by Harms (1986) in the Sylvester allochthon. In the Yukon, Erdmer (1987) describes eclogites and blueschist facies rocks of Permo-Triassic age. In the southwestern United States, rocks very similar in age and composition to the Slide Mountain assemblage were imbricated in Permo-Triassic time, during the Sonoman Orogeny (Silberling and Roberts, 1962; Silberling, 1973).

In the Manson Creek area, the basal parts of the Slate Creek succession contain sequences of very fine grained, quartzose sands and siltstones. Bloodgood (1990) also describes thick (up to 150 metres), quartz-rich sandstone sequences at the base of the Middle to Upper Triassic black phyllite unit in the Quesnel Lake area. Prograding epiclastics of the Takla arc, that contain little or no quartz, are found above these quartz-rich sediments. A source for the basal quartzose sands may have been the continent to the east. The implications of this and the preceding paragraphs are enormous. We know that clastic sedimentation was occurring in Middle and Late Triassic time along the miogeocline to the east (Thompson, 1989). Basal Slate Creek succession must have been deposited close enough to the continental margin to receive abundant quartz detritus which the underlying Nina Creek sediments lack. This suggests that the Nina Creek or Slide Mountain basin had partially or totally collapsed by Late Permian to Early Triassic time (Figure 67e).

Basin collapse probably led to obduction of Nina Creek rocks onto distal parts of the North American miogeocline (*i.e.*, Kootenay Terrane). There is however, no evidence within North American rocks of the Cassiar Terrane for compressional deformation and metamorphism of Permian or Triassic age. Constraints on this compressional event in Kootenay, Slide Mountain and Quesnel terranes are limited and the regional extent of this deformation is speculative.

MIDDLE TRIASSIC TO EARLY JURASSIC

By the end of the Middle Triassic, basinal shales and limestones of the Slate Creek succession had been deposited within parts of Quesnellia and probably blanketed deformed(?) rocks of the Slide Mountain Terrane. Sedimentation on the miogeocline consisted of shallow water clastics which were succeeded by Upper Triassic carbonate shoals of the Baldonnel Formation (Thompson, 1989).

In the Upper Triassic, shales of the Slate Creek succession pass upwards and westwards into volcanic siltstones, sandstones and conglomerates shed from the emerging Upper Triassic Quesnel arc. This arc was superimposed on the Lay Range arc. Its formation was due to the eastward subduction and consumption of the Cache Creek oceanic crust (Monger *et al.*, 1982; Monger, 1984). Arc volcanism and related sedimentation continued until the Early Jurassic (Figure 67f).

Huge coeval alkaline to calcalkaline magmatic bodies intruded Takla volcanic rocks (Hogem batholith). Many of these produced porphyry systems with significant copper and copper-gold concentrations (*e.g.*, Mount Milligan).

LATEST EARLY JURASSIC TO LATE JURASSIC

Obduction of the collapsed Slide Mountain basin and the Quesnel arc onto North America occurred in latest Early Jurassic to Middle Jurassic time (Figure 67g). Time constraints are based, in part, on metamorphic cooling dates from the map area and the southern Omineca Belt (Greenwood *et al.*, 1991). Obduction resulted from the closure of the Cache Creek basin and the collision of the Stikine landmass with the Quesnel arc. Pre-obduction Slide Mountain basin configuration is unknown as the extent of imbrication during Permian basin-collapse is only speculative. However, the present stacking order of lithologies within the Slide Mountain assemblage is a reflection of the original configuration of the various units. Telescoping has preserved the most westerly part of the basin in the uppermost part of the thrust stack. This implies that the Pillow Ridge basalts represent deeper, more distal parts of the Nina Creek - Slide Mountain basin and that the siliceous sediments of the Mount Howell succession were deposited closer to North America and may, at one time, have rested on ocean-floor basalts. A similar arrangement of thrust sheets is even more evident in the Sylvester allochthon, where the most westerly parts of the Slide Mountain basin (represented by arc volcanics and sediments of Division III) sit structurally above basinal basalts, ultramafics and sediments of Division II, which in turn rest on Division I sediments of North American affinity. Repetition of this pattern of imbrication is apparent in other areas underlain by the Slide Mountain assemblage.

Evidence for timing of obduction in the map area is provided by a 171 Ma K-Ar cooling age for metamorphosed Proterozoic rocks in the hangingwall of the Wolverine fault zone. We argue that the emplacement of the Nina Creek group on top of the miogeocline resulted in concurrent thickening, heating and metamorphism of the lower continental crust. Differential thickening along the length of the continental succession through folding and faulting in conjunction with obduction of oceanic rocks resulted in metamorphic isograds crosscutting stratigraphy.

Obduction led to the development of easterly directed D_1 structures and a ubiquitous layer-parallel fabric. This fabric is pronounced in relatively deeply buried and hotter rocks, or in incompetent units. No large-scale, northeast-directed nappes were mapped in the study area, but considerable thickening of the sedimentary package is believed to have occurred at this time. Thickening led to the emergence of a significant landmass which shed sediments into the contemporaneous foreland basin to the east. First occurrences of westerly sourced detritus in the foreland are recorded by the Passage beds of the Middle Jurassic Fernie Formation (Thompson, 1989).

During the Jurassic, obduction was limited to the Omineca Belt and deformation had yet to extend eastward to the Foreland Belt. Continued eastward impingement of the Quesnel arc led to further compression along the western edge of North America. Due to the size of the arc system, extensive eastward obduction (as with the relatively thin sheets of Slide Mountain ocean-floor material) was not possible. Instead, the Quesnel arc was wedged against the thicker part of the deformed miogeocline (Price, 1986; Figure 67h). This wedging led to the formation of D_2 structures. In this model, structures in the upper part of the wedge are antithetic to the motion within the entire deforming pile (*i.e.*, southwesterly directed fold and fault structures seen all along the western margin of the Omineca Belt). In the lower parts of the wedge, synthetic D_2 structures predominate. The presence of antithetic D_2 structures in the Manson Creek area may indicate its position in the lower part of the wedge. Alternatively, this may also be explained by obduction without wedging.

The age of D_2 (wedging) deformation is Middle Jurassic, as inferred from the presence of metamorphic micas growing along S_2 cleavage planes in the Boulder Creek group. In the Ingenika Group, D_2 deformation outlasted metamorphism which suggests that it may be younger than Middle Jurassic. Southwest-directed deformation in the southern and northern Cordillera is Middle Jurassic in age (Brown *et al.*, 1986; Bellefontaine, 1990).

EARLY TO MIDDLE CRETACEOUS

Metamorphosed rocks of the Omineca Belt were broadly warped and uplifted subsequent to obduction-related tectonism. This resulted in the development of regional-scale, postmetamorphic anticlinoria (Wolverine antiform; D_3) that are found along the northern part of the Omineca Belt. This deformation may be related to continued accretion of allochthonous rocks to the west.

The age of D_3 deformation is not well constrained within the map area. It must range from Late Jurassic to possibly Late Cretaceous time. This corresponds to the period between the end of D_2 deformation and the onset of extensional tectonism in the Omineca Belt. Metamorphic cooling ages within large postmetamorphic antiforms suggest D_3 deformation occurred between Early and middle Cretaceous time (Evenchick, 1988). Wide reaching effects of D_3 deformation are preserved in the stratigraphic record within the Foreland basin to the east. This basin was formed beginning in the Early Jurassic by downwarping of the lithosphere in response to loading of the continental crust to the west. Emergent western landmasses, which caused the loading, also provided the sediments deposited in the Foreland Basin. Large clastic wedges of the Foreland Belt are known to be separated by major unconformities (Thompson, 1989) which must have formed in response to major tectonism and uplift to the west. Directly northeast of the map area, the lowermost clastic wedge of the Foreland Belt comprises the Early Jurassic to earliest Cretaceous Fernie and Minnes groups (Thompson, 1989) and probably represents loading and detritus produced during D_1 and D_2 deformation. The next clastic wedge comprises the Barremian to earliest Albian (middle Cretaceous) Bullhead Group (Thompson, 1989) and may correspond to D_3 deformation.

Upper crustal rocks cooled immediately after Middle Jurassic metamorphism. Lower parts of the thickened pile remained at considerable depth and experienced partial melting leading to the formation of granitic plutons, such as the Germansen batholith, and associated vein and porphyry-style prospects in rocks of the Takla and Nina Creek groups.

LATE CRETACEOUS TO EARLY TERTIARY

The youngest period of deformation recorded in the map area is right-lateral motion on the Manson fault zone, concurrent with uplift of the Wolverine metamorphic core-complex along the Wolverine fault zone (Figure 67h). The Manson fault zone is one of many right-lateral fault systems that were active along the length of the Canadian Cordillera during Cretaceous and Tertiary time (Gabrielse, 1985). Oldest strike-slip motion is at least as old as earliest Late Cretaceous as a strand of the Manson fault zone is plugged by the 106 Ma Germansen batholith. An Early Tertiary upper age limit for motion on the Manson fault zone is based on the age of the Uslika basin, which may be a negative flower structure at the northern termination of the fault.

Polymetallic veins are the most common mineral occurrences within the map area. They are spatially related to the Manson fault zone and to strongly altered ultramafic bodies that crop out along the fault. Movement along the Manson fault zone led to the dissection of previously obducted sheets of the Manson Lakes ultramafics. Fluid migration along the Manson fault system undoubtedly led to the alteration of these bodies. A 134 Ma K-Ar age obtained from mariposite from an ultramafic body near Manson Creek may record alteration related to earliest motion on the Manson fault zone or may be a reset partial record of alteration during obduction or even during the suggested Permian basin collapse. Early collisional deformation events must have produced numerous shear zones which, in conjunction with those produced during motion on the Manson fault zone, may have facilitated fluid migration driven by high heat-flow from the Wolverine Metamorphic Complex.

Uplift of the Wolverine Metamorphic Complex began in Late Cretaceous time, culminating in the Early Tertiary.

This is well documented by K-Ar metamorphic cooling ages within the complex (Appendix II, Figure 57). A single exception is the Late Cretaceous date from the northern part of the Wolverine fault zone.

A single apatite fission-track analysis indicates cooling below 100°C at approximately 48 Ma. Considering that K-Ar blocking temperatures of metamorphic minerals require that they passed through approximately 400°C at about 50 to 60 Ma, rapid uplift of the complex is required in the Early Tertiary to explain the up to 100°C per million years cooling profile. This is supported by the presence of metamorphic detritus in the Late Cretaceous to Early Tertiary Uslika and Sifton basins.

Uplift of the Wolverine Complex led to the development of the Wolverine fault zone, a moderately dipping, layer-parallel ductile shear zone with dip-slip motion. In the southern part of the map area it is overprinted by a steeply dipping, brittle shear zone which juxtaposes relatively unmetamorphosed, higher level rocks of the Nina Creek group against sillimanite-grade rocks of the metamorphic complex. The high-level, brittle faults were concurrent with and may have passed into ductile motion in the lower crust. As lower level, ductile zones were uplifted and cooled, they were overprinted by brittle fault structures.

In the northern part of the study area offset on the Wolverine fault zone decreases as it cuts down-section into rocks of the Swannell Formation. Rocks of similar metamorphic grade on each side of the fault indicate that motion has decreased and mapping by Gabrielse (1975) and Roots (1954) immediately north of the map area indicates that the fault is no longer present.

The reason for rapid uplift of the metamorphic complex is uncertain. It may have been related to instability of the thickened crust following cessation of compressional deformation (Brown and Carr, 1990) or to transcurrent motion along the Canadian Cordillera (Evenchick, 1988; Struik, 1988c). In the northern Omineca Belt detailed work by Evenchick (1988) demonstrates the relationship between uplift and transcurrent motion. Furthermore, in the northern Cordillera, transcurrent fault systems usually bound portions of core complexes. Motion on these faults is contemporaneous with core complex uplift suggesting a genetic relationship.

Igneous and sedimentary rocks in the lower parts of the Wolverine Complex were subjected to upper amphibolite grade metamorphism which led to partial melting and the production of significant quantities of granitic magma. Some or all of this magma may also have been produced by sudden decompression of these rocks during the rapid rise of the Wolverine Complex. Most magmatic material thus generated was confined to the Wolverine Complex, but significant amounts of monzonite and quartz monzonite of slightly younger age intrude the surrounding rocks. Some of the Wolverine Range intrusions are alkaline and contain significant amounts of rare earth elements.

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APPENDICES

APPENDIX I

MICRO AND MACROFOSSIL AGE DETERMINATIONS

Map Loc	Map Unit (Lithology)	Field Number (Sampler)	GSC Number	Easting	Northing	Fossils	Taxa (Number of Specimens)	CAI	Age (*Remarks*)
F_1	Ingenika Group (carbonate)	FF87-51-4 (F. Ferri)	C-153780	414230	6168100	conodonts	protoconodont (1)	n/a	Probably Phanerozoic, ?Cambrian[1]
F_2	Atan Group (carbonate)	FFe89-28-2 (F. Ferri)	C-168387	384535	6215754	sponges	spicules	n/a	Phanerozoic
F_3	Atan Group (carbonate)	DMe89-28-3 (D. Melville)	C-167990	384154	6218230	archaeocyathids	archaeocyathids, several genera	n/a	Early Cambrian[2]
F_4	Razorback group (shale)	(B. Mauer)[5]		390550	6206350	trilobites	*Ogygopsis* cf. *Klotzi* (Rominger) *Chancia latigena* Rasetti *Zacanthoides* sp.	n/a	Early Middle Cambrian (Oryctocephalus zone)[3]
F_5	Echo Lake group (carbonate)	FFe89-7-12 (F. Ferri)	C-168366	389159	6203403	conodonts	*Ozarkodina?* sp. (1) ramiform elements (1)	5	Silurian-Early Devonian[1]
F_6	Echo Lake group (carbonate)	FFe89-7-4-2 (F. Ferri)	C-168365	388480	6203882	conodonts	*Pandorinellina exigua* (Philip) (3) *Pandorinellina steinhornensis* (Ziegler) (1) Pb element (1)	5.5	Early Devonian (Emsian)[1]
F_7	Echo Lake group (carbonate)	FFe89-33-3 (F. Ferri)	C-168390	384321	6221036	conodonts	(Proto-)*Panderodus* sp. (1)	5	Late Cambrian-Middle Devonian[1]
F_8	Echo Lake group (shale)	DMe89-28-8 (D. Melville)	C-167989	381890	6218250	graptolites	*Monograptus spp.* (2) ?*Pristograptus* sp. ?retiolitid graptolite	n/a	Silurian (perhaps Llandoverian)[2]
F_9	Otter Lakes group (carbonate)	FFe89-23-17 (F. Ferri)	C-168385	375978	6218272	conodonts	*Belodella* sp. (8) *Pandorinellina* sp. (4) ramiform elements (2)	6	Early-Middle Devonian[1]
F_{10}	Otter Lakes group (carbonate)	FFe89-23-4 (F. Ferri)	C-168383	375881	6219203	brachiopods conodonts	inarticulate brachiopods, tubes, ?protoconodonts	n/a	Early Paleozoic, ?Cambrian[1]
F_{11}	Otter Lakes group (carbonate)	FFe89-33-12 (F. Ferri)	C-168392	380826	6220334	conodonts	ramiform elements (1)	5	Silurian-Triassic[1]
F_{12}	Otter Lakes group (carbonate)	FFe89-23-17 (F. Ferri)	C-154391	376000	6218300	echinoderms	echinoderm debris, columnals with twin axial canals	n/a	Devonian (probably Emsian-early Eifelian)[2]

Map Loc	Map Unit (Lithology)	Field Number (Sampler)	GSC Number	Easting	Northing	Fossils	Taxa (Number of Specimens)	CAI	Age (*Remarks*)
F_{13}	Big Creek group (carbonate)	DMe89-4-3 (D. Melville)	C-154398	388348	6202405	conodonts	*Siphonodella* spp. (20) *Polygnathus communis communis* Branson & Mehl (3) *Polygnathus communis carina* Hass (1) *Polygnathus* spp. (5) *Pseudopolygnathus* spp. (8) *Mestognathus praebeckmanni* von Bitter, Sandberg & Orchard (4) *Dinodus* sp. (1) ramiform elements (10)	5	Early Carboniferous (Tournaisian)[1]
F_{14}	Big Creek group (carbonate)	FFe89-22-6 (F. Ferri)	C-167988	386251	6206521	conodonts	*Streptognathodus elongatus* Gunnell (2) *Diplognathodus* sp. (1) *Sweetognathus inornatus* Ritter 1976 (6) *Sweetognathus whitei* Rhodes 1963 (43) *Neogondolella* sp. (11) ramiform elements (120)	5	Early Permian (Sakmarian-early Artinskian)[1]
F_{15}	Big Creek group (carbonate)	(J.M.W. Monger)	C-37898	386620	6206550	fusulinids	*Pseudofusulinella (Kanmeraia) meeki* (Skinner and Wilde) *Triticites* sp.		Late Carboniferous (Late Pennsylvanian)-Early Permian[4]
F_{16}	Nina Creek group (chert)	FF87-19-4 (F. Ferri)	C-153791	409464	6171645	conodonts	*Idiognathodus* sp. (6) *Idiognathoides* sp. (7) *Streptognathodus* sp. (6) ramiform elements (20)	n/a	Late Carboniferous (Bashkirian-Moscovian)[1]
F_{17}	Nina Creek group (chert)	FFe88-29-7-1 (F. Ferri)	C-154380	394045	6185991	conodonts	gnathodids (2) ramiform elements (4)	4.5	Probably Carboniferous[1]
F_{18}	Nina Creek group (chert)	FFe88-36-7-1 (F. Ferri)	C-154381	391629	6192729	conodonts	*Idiognathoides* sp. (3) ichthyoliths, ramiform elements (4)	5-6	Late Carboniferous (Bashkirian to Moscovian)[1]
F_{19}	Nina Creek group (chert)	FFe88-41-3-1 (F. Ferri)	C-154383	396180	6191635	conodonts	sphaeomorphs	n/a	Indeterminate[1]
F_{20}	Nina Creek group (chert)	FFe89-16-16 (F. Ferri)	C-167977	382717	6200386	conodonts	ramiform elements (4)	6-7	Ordovician - Triassic[1]
F_{21}	Nina Creek group (chert)	FFe89-16-8 (F. Ferri)	C-167976	383535	6200707	conodonts	*Idiognathoides* sp. (2) ramiform elements (4)	6	Late Carboniferous (Bashkirian to Moscovian)[1]
F_{22}	Nina Creek group (chert)	FFe89-6-4 (F. Ferri)	C-167973	386497	6204076	conodonts	ramiform elements (1)	n/a	Ordovician - Triassic[1]
F_{23}	Nina Creek group (chert)	DMe89-12-5 (D. Melville)	C-168400	382655	6200088	conodonts	*Neogondolella serrata* Clark & Ethington (8) ramiform elements (2)	7	Late Permian (Guadalupian)[1]

Map Loc	Map Unit (Lithology)	Field Number (Sampler)	GSC Number	Easting	Northing	Fossils	Taxa (Number of Specimens)	CAI	Age (*Remarks*)
F_{24}	Nina Creek group (chert)	FFe89-21-12-1 (F. Ferri)	C-168380	385356	6211648	conodonts	*Streptognathodus* ex gr. excelsus (Stauffer & Plumer) (5) *Neognathodus?* sp. (1) *Neogondolella* sp. (100) *Gondolelloides* sp.(1) ramiform elements (4)	5	Early Permian (Asselian-Sakmarian)[1]
F_{25}	Nina Creek group (chert)	JHW89-3-4 (J.H. Whittles)	C-167968	377717	6212260	conodonts	*Neogondolella* sp. (2)	6.5-7	Permian[1]
F_{26}	Nina Creek group (chert)	FFe89-24-7 (F. Ferri)	C-167983	380903	6213307	conodonts	*Neogondolella* sp. (3) ramiform elements (5)	6-7	Permian[1]
F_{27}	Nina Creek group (chert)	FFe89-21-12-2 (F. Ferri)	C-167981	385356	6211648	conodonts	*Neogondolella* sp. (3) ramiform elements (5)	5	Permian[1]
F_{28}	Nina Creek group (chert)	FFe89-20-6-2 (F. Ferri)	C-168379	383633	6212702	conodonts	*Neogondolella* sp. (1) ramiform elements (1)	6.5-7	Permian[1]
F_{29}	Nina Creek group (chert)	DMe89-21-4 (D. Melville)	C-167966	378449	6216855	conodonts sphaeomorphs	ramiform elements (1)	5	Ordovician-Triassic[1]
F_{30}	Nina Creek group (chert)	FFe92-37-9-1	C-208306	379260	6220280	conodonts	ramiform elements (3) *Gnathodus* sp. (4)	5	Early Carboniferous[1]
F_{31}	Evans Creek limestone	DMe88-22-8-1 (D. Melville)	C-154369	385560	6182838	conodonts	*Ellisonia* sp. (2) *Neogondolella* sp. (6) *Hindrodus?* sp. (1)	5	Middle Permian-Early Triassic[1]
F_{32}	Evans Creek limestone	DMe88-30-2-1 (D. Melville)	C-154375	376373	6188431	conodonts sphaeomorphs	*Metapolygnathus* sp. (1)	4.5	Late Triassic (Carnian)[1]
F_{33}	Evans Creek limestone	FFe88-24-9-1 (F. Ferri)	C-154359	382438	6183992	conodonts	*Neogondolella cf. N. constricta* (Mosher & Clark) (1) *Neogondolella* sp. (6) ramiform elements (2)	5	Middle Permian-Middle Triassic[1] (*Anomalous association of neogondolellids, apparently a mixed fauna*)
F_{34}	Evans Creek limestone	RAR88-7-3-1 (R. Arksey)	C-154371	385021	6182878	conodonts	*Neogondolella* sp. (2)	5-6	Middle to Late Permian[1]
F_{35}	Evans Creek limestone	DMe88-30-2a (D. Melville)	C-154396	376347	6188558	conodonts	*Neogondolella* sp. (3)	5	Middle-Late Triassic(Ladinian-Carnian)[1]

Map Loc	Map Unit (Lithology)	Field Number (Sampler)	GSC Number	Easting	Northing	Fossils	Taxa (Number of Specimens)	CAI	Age (*Remarks*)
F_{36}	Evans Creek limestone	DMe88-30-2b (D. Melville)	C-154394	376347	6188558	conodonts	*Budurovignathus* ? sp. (1) *Metapolygnathus* spp. (9) *Neospathodus* cf. N. dieneri (Sweet) (1)	4.5-5	Late Triassic Carnian; Early Triassic[1] (*Neospathodus sp. is anomalous, presumably reworked)*
F_{37}	Evans Creek limestone	DMe88-30-2d (D. Melville)	C-154395	376347	618855	conodonts	*Metapolygnathus* sp. (1)	4.5-5.5	Late Triassic (Carnian)[1]
F_{38}	Evans Creek limestone	DMe88-30-2c (D. Melville)	C-154393	376347	6188558	conodonts	*Neogondolella ex gr. constricta* (Mosher & Clark) (8) ramiform elements (1)	4.5-5.5	Middle Triassic (late Anisian-early Ladinian)[1]
F_{39}	Takla Group (carbonate)	FF87-50-6 (F. Ferri)	C-153782	421720	6154450	conodonts	*Neogondolella* sp. indet. (4)	5-5.5	Middle-Late Triassic (Ladinian to Carnian)[1]
F_{40}	Takla Group (carbonate)	DMe88-4-9-1 (D. Melville)	C-154364	403705	6168728	conodonts	ramiform elements (1)	5	Ordovician to Triassic[1]
F_{41}	Takla Group (carbonate)	FFe88-3-3-2 (F. Ferri)	C-154355	404219	6170407	conodonts	*Metapolygnathus* sp. (2)	5	Late Triassic Carnian[1]

[1]M. J. Orchard, Cordilleran Division, Geological Survey of Canada, Vancouver, B. C.

[2]B. S. Norford, Paleontology Subdivision, Institute of Sedimentary and Petroleum Geology, Geological Survey of Canada, Calgary, Alberta.

[3]R. Ludvigsen, Denman Institute for Research on Trilobites, 4062 Wren Rd., Denman Is, B.C.

[4]Ross and Monger (1978)

[5]B. Mauer, Cominco Exploration Ltd., Vancouver, B.C.

CAI = Conodont Alteration Index. n/a = not available or not applicable

APPENDIX II
GEOCHRONOLOGY FOR ROCKS IN THE MANSON RIVER MAP AREA (93N/09 and 15)

U-Pb DATA

Rocks from the Wolverine Complex, Wolf Ridge gabbro and Big Creek group, in the Manson Lake area, were dated by U-Pb methods. The analytical data are listed in Table 7.

FF87-34-2, Dacite Tuff

Zircons separated from this dacite tuff were clear, nearly colourless to light brown, doubly terminated square sectioned prisms with aspect ratio 1:1-3. About 10% of the crystals were dark and opaque; these were avoided. Six fractions were air abraded, and the finest fraction was left intact to obtain a measure of lead loss. Acicular crystals with aspect ratio 1:4-6 were picked from the intermediate magnetic fraction. Cloudy cores were visible in 20% of the crystals; these were avoided in picked fractions.

The fractions analysed yield a pattern of combined lead loss and inheritance, as shown on the concordia plot in Figure 68. All fractions lie below concordia, but do not lie on a single discordia line. The four coarsest abraded fractions give a strong indication of inherited old zircon with an average age of 2.4±0.01 (2σ) Ga. Fractions b, c and d are less discordant but fall below the discordia line, thus indicating lead loss from the zircons. If these fine zircons have lost lead then the coarse ones may also have done so. Thus the lower intercept of the three-point discordia line through the coarse fractions defines the lower limit for the age of the rock, 377±12 (2σ) Ma. Since a rock should not be significantly older than the $^{207}Pb/^{206}Pb$ date of the most concordant fraction, the upper limit on the age is 533±7 Ma, from fraction d. Further analyses are required to define the age of the rock more precisely.

FF87-4-4-1, Wolf Ridge Gabbro

This gabbro yielded very few zircons, all of which were relatively magnetic. The zircons extracted were mostly fragments of euhedral to subhedral, doubly terminated prisms. They were clear and colourless, although some were stained by iron. All the zircons were used in the three analyses, divided by size because of the small amount of available material. They were not abraded prior to dissolution.

The fractions are plotted on a concordia diagram in Figure 69. The age of this rock is not well defined by the three analyses. Fraction a is relatively imprecise, but is essentially concordant. A minimum age for the rock is given by the $^{206}Pb/^{238}U$ date for this coarse fraction, 245.4 ± 0.7 Ma (2σ error), as listed in Table 7. Fractions b and c appear to have lost lead.

The three fractions have low uranium and lead contents (Table 7), and low measured $^{206}Pb/^{204}Pb$ ratios (under 1000). These two factors increase the analytical errors. The low $^{206}Pb/^{204}Pb$ ratios suggest that the zircons contained large amounts of common lead, or that the fractions were contaminated with either pyrite or feldspar. Unfortunately there was insufficient zircon available to repeat the analysis. This date is not precise, but gives an indication of the approximate stratigraphic age of the unit.

FF87-37-7, Wolverine Complex Granodiorite

The zircons extracted were clear and colourless, euhedral to subhedral acicular doubly terminated prisms. About 30% were fragments, and a few had cloudy, radiation-damaged cores. The best, clearest crystals were chosen for analysis. One of the zircon fractions was abraded. The monazites were clear, bright yellow, blocky, subhedral grains.

Two of the zircon fractions are strongly discordant, and are interpreted to contain inherited zircon. An analysis of the fine magnetic zircon fraction lies on concordia at about 71 Ma. Although the three zircon fractions do not fall on a single discordia line, they can be used to define limits on the age of this rock. The average age of the inherited zircon is 1.8±0.1 Ga (upper intercept of a two point regression through fractions b and c. The minimum age of intrusion is derived from the lower intercept of this regression (Figure 70), at 71.0±0.6 (2σ) Ma. Two fractions of monazite were analysed; they lie above concordia indicating the presence of excess ^{206}Pb resulting from ^{230}Th disequilibrium (Parrish, 1990). The $^{207}Pb/^{235}U$ age is the most reliable for monazite analyses; the mean of fractions e and f is 72.8±0.2 Ma, which is the same, within error, as the zircon age, and is considered to represent the intrusive age of the rock. The mean age is 72.6±0.2 Ma.

CONCLUSIONS

The interpreted results of U-Pb zircon dating of three samples in this area are as follows:

- The oldest rock is the dacite tuff from the Big Creek group, which gives a minimum age of 377±12 (2σ) Ma with lead loss, and inherited old zircon of average age 2.4±0.01 Ga.
- The date from the Wolf Ridge gabbro is of poor quality because of lack of material available, and is tentatively placed at a minimum of 245 ± 0.7 (2σ) Ma, based on three fractions.
- The youngest of the three rocks is the Wolverine Complex granodiorite, at 72.6± 0.2 Ma.

ANALYTICAL METHODS

Zircons and monazite are separated from finely crushed 10 to 40-kilogram rock samples using a wet shaking table, heavy liquids, and magnetic separator. The heavy mineral concentrates of samples FF87-34-2 and FF87-4-4-1 were washed in approximately 3N nitric acid for half an hour before separation to remove rust and some of the pyrite. The

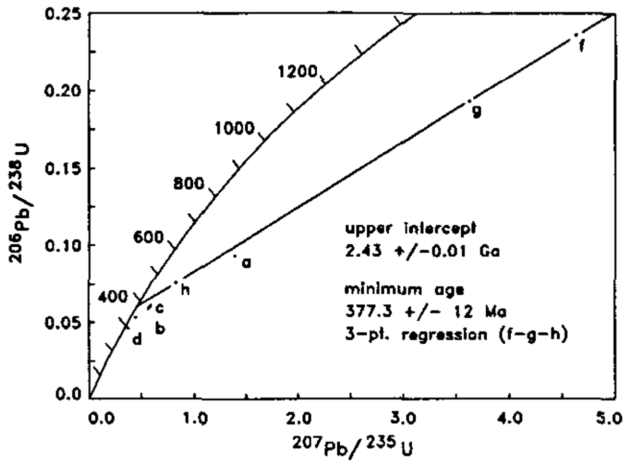

Figure 68. U-Pb concordia plot for Gilliland tuff. The fractions are labeled as in Table 7. Error envelopes are given at the 2σ level.

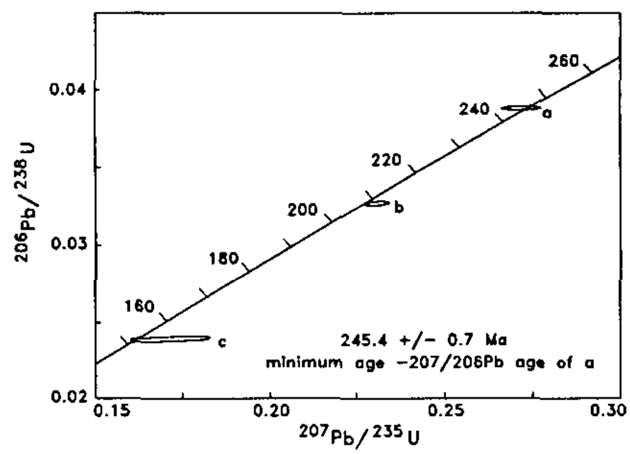

Figure 69. U-Pb concordia plot for Wolf Ridge gabbro. The fractions are labeled as in Table 7. Error envelopes are given at the 2σ level.

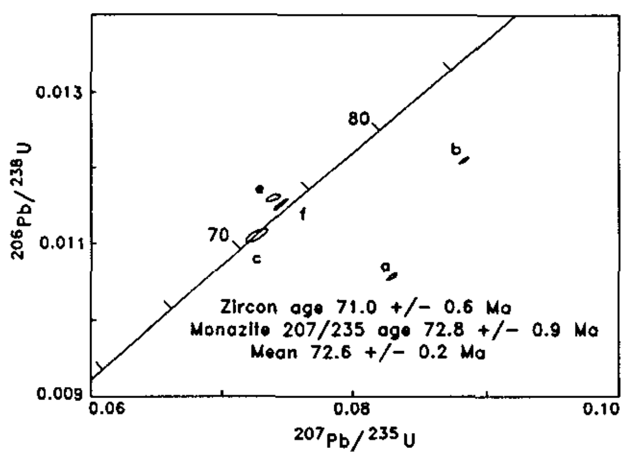

Figure 70. U-Pb concordia plot for Wolverine Range granodiorite. The fractions are labeled as in Table 7. Error envelopes are given at the 2σ level.

TABLE 7
U-PB DATA FOR SELECTED VOLCANIC AND IGNEOUS ROCKS IN THE MAP AREA.

Fraction:[1,2] Magnetic & size split	wt mg	U[3] ppm	Pb[3] ppm	^{208}Pb %	^{206}Pb/^{204}Pb Meas.[4]	^{206}Pb/^{238}U ratio±%1σ Date±2σ	^{207}Pb/^{235}U ratio±%1σ Date±2σ	^{207}Pb/^{206}Pb ratio±%1σ Date±2σ
FF87-34-2	**Dacite tuff**							
a NM1.8A/1°	1.0	276	28.1	11.9	2841	0.09323(.179)	1.3869(.201)	0.10789(.061)
+134μm abr						574.6±2.0	883.4±2.2	1764.0±2.2
b M1.8A/1°	0.30	670	35.5	7.5	2864	0.05330(.113)	0.4360(.130)	0.05933(.046)
-44μm						334.8±0.7	367.4±0.8	579.1±2.0
c M1.5A/3°	0.60	450	27.6	8.4	2546	0.06028(1.36)	0.5764(1.37)	0.06936(.089)
-74+44μm abr						377.3±10.0	462.1±10.2	909.3±3.7
d M1.8A/1°	0.10	638	30.8	9.8	877	0.04642(.085)	0.3717(.223)	0.05807(.168)
-74+44μm abr						292.5±0.5	320.9±1.2	532.5±7.4
f NM1.8A/1°	0.059	182	48.6	13.1	7827	0.23563(.060)	4.609(.097)	0.14188(.046)
+149μm abr						1363.9±1.5	1751.0±1.6	2250.3±1.6
g NM1.8A/1°	0.062	245	51.4	9.9	9387	0.19324(.047)	3.622(.051)	0.13594(.018)
+149μm abr						1138.9±1.0	1554.4±0.8	2176.2±0.6
h NM1.8A/1°	0.046	231	27.8	40.9	3075	0.07630(.103)	0.8287(.133)	0.07877(.081)
-104+74μm abr						474.0±0.9	612.9±1.2	1166.3±3.2
FF87-4-4-1	**Wolf Ridge Gabbro**							
a M1.5A/3°	0.20	43.6	1.75	12.5	316	0.03880(.140)	0.2718(1.04)	0.05082(.978)
+74μm						245.4±0.7	244.2±4.5	233±46
b M1.5A/3°	0.30	61.0	2.08	12.1	367	0.03271(.127)	0.2307(.807)	0.05115(.746)
-74μm						207.5±0.5	210.8±3.1	247±35
c bulk	0.020	92.1	2.82	18.4	88	0.02395(.364)	0.1714(3.33)	0.05191(3.13)
						152.6±1.1	160.6±9.9	282±150
FF87-37-7	**Wolverine Complex Granodiorite**							
a NM2A/1°	0.6	2281	23.6	5.9	1576	0.01055(.176)	0.0829(.222)	0.05700(.107)
-149+74μm						67.7±0.2	80.9±0.3	491.4±4.7
b M2A/1°	0.10	3430	39.6	5.0	8070	0.01209(.165)	0.0883(.185)	0.05300(.056)
+74μm						77.4±0.3	85.9±0.3	328.6±2.6
c M1.5A/3°	0.3	3803	177	78.2	778	0.01109(.375)	0.0725(.556)	0.04741(.337)
-74μm abr						71.1±0.5	71.0±0.8	70±16
e monazite	0.057	2093	208	88.9	632	0.01157(.239)	0.0739(.396)	0.04633(.259)
						74.2±0.4	72.4±0.6	14.9±12.5
f monazite	0.09	3983	283	85.2	1954	0.01148(.073)	0.0744(.147)	0.04700(.099)
						73.6±0.1	72.8±0.2	49.3±4.7

Notes: Analyses by J.E. Gabites, 1989 - 93, in the geochronology laboratory, Department of Geological Sciences, U.B.C.. IUGS conventional decay constants (Steiger and Jäger, 1977) are: $^{238}U\lambda=1.55125\times10^{-10}a^{-1}$, $^{235}U\lambda=9.8485\times10^{-10}a^{-1}$, $^{238}U/^{235}U=137.88$ atom ratio.

1. Column one gives the label used in the Figures.
2. Zircon fractions are labelled according to magnetic susceptibility and size. NM = non-magnetic at given amperes on magnetic separator, M = magnetic. Side slope is given in degrees. The - indicates zircons are smaller than, + larger than the stated mesh (μ). Abr = air abraded.
3. U and Pb concentrations in mineral are corrected for blank U and Pb. Isotopic composition of Pb blank is 206:207:208:204 = 17.299:15.22:35.673:1.00, based on ongoing analyses of total procedural blanks of 37 ±1 pg (Pb) and 6 ± 0.5 pg (U) during the time of this study.
4. Initial common Pb is assumed to be Stacey and Kramers (1975) model Pb at the $^{207}Pb/^{206}Pb$ age for each fraction.

TABLE 8
APPARENT AGE AND TRACK LENGTHS FROM APATITE GRAINS IN SELECTED SAMPLES FROM THE LOWER INGENIKA GROUP

Sample Number	Apparent Age(Ma) (Number of Grains)	Uranium (ppm)	Track Length(μm) (Number of Tracks)
FF87-38-4	48.3 ±3.5 (20)	29	13.3 ±1.6 (76)
DM87-31-12	42.4 ±3.4 (13)	22	12.4 ±1.9 (30)

Samples were analyzed and modeled by D.S. Miller of Rensselaer Polytechnic Institute, 1989.
Model based on zeta method using standard apatites from Fish Canyon tuff, Durango (Laslett *et al.*, (1987) and Green (1988).
Questions concerning analytical techniques and modeling should be addressed to Dr. Miller.
1σ standard deviation.
See Figure 58 for location of sample FF87-38-4

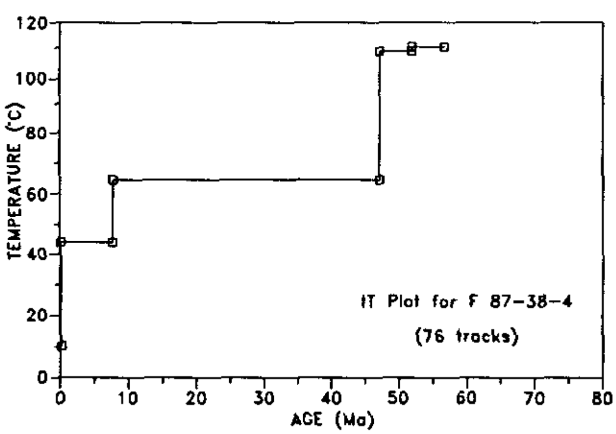

Figure 71. Apatite fission-track cooling curve history for sample FF87-38-4 from within high-grade rocks of the lower Ingenika Group. Pertinent data are shown in Table 8.

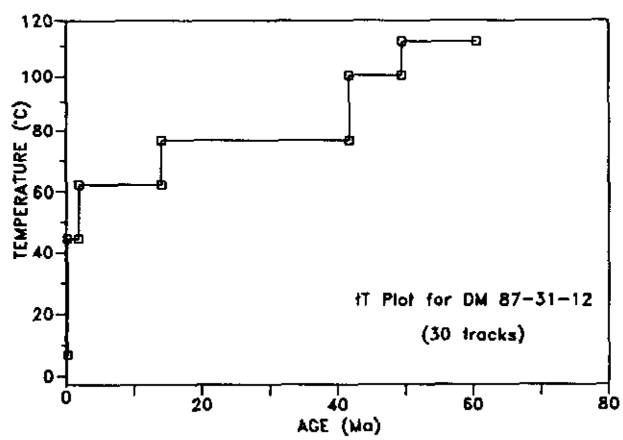

Figure 72. Apatite fission-track cooling curve history for sample DM87-31-12 from within high-grade rocks of the lower Ingenika Group. Pertinent data are shown in Table 8.

TABLE 9
K-Ar ANALYTICAL DATA

FIELD NUMBER	NTS MAP	UTM Easting	UTM Northing	ROCK UNIT	ROCK TYPE	MINERAL	K (%)	40*Ar (x10-6cc/gm)	40Ar (%)	AGE (Ma)
DM87-50-3	93N/9	405379	6160701	Ingenika Group	amphibolite gneiss	Hornblende	1.35 +/- 0.02	2.7	76.1	50.7 +/- 1.8
FF87-15-4	93N/9	405539	6169966	Manson Lks Umfcs	talc-ankerite schist	Muscovite	8.32 +/- 0.03	44.995	95.1	134 +/- 5
FF87-18-8	93N/9	425259	6159563	Ingenika Group	schist	Biotite	4.22 +/- 0.02	5.406	46.1	32.7 +/- 1.2
FF87-22-1	93N/9	421917	6155095	Unnamed	sub-volcanic andesite	Biotite	6.87 +/- 0.06	13.164	87.2	48.6 +/- 1.7
FFE88-21-1	93N/10	382415	6166366	Germansen Bath.	quartz monzonite	Biotite	4.80 +/- 0.05	9.913	90.2	52.4 +/- 1.8
FFE89-38-10	94C/2	405433	6217889	Ingenika Group	micaceous quartzite	Biotite	6.45 +/- 0.01	12.247	84.9	48.2 +/- 1.7
FFE89-38-17	94C/2	398867	6215476	Ingenika Group	micaceous quartzite	Biotite	7.23 +/- 0.06	16.889	90.1	59.1 +/- 2.1
FFE89-38-18	94C/2	394645	621635	Ingenika Group	micaceous quartzite	Whole Rock	0.709 +/- 0.014	4.95	95.8	171 +/- 6
FFE89-39-1	94C/2	399003	6213339	Ingenika Group	micaceous quartzite	Biotite	7.45 +/- 0.03	24.381	95.6	82.3 +/- 2.8
GM87-12-4	93N/9	409097	6153355	Germansen Bath.	granite	Biotite	7.10 +/- 0.07	30.187	90.1	106 +/- 4
GM87-9-1	93N/9	417740	6174775	Ingenika Group	schist	Muscovite	8.07 +/- 0.08	15.737	70.9	49.5 +/- 1.7

* = Radiogenic argon
Decay constants: 40K epsilon=0.581 x 10- 10 year; 40K beta=4.96 x 10- 10 year-1; 40k/k = 1.167 x 10-4.
Potassium determined at the The University of British Columbia geochronology laboratory; ages given with 1 sigma error.
Argon determination and age calculation by J.E. Harakal, The University of British Columbia.

concentrates are split into magnetic (M) and nonmagnetic (NM) fractions, sized using new nylon mesh screens, and hand picked to 100% purity. Concordance is improved by air abrasion techniques (Krogh, 1982). Chemical dissolution and mass spectrometry procedures are modified slightly from those of Parrish *et al.*, (1987). A mixed ^{205}Pb-^{233}U-^{235}U spike is used (Parrish and Krogh, 1987; Roddick *et al.*, 1987). The dissolution is in small-volume teflon capsules contained in a large Parr bomb (Parrish, 1987). Both uranium and lead are run on the same Re filament with silica gel and phosphoric acid. Lead is run first at 1250-1300°C, then the uranium at 1350-1400°C. A Daly collector is used to improve the quality of measurement of low-intensity ^{204}Pb signals. The error propogation technique of Roddick *et al.* (1987) is used to calculate errors associated with individual analyses. The laboratory blank has an isotopic composition: Pb 206:207:208:204 = 17.299:15.22:35.673:1.00. Current laboratory blanks for uranium and lead are approximately 6 ± 0.5 and 37 ± 0.4 picograms respectively, based on ongoing analyses of total procedural blanks. A larger value may be used in data reduction to correct for unusually large amounts of common lead incorporated into some fractions. The isotopic composition of common lead is based on the Stacey and Kramers (1975) common lead growth curve, and is taken at the age of the $^{207}Pb/^{206}Pb$ age of the fraction. The decay constants are those recommended by the IUGS Subcommission on Geochronology (Steiger and Jäger, 1977). Concordia intercepts are calculated using a modified York-II regression model (Parrish *et al.*, 1987) and Ludwig (1980) error algorithm. Errors reported for the raw U-Pb data are one sigma; those for final dates and shown on concordia plots are two sigma (95% confidence limits).

APATITE FISSION-TRACK

The following account was provided by Donald S. Miller (Geology, Rensselaer Polytechnic Institute) who performed the analyses on these samples.

These two samples do not seem to have very similar cooling histories, however, with only 30 tracks suitable for track length measurement we have little faith in the thermal history plot for DM87-31-12 and thus discount it completely. The cooling history for FF87-38-4 seems to be very similar to SDU88-15-11. We are somewhat perplexed by the young K-Ar ages on biotite which indicate temperatures in the range of 200°C at 40 Ma while the apatite tracks start to be retained at 45 to 50 Ma (requiring temperatures below 100°C)! The hornblende data of 512 Ma suggest that the cooling from approximately 500°C to 100°C occurred very rapidly, perhaps over a period of a few million years.

APPENDIX III

Sample location maps and data tables for whole-rock and trace element data Manson Creek area. Figures 8a, b and c correspond to the area covered by the geology map in the pocket at the back of this report.

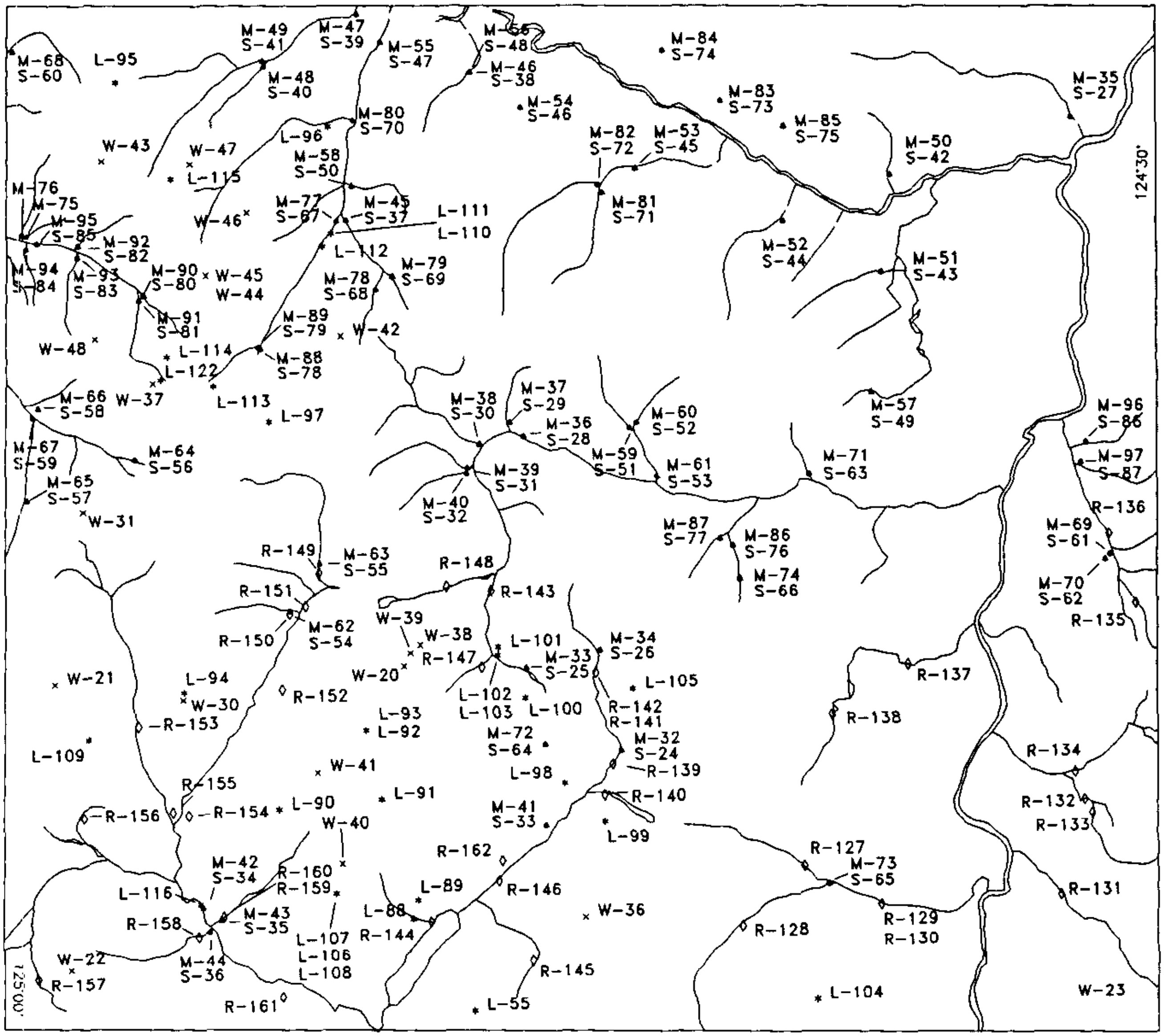

Figure 8a.

LEGEND

× –Whole Rock and Trace element lithogeochemistry sample site

• –Lithogeochemistry of mineralized and non-mineralized rocks. sample site

▴ –Stream and moss-mat geochemistry sample site

◊ –1983 Regional geochemical stream sediment sample site

• –Bulk, moss-mat and stream sediment geochemicstry

Sample numbers refer to listings in appendices III and IX

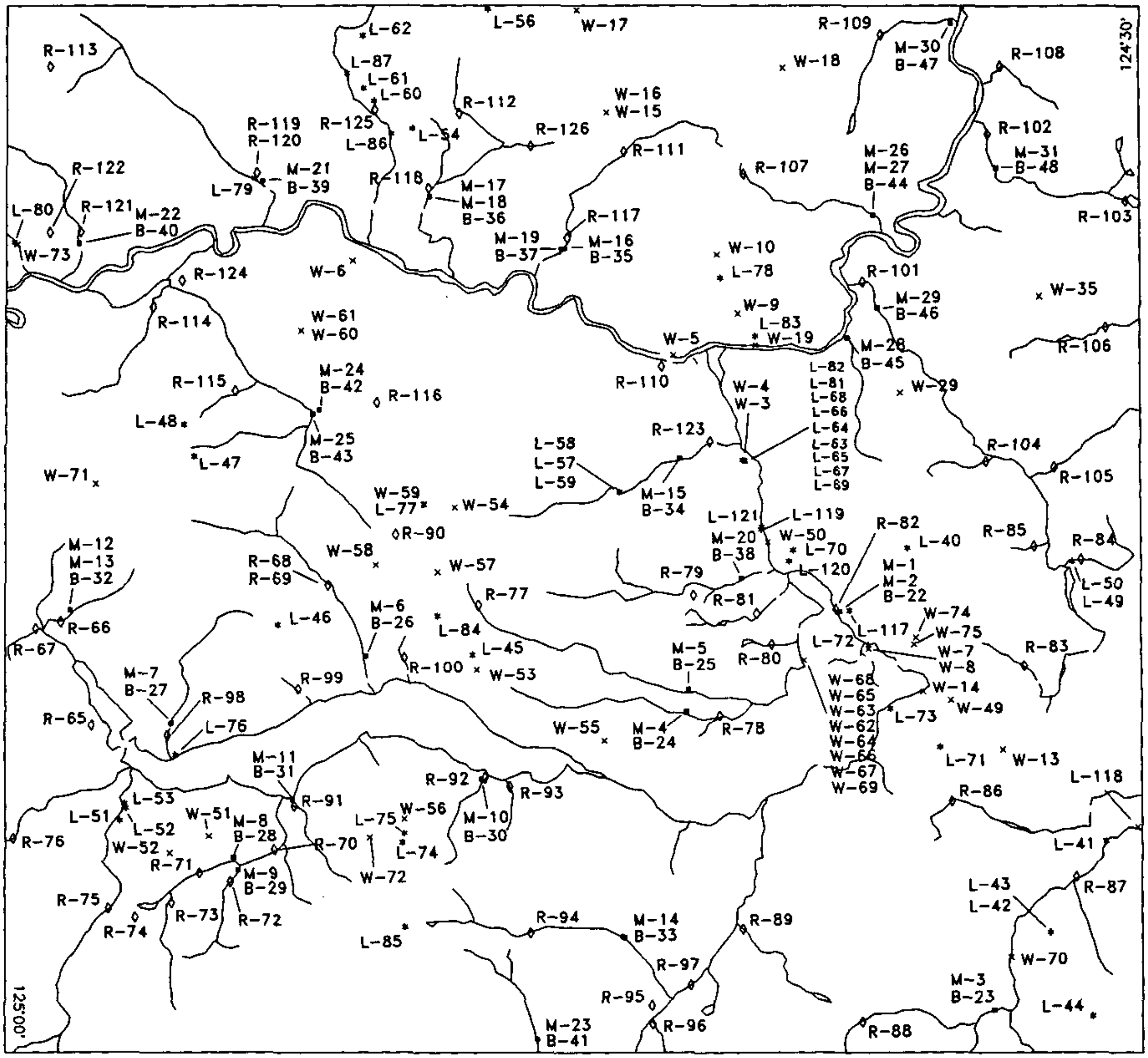

Figure 8b.

LEGEND

× –Whole Rock and Trace element lithogeochemistry sample site

* –*Lithogeochemistry of mineralized and non-mineralized rocks. sample site*

▴ –Stream and moss-mat geochemistry sample site

◊ –1983 Regional geochemical stream sediment sample site

▪ –Bulk, moss-mat and stream sediment geochemicstry

Sample numbers refer to listings in appendices III and IX

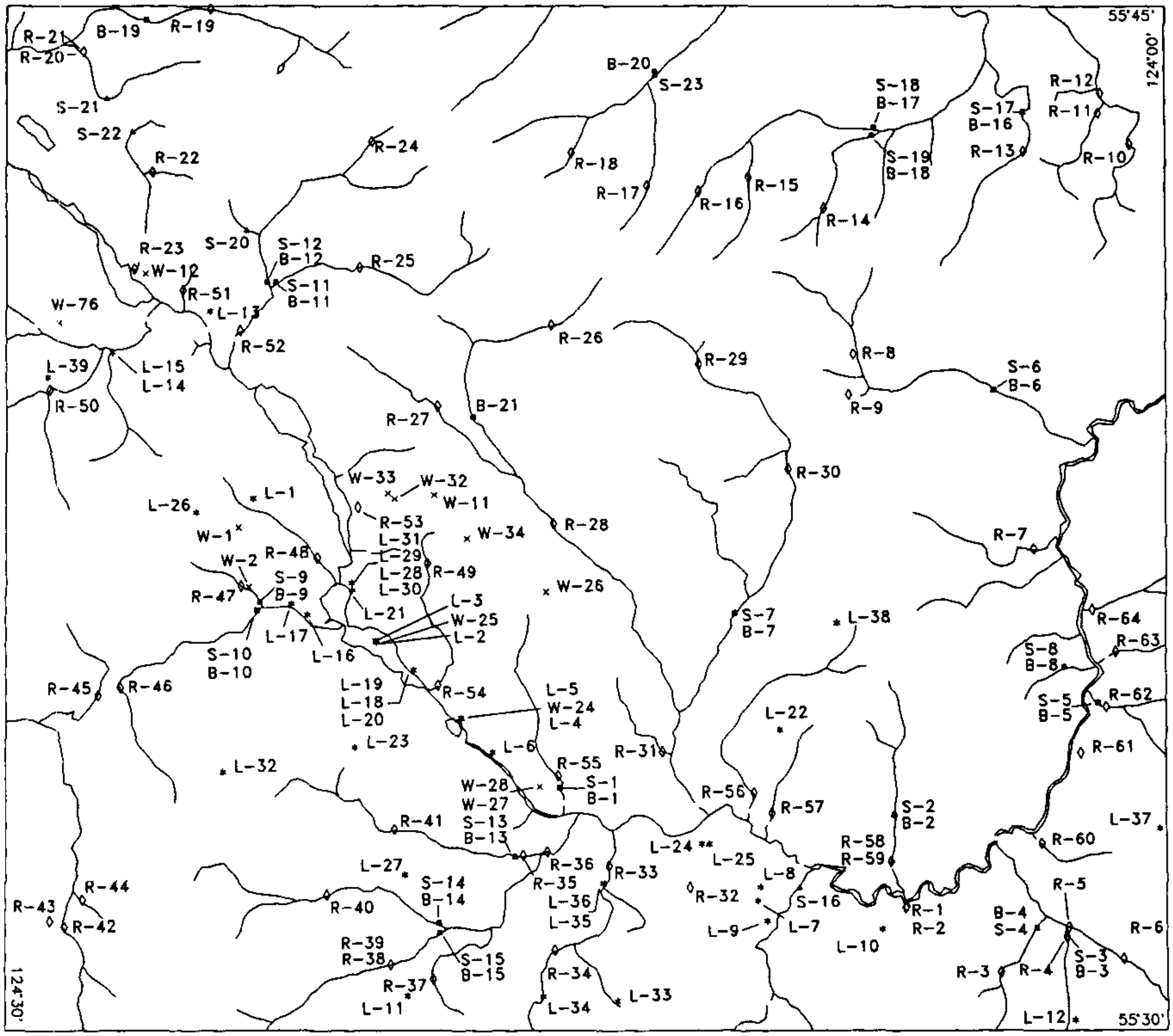

Figure 8c.

LEGEND

× –Whole Rock and Trace element lithogeochemistry sample site

* –Lithogeochemistry of mineralized and non-mineralized rocks. sample site

▴ –Stream and moss-mat geochemistry sample site

◊ *–1983 Regional geochemical stream sediment sample site*

• –Bulk, moss-mat and stream sediment geochemicstry

Sample numbers refer to listings in appendices III and IX

APPENDIX III

LIST OF WHOLE-ROCK AND TRACE ELEMENT DATA FOR VARIOUS VOLCANIC AND IGNEOUS ROCKS

Map No.	GROUP	ROCK TYPE	FIELD NUMBER	UTM Easting	UTM Northing	SiO_2 %	TiO_2 %	Al_2O_3 %	Fe_2O_3 %	MnO %	MgO %	CaO %	Na_2O %	K_2O %	P_2O_5 %	LOI %	SUM %	FeO %	CO_2 %	S %
W-1	Boulder Creek	amphibolite	DME87-10-01	411856	6164736	50.40	1.04	14.82	10.21	0.15	6.80	8.34	2.35	0.03	0.09	6.80	99.05	na	na	na
W-2	Boulder Creek	amphibolite	FFE87-13-10	412089	6163116	48.95	1.43	16.70	10.07	0.21	5.82	8.95	3.76	0.46	0.16	3.07	99.71	na	na	na
W-3	Big Creek	felsic tuff	DME88-46-7	394988	6180580	67.94	0.71	15.59	3.30	0.03	0.66	1.41	3.31	2.80	0.15	3.15	99.05	1.27	1.81	0.64
W-4	Big Creek	felsic tuff	DME88-46-8	394988	6180580	67.67	0.55	15.20	2.71	0.04	1.21	1.89	1.55	3.54	0.15	4.49	99.00	1.56	3.07	0.38
W-5	Big Creek	felsic tuff	FFE88-34-2	393078	6183563	70.25	0.71	14.66	3.50	0.03	0.83	0.44	1.46	5.71	0.17	2.16	99.92	1.27	0.75	<0.01
W-6	Gabbro	gabbro	FFE88-39-1	384251	6186423	47.04	0.22	14.66	5.02	0.11	9.53	17.35	1.23	0.27	0.00	4.55	99.98	3.41	2.21	0.10
W-7	Takla?	basalt	FFE88-9-1	398275	6175243	50.64	1.50	15.86	10.12	0.17	5.60	8.52	4.15	0.02	0.17	2.88	99.65	na	na	na
W-8	Takla?	basalt	FFE88-9-1-1	398275	6175243	45.37	0.78	12.98	10.41	0.19	9.86	6.88	1.83	0.63	0.11	10.81	99.85	8.31	6.51	<0.01
W-9	Nina Creek	basalt	FFE88-28-11	394888	6184687	48.22	1.38	15.17	10.58	0.16	7.83	9.63	2.36	1.04	0.11	3.38	99.86	5.94	0.15	0.11
W-10	Nina Creek	basalt	FFE88-29-10	394341	6186346	49.70	1.61	13.94	11.66	0.21	5.91	10.78	3.15	0.06	0.13	2.68	99.83	8.34	0.18	0.11
W-11	Nina Creek	basalt	DME87-49-3	417163	6165518	48.65	1.92	15.57	11.27	0.18	4.92	10.57	3.95	0.17	0.22	1.82	99.27	na	na	na
W-12	Nina Creek	basalt	FFE87-19-4	409468	6171661	48.27	1.68	14.08	11.27	0.20	7.02	9.72	3.64	0.07	0.17	3.19	99.35	na	na	na
W-13	Takla?	basalt	FFE88-3-6	401902	6172297	48.37	0.87	17.03	10.08	0.19	5.29	6.96	3.62	2.47	0.15	4.52	99.55	4.97	1.85	<0.01
W-14	Takla?	basalt	FFE88-8-10	399739	6173963	42.12	0.58	13.21	7.58	0.14	6.19	13.06	1.60	1.62	0.14	13.78	100.02	6.53	10.1	<0.01
W-15	Nina Creek(Duplicate)	basalt	FFE88-35-1	391381	6190394	51.91	1.53	13.63	11.35	0.20	5.83	9.20	3.09	0.35	0.13	2.66	99.88	8.95	0.46	<0.01
W-16	Nina Creek	basalt	FFE88-35-1	391381	6190394	51.88	1.53	13.61	11.39	0.20	5.87	9.24	3.11	0.34	0.13	2.66	99.96	8.17	0.43	<0.01
W-17	Nina Creek	basalt	FFE88-37-1	390625	6193262	51.33	1.57	13.99	11.25	0.19	6.04	8.82	4.25	0.06	0.13	2.47	100.10	6.46	0.21	<0.01
W-18	Nina Creek	basalt	FFE88-41-4	396299	6191518	50.60	1.76	14.06	11.61	0.20	6.35	9.50	3.77	0.08	0.17	1.98	100.08	8.52	0.29	0.01
W-19	Nina Creek	basalt	FFE88-48-1	395358	6183799	49.30	1.30	14.78	10.49	0.17	7.66	9.42	2.90	0.67	0.10	3.05	99.84	6.55	0.60	0.03
W-20	Nina Creek	basalt	FFE89-6-10	385919	6203446	48.76	1.49	14.04	10.72	0.16	8.22	12.60	2.59	0.03	0.15	2.97	99.73	7.26	<0.14	<0.01
W-21	Nina Creek	basalt	FFE89-18-09	376490	6203168	48.61	1.34	14.40	10.63	0.17	7.20	10.34	3.38	0.06	0.11	3.15	99.39	6.75	<0.14	0.08
W-22	Nina Creek	basalt	FFE89-41-14	376722	6195365	50.55	1.21	16.08	10.27	0.18	5.26	7.55	4.93	0.20	0.10	2.89	99.22	6.75	<0.14	0.05
W-23	Blue Lake Volcanics	basalt	FFE89-50-3	405507	6193793	49.57	1.33	16.16	10.17	0.15	5.86	7.81	4.03	2.08	0.85	1.23	99.35	na	na	na
W-24	Nina Creek	gabbro	DME87-15-1-1	417769	6159455	48.76	0.5	16.14	7.56	0.14	7.51	11.16	1.36	0.8	0.01	5.91	99.83	4.39	0.14	<0.01
W-25	Nina Creek	gabbro	DME87-15-1-3	415500	6161584	48.21	0.42	16.95	6.84	0.13	7.44	11.07	1.75	0.33	0.03	6.68	99.85	4.13	0.55	0.02
W-26	Nina Creek	gabbro	FFE87-7-2	420136	6162824	55.20	2.18	14.16	12.11	0.23	2.41	4.42	6.66	0.21	0.39	1.55	99.58	na	na	na
W-27	Nina Creek(Duplicate)	gabbro	FFE87-29-1	419877	6157562	48.44	1.83	15.08	5.89	0.12	6.56	17.45	1.82	0.2	0.17	2.74	100.23	4.45	0.07	0.02
W-28	Nina Creek	gabbro	FFE87-29-1	419877	6157562	47.37	1.95	15.03	6.09	0.12	6.56	16.90	1.97	0.21	0.21	2.95	99.49	na	na	na
W-29	Nina Creek	basalt	FFE88-42-7	399315	6182367	50.30	1.65	15.48	11.47	0.23	5.66	8.63	3.66	0.21	0.15	2.47	99.91	8.45	0.15	<0.01
W-30	Nina Creek	basalt	DME89-15-6	379941	6202679	47.39	1.68	13.46	12.32	0.20	7.94	9.43	3.49	0.07	0.13	3.04	99.15	9.13	<0.14	0.10
W-31	Nina Creek	basalt	DME89-16-9	377366	6207814	49.38	1.47	13.80	10.45	0.19	5.87	14.00	0.78	0.09	0.14	3.56	99.73	6.75	<0.14	<0.01
W-32	Nina Creek	gabbro	DME87-13-10	416089	6165443	49.13	1.43	16.42	10.45	0.23	5.72	9.35	3.46	0.43	0.12	2.93	99.67	6.16	0.07	<0.01
W-33	Nina Creek	gabbro	DME87-13-11	415912	6165595	48.92	1.44	14.99	10.45	0.18	6.83	8.68	3.20	0.84	0.14	3.10	98.90	na	na	na
W-34	Nina Creek	gabbro	DME87-49-10	418020	6164320	48.23	1.23	14.32	10.14	0.17	7.83	11.21	2.94	0.20	0.12	3.16	99.63	na	na	na
W-35	Nina Creek	gabbro	FFE88-43-1	403211	6184950	60.09	0.87	15.34	9.81	0.19	1.13	4.45	5.22	0.41	0.26	2.27	100.04	1.20	0.15	<0.01
W-36	Nina Creek	gabbro	DME89-8-7	390696	6196554	47.14	1.32	15.85	10.00	0.17	6.80	10.73	3.26	0.08	0.12	3.60	99.07	7.40	<0.14	<0.01
W-37	Nina Creek	basalt	DME89-18-4	379314	6211280	49.14	1.78	15.14	11.49	0.17	7.15	7.12	3.54	0.43	0.16	3.08	99.20	8.69	<0.14	<0.01
W-38	Nina Creek	gabbro	FFE89-6-5	386366	6203993	47.14	1.27	11.57	10.92	0.20	11.20	11.56	1.54	0.96	0.11	3.05	99.52	8.60	<0.14	<0.01
W-39	Nina Creek	gabbro	FFE89-6-7	386093	6203782	50.23	1.55	14.32	10.79	0.18	6.96	7.94	4.23	0.26	0.14	2.67	99.27	8.41	<0.14	<0.01
W-40	Nina Creek	basalt	FFE89-15-08	384117	6198147	49.10	1.56	12.65	11.59	0.20	7.40	11.99	1.77	0.24	0.13	3.28	99.91	7.55	<0.14	0.10

Map No.	GROUP	ROCK TYPE	FIELD NUMBER	UTM Easting	UTM Northing	SiO2 %	TiO2 %	Al2O3 %	Fe2O3 %	MnO %	MgO %	CaO %	Na2O %	K2O %	P2O5 %	LOI %	SUM %	FeO %	CO2 %	S %
W-41	Nina Creek	gabbro	FFE89-16-09	383513	6200640	48.83	1.01	15.06	9.66	0.17	7.13	11.59	2.13	0.04	0.08	4.11	99.81	7.26	<0.14	<0.01
W-42	Nina Creek	gabbro	FFE89-20-12	384420	6212444	46.12	2.88	12.64	16.05	0.25	5.27	9.43	2.70	0.41	0.14	3.35	99.24	8.12	<0.14	0.02
W-43	Nina Creek	gabbro	FFE89-23-27	378089	6217301	48.91	1.07	13.93	9.74	0.20	8.47	11.04	2.58	0.71	0.09	2.72	99.46	7.69	<0.14	<0.01
W-44	Nina Creek	gabbro	FFE89-24-12	380816	6214157	49.40	1.65	14.11	10.58	0.21	6.53	10.40	3.41	0.11	0.15	2.74	99.29	8.34	032	<0.01
W-45	Nina Creek(Duplicate)	gabbro	FFE89-24-12D	380816	6214157	49.28	1.65	14.11	10.58	0.20	6.48	10.39	3.41	0.12	0.14	2.73	99.09	8.26	<0.14	<0.01
W-46	Nina Creek	gabbro	FFE89-29-17	381971	6215827	47.74	1.71	14.10	11.74	0.20	7.45	10.35	3.38	0.02	0.13	2.94	99.76	8.91	0.26	<0.01
W-47	Nina Creek	gabbro	JWH89-5-6	380465	6217169	48.33	1.79	13.89	11.55	0.23	7.12	10.14	3.22	0.04	0.17	2.82	99.30	8.77	0.43	<0.01
W-48	Nina Creek	ultramafic	JWH89-3-7	377801	6212518	36.79	0.43	3.16	17.20	0.25	29.87	2.59	0.00	0.02	0.04	9.36	99.71	8.38	<0.14	0.01
W-49	Takla	basalt	DME88-6-12	400493	6173710	47.15	0.88	14.60	10.19	0.16	5.03	9.47	3.69	0.34	0.24	8.06	99.81	7.81	5.19	0.01
W-50	Takla	basalt	DME88-8-5	395556	6178281	37.70	0.01	0.46	12.85	0.06	37.20	0.05	0.00	0.00	0.00	12.69	101.02	2.90	2.13	0.06
W-51	Takla	basalt	DME88-10-5	379844	6170461	50.18	0.72	14.52	9.10	0.14	5.89	12.11	3.30	0.80	0.21	3.04	100.01	7.10	2.97	<0.01
W-52	Takla	basalt	DME88-10-9	378744	6170023	50.82	0.63	11.38	10.94	0.21	8.57	11.72	1.03	2.74	0.36	1.28	99.66	7.61	<0.15	0.08
W-53	Takla	basalt	DME88-11-14	387414	6174912	52.63	0.81	18.83	6.84	0.14	4.43	7.69	3.28	1.58	0.20	3.11	99.54	3.55	0.15	0.01
W-54	Takla	basalt	DME88-14-6	386911	6179481	42.76	2.38	12.52	13.42	0.28	9.89	10.57	1.60	0.92	0.67	4.39	99.40	9.95	0.78	<0.01
W-55	Takla	basalt	FFE88-7-9	390909	6172814	49.90	0.91	15.16	10.80	0.19	6.12	7.55	3.49	1.97	0.58	3.02	99.69	7.39	0.15	<0.01
W-56	Takla	basalt	FFE88-13-14	385281	6170807	48.01	0.83	17.81	10.56	0.22	4.98	8.35	3.33	2.20	0.30	3.11	99.70	6.89	1.55	0.18
W-57	Takla	basalt	FFE88-17-4	386390	6177694	49.69	2.11	15.48	11.76	0.19	3.53	7.85	4.66	1.25	0.41	3.05	99.98	4.76	0.92	0.01
W-58	Takla	basalt	FFE88-17-12	384680	6177929	46.70	1.71	17.56	11.29	0.19	4.79	8.93	3.23	1.35	0.28	3.89	99.92	6.53	0.15	0.05
W-59	Takla	basalt	FFE88-18-6-2	386061	6179595	45.23	1.78	17.88	10.68	0.17	8.11	6.61	1.63	2.29	0.36	5.10	99.84	5.40	0.15	0.01
W-60	Takla(Duplicate)	basalt	FFE88-24-12	382788	6184523	50.17	1.01	14.02	11.24	0.17	7.92	8.20	3.67	0.15	0.15	3.19	99.89	5.68	<0.15	<0.01
W-61	Takla	basalt	FFE88-24-12	382788	6184523	50.19	1.01	14.01	11.20	0.17	7.92	8.18	3.65	0.13	0.15	3.21	99.82	5.97	<0.15	<0.01
W-62	Takla	basalt	GRP-1	396471	6174960	47.75	0.90	16.27	11.77	0.21	6.17	6.05	3.99	0.74	0.06	5.65	99.56	4.12	2.41	<0.01
W-63	Takla	basalt	GRP-2	396471	6174960	46.84	0.84	16.31	11.28	0.18	5.57	6.74	3.57	1.45	0.24	6.70	99.72	4.69	3.26	<0.01
W-64	Takla	basalt	GRP-3	396471	6174960	48.64	0.86	16.44	11.20	0.17	6.06	5.10	3.73	1.22	0.05	6.31	99.78	5.25	3.11	<0.01
W-65	Takla	basalt	GRP-4	396471	6174960	47.74	0.72	14.50	9.61	0.20	6.09	8.00	2.51	1.33	0.18	8.86	99.74	5.11	5.13	<0.01
W-66	Takla	basalt	GRP-5	396471	6174960	45.89	0.82	15.51	10.53	0.14	5.61	5.85	2.67	1.69	0.04	11.17	99.92	6.11	8.74	<0.01
W-67	Takla	basalt	GRP-6	396471	6174960	43.44	0.76	15.11	10.07	0.16	5.64	6.74	2.27	2.14	0.11	13.08	99.52	6.11	10.1	<0.01
W-68	Takla	basalt	GRP-7	396471	6174960	46.57	0.72	15.19	9.73	0.16	3.93	5.86	1.96	2.79	0.05	12.98	99.94	3.12	10.1	<0.01
W-69	Takla	basalt	GRP-8	396471	6174960	44.87	0.63	12.53	8.63	0.21	4.10	8.99	1.54	2.62	0.16	15.30	99.58	3.69	13.2	0.01
W-70	Takla	basalt	FFE88-4-1-1	401981	6166512	48.26	1.62	17.01	12.32	0.12	5.30	10.45	2.66	0.56	0.29	1.12	99.71	9.16	0.68	0.01
W-71	Takla	basalt	FFE88-23-7	376996	6180419	50.62	0.64	16.33	8.83	0.21	3.86	6.33	3.32	4.76	0.71	3.96	99.57	4.40	0.96	0.01
W-72	Takla	diorite	FFE88-13-7	384307	6170301	53.49	0.67	11.79	9.02	0.17	10.25	7.27	2.05	2.08	0.26	2.66	99.71	7.60	<0.15	0.01
W-73	Takla	gabbro	FFE88-33-1	374984	6187123	49.06	1.29	14.62	10.94	0.19	7.72	8.04	3.73	0.16	0.12	3.88	99.75	6.96	0.89	0.01
W-74	Wolf Ridge Gabbro	gabbro	DME88-2-8	399599	6175522	58.32	1.41	13.66	9.96	0.21	2.69	5.29	5.75	0.27	0.27	1.81	99.66	na	na	na
W-75	Wolf Ridge Gabbro	gabbro	DME88-2-9	399527	6175333	49.29	1.80	14.89	12.16	0.21	6.44	7.87	3.65	0.24	0.18	2.82	99.59	na	na	na
W-76	Wolf Ridge Gabbro	gabbro	FFE87-4-2	407119	6170389	47.62	0.89	17.44	8.47	0.14	6.62	13.93	2.00	0.08	0.05	2.31	99.61	na	na	na

Map No.	GROUP	Cr2O3 %	Cu ppm	Pb ppm	Zn ppm	Ni ppm	Mo ppm	Cr ppm	Ba ppm	Sr ppm	Rb ppm	Zr ppm	Y ppm	Nb ppm	Ta ppm	U ppm	Th ppm	Cs ppm	La ppm	Ce ppm	Co ppm	W ppm
W-1	Boulder Creek	0.01	64	5	121	29	8	51	<50	77	16	56	30	10	0.5	0.5	0.2	1	2	7	31	1
W-2	Boulder Creek	0.02	is	is	is	is	is	62	990	na	na	na	na	na	0.5	0.5	0.2	1	2.8	9	31	1
W-3	Big Creek	na	8	18	40	8	<8	<50	4100	130	120	190	19	21	1.2	3.1	17.0	2.7	48	91	13	
W-4	Big Creek	na	19	10	42	6	<8	<50	4100	125	120	250	31	10	1.5	4.1	17.0	4.7	47	100	16	
W-5	Big Creek	na	12	15	63	10	<8	<50	2400	110	190	185	30	19	1.5	3.9	16.0	3.7	30	73	24	
W-6	Gabbro	na	101	<5	27	193	<8	950	990	330	<10	48	12	20	<1.0	<0.5	<0.5	<1.0	<5	<10	35	
W-7	Takla?	0.01	33	5	75	46	8	59	150	304	10	131	41	10	0.5	0.5	0.2	1	4	13	30	1
W-8	Takla?	na	60	<3	72	92	<10	230	220	270	<10	82	17	22	<1.0	1.1	1.2	1.2	6	14	35	<2
W-9	Nina Creek	na	74	<5	77	82	<8	210	150	135	17	120	30	19	<1.0	<0.5	<0.5	1.2	<5	15	40	
W-10	Nina Creek	na	53	<5	84	42	<8	130	120	110	<10	130	34	23	<1.0	<0.5	<0.5	1.0	<5	<10	42	
W-11	Nina Creek	0.01	35	5	82	26	8	37	180	237	10	143	49	10	0.5	0.5	0.2	1	5.1	17	30	1
W-12	Nina Creek	0.03	15	5	64	77	8	190	190	208	10	103	46	10	1.2	0.5	0.2	1	3.9	15	36	1
W-13	Takla?	na	122	<3	109	16	<10	<50	300	200	44	95	25	19	<1.0	<0.5	2.0	1.5	14	27	31	<2
W-14	Takla?	na	104	<3	61	77	<10	280	310	170	22	94	23	12	<1.0	<0.5	1.3	<1.0	7	<10	29	<2
W-15	Nina Creek(Duplicate)	na	51	<5	86	52	<8	140	150	235	<10	120	33	21	<1.0	<0.5	<0.5	<1.0	<5	<10	41	
W-16	Nina Creek	na	50	<5	83	50	<8	140	180	180	<10	125	27	<5	<1.0	<0.5	0.5	<1.0	<5	16	38	
W-17	Nina Creek	na	63	<5	94	64	<8	170	<100	100	<21	135	39	11	<1.0	<0.5	<0.5	<1.0	<5	<10	43	
W-18	Nina Creek	na	44	6	83	60	<8	230	<100	89	<21	140	43	22	<1.0	<0.5	<0.5	<1.0	5	<10	40	
W-19	Nina Creek	na	67	<5	73	75	<8	220	<100	160	<10	105	26	15	<1.0	<0.5	<0.5	<1.0	5	<10	38	
W-20	Nina Creek	na	57	6	111	76	<8	229	22	30	10	112	36	11	na	na	na	5	23	22	33	
W-21	Nina Creek	na	68	4	85	90	<8	232	35	47	1	87	31	8	na	na	na	6	20	27	32	
W-22	Nina Creek	na	91	<4	76	23	<8	24	78	82	5	85	29	8	na	na	na	8	9	22	25	
W-23	Blue Lake Volcanics	na	26	7	100	51	8	100	800	1046	28	295	27	24	0.5	0.5	4.4	1	38	77	30	
W-24	Nina Creek	na	52	8	34	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
W-25	Nina Creek	na	60	10	32	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na	na
W-26	Nina Creek	0.01	4	5	70	2	8	20	430	111	15	193	93	13	0.5	0.5	0.2	7	10	32	18	1
W-27	Nina Creek(Duplicate)	na	25	15	44	na	na	120	850	160	10	110	46	10	0.5	0.5	0.4	1	2.1	10	27	1
W-28	Nina Creek	0.02	25	15	44	na	na	120	850	160	10	110	46	10	0.5	0.5	0.4	1	2.1	10	27	1
W-29	Nina Creek	na	53	5	102	48	<8	<50	240	150	<21	135	33	<5	<1.0	<0.5	<0.5	<1.0	<5	<10	33	
W-30	Nina Creek	na	67	4	87	88	<8	277	195	67	3	104	37	11	na	na	na	7	21	26	40	
W-31	Nina Creek	na	50	4	81	64	<8	181	55	126	1	108	38	8	na	na	na	3	11	20	33	
W-32	Nina Creek	na	10	20	78	na	na	na	na	548	19	154	37	10	is	is	is	is	is	is	is	is
W-33	Nina Creek	0.04	is	is	Is	is	is	is	is	81	45	90	34	10	is	is	is	is	is	is	is	is
W-34	Nina Creek	0.04	66	5	66	92	8	220	420	150	10	89	32	10	40	0.5	0.2	1	2.5	11	39	1
W-35	Nina Creek	na	8	5	48	4	<8	<50	600	160	<23	270	67	12	<1.3	<0.5	<0.5	4.8	13	24	20	
W-36	Nina Creek	na	18	<4	63	60	<8	24	84	179	1	95	31	7	na	na	na	6	14	22	35	
W-37	Nina Creek	na	64	<4	88	79	<8	226	121	154	6	125	39	11	na	na	na	4	16	32	36	
W-38	Nina Creek	na	15	4	65	188	<8	481	1727	72	24	83	28	11	na	na	na	7	6	22	46	
W-39	Nina Creek	na	50	6	77	72	<8	238	435	278	7	109	39	7	na	na	na	6	15	16	31	
W-40	Nina Creek	na	86	4	194	100	<8	301	29	229	5	105	37	9	na	na	na	5	10	16	37	

Map No.	GROUP	Cr2O3 %	Cu ppm	Pb ppm	Zn ppm	Ni ppm	Mo ppm	Cr ppm	Ba ppm	Sr ppm	Rb ppm	Zr ppm	Y ppm	Nb ppm	Ta ppm	U ppm	Th ppm	Cs ppm	La ppm	Ce ppm	Co ppm	W ppm
W-41	Nina Creek	na	31	4	84	67	<8	183	78	58	10	59	24	9	na	na	na	7	7	16	30	
W-42	Nina Creek	na	60	4	116	17	<8	50	1006	231	20	117	39	10	na	na	na	5	11	5	42	
W-43	Nina Creek	na	28	4	92	122	<8	307	652	142	22	73	32	9	na	na	na	6	10	8	34	
W-44	Nina Creek	na	6	4	52	76	<8	160	426	138	3	113	39	10	na	na	na	8	14	32	33	
W-45	Nina Creek(Duplicate)	na	6	<4	55	65	<8	156	428	134	10	109	36	7	na	na	na	4	12	25		
W-46	Nina Creek	na	7	4	82	85	<8	228	133	100	1	94	31	9	na	na	na	3	4	21	38	
W-47	Nina Creek	na	7	<4	82	92	<8	237	100	90	10	136	40	10	na	na	na	6	9	21	37	
W-48	Nina Creek	na	11	<4	76	0.10%	<8	1201	13	15	6	27	8	7	na	na	na	na	na		123	
W-49	Takla	na	122	<3	97	31	<10	110	130	375	<10	105	26	<5	<1.0	0.6	2.6	<1.0	13	23	30	<2
W-50	Takla	na	10	<3	38	0.22%	<10	3000	<100	34	<10	60	<5	14	<1.0	<0.5	<0.5	<1.0	<5	<10	102	<2
W-51	Takla	na	105	<3	85	52	<10	170	530	790	27	59?	15	22	<1.0	0.7	1.3	1.7	8	<10	29	<2
W-52	Takla	na	134	<3	100	89	<10	380	1000	560	53	59?	<5	7	<1.0	0.8	1.0	2.0	6	<10	43	<2
W-53	Takla	na	132	<3	67	5	<10	<50	1900	470	36	62	15	22	<1.0	<0.5	0.7	1.5	6	<10	17	<2
W-54	Takla	na	74	<3	140	205	<10	300	220	490	20	190	21	37	3.5	1.7	4.1	<1.0	40	85	51	<2
W-55	Takla	na	146	<3	93	42	15	120	310	375	69	110	14	14	<1.0	1.5	2.4	1.8	14	32	27	<2
W-56	Takla	na	222	<3	93	4	<10	<50	720	660	65	59?	11	16	<1.0	0.9	1.8	5.0	11	<10	33	<2
W-57	Takla	na	26	<3	129	4	15	<50	210	375	<10	180	25	29	2.0	0.7	2.8	1.2	22	51	31	<2
W-58	Takla	na	132	<3	85	15	<10	<50	200	805	29	110?	18	10	2.3	<0.5	1.3	<1.0	15	44	29	<2
W-59	Takla	na	115	<3	104	85	<10	130	270	955	41	130?	20	19	1.7	1.4	3.4	1.3	19	41	35	<2
W-60	Takla(Duplicate)	na	121	<3	90	85	<10	270	<100	250	<10	79	20	7	<1.0	<0.5	0.8	<1.0	8	16	37	<2
W-61	Takla	na	130	<3	100	88	<10														38	
W-62	Takla	na	215	<3	92	28	<10	130	<100	590	27	81?	8	21	<1.0	<0.5	2.2	<1.0	13	34	29	<2
W-63	Takla	na	190	<3	92	27	<10	120	340	480	38	92	29	19	<1.0	<0.5	2.5	2.3	26	27	25	<2
W-64	Takla	na	81	<3	108	42	<10	120	250	375	32	100	14	11	<1.0	<0.5	3.0	1.5	8	28	38	<2
W-65	Takla	na	79	<3	95	30	<10	87	230	360	23	86	23	12	<1.0	<0.5	2.2	1.7	17	32	32	<2
W-66	Takla	na	56	<3	86	39	<10	140	260	290	52	94	15	6	<1.0	<0.5	2.5	1.5	8	25	34	<2
W-67	Takla	na	33	<3	104	27	<10	77	240	275	57	94	16	23	<1.0	<0.5	2.3	2.7	20	30	32	<2
W-68	Takla	na	15	<3	88	30	<10	130	300	275	69	91	11	14	<1.0	<0.5	2.3	2.7	11	26	29	<2
W-69	Takla	na	91	<3	56	26	<10	120	300	385	93	77	20	10	<1.0	<0.5	1.8	2.5	14	<10	23	<2
W-70	Takla	na	6	<3	203	137	<10	370	130	270	<10	150	27	12	<1.0	0.6	4.7	1.8	19	42	49	<2
W-71	Takla	na	230	<3	99	27	<10	62	940	1000	120	56?	9	<5	<1.0	1.0	1.5	3.8	10	14	23	<2
W-72	Takla	na	22	<3	79	195	<10	600	630	465	66	85	17	19	<1.0	0.9	2.2	2.9	10	25	29	<2
W-73	Takla	na	26	<5	85	65	<8	230	<100	190	<21	86	15	13	<1.0	<0.5	<0.5	1.0	<5	<10	37	
W-74	Wolf Ridge Gabbro	0.01	14	5	41	2	8	13	190	435	13	194	68	10	0.5	0.5	0.7	17	5.3	17	13	1
W-75	Wolf Ridge Gabbro	0.02	52	5	90	43	8	110	150	105	13	102	49	10	0.5	0.5	0.5	1	4	14	36	1
W-76	Wolf Ridge Gabbro	0.03	69	5	51	44	8	250	300	267	10	66	20	10	0.5	1.1	0.2	1	1.2	2	33	1

APPENDIX IV
LIST OF TRACE AND RARE-EARTH-ELEMENT DATA FOR SEVERAL NINA CREEK, TAKLA AND WOLF RIDGE BASALTS AND GABBROS

MAP NUMBER	GROUP	ROCK TYPE	UTM Easting	UTM Northing	FIELD NUMBER	Sc ppm	V ppm	Pb ppm	Bi ppm	Mo ppm	Rb ppm	Cs ppm	Ba ppm	Sr ppm	Tl ppm	U ppm	Ta ppm	Nb ppm	Hf ppm	Be ppm	87Rb/86Sr	7Sm/144Nd
W-10	Nina Creek	Basalt	394341	6186346	FFE88-29-10	40	362	1	0.05	0.50	2	0.22	67	104	-0.05	5.26	0.24	2.3	2.57	-1.75	0.057500	0.206300
W-20	Nina Creek(I	basalt	385919	6203446	FFE89-6-10	36	297	3	0.08	0.33	0	-0.80	18	34	0.00	2.13	0.36	3.0	2.43	0.62	0.020700	0.190100
W-21	Nina Creek	basalt	376490	6203168	FFE89-18-09	39	302	2	0.06	-0.12	1	0.08	41	53	0.02	3.93	0.23	2.4	1.95	-2.21	0.040600	0.198700
W-23	Nina Creek	basalt	405507	6193793	FFE89-23-27	40	238	2	0.04	0.20	18	0.08	674	150	0.08	7.73	0.26	1.4	1.20	1.48	0.347700	0.179100
W-27	Nina Creek	gabbro	419677	6157562	FFE87-29-1	42	360	0	0.04	0.23	3	0.16	1195	175	0.02	13.05	0.41	2.4	1.26	0.43	0.047700	0.213000
W-39	Nina Creek	gabbro	386093	6203782	FFE89-6-7	39	318	2	0.06	0.26	7	0.30	444	287	0.05	26.61	0.24	2.3	1.44	0.97	0.071400	0.204000
W-46	Nina Creek	gabbro	381971	6215827	FFE89-29-17	38	361	0	0.03	0.17	0	0.12	128	108	0.02	8.29	0.28	2.2	1.97	-0.71	0.013300	0.187100
W-52	Takla	basalt	378744	6170023	DME88-10-9	39	384	1	0.06	-0.08	5	0.13	160	114	0.12	26.99	0.34	2.7	1.27	-0.20	0.127900	0.202300
W-52	Takla	basalt	378744	6170023	DME88-10-9	36	260	8	0.05	0.61	41	1.45	1063	581	0.38	25.46	0.48	2.3	0.87	0.60	0.206600	0.165500
W-55	Takla	basalt	390909	6172814	FFE88-7-9	32	282	4	0.04	0.70	54	0.99	338	399	0.06	23.25	0.55	6.5	1.85	0.89	0.394000	0.144100
W-71	Takla	basalt	376996	6180419	FFE88-23-7	12	217	7	0.04	0.73	90	3.14	755	879	0.08	25.94	0.32	1.9	1.34	0.21	0.297500	0.141400
W-76	Wolf Ridge	gabbro	407119	6170389	FFE87-4-2	38	280	1	0.04	5.73	1	0.05	362	226	0.01	17.81	0.34	0.5	0.70	0.11	0.016000	0.224500

MAP NUMBER	Zr ppm	Y ppm	Th ppm	U ppm	La ppm	Ce ppm	Pr ppm	Nd ppm	Sm ppm	Eu ppm	Gd ppm	Tb ppm	Dy ppm	Ho ppm	Er ppm	Tm ppm	Yb ppm	Lu ppm
W-10	84	33	0.28	0.07	3.57	11.53	1.94	10.80	3.72	1.36	5.27	0.91	6.18	1.34	3.76	0.55	3.51	0.52
W-20	81	30	0.25	0.10	3.67	12.13	2.06	11.14	3.55	1.26	4.91	0.90	5.84	1.21	3.52	0.53	3.36	0.47
W-21	62	26	0.19	0.09	3.53	10.65	1.78	9.80	3.26	1.22	4.42	0.78	5.03	1.02	2.98	0.44	2.89	0.42
W-23	35	27	0.10	0.05	5.39	9.38	2.12	10.56	3.18	1.17	4.97	0.73	4.69	1.02	2.96	0.45	2.76	0.40
W-27	28	35	0.17	0.03	2.68	9.91	1.91	11.30	4.04	1.61	6.41	1.03	6.73	1.46	4.18	0.59	3.76	0.56
W-39	34	30	0.16	0.04	4.32	13.06	2.14	11.07	3.83	1.28	5.27	0.89	5.66	1.21	3.46	0.48	3.06	0.44
W-46	59	28	0.33	0.05	4.30	12.77	2.04	10.81	3.36	1.22	4.60	0.79	5.19	1.10	3.17	0.48	2.88	0.43
W-52	23	35	0.38	0.07	4.58	14.56	2.39	13.14	4.43	1.61	6.01	1.04	7.15	1.48	4.25	0.61	4.08	0.59
W-52	21	12	1.34	0.60	6.51	14.14	1.96	9.01	2.45	0.77	3.16	0.40	2.41	0.51	1.35	0.21	1.29	0.18
W-55	55	17	2.32	0.93	14.15	28.44	3.48	14.52	3.45	1.08	4.00	0.56	3.61	0.69	2.02	0.27	1.83	0.27
W-71	43	12	1.22	0.78	9.09	17.68	2.25	9.70	2.30	0.80	2.81	0.38	2.32	0.47	1.39	0.19	1.29	0.19
W-76	20	14	0.07	0.01	1.27	4.03	0.70	3.82	1.43	0.67	2.53	0.38	2.67	0.56	1.68	0.23	1.44	0.21

APPENDIX V
MINERAL ANALYSES USED IN GEOTHERMOMETRY CALCULATIONS

	SAMPLE FFE 35-7						SAMPLE DME 33-7			
	gar-core	gar-mid	gar-rim	bio-rim	gar-rim*	bio-rim*	gar-core	gar-mid	gar-rim	bio-rim
	n=1	n=1	n=8	n=6	n=5	n=6	n=5	n=1	n=5	n=5
SiO2	36.89	36.69	37.02	35.90	37.16	36.25	37.62	37.21	37.43	35.86
TiO2	0.00	0.01	0.02	1.89	0.01	2.68	0.00	0.00	0.01	1.85
Al2O3	20.20	20.26	21.03	19.93	21.04	19.27	21.42	20.55	20.81	20.17
Fe2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Cr2O3	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
FeO	31.55	30.66	29.44	19.96	29.32	19.39	31.08	32.18	33.63	19.40
MnO	6.23	7.63	8.45	0.39	8.50	0.31	5.83	4.97	3.37	0.18
MgO	2.96	2.82	2.71	9.11	2.72	9.31	3.38	3.33	3.41	9.74
BaO	0.00	0.00	0.00	0.12	0.00	0.15	0.00	0.00	0.00	0.05
CaO	1.35	1.28	1.41	0.01	1.42	0.00	1.34	1.54	1.62	0.00
Na2O	0.00	0.00	0.00	0.14	0.00	0.18	0.00	0.00	0.00	0.35
K2O	0.00	0.00	0.00	9.37	0.00	9.40	0.00	0.00	0.00	9.01
F	0.03	0.07	0.03	0.28	0.03	0.24	0.03	0.02	0.03	0.33
TOTAL	99.21	99.42	100.11	97.10	100.20	97.18	100.70	99.80	100.31	96.94
Si	3.002	2.981	2.984	2.694	2.992	2.710	2.999	3.000	2.999	2.681
Ti	0.000	0.001	0.001	0.107	0.001	0.151	0.000	0.000	0.001	0.104
AlIV	0.000	0.019	0.016	1.306	0.008	1.290	0.001	0.000	0.001	1.319
AlVI	1.935	1.919	1.980	0.456	1.987	0.409	2.009	1.951	1.962	0.458
Fe3+	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Cr	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Fe2+	2.147	2.083	1.985	1.252	1.974	1.212	2.072	2.170	2.253	1.213
Mn	0.429	0.525	0.577	0.025	0.580	0.020	0.394	0.339	0.229	0.011
Mg	0.359	0.341	0.326	1.019	0.326	1.038	0.402	0.400	0.407	1.085
Ba	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Ca	0.118	0.111	0.122	0.001	0.123	0.000	0.114	0.133	0.139	0.000
Na	0.000	0.000	0.000	0.020	0.000	0.026	0.000	0.000	0.000	0.000
K	0.000	0.000	0.000	0.897	0.000	0.897	0.000	0.000	0.000	0.859
Xal	0.703	0.681	0.660		0.657		0.695	0.713	0.744	
Xsp	0.141	0.172	0.192		0.193		0.132	0.112	0.076	
Xpy	0.118	0.112	0.108		0.109		0.135	0.132	0.134	
Xgr	0.039	0.036	0.040		0.041		0.038	0.044	0.046	

* Analysis pair is from a biotite inclusion in garnet.
Abbreviations: gar = garnet, bio = biotite, core = core of crystal, mid = middle of crystal, rim = rim of crystal, n = number of analyses averaged.

APPENDIX VI

LITHOGEOCHEMISTRY OF VARIOUS MINERALIZED AND NON-MINERALIZED ROCKS FROM WITHIN THE MAP AREA

Map No.	FIELD NUMBER	UTM Easting	UTM Northing	Rock Type	Au ppb	Ag ppm	Cu ppm	Pb ppm	Zn ppm	Hg ppb	As ppm	Sb ppm	Co ppm	Ni ppm	Ba ppm	W ppm	Mo ppm	Bi ppm	Ge ppm
L-1	DME87-3-6	412264	6165526	fault gouge	<20	<0.5	9	8	23	<10	1	<0.5	n/a	n/a	na	na	na	na	na
L-2	DME87-14-2-1	415521	6161540	quartz vein	<20	<0.5	3	5	3	10	<1	<0.5	3	5	na	na	na	na	na
L-3	DME87-14-4	415500	6161584	quartz vein	<20	<0.5	8	61	8	11	7	<0.5	6	48	na	na	na	na	na
L-4	DME87-15-1-4	417768	6159455	fault gouge	<20	<0.5	68	11	35	34	<1.0	0.8	n/a	n/a	na	na	na	na	na
L-5	DME87-15-1-5	417769	6159453	altered rock	<20	<0.5	31	6	40	<10	17	0.7	n/a	n/a	na	na	na	na	na
L-6	DME87-15-4-2	418611	6158512	quartz vein	<20	<0.5	9	<4	6	25	1	<0.5	<3	6	na	na	na	na	na
L-7	DME87-16-8	425767	6154371	chert	<20	<0.5	44	15	28	25	<1	<0.5	11	20	na	na	na	na	na
L-8	DME87-16-13	425853	6154745	chert	<20	<0.5	40	13	55	46	<1.0	<0.5	n/a	n/a	na	na	na	na	na
L-9	DME87-16-16	426013	6153807	fault gouge	<20	<0.5	375	23	106	118	25	5	n/a	n/a	na	na	na	na	na
L-10	DME87-18-4	429134	6153514	altered rock	<20	<0.5	5	12	14	15	<1.0	<0.5	n/a	n/a	na	na	na	na	na
L-11	DME87-22-4	416180	6151936	hornfels	<20	<0.5	12	16	80	<10	2	<0.5	n/a	n/a	na	na	na	na	na
L-12	DME87-41-2	434347	6150516	silicified gneiss	<20	<0.5	16	<4	31	44	9	<0.5	12	20	na	na	na	na	na
L-13	FFE87-1-1	411203	6170629	silicified phyllite	427	273	461	37	0.11%	20	34	258	na	25	na	na	na	na	na
L-14	FFE012	408541	6169558	quartz vein	<20	254	0.32%	12.60%	0.25%	10	6	235	57	38	na	na	na	na	na
L-15	FFE1102	408541	6169558	quartz vein	188	31	720	137	396	90	58	400	na	5	na	na	na	na	na
L-16	FFE11-1	413670	6162317	quartz vein	136	80	3	0.98%	3	<10	13	14	155	<4	na	na	na	na	na
L-17	FFE87-13-2	413244	6162619	altered rock	<20	2	72	n/a	1502	n/a	n/a	n/a	n/a	70	na	na	na	na	na
L-18	FFE87-16-2-2	416510	6160772	quartz vein	<20	<0.5	37	7	14	<10	2	2	n/a	n/a	na	na	na	na	na
L-19	FFE87-16-2-2	416510	6160772	quartz vein	<20	<0.5	11	<4	8	32	<1	0.7	9	229	na	na	na	na	na
L-20	FFE87-16-2-4	416510	6160772	quartz vein	<20	<0.5	5	<4	20	34	<1	0.5	<8	194	na	na	na	na	na
L-21	FFE87-16-9-2	414876	6162974	serpentine	<20	<0.5	7	6	43	268	6	5	n/a	n/a	na	na	na	na	na
L-22	FFE87-20-3-2	426435	6158984	quartz vein	<20	<0.5	3	<4	3	11	<1	<0.5	3	6	na	na	na	na	na
L-23	FFE87-21-9	414889	6158708	quartz vein	<20	<0.5	3	<4	4	24	12	0.6	3	6	na	na	na	na	na
L-24	FFE87-22-7	424251	6155929	quartz vein	<20	<0.5	9	<4	14	<10	<1	<0.5	9	20	na	na	na	na	na
L-25	FFE87-22-7-4	424456	6155918	quartz vein	<20	<0.5	2	<4	5	<10	<1	<0.5	<3	7	na	na	na	na	na
L-26	FFE87-26-2	410720	6165177	greenstone	<20	<0.5	2	<4	3	28	<1	<0.5	3	6	na	na	na	na	na
L-27	FFE87-27-10	416152	6155234	serpentine	<20	<0.5	8	12	64	<10	4	0.5	n/a	n/a	na	na	na	na	na
L-28	FFE87-29-2-1	414873	6163174	altered rock	31	<0.5	10	10	59	1165	<1.0	<0.5	n/a	n/a	na	na	na	na	na
L-29	FFE87-29-2-1a	414873	6163174	quartz vein	61	<0.5	9	<4	23	290	7	2	67	0.16%	na	na	na	na	na
L-30	FFE87-29-2-1b	414873	6163174	quartz vein	<20	<0.5	61	14	29	404	1	0.8	65	0.13%	na	na	na	na	na
L-31	FFE87-29-2-5	414873	6163174	fault gouge	<20	<0.5	210	13	66	28	8	0.8	n/a	n/a	na	na	na	na	na
L-32	FFE87-48-3-1	411305	6158113	quartz vein	<20	<0.5	8	<4	12	<10	2	<0.5	5	28	na	na	na	na	na
L-33	FFE87-49-1	421889	6151701	greenstone	<20	<0.5	40	<4	75	90	3	<0.5	16	24	na	na	na	na	na
L-34	FFE87-49-4	419860	6151848	altered rock	<20	<0.5	6	17	30	52	4	3	n/a	n/a	na	na	na	na	na
L-35	FFE87-50-3	421557	6154920	quartz vein	<20	<0.5	7	n/a	18.7	n/a	n/a	n/a	n/a	0.10%	na	na	na	na	na
L-36	FFE87-50-3	421557	6154920	listwanite	<20	<0.5	10	33	10	388	2	0.8	24	480	na	na	na	na	na
L-37	FFE87-52-7-1	436842	6156137	chert	<20	<0.5	240	8	163	<10	<1.0	<0.5	n/a	n/a	na	na	na	na	na
L-38	GM87-6-4-1	428064	6161844	quartz vein	<20	<0.5	3	<4	3	22	<1	<0.5	4	5	na	na	na	na	na
L-39	GM87-18-2	406779	6168923	serpentine	<20	<0.5	8	11	22	<10	130	3	n/a	n/a	na	na	na	na	na
L-40	DME88-2-4-5	399408	6178021	quartz vein	164	128	0.78%	3	640	137m	480	0.32%	32	na	na	18	<7	na	na
L-41	DME88-4-8	404692	6169676	quartz vein	1	2	83	17	360	57	7	6	24	na	na	736	<7	na	na
L-42	DME88-5-1-1	403089	6167185	quartz vein	24	3	165	112	29	23	66	0.5	29	na	na	28	<7	na	na
L-43	DME88-5-1-2	403087	6167186	silicified volcanic	5	.5	7	12	78	12	13	<0.5	44	na	na	6	<7	na	na
L-44	DME88-5-3	404201	6164820	silicified andesite	1	.5	11	3	53	10	4	<0.5	9	na	na	5	<7	na	na
L-45	DME88-11-6	387307	6175361	silicified volcaniclastic	6	.5	103	3	61	10	3	0.5	5	na	na	5	<7	na	na
L-46	DME88-19-4-3	381932	6176360	quatrz vein	11	.5	32	7	18	135m	9	12	9	na	na	143	<7	na	na
L-47	DME88-21-10	379738	6181119	andesite	1	.5	141	9	104	240	4	0.6	24	na	na	22	<7	na	na
L-48	DME88-21-16	379465	6182020	basalt	1	.5	73	7	108	25	3	<0.5	27	na	na	39	<7	na	na
L-49	DME88-25-1-1	403945	6177532	silicified argillite	2	.5	46	10	60	130	55	8	51	na	na	26	<7	na	na
L-50	DME88-25-1-2	403945	6177532	quartz vein	1	.5	20	4	28	175	5	3	24	na	na	441	<7	na	na
L-51	DME88-26-3	377395	6170972	shear zone	1	1	7	44	48	37	15	3	15	na	na	237	<7	na	na
L-52	DME88-26-5	377577	6171303	altered volcanic	1	.5	141	12	90	10	1	0.7	12	na	na	37	<7	na	na
L-53	DME88-26-6	377545	6171439	shear zone	26	450	0.53%	980	0.11%	100	249	0.24%	10	na	na	448	<7	na	na
L-54	DME88-27-1-2	386003	6190084	quartz vein	1	0.5	187	3	21	14	2	<0.5	20	na	2300	na	<6	na	na
L-55	DME88-33-5	387610	6193976	quartz vein	1	<0.5	2	5	3	<10	1	<0.5	51	na	<100	na	<6	na	na
L-56	DME88-34-4	388162	6193354	silicified agglomerate	1	<0.5	58	3	99	12	1	<0.5	46	na	150	na	<6	na	na
L-57	DME88-37-3-1	391488	6179794	carbonate vein	1	<0.5	1	4	5	<10	1	<0.5	77	na	120	na	<6	na	na
L-58	DME88-37-3-2	391488	6179794	listwanite	1	<0.5	102	3	106	13	225	3	44	na	610	na	<6	na	na

Map No.	FIELD NUMBER	UTM Easting	UTM Northing	Rock Type	Au ppb	Ag ppm	Cu ppm	Pb ppm	Zn ppm	Hg ppb	As ppm	Sb ppm	Co ppm	Ni ppm	Ba ppm	W ppm	Mo ppm	Bi ppm	Ge ppm
L-59	DME88-37-3-3	391488	6179793	quartz vein	1	6	50	4	31	310	21	54	52	na	<100	na	<6	na	na
L-60	DME88-44-1	384959	6190873	quartz stringers	1	<0.5	51	14	55	36	4	3	32	na	260	na	<6	na	na
L-61	DME88-44-2	384677	6191238	quartz stringers	1	<0.5	162	3	29	34	150	3	48	na	180	na	<6	na	na
L-62	DME88-44-6-2	384700	6192712	gausson	1	<0.5	55	3	72	47	5	2	46	na	<100	na	<6	na	na
L-63	DME88-46-1	394988	6180580	quartz vein	1	0.6	12	4	40	42	3	5	65	na	230	na	<6	na	na
L-64	DME88-46-2	394988	6180580	quartz vein	1	<0.5	5	4	14	20	<1	<0.5	50	na	<100	na	<6	na	na
L-65	DME88-46-3	394988	6180580	quartz vein	1	<0.5	7	4	31	18	23	2	45	na	150	na	<6	na	na
L-66	DME88-46-4	394988	6180580	quartz vein	1	<0.5	3	3	16	11	7	<0.5	6	na	200	na	<6	na	na
L-67	DME88-46-5	394988	6180580	quartz vein	7	<0.5	7	6	18	30	5	<0.5	9	na	220	na	<6	na	na
L-68	DME88-46-6	394988	6180580	quartz vein	1	<0.5	2	3	8	<10	1	<0.5	4	na	<100	na	<6	na	na
L-69	DME88-46-9	394988	6180580	quartz vein	1	1	8	412	480	200	14	<0.5	10	na	110	na	<6	na	na
L-70	FFE88-2-7	396250	6178041	quartz vein	1	<0.5	11	19	5	28	2	5	61	na	<100	na	<6	na	na
L-71	FFE88-8-1	400177	6172403	quartz vein	143	<0.5	101	3	88	11	32	1	27	na	730	na	<6	na	na
L-72	FFE88-9-1-1	398275	6175343	silicified andesite	10	.5	104	9	84	10	2	0.9	98	na	na	5	<7	na	na
L-73	FFE88-10-2	398817	6173510	quartz stringers	20	.5	40	10	32	20	33	<0.5	9	na	na	5	<7	na	na
L-74	FFE88-13-10	385208	6170146	silicified andesite	10	.5	117	15	74	10	1	2	14	na	na	6	<7	na	na
L-75	FFE88-13-11	385265	6170398	quartz vein	1	<0.5	63	3	23	<10	<1	<0.5	7	na	1400	na	<6	na	na
L-76	FFE88-14-1	378994	6172754	volcaniclastic	8	.5	103	14	82	15	12	2	78	na	na	5	<7	na	na
L-77	FFE88-18-6	386060	6179594	andesite	1	.5	106	7	125	424	3	0.7	30	na	na	6	<7	na	na
L-78	FFE88-28-5-2	394411	6185686	volcanic breccia	3	<0.5	71	3	94	13	<1	<0.5	38	na	330	na	<6	na	na
L-79	FFE88-31-1	381610	6188804	altered rock	1	<0.5	99	4	54	83	4	1	42	na	<100	na	<6	na	na
L-80	FFE88-33-2	374911	6187185	quartz vein	1	<0.5	30	4	58	376	6	4	23	na	<100	na	<6	na	na
L-81	FFE88-34-4-4	394926	6180612	quartz vein	66	52	1.60%	337	690	8m	22	5	3	na	6500	na	<6	na	na
L-82	FFE88-34-4-5	394926	6180612	quartz vein	3	<0.5	4	4	20	30	3	<0.5	7	na	200	na	<6	na	na
L-83	FFE88-48-4-1	395357	6184044	sheared basalt	1	<0.5	24	3	32	31	10	<0.5	6	na	210	na	<6	na	na
L-84	RAR88-4-5	386368	6176473	andesite	3	.5	119	15	96	10	3	0.7	15	na	na	5	<7	na	na
L-85	RAR88-5-4-2	385216	6167786	quartz vein	1	0.6	3	5	13	<10	<1	<0.5	5	na	<100	na	<6	na	na
L-86	RAR88-10-3	385408	6189945	quartz vein	1	<0.5	38	3	78	140	6	1	7	na	280	na	<6	na	na
L-87	RAR88-10-8	384225	6191676	quartz vein	1	<0.5	10	15	25	45	1	<0.5	6	na	170	na	<6	na	na
L-88	DME89-1-5	386016	6196620	silicified tuff	<2	<0.3	45	<3	82	52	2	0.8	26	51	na	na	<8	na	na
L-89	DME89-3-1	386149	6197123	silicified diorite	<2	<0.3	58	<3	84	<20	<1	<0.5	40	102	na	na	<8	na	na
L-90	DME89-12-3	382455	6199658	silicified basalt	6	<0.3	51	<3	73	<20	1	0.6	30	63	na	na	<8	na	na
L-91	DME89-13-4	385231	6199864	diorite	<2	<0.3	55	<3	82	<20	<1	3	36	49	na	na	<8	na	na
L-92	DME89-14-2	384837	6201744	quartz vein	6	<0.3	142	3	87	72	13	0.6	20	17	na	na	14	na	na
L-93	DME89-14-2D	384837	6201744	quartz vein	6	<0.3	144	6	88	63	12	0.5	23	23	na	na	8	na	na
L-94	DME89-15-7	379964	6202872	basalt	2	<0.3	49	4	89	<20	<1	0.5	34	44	na	na	<8	na	na
L-95	DME89-20-13	378533	6219441	quartz vein	4	<0.3	67	10	56	22	5	<0.5	11	50	na	na	<8	na	na
L-96	DME89-28-2	384198	6218091	calcareous siltstone	2	0.3	27	24	270	309	1	0.7	24	na	na	na	8	10	0.1
L-97	DME89-43-2	382428	6210161	altered chert	2	<0.3	345	4	37	<20	2	<0.5	4	10	na	na	<8	na	na
L-98	FFE89-3-1-3	390200	6200191	massive sulphide	2	84	51	5.2%	8.70%	173m	16	58	6	na	na	na	10	10	3.2
L-99	FFE89-4-3-2	391280	6199124	breccia	2	0.3	2	15	10	20	1	0.5	3	na	na	na	8	10	0.1
L-100	FFE89-7-21	389194	6202531	massive sulphide	2	115	150	0.67%	14.70%	185m	13	18	3	na	na	na	8	10	8.4
L-101	FFE89-7-4-3	388480	6203882	breccia	2	28	88	10	4.11%	82m	3	3	3	na	na	na	8	10	0.4
L-102	FFE89-7-5	388463	6203670	brecciated siltstone	2	32	18	5.40%	20	308	240	42	9	na	na	na	8	10	0.1
L-103	FFE89-7-5D	388463	6203670	brecciated siltstone	4	32	17	5.50%	16	335	244	36	7	na	na	na	8	10	0.1
L-104	FFE89-10-10	396937	6194074	dolomite	2	0.3	3	19	15	29	3	0.9	3	na	na	na	8	10	0.2
L-105	FFE89-13-18	392121	6202705	carbonate breccia	2	0.3	3	60	64	31	2	0.6	3	na	na	na	8	10	0.1
L-106	FFE89-15-4-1	383933	6197341	altered basalt	<2	<0.3	48	<4	47	136	3	<0.5	30	58	na	na	<8	na	na
L-107	FFE89-15-4-2	383933	6197341	altered basalt	<2	<0.3	22	4	36	50	2	<0.5	16	34	na	na	<8	na	na
L-108	FFE89-15-4-3	383933	6197341	altered basalt	16	<0.3	29	<4	41	47	3	<0.5	17	42	na	na	<8	na	na
L-109	FFE89-18-4	377358	6201662	altered basalt	10	<0.3	52	<3	59	<20	1	<0.5	34	81	na	na	<8	na	na
L-110	FFE89-28-8-2A	384229	6215216	dolomite	4	0.3	6	65	38	178	61	4	3	na	na	na	8	10	0.1
L-111	FFE89-28-8-2B	384229	6215216	dolomite	4	0.3	9	47	17	114	59	4	3	na	na	na	8	10	0.2
L-112	FFE89-28-10	383973	6214855	massive sulphide	2	0.8	46	0.32%	6.60%	133	7	8	3	na	na	na	48	10	0.6
L-113	JWH89-4-7	380944	6211173	altered chert	4	<0.3	149	6	112	<20	6	<0.5	22	63	na	na	12	na	na
L-114	JWH89-4-13	379724	6211987	quartz vein	8	<0.3	114	25	26	<20	13	<0.5	2	8	na	na	12	na	na
L-115	JWH89-5-3	379947	6216777	altered gabbro	6	<0.3	217	<3	45	<20	<1	<0.5	32	74	na	na	<8	na	na
L-116	JWH89-06-2	380270	6197148	altered argillite	22	0.6	48	13	64	485	10	2	5	30	na	na	20	na	na

				Ultramafic Rocks	Au ppb	Ni %	Cr ppm	Hg ppb	As ppm	Sb ppm	Pt ppb	Pd ppb
L-117	DME88-2-1	397784	6176334	serpentine	1	0.19	2556	<10	<1	<0.5	4	6
L-118	DME88-4-3-2	405618	6170023	listwanitic serpentine	1	0.10	3403	15	19	0.9	8	6
L-119	DME88-8-2	395410	6178720	serpentine	1	0.25	2965	<10	1	3	8	7
L-120	DME88-24-12	396127	6177740	serpentine	2	0.20	2435	<10	1	<0.5	4	5
L-121	FFE88-10-9	395374	6178647	serpentine	1	0.25	3096	<10	335	13	7	9
L-122	DME89-43-5	379517	6211375	serpentine	2	750m	na	57	na	na	na	na

m - ppm

na - not analyzed

APPENDIX VII

1983 REGIONAL GEOCHEMICAL SURVEY; STREAM SEDIMENT GEOCHEMISTRY FOR SAMPLES COLLECTED DURING 1987 AND 1989 (1)

MAP NO.	SAMPLE NUMBER	NTS Sheet	UTM Easting	UTM Northing	Ag ppm	Zn ppm	Cu ppm	Pb ppm	Ni ppm	Co ppm	Mn ppm	Fe %	Mo ppm	Wo ppm	As ppm	Sb ppm	Hg ppb	U ppm	U in Water (ppb)	Fl in Water (ppb)	pH of Water (ppb)
R-1	831502	93N/9	429806	6154153	0.1	59	25	3	30	7	377	1.80	1	3	7.0	0.2	30	3.4	0.49	66	7.6
R-2	831503	93N/9	429806	6154153	0.1	55	24	2	31	6	380	1.70	1	4	5.5	0.4	30	3.8	0.45	56	7.6
R-3	831504	93N/9	432246	6152294	0.1	108	30	5	50	11	1240	2.30	1	1	8.0	0.9	50	2.4	0.03	60	7.7
R-4	831505	93N/9	433869	6153439	0.1	72	25	7	35	8	377	2.20	1	2	6.0	0.3	50	6.7	0.06	50	7.5
R-5	831506	93N/9	434207	6153499	0.1	35	11	2	17	4	207	1.20	1	2	2.5	0.1	20	10.4	0.13	46	7.2
R-6	831507	93N/9	435937	6152938	0.1	28	8	1	12	3	160	1.00	1	3	1.5	0.1	20	9.3	0.14	40	7.0
R-7	831508	93N/9	433434	6163770	0.2	65	10	4	17	6	302	1.40	1	11	5.0	0.1	40	10.0	0.16	42	6.1
R-8	831509	93N/9	428629	6169150	0.1	33	6	1	11	3	240	0.90	1	2	2.0	0.1	20	5.6	0.45	24	6.5
R-9	831510	93N/9	428482	6168068	0.2	33	7	1	16	2	127	0.90	1	2	1.5	0.1	30	9.2	0.47	30	7.5
R-10	831512	93N/9	436136	6174717	0.3	58	13	10	16	6	112	1.50	1	2	2.5	0.1	40	12.8	0.34	54	6.7
R-11	831513	93N/9	435593	6175642	0.3	51	11	10	16	3	144	1.20	1	1	1.0	0.1	40	16.4	0.24	40	6.8
R-12	831514	93N/9	435257	6175888	0.2	60	12	8	17	15	3130	7.60	1	1	8.0	0.1	60	6.0	0.01	34	6.3
R-13	831515	93N/9	433249	6174595	0.1	32	3	4	9	4	430	1.20	1	2	6.0	0.3	20	6.2	0.04	52	6.8
R-14	831516	93N/9	427722	6173161	0.1	25	1	5	3	1	131	0.45	1	1	1.5	0.2	20	10.2	0.40	34	6.5
R-15	831517	93N/9	425816	6173994	0.2	25	1	3	3	2	373	0.65	1	1	1.0	0.1	20	11.0	0.17	30	6.2
R-16	831518	93N/9	424527	6173588	0.2	26	1	2	4	3	144	0.50	1	1	1.0	0.1	30	6.9	0.60	30	6.1
R-17	831519	93N/9	423029	6173843	0.3	36	2	6	7	27	2980	2.70	1	2	1.5	0.1	40	6.9	0.21	30	6.1
R-18	831520	93N/9	420916	6174739	0.3	34	3	4	8	6	335	0.95	1	2	1.5	0.1	40	18.4	0.16	30	6.3
R-19	831522	93N/9	411384	6179055	0.1	24	6	1	9	5	174	0.80	1	2	2.5	0.1	40	10.0	0.04	28	6.4
R-20	831523	93N/9	407934	6177774	0.1	30	18	1	16	4	409	2.85	1	1	1.5	0.1	190	7.2	0.01	46	7.0
R-21	831524	93N/9	407934	6177774	0.4	42	17	2	22	7	174	1.65	1	1	1.5	0.1	110	6.3	0.01	52	7.1
R-22	831525	93N/9	409666	6174583	0.3	36	2	11	21	6	375	1.65	1	4	1.5	0.2	60	11.4	1.20	68	7.5
R-23	831526	93N/9	409079	6171787	0.1	36	15	1	22	8	313	1.70	1	3	3.0	0.3	50	9.6	0.22	52	7.4
R-24	831527	93N/9	415585	6175345	0.1	16	1	1	7	2	69	0.60	1	3	1.0	0.1	30	11.2	0.04	24	6.6
R-25	831528	93N/9	415247	6171740	0.1	29	5	1	11	5	236	0.95	1	1	1.0	0.2	40	11.9	0.12	38	6.4
R-26	831529	93N/9	420434	6170192	0.2	48	7	3	12	7	576	1.50	1	1	1.0	0.2	50	10.1	0.01	36	6.0
R-27	831530	93N/9	417291	6167949	0.1	43	8	1	18	6	126	1.40	1	2	1.0	0.2	40	3.2	0.20	60	7.7
R-28	831531	93N/9	420541	6164719	0.2	45	29	1	11	2	132	0.50	1	1	1.0	0.1	140	14.8	0.12	62	6.3
R-29	831532	93N/9	424265	6168926	0.1	36	4	2	10	4	242	1.00	1	1	1.0	0.1	40	11.4	0.50	36	6.5
R-30	831534	93N/9	426814	6166079	0.1	48	11	4	15	8	239	1.40	1	2	1.5	0.2	30	8.0	0.48	38	6.0
R-31	831535	93N/9	423240	6158443	0.1	62	30	4	37	12	498	2.20	1	2	6.0	0.3	60	2.8	0.10	52	7.6
R-32	831536	93N/9	423922	6154756	0.2	25	6	1	7	2	210	0.50	2	1	1.5	0.1	80	1.5	0.01	56	7.6
R-33	831537	93N/9	421705	6155382	0.6	118	38	5	78	14	427	2.20	2	2	6.0	1.0	50	3.7	0.10	54	7.8
R-34	831538	93N/9	420210	6153229	0.3	82	29	4	63	11	272	1.70	2	2	3.0	0.4	30	3.6	0.06	56	7.3
R-35	831539	93N/9	419398	6155770	0.2	60	21	5	40	10	284	2.10	1	2	4.5	0.4	20	2.8	0.03	56	7.4
R-36	831540	93N/9	420068	6155851	0.2	62	23	6	42	10	305	2.10	2	14	5.5	0.2	30	6.1	0.04	48	7.2
R-37	831542	93N/9	416804	6152366	0.2	20	4	1	3	1	228	3.40	5	1	1.5	0.1	60	0.8	0.04	42	6.7
R-38	831543	93N/9	415798	6152924	0.2	48	20	1	16	10	251	1.55	2	3	1.5	0.2	20	9.4	0.27	38	6.6
R-39	831544	93N/9	415798	6152924	0.1	50	21	2	19	10	268	1.60	2	2	1.0	0.1	20	10.5	0.27	38	6.5
R-40	831545	93N/9	414033	6154814	0.1	80	27	4	16	7	164	1.20	5	1	1.5	0.2	30	14.8	1.15	32	6.6
R-41	831546	93N/9	415903	6156580	0.1	74	21	3	46	9	326	1.70	3	21	3.0	0.2	20	3.6	0.04	36	7.0
R-42	831547	93N/9	406866	6153969	0.2	34	4	4	5	5	1030	1.45	3	1	1.0	0.2	30	23.6	0.80	32	6.2
R-43	831548	93N/9	406541	6154150	0.2	55	6	2	5	5	1570	1.90	3	1	1.5	0.2	40	17.0	0.06	30	6.3
R-44	831549	93N/9	407448	6154714	0.2	47	15	3	7	4	391	1.20	1	1	1.5	0.2	30	8.8	0.18	32	6.5
R-45	831550	93N/9	407966	6160245	0.2	32	17	2	16	3	211	1.05	2	1	2.0	0.1	50	20.2	0.12	40	6.8
R-46	831552	93N/9	408542	6160405	1.0	37	54	1	12	7	427	5.30	12	1	11.0	0.5	130	155.5	0.26	46	7.7
R-47	831553	93N/9	411881	6163011	0.2	64	20	9	56	12	335	2.10	1	3	11.0	1.2	50	3.9	0.10	60	7.2
R-48	831554	93N/9	413847	6163745	0.5	240	4	99	80	12	398	2.10	4	1	12.5	1.7	70	2.7	0.47	58	7.9
R-49	831555	93N/9	416887	6163641	0.1	30	80	1	25	8	697	2.10	1	1	2.0	0.1	110	1.4	0.01	56	7.5
R-50	831556	93N/9	406642	6168302	0.3	118	55	14	88	16	716	2.90	5	4	12.5	0.9	30	2.8	0.30	64	7.6
R-51	833018	93N/9	410358	6171208	0.5	110	34	15	48	12	768	2.55	2	1	9.5	1.2	60	4.8	0.12	160	8.0
R-52	833019	93N/9	411895	6170170	0.3	40	12	3	20	8	324	1.40	1	1	1.0	0.1	40	11.2	0.24	28	7.3
R-53	833020	93N/9	415087	6165239	0.8	72	45	5	48	14	749	2.45	1	1	5.0	0.6	50	2.9	0.20	64	8.1
R-54	833022	93N/9	417063	6160465	0.3	51	35	5	32	4	248	0.80	1	1	2.0	0.1	150	30.8	0.08	36	7.6
R-55	833023	93N/9	420356	6157602	0.4	60	31	5	39	13	562	2.25	1	1	4.5	0.7	70	2.7	0.07	54	8.1
R-56	833024	93N/9	425586	6157247	0.2	37	11	3	20	6	309	1.20	1	5	1.5	0.1	30	3.4	0.13	44	7.4
R-57	833025	93N/9	426117	6156736	0.2	36	15	5	28	7	303	1.50	1	8	1.0	0.1	30	3.8	0.03	48	7.5
R-58	833026	93N/9	429265	6155376	0.2	32	12	4	20	6	225	1.25	1	5	1.5	0.2	20	4.1	0.05	42	7.2
R-59	833027	93N/9	429265	6155376	0.2	32	13	4	21	6	237	1.35	1	9	1.5	0.2	30	5.0	0.23	42	7.4
R-60	833028	93N/9	433456	6155745	0.4	51	37	5	32	10	598	2.10	1	1	4.5	0.4	30	4.9	0.04	46	7.4

MAP NO.	SAMPLE NUMBER	NTS Sheet	UTM Easting	UTM Northing	Ag ppm	Zn ppm	Cu ppm	Pb ppm	Ni ppm	Co ppm	Mn ppm	Fe %	Mo ppm	Wo ppm	As ppm	Sb ppm	Hg ppb	U ppm	U in Water (ppb)	Fl in Water (ppb)	pH of Water (ppb)
R-61	833029	93N/9	434624	6158213	0.2	44	20	4	26	8	620	1.70	1	1	2.0	0.2	40	6.8	0.12	46	7.3
R-62	833030	93N/9	435335	6159449	0.1	21	11	2	13	4	234	0.95	1	1	1.0	0.1	20	5.1	0.08	40	7.1
R-63	833032	93N/9	435625	6161048	0.2	28	14	2	18	6	319	1.15	1	1	1.5	0.1	20	5.8	0.04	44	7.3
R-64	833033	93N/9	435015	6162083	0.1	50	15	3	23	6	456	1.35	1	1	2.0	0.1	30	5.1	0.04	42	7.5
R-65	831002	93N/10	376691	6173604	0.1	38	27	1	25	8	319	2.00	1	1	3.0	0.7	100	1.8	0.01	30	6.8
R-66	831003	93N/10	375918	6176594	0.1	54	60	1	40	12	661	3.90	2	1	6.0	0.5	270	1.4	0.01	32	7.8
R-67	831004	93N/10	375214	6176425	0.1	26	39	1	6	4	3360	18.00	2	1	29.5	0.3	260	0.8	0.01	34	7.9
R-68	831005	93N/10	383343	6177405	0.1	70	105	1	50	20	1540	4.70	2	1	11.5	1.4	550	1.1	0.01	30	7.6
R-69	831006	93N/10	383343	6177405	0.1	75	102	2	52	21	876	4.45	2	1	9.5	1.2	400	1.0	0.01	30	7.5
R-70	831007	93N/10	381632	6170036	0.1	28	14	1	14	6	257	2.00	1	85	3.0	0.6	60	19.3	0.39	30	7.2
R-71	831008	93N/10	379379	6169685	0.2	29	16	1	14	6	266	1.70	1	10	2.0	0.5	40	6.5	0.40	30	7.1
R-72	831009	93N/10	380487	6169150	0.2	55	16	1	16	7	246	1.80	1	15	1.5	0.4	40	28.0	0.51	28	7.0
R-73	831011	93N/10	378757	6168637	0.1	29	22	1	15	7	389	1.15	1	22	2.5	0.4	50	13.8	0.43	26	7.1
R-74	831012	93N/10	377735	6168248	0.6	66	35	1	17	16	4200	4.45	4	6	10.0	0.4	120	19.5	0.08	30	7.4
R-75	831013	93N/10	376678	6168795	1.0	21	143	2	13	6	290	1.30	1	3	2.5	0.5	220	37.6	0.12	28	7.0
R-76	831014	93N/10	374383	6170014	0.1	50	27	1	25	14	602	3.00	1	1	4.5	0.5	50	1.9	0.01	26	7.5
R-77	831015	93N/10	387497	6176733	0.1	68	51	1	15	14	553	3.50	1	1	2.0	0.6	70	1.9	0.01	28	7.2
R-78	831016	93N/10	394080	6173453	0.2	76	70	2	25	13	317	3.60	2	1	11.0	1.3	80	3.9	0.04	34	7.8
R-79	831017	93N/10	393459	6176852	0.2	54	65	1	20	14	579	3.40	1	1	2.5	0.5	60	1.5	0.01	32	7.4
R-80	831018	93N/10	395583	6175434	0.2	52	69	1	19	8	306	2.30	1	1	0.5	0.4	130	2.4	0.01	34	7.1
R-81	831020	93N/10	395196	6176310	0.1	46	72	1	15	10	354	2.60	1	1	3.0	0.6	160	1.2	0.01	26	7.5
R-82	831022	93N/10	397396	6176358	0.1	74	17	4	15	10	588	3.30	1	2	3.5	0.5	40	1.8	0.01	34	7.9
R-83	831023	93N/10	402632	6174751	0.1	69	29	8	143	16	812	3.40	1	4	28.5	1.4	70	2.3	0.01	40	8.0
R-84	831024	93N/10	404119	6177673	0.1	46	21	2	30	10	345	1.90	1	2	2.0	0.6	50	8.5	0.12	26	7.2
R-85	831025	93N/10	402894	6178111	0.2	52	58	4	51	13	636	3.30	1	1	8.5	1.4	140	2.4	0.01	42	7.5
R-86	831026	93N/10	400383	6170963	0.4	66	58	1	12	6	487	2.20	1	2	2.0	0.6	180	3.3	0.08	40	7.7
R-87	831027	93N/10	403840	6168717	0.3	98	53	11	52	14	709	3.25	4	7	11.0	0.9	30	3.0	0.13	36	6.9
R-88	831030	93N/10	397832	6164820	0.1	29	17	1	10	5	353	1.45	1	2	1.0	0.4	20	7.3	0.22	28	6.9
R-89	831031	93N/10	394585	6167491	0.1	57	30	2	26	10	575	2.55	1	1	2.5	0.5	30	5.3	0.23	32	7.0
R-90	831672	93N/10	385240	6178765	0.1	66	120	2	21	19	768	3.45	2	1	2.0	0.3	100	1.1	0.01	44	7.5
R-91	831673	93N/10	382115	6171489	0.1	70	28	7	20	11	386	2.20	2	5	4.5	--	60	4.6	0.05	42	7.2
R-92	831674	93N/10	387397	6171991	0.3	122	80	4	28	21	514	3.30	2	2	16.5	0.4	50	4.2	0.30	48	7.6
R-93	831675	93N/10	388399	6171954	1.2	430	100	8	72	28	1220	5.25	13	1	73.0	3.4	50	4.0	0.09	52	7.8
R-94	831676	93N/10	388697	6167529	3.2	235	26	10	22	11	1050	3.00	3	1	3.5	0.1	180	39.2	0.22	44	7.2
R-95	831677	93N/10	392025	6165428	0.1	54	35	4	14	10	358	2.00	1	1	3.0	0.1	30	11.3	0.26	44	7.0
R-96	831678	93N/10	392022	6164907	0.1	53	22	2	14	10	478	2.05	1	2	2.0	0.1	50	10.1	0.24	50	7.0
R-97	831680	93N/10	392894	6166215	0.1	48	33	2	25	11	407	2.05	1	1	5.5	0.1	60	5.8	0.33	52	7.0
R-98	833002	93N/10	378733	6173275	0.1	65	50	4	46	16	513	3.00	1	1	3.0	0.4	210	1.0	0.01	28	7.9
R-99	833003	93N/10	382422	6174492	0.1	78	78	4	56	17	597	3.20	1	1	3.0	0.4	100	1.1	0.01	54	8.0
R-100	833004	93N/10	385395	6175317	0.1	48	45	2	21	9	400	1.30	3	1	18.0	0.8	70	1.8	0.26	62	8.2
R-101	831585	93N/15	398191	6185769	0.4	53	36	4	68	15	430	2.60	1	1	10.0	0.7	40	3.7	0.12	42	7.4
R-102	831616	93N/15	401888	6189532	0.1	25	11	2	18	6	204	1.25	1	1	1.5	0.2	20	5.8	0.13	44	7.2
R-103	831617	93N/15	405955	6187491	0.2	30	15	1	16	7	188	1.30	1	1	1.0	0.2	20	7.3	0.09	44	7.2
R-104	831618	93N/15	401575	6180508	0.1	62	30	5	37	17	756	3.00	1	1	11.0	1.1	90	2.5	0.01	72	7.9
R-105	831619	93N/15	403515	6180176	0.1	24	12	1	15	7	181	1.10	1	1	1.0	0.3	20	5.5	0.19	42	7.0
R-106	831620	93N/15	405060	6184360	0.1	43	23	1	28	12	1540	1.95	1	1	1.5	0.2	40	1.4	0.01	60	7.5
R-107	831622	93N/15	395131	6188574	0.2	35	82	2	23	8	300	1.50	1	2	1.5	0.3	160	1.1	0.01	38	7.1
R-108	831623	93N/15	402300	6191591	0.1	35	15	1	57	8	740	1.45	1	1	6.0	0.2	50	5.2	0.12	110	7.8
R-109	831624	93N/15	398964	6192403	0.3	203	72	17	62	19	816	3.10	2	1	4.5	0.8	60	4.5	2.28	66	7.4
R-110	831645	93N/15	392721	6183259	0.2	114	36	1	70	18	972	13.50	3	1	79.0	0.2	140	1.6	0.08	84	7.3
R-111	831647	93N/15	391818	6189284	0.2	42	34	1	28	15	378	2.30	1	1	1.5	0.1	90	1.4	0.01	54	7.3
R-112	831648	93N/15	387292	6190469	0.2	53	53	1	39	21	580	3.35	1	1	2.5	0.2	90	1.0	0.01	46	7.4
R-113	831667	93N/15	376014	6192074	1.1	42	215	2	40	14	42	2.40	1	1	4.5	2.2	1200	2.8	0.02	42	7.4
R-114	831668	93N/15	378700	6185300	0.1	42	90	3	26	10	285	1.45	3	1	3.0	0.1	210	1.5	0.01	54	7.3
R-115	831669	93N/15	380900	6182900	0.1	37	42	1	13	10	656	2.00	1	1	2.5	0.1	140	1.4	0.01	54	8.0
R-116	831670	93N/15	384806	6182475	0.1	88	73	4	23	15	737	2.60	1	1	8.5	0.6	160	2.2	0.14	48	7.7
R-117	833067	93N/15	390100	6186900	0.1	64	33	4	40	9	972	1.85	2	2	10.0	2.2	120	3.1	0.01	28	7.7
R-118	833068	93N/15	386400	6188400	--	--	--	--	--	--	--	--	--	1	--	--	--	--	0.01	28	7.8
R-119	833069	93N/15	381668	6188949	0.3	44	63	2	51	17	684	3.20	1	1	3.5	0.1	50	0.9	0.01	26	7.7
R-120	833070	93N/15	381668	6188949	0.2	44	61	1	51	17	642	3.25	1	1	3.5	0.2	50	0.9	0.01	26	7.8
R-121	833071	93N/15	376743	6187420	--	--	--	--	--	--	--	--	--	1	--	--	--	--	0.01	26	7.8
R-122	833072	93N/15	375892	6187427	--	--	--	--	--	--	--	--	--	1	--	--	--	--	0.01	26	7.6
R-123	833075	93N/15	393980	6181423	0.4	70	80	7	81	16	568	2.75	1	1	12.0	0.6	70	1.8	0.01	38	7.8

MAP NO.	SAMPLE NUMBER	NTS Sheet	UTM Easting	UTM Northing	Ag ppm	Zn ppm	Cu ppm	Pb ppm	Ni ppm	Co ppm	Mn ppm	Fe %	Mo ppm	Wo ppm	As ppm	Sb ppm	Hg ppb	U ppm	U in Water (ppb)	Fl in Water (ppb)	pH of Water (ppb)
R-124	833245	93N/15	379500	6186000	--	--	--	--	--	--	--	--	--	--	--	--	--	--	0.01	38	8.0
R-125	833249	93N/15	384953	6190622	0.1	67	58	2	41	15	745	3.25	2	1	3.5	0.8	100	1.7	0.17	28	7.8
R-126	833250	93N/15	389269	6189653	0.1	49	58	1	35	14	467	2.70	1	1	1.5	0.1	70	1.2	0.04	30	7.8
R-127	831625	93N\15	396657	6197797	0.4	285	46	30	61	18	552	2.80	2	1	6.0	1.0	80	4.2	1.50	70	8.2
R-128	831626	93N\15	394951	6196210	0.1	57	56	1	56	24	800	3.60	1	1	1.5	0.2	30	1.5	0.04	46	7.7
R-129	831627	93N\15	398721	6196725	0.2	88	56	11	50	23	710	3.35	1	1	3.0	0.6	60	2.9	0.47	54	7.8
R-130	831628	93N\15	398721	6196725	0.2	86	54	10	48	22	658	3.30	1	1	2.5	0.4	40	2.7	0.64	56	7.8
R-131	831629	93N\15	403604	6196869	0.1	34	15	5	19	8	241	1.50	1	1	1.5	0.3	10	5.0	0.20	56	7.3
R-132	831630	93N\15	404553	6199636	0.2	58	35	11	34	13	740	2.65	1	1	2.5	0.2	50	7.4	2.24	70	7.8
R-133	831632	93N\15	404580	6199298	0.1	16	7	1	2	2	3250	0.15	2	1	0.5	0.2	70	2.3	0.20	84	7.8
R-134	831633	93N\15	404061	6200172	0.1	30	14	3	17	7	187	1.25	1	1	1.5	0.2	20	8.2	0.21	64	7.3
R-135	831635	93N\15	405818	6204699	0.1	25	10	2	13	5	105	1.05	1	1	1.0	0.1	20	8.0	0.12	72	6.4
R-136	831636	93N\15	405080	6206316	0.1	40	13	4	17	6	126	1.30	1	1	1.0	0.1	20	11.2	0.13	110	6.5
R-137	831637	93N\15	399616	6202962	0.2	53	32	9	35	15	490	2.30	1	1	3.5	0.1	30	2.2	0.53	52	7.9
R-138	831638	93N\15	398118	6201971	0.1	65	37	10	31	10	173	1.70	1	1	2.0	0.1	50	4.2	0.60	54	7.7
R-139	831639	93N\15	391623	6200630	0.3	280	74	66	36	7	557	1.25	4	1	6.0	1.0	200	9.3	0.90	52	7.8
R-140	831640	93N\15	391275	6199840	0.2	74	33	23	16	5	286	0.60	3	1	3.5	0.2	160	2.8	0.74	56	7.7
R-141	831642	93N\15	391103	6203155	0.9	980	40	437	56	16	1000	2.05	3	1	10.0	2.0	900	2.8	0.20	30	7.8
R-142	831643	93N\15	391103	6203155	1.0	1160	56	530	76	19	1180	3.10	4	1	9.5	2.4	1300	3.6	0.13	36	7.6
R-143	831644	93N\15	388376	6205417	0.3	400	72	18	72	20	710	2.90	4	1	5.5	0.8	170	5.6	0.59	60	7.5
R-144	831649	93N\15	386486	6196529	0.1	76	84	1	81	31	1160	4.60	1	1	5.5	0.2	90	0.6	0.04	40	7.5
R-145	831650	93N\15	389213	6195347	0.2	66	85	1	41	26	816	4.20	1	1	1.5	0.1	80	0.6	0.04	32	7.2
R-146	831651	93N\15	388341	6197572	0.3	185	51	33	54	10	286	1.85	1	1	3.0	0.2	180	8.5	0.70	54	7.2
R-147	831652	93N\15	388009	6203357	1.4	1200	115	30	640	14	522	2.10	6	1	7.0	2.6	710	129.8	0.39	110	7.4
R-148	831653	93N\15	387119	6205639	0.3	25	28	2	11	4	198	1.05	3	1	2.5	0.1	120	11.7	0.03	56	7.3
R-149	831654	93N\15	383744	6206002	0.1	43	73	2	33	15	431	2.15	1	1	2.5	0.1	60	1.9	--	--	--
R-150	831655	93N\15	382828	6204924	0.1	65	83	1	52	20	688	1.15	1	1	1.5	0.1	70	0.8	0.01	46	7.3
R-151	831656	93N\15	383346	6205042	0.1	50	59	1	35	20	669	3.10	1	1	1.5	0.1	50	0.3	0.01	34	6.8
R-152	831657	93N\15	382601	6202891	0.1	41	52	1	37	20	573	3.10	1	1	1.5	0.1	50	0.6	0.03	32	7.0
R-153	831658	93N\15	378692	6201980	0.1	50	54	1	40	22	609	3.45	1	1	1.5	0.1	40	0.5	0.01	36	6.9
R-154	831659	93N\15	380003	6199552	0.1	52	56	1	43	22	635	3.25	1	1	1.5	0.1	40	0.8	0.02	30	7.0
R-155	831660	93N\15	379580	6199647	0.1	42	43	1	38	23	578	3.30	1	1	1.0	0.1	50	0.4	0.01	40	7.1
R-156	831662	93N\15	377182	6199548	0.1	48	56	1	23	15	359	2.90	1	1	3.0	0.1	90	1.4	0.01	38	7.7
R-157	831663	93N\15	375973	6195118	0.4	63	134	3	47	17	807	3.40	2	1	5.0	0.6	200	1.8	0.01	34	6.2
R-158	831664	93N\15	380201	6196255	0.1	63	88	3	30	20	616	3.50	1	1	5.0	0.2	110	1.6	0.01	36	7.5
R-159	831665	93N\15	380888	6196704	0.2	142	88	14	70	26	861	4.10	8	1	18.0	2.6	310	3.4	0.02	40	7.5
R-160	831666	93N\15	380888	6196704	0.3	148	87	14	70	26	923	4.10	8	2	18.0	4.0	350	4.1	0.04	40	7.4
R-161	833246	93N\15	382402	6194479	0.1	72	65	3	40	16	771	3.20	1	2	3.5	0.7	160	1.6	0.01	32	7.5
R-162	833247	93N\15	388447	6198128	0.2	73	86	4	56	18	1000	3.15	2	1	2.5	0.3	70	2.1	0.02	28	7.6

(1) *Hornbrook, E. H.W. and McMillan, W.J. (1993)*; National Geochemical Reconnaissance 1:250 000 Map Series; Geological Survey of Canada Open File 1001.

(Appendix VII continued)

Map No.	Sample Number	UTM Easting	UTM Northing	Au ppb	Ag ppm	Cu ppm	Pb ppm	Zn ppm	Mo ppm	Ni ppm	Co ppm	Mn ppm	Fe %	U ppm	Th ppm	Sr ppm	V ppm	Hg ppb	As ppm	Sb ppm	Bi ppm	Se ppm	Te ppm	LOI %	Ca %	P %	La ppm	Cr ppm	Mg %	Ba ppm	Ti %	B ppm	Al %	Na %	K %	W ppm
S-1	MC87-S1-01	420415	6157518	1	0.1	31	14	68	1	37	13	558	3.12	5	3	31	46	40	2.8	0.8	0.4	0.2	0.3	7.3	n	n	n	n	n	n	n	n	n	n	n	n
S-2	MC87-S1-02	429509	6156656	1	0.1	18	9	39	1	19	6	269	1.73	5	4	14	20	10	6.8	1.1	0.4	0.4	0.3	3.6	n	n	n	n	n	n	n	n	n	n	n	n
S-3	MC87-S1-03	434071	6153362	3	0.3	35	19	77	1	37	9	462	2.99	5	5	40	40	20	6.5	0.5	0.3	0.3	0.4	6.3	n	n	n	n	n	n	n	n	n	n	n	n
S-4	MC87-S1-04	433263	6153514	4	0.1	39	13	88	1	48	12	561	3.00	5	6	37	46	10	6.7	0.7	0.3	0.3	0.2	3.9	n	n	n	n	n	n	n	n	n	n	n	n
S-5	MC87-S1-05	435109	6159573	2	0.1	19	5	29	1	15	6	244	2.11	5	17	36	36	5	1.8	0.2	0.3	0.2	0.2	2.4	n	n	n	n	n	n	n	n	n	n	n	n
S-6	MC87-S1-06	432418	6168129	3	0.2	20	7	45	1	24	6	258	1.77	5	7	17	26	5	3.1	0.2	0.3	0.2	0.2	2.2	n	n	n	n	n	n	n	n	n	n	n	n
S-7	MC87-S1-07	425290	6162162	16	0.1	28	9	45	1	27	6	288	1.94	5	6	24	29	5	3.6	0.4	0.3	0.2	0.2	2.7	n	n	n	n	n	n	n	n	n	n	n	n
S-8	MC87-S1-08	434218	6160561	3	0.2	19	11	72	1	27	7	448	1.87	5	2	20	24	20	6.2	0.3	0.4	0.2	0.2	4.8	n	n	n	n	n	n	n	n	n	n	n	n
S-9	MC87-S1-09	412397	6162704	630	0.1	28	13	76	2	78	14	1408	3.06	5	5	36	33	20	13.2	0.7	0.5	0.4	0.3	5.8	n	n	n	n	n	n	n	n	n	n	n	n
S-10	MC87-S1-10	412309	6162481	2	0.2	13	2	30	1	7	3	248	1.24	5	7	20	26	5	1.5	0.2	0.2	0.2	0.2	2.2	n	n	n	n	n	n	n	n	n	n	n	n
S-11	MC87-S1-11	412969	6171381	1	0.1	6	2	21	1	8	4	254	0.92	5	3	15	13	5	0.4	0.2	0.4	0.2	0.2	1.6	n	n	n	n	n	n	n	n	n	n	n	n
S-12	MC87-S1-12	412742	6171390	2	0.1	14	2	23	1	8	3	185	0.98	5	4	31	12	5	0.4	0.2	0.2	0.2	0.3	1.4	n	n	n	n	n	n	n	n	n	n	n	n
S-13	MC87-S1-13	419162	6155691	3	0.1	36	23	122	3	104	14	947	3.55	5	5	56	38	20	11.5	0.6	0.2	1.6	0.3	7.6	n	n	n	n	n	n	n	n	n	n	n	n
S-14	MC87-S1-14	417068	6153910	1	0.1	23	4	92	2	50	8	757	1.66	5	2	25	34	5	2.8	0.2	0.3	0.7	0.2	5.2	n	n	n	n	n	n	n	n	n	n	n	n
S-15	MC87-S1-15	417083	6153646	3	0.1	41	2	82	3	28	8	469	2.37	5	5	59	59	5	2.1	0.2	0.2	1.2	0.2	3.7	n	n	n	n	n	n	n	n	n	n	n	n
S-16	MC87-S1-16	426911	6154723	4	0.3	43	6	101	3	41	11	707	2.87	5	6	40	45	40	12.2	1.2	0.4	1.8	0.3	4.3	n	n	n	n	n	n	n	n	n	n	n	n
S-17	MC87-S1-17	433348	6175678	1	0.1	12	6	43	1	12	5	416	1.49	5	7	11	12	5	3.8	0.4	0.4	0.2	0.2	3.0	n	n	n	n	n	n	n	n	n	n	n	n
S-18	MC87-S1-18	429281	6175315	1	0.1	5	2	15	1	1	1	151	0.38	6	13	7	3	5	0.4	0.2	0.3	0.2	0.4	0.9	n	n	n	n	n	n	n	n	n	n	n	n
S-19	MC87-S1-19	429227	6175108	1	0.2	5	3	26	1	2	2	297	0.48	5	5	4	3	5	0.8	0.2	0.3	0.2	0.3	2.2	n	n	n	n	n	n	n	n	n	n	n	n
S-20	MC87-S1-30	412224	6172825	1	0.2	31	9	67	1	40	12	674	3.04	5	8	147	31	20	1.5	0.2	0.4	0.3	0.2	9.2	n	n	n	n	n	n	n	n	n	n	n	n
S-21	MC87-S1-31	408524	6176497	2	0.1	15	2	47	1	21	10	767	2.20	5	4	27	28	20	0.8	0.2	0.3	0.7	0.2	7.1	n	n	n	n	n	n	n	n	n	n	n	n
S-22	MC87-S1-32	409187	6175565	1	0.1	12	4	36	1	16	6	278	1.56	5	6	20	23	30	0.9	0.2	0.3	0.6	0.2	4.4	n	n	n	n	n	n	n	n	n	n	n	n
S-23	MC87-S1-33	423373	6176864	1	0.1	26	14	66	1	30	8	448	2.68	5	6	48	35	30	2.0	0.2	0.3	0.3	0.2	11.0	n	n	n	n	n	n	n	n	n	n	n	n
S-24	MC89-S1-01	391873	6201020	1	0.3	22	72	292	4	24	6	324	1.66	5	1	36	33	460	5	2	2	n	n	26.0	8.63	0.089	9	18	4.48	190	0.03	13	0.61	0.01	0.04	2
S-25	MC89-S1-02	389248	6203324	1	0.2	10	22	177	1	16	3	190	0.85	5	1	32	23	260	3	7	2	n	n	25.2	10.92	0.055	3	8	5.76	206	0.06	2	0.44	0.01	0.02	2
S-26	MC89-S1-03	391255	6203744	1	0.2	20	18	188	1	15	3	286	0.76	5	1	27	17	340	8	9	2	n	n	40.7	14.93	0.061	3	8	8.65	76	0.01	6	0.37	0.01	0.03	2
S-27	MC89-S1-04	404392	6217887	1	0.1	21	6	74	1	26	9	255	2.72	5	8	49	20	60	4	2	2	n	n	4.8	0.83	0.046	21	23	0.83	50	0.05	3	1.45	0.02	0.12	3
S-28	MC89-S1-05	389329	6209605	1	0.2	37	18	225	2	49	12	499	2.75	5	1	24	63	110	7	2	2	n	n	7.4	2.37	0.069	6	36	1.63	480	0.21	2	1.48	0.01	0.03	1
S-29	MC89-S1-06	388958	6209996	13	0.2	29	27	151	2	37	12	488	2.97	5	2	34	45	90	6	2	2	n	n	10.4	3.06	0.058	10	30	1.91	269	0.13	6	1.22	0.01	0.03	1
S-30	MC89-S1-07	388129	6209406	9	0.4	53	25	285	6	78	12	538	2.70	5	1	36	49	270	10	2	2	n	n	13.6	4.37	0.087	8	40	2.56	642	0.10	13	0.99	0.01	0.04	1
S-31	MC89-S1-08	387782	6208766	1	3.9	40	107	945	4	233	22	720	1.87	5	1	36	36	690	16	6	2	n	n	22.4	10.01	0.226	8	12	5.35	470	0.02	2	0.48	0.01	0.04	1
S-32	MC89-S1-09	387766	6208614	1	4.4	40	111	1024	4	265	22	1007	1.88	5	1	35	35	750	12	2	2	n	n	21.8	8.97	0.226	9	13	4.92	492	0.02	12	0.49	0.01	0.04	1
S-33	MC89-S1-10	389688	6199065	2	0.6	66	15	163	1	67	16	838	3.59	5	1	21	82	90	5	2	2	n	n	11.3	1.88	0.062	7	50	1.56	420	0.25	3	2.01	0.01	0.03	2
S-34	MC89-S1-11	380507	6197109	4	0.2	62	6	82	1	34	15	591	4.93	5	1	33	128	80	7	2	2	n	n	5.0	1.70	0.058	5	48	1.34	79	0.24	6	2.05	0.01	0.03	1
S-35	MC89-S1-12	380864	6196642	2	0.4	80	19	138	5	61	19	880	5.15	5	1	31	92	220	18	2	2	n	n	8.4	1.40	0.056	6	48	1.18	141	0.19	11	1.75	0.01	0.03	1
S-36	MC89-S1-13	380639	6196304	5	0.1	89	6	100	1	30	17	725	5.01	5	1	72	117	120	9	2	2	n	n	10.7	1.60	0.059	8	50	1.42	71	0.22	11	2.59	0.01	0.04	1
S-37	MC89-S1-14	384710	6215571	6	0.3	30	19	280	1	41	10	637	2.39	5	2	26	56	160	4	2	2	n	n	8.2	2.07	0.092	9	33	1.39	527	0.13	3	1.13	0.01	0.05	1
S-38	MC89-S1-15	388190	6219452	1	0.1	18	18	69	1	22	10	369	2.40	5	5	42	11	100	4	2	2	n	n	7.8	0.60	0.056	31	14	0.32	128	0.01	4	0.76	0.01	0.07	1
S-39	MC89-S1-16	385066	6221158	7	0.8	56	44	350	6	77	12	838	2.90	5	1	50	32	150	11	2	2	n	n	12.7	3.27	0.094	11	24	2.01	1091	0.02	2	0.79	0.01	0.06	1
S-40	MC89-S1-17	382731	6219843	9	0.8	70	25	433	10	98	15	1061	3.46	5	2	57	36	260	14	2	2	n	n	8.0	1.05	0.109	12	26	0.88	1267	0.03	11	0.91	0.01	0.06	1
S-41	MC89-S1-18	382657	6219921	2	0.5	51	18	407	11	119	14	890	2.98	5	1	41	38	120	9	2	2	n	n	7.3	0.96	0.077	11	27	0.80	1264	0.03	4	0.87	0.01	0.05	1
S-42	MC89-S1-19	399434	6216447	3	0.1	20	10	56	1	25	8	244	2.01	5	5	17	26	90	2	2	2	n	n	4.0	0.36	0.060	23	19	0.47	126	0.05	2	0.87	0.01	0.11	1
S-43	MC89-S1-20	399140	6213860	1	0.1	19	14	65	1	28	10	360	2.59	5	6	13	16	30	2	2	2	n	n	6.5	0.30	0.054	22	23	0.63	49	0.05	2	1.13	0.01	0.09	1
S-44	MC89-S1-21	396517	6215274	1	0.1	27	17	65	1	34	12	431	3.18	5	9	20	21	90	8	2	2	n	n	6.6	0.36	0.056	29	26	0.64	49	0.02	10	1.18	0.01	0.03	1

(Appendix VII continued)

Map No.	Sample Number	UTM Easting	UTM Northing	Au ppb	Ag ppm	Cu ppm	Pb ppm	Zn ppm	Mo ppm	Ni ppm	Co ppm	Mn ppm	Fe %	U ppm	Th ppm	Sr ppm	V ppm	Hg ppb	As ppm	Sb ppm	Bi ppm	Se ppm	Te ppm	LOI %	Ca %	P %	La ppm	Cr ppm	Mg %	Ba ppm	Ti %	B ppm	Al %	Na %	K %	W ppm
S-45	MC89-S1-22	392524	6216774	3	0.1	23	23	73	1	29	12	347	3.75	5	9	63	37	100	5	2	2	n	n	8.0	1.38	0.091	45	26	0.78	125	0.03	9	1.14	0.01	0.04	1
S-46	MC89-S1-23	389464	6218504	2	0.1	20	14	83	1	25	12	447	3.44	5	6	65	26	80	2	2	2	n	n	8.9	1.10	0.064	34	18	0.50	102	0.02	9	0.93	0.01	0.06	1
S-47	MC89-S1-24	385784	6220352	1	0.1	39	26	123	3	40	12	518	2.98	5	1	41	61	150	4	2	2	n	n	6.4	2.07	0.061	8	35	1.45	771	0.18	9	1.31	0.01	0.04	1
S-48	MC89-S1-25	388177	6219439	1	0.1	18	9	50	1	22	10	367	2.41	5	5	39	11	120	3	2	2	n	n	7.4	0.60	0.053	32	13	0.34	151	0.01	6	0.75	0.01	0.07	1
S-49	MC89-S1-26	398791	6210613	1	0.1	21	6	67	1	42	11	498	2.44	5	6	18	19	60	3	2	2	n	n	8.5	0.48	0.040	28	19	0.45	57	0.03	2	0.99	0.01	0.04	1
S-50	MC89-S1-27	384821	6216459	2	0.2	24	19	53	1	25	12	455	2.55	5	4	31	15	100	6	2	2	n	n	7.7	0.70	0.075	21	14	0.45	135	0.03	2	0.69	0.01	0.06	1
S-51	MC89-S1-28	392296	6209759	1	0.2	27	23	107	1	39	15	731	3.78	5	8	81	30	80	3	2	2	n	n	11.0	1.70	0.054	34	30	1.00	132	0.06	2	1.17	0.01	0.03	1
S-52	MC89-S1-29	392450	6209806	1	0.1	21	10	61	1	33	11	455	2.51	5	8	34	12	50	4	2	2	n	n	8.8	0.51	0.053	35	22	0.56	48	0.01	2	1.03	0.01	0.03	1
S-53	MC89-S1-30	392988	6208419	1	0.1	23	18	83	1	36	12	703	3.05	5	8	60	21	290	3	2	2	n	n	8.9	1.27	0.065	38	28	0.86	103	0.04	9	1.04	0.01	0.03	1
S-54	MC89-S1-31	382867	6204965	1	0.2	78	6	96	1	54	17	766	4.05	5	1	20	107	90	3	2	2	n	n	11.4	1.94	0.051	6	77	1.46	274	0.37	9	2.63	0.02	0.02	1
S-55	MC89-S1-32	383801	6206208	5	0.3	52	9	90	1	37	16	600	3.78	5	1	15	108	80	2	2	2	n	n	9.3	1.96	0.051	3	50	1.41	111	0.43	4	2.56	0.01	0.02	1
S-56	MC89-S1-33	378814	6209195	1	0.2	43	2	133	1	36	18	1036	3.90	5	1	16	116	120	2	2	2	n	n	10.4	1.69	0.048	4	52	1.26	271	0.37	8	2.41	0.02	0.02	1
S-57	MC89-S1-34	375863	6208150	1	0.2	44	6	83	1	31	16	660	3.84	5	1	12	112	80	3	2	3	n	n	5.5	1.68	0.042	3	32	1.29	250	0.44	5	2.25	0.01	0.02	1
S-58	MC89-S1-35	376231	6210672	1	0.2	121	8	86	1	47	18	762	4.61	5	1	29	132	100	4	2	2	n	n	21.7	2.06	0.087	7	75	1.42	117	0.32	9	3.03	0.02	0.05	1
S-59	MC89-S1-36	376072	6210421	1	0.2	84	9	194	1	39	17	733	3.92	5	1	23	108	120	2	2	2	n	n	17.6	1.82	0.068	5	54	1.27	251	0.32	2	2.47	0.02	0.04	1
S-60	MC89-S1-37	375787	6220349	1	0.6	67	11	290	5	91	11	918	2.21	5	3	60	23	60	13	3	2	n	n	6.5	1.11	0.065	11	21	0.75	1301	0.01	4	0.71	0.01	0.05	1
S-61	MC89-S1-38	405175	6206027	1	0.2	18	7	67	1	23	13	307	1.72	5	5	19	16	20	4	2	3	n	n	5.5	0.48	0.126	15	18	0.44	341	0.06	4	0.87	0.01	0.21	1
S-62	MC89-S1-39	405044	6205890	1	0.1	6	2	26	1	10	3	99	1.00	5	4	6	13	50	2	2	2	n	n	2.3	0.17	0.049	13	15	0.32	27	0.07	2	0.71	0.01	0.17	1
S-63	MC89-S1-49	397171	6208376	3	0.2	20	7	69	1	31	10	394	2.35	5	9	15	10	60	7	2	2	n	n	6.4	0.27	0.049	27	21	0.53	24	0.01	4	1.04	0.01	0.03	2
S-64	MC89-S1-51	389705	6201252	1	0.6	55	16	522	14	139	16	1173	3.11	18	1	34	66	190	16	2	2	n	n	12.0	1.06	0.092	11	41	0.69	676	0.12	3	1.38	0.01	0.05	1
S-65	MC89-S1-52	397338	6197296	1	0.4	45	12	106	1	51	18	636	4.35	5	4	41	95	60	3	2	2	n	n	7.4	2.07	0.042	11	54	1.40	164	0.27	5	2.26	0.01	0.02	2
S-66	MC89-S1-53	395269	6205589	5	0.2	17	10	58	1	22	9	548	2.31	5	4	161	11	50	7	2	2	n	n	20.7	8.70	0.052	22	19	0.55	47	0.01	3	0.68	0.01	0.04	1
S-67	MC89-S1-56	384492	6215513	1	0.5	64	41	117	1	49	14	691	3.38	5	1	45	79	40	3	2	2	n	n	7.9	1.95	0.049	6	44	1.59	1125	0.29	2	1.90	0.01	0.03	1
S-68	MC89-S1-57	385502	6213669	1	0.4	49	29	450	3	56	11	621	2.18	5	1	33	59	70	5	2	2	n	n	13.8	2.78	0.072	11	41	1.60	616	0.09	2	1.03	0.01	0.06	1
S-69	MC89-S1-58	385905	6214053	1	0.5	31	33	682	4	55	10	1212	2.33	5	2	35	56	80	10	2	2	n	n	14.5	3.27	0.180	12	34	1.59	548	0.06	8	0.94	0.01	0.08	1
S-70	MC89-S1-59	384904	6218237	4	0.4	49	26	137	21	43	9	481	2.32	5	2	70	51	60	15	2	2	n	n	8.1	1.73	0.062	10	20	0.75	766	0.04	3	0.60	0.01	0.05	3
S-71	MC89-S1-60	391617	6216135	2	0.1	20	12	59	1	31	12	363	3.01	5	8	55	17	20	3	2	4	n	n	8.1	0.84	0.051	42	24	0.57	56	0.02	2	1.15	0.01	0.02	1
S-72	MC89-S1-61	391508	6216341	1	0.1	19	16	93	1	27	12	361	3.41	5	14	89	31	40	10	2	3	n	n	6.4	2.27	0.100	56	25	0.79	119	0.02	2	1.02	0.01	0.04	1
S-73	MC89-S1-62	394896	6218558	1	0.1	11	2	40	1	12	9	189	1.21	5	4	8	13	30	2	2	2	n	n	2.7	0.18	0.051	19	12	0.29	35	0.04	3	0.65	0.01	0.11	1
S-74	MC89-S1-63	393354	6219983	1	0.2	13	5	38	1	14	9	147	1.31	5	4	12	13	20	2	2	2	n	n	4.2	0.16	0.038	20	13	0.33	42	0.05	4	0.77	0.01	0.15	2
S-75	MC89-S1-64	396582	6217829	1	0.2	12	4	29	1	12	5	200	1.29	5	8	12	20	20	2	2	2	n	n	1.8	0.34	0.089	24	11	0.27	45	0.04	3	0.57	0.01	0.08	2
S-76	MC89-S1-65	394987	6206499	2	0.1	11	19	67	1	14	6	330	1.71	5	3	43	11	40	4	2	2	n	n	19.1	5.10	0.069	18	16	2.72	61	0.01	2	0.59	0.01	0.05	1
S-77	MC89-S1-66	394635	6206673	1	0.1	16	17	85	1	21	10	395	2.41	5	5	128	12	20	6	2	2	n	n	16.4	7.58	0.049	22	19	0.87	40	0.02	3	0.68	0.01	0.04	2
S-78	MC89-S1-67	382255	6212150	4	0.3	65	8	79	1	45	18	692	3.95	5	1	20	100	50	2	2	2	n	n	6.8	2.02	0.043	3	48	1.55	118	0.39	2	2.42	0.01	0.02	1
S-79	MC89-S1-68	382200	6212190	3	0.4	78	2	77	1	63	19	626	4.19	5	1	13	110	30	2	2	2	n	n	9.4	1.75	0.045	3	62	1.76	113	0.35	2	2.59	0.01	0.02	1
S-80	MC89-S1-69	379207	6213700	2	0.7	69	11	135	4	66	13	771	2.87	18	2	38	71	60	8	2	2	n	n	8.7	1.07	0.054	8	64	0.86	862	0.19	3	1.52	0.01	0.03	2
S-81	MC89-S1-70	379101	6213525	1	0.4	70	2	146	1	90	21	1234	4.31	5	1	20	95	30	2	2	2	n	n	8.0	1.29	0.037	6	60	1.80	369	0.29	2	2.33	0.01	0.02	1
S-82	MC89-S1-71	377522	6214976	1	0.4	94	25	463	5	90	16	927	2.97	7	3	61	35	100	16	2	2	n	n	7.0	0.54	0.065	14	33	0.56	2524	0.07	6	1.11	0.01	0.06	1
S-83	MC89-S1-72	377414	6214712	1	0.4	103	3	131	7	104	22	845	4.37	5	1	38	108	210	7	2	2	n	n	12.7	1.60	0.063	6	74	1.53	304	0.29	4	2.55	0.02	0.03	1
S-84	MC89-S1-73	376008	6214963	1	0.4	76	9	124	1	66	16	729	4.05	5	2	35	88	60	8	2	2	n	n	16.7	1.29	0.092	12	89	1.09	586	0.16	5	2.41	0.01	0.05	1
S-85	MC89-S1-74	376252	6215046	22	0.3	88	29	386	7	115	19	1107	3.61	5	1	66	64	80	14	2	2	n	n	10.5	1.04	0.065	9	48	1.03	1523	0.14	2	1.61	0.01	0.04	1
S-86	MC89-S1-75	404591	6209094	2	0.1	14	2	56	1	20	9	220	1.45	5	3	15	15	30	2	2	2	n	n	6.3	0.29	0.077	15	13	0.35	255	0.06	2	0.86	0.01	0.18	1
S-87	MC89-S1-76	404450	6208538	7	0.1	18	7	88	1	24	10	227	1.78	5	5	17	17	20	2	2	2	n	n	5.9	0.35	0.087	17	20	0.44	62	0.07	2	1.02	0.01	0.20	1

APPENDIX VIII

REGIONAL GEOCHEMICAL SURVEY; BULK STREAM SEDIMENT GEOCHEMISTRY FOR SAMPLES COLLECTED DURING THE YEARS 1987 AND 1988

-60+100 FRACTION - 1987 RGS

Map No.	Field Number	UTM Easting	UTM Northing	Original Field Wt.	Fraction (-60-100)	Au ppb	Ag ppm	Zn ppm	As ppm	Sb ppm	Mo ppm	Ni ppm	Co ppm	Cr ppm	Ba ppm	Ca %	Fe %	Hf ppm	Na %	Sc ppm	Se ppm	Ta ppm	Th ppm	U ppm	W ppm	La ppm	Ce ppm	Sm ppm	Eu ppm	Yb ppm	Lu ppm	Ir ppb
B-1	MC87-H1-01	420415	6157518	5.000	21.07	<15	<5	<200	4	1.3	<20	400	24	300	600	15	4.87	5	1.2	35.1	<20	7	28	4.2	<6	263	414	38.1	6.7	7.4	1.24	<50
B-2	MC87-H1-02	429509	6156656	6.100	5.72	14000	<5	<200	<2	1.3	<20	<400	12	230	900	7	5.06	34	1	34.2	<20	52	88	15.3	490	324	580	40.9	7	16	2.4	<50
B-3	MC87-H1-03	434071	6153362	5.700	7.82	7400	<5	<200	<19	<1.9	<20	INT	14	260	4200	8	3.23	110	0.81	25.1	<20	9	1100	109	99	2780	3660	271	23.3	22.1	2.45	<50
B-4	MC87-H1-04	433263	6153514	5.400	15.37	<19	<5	<200	7	1.6	<20	<300	21	380	3600	14	4.55	11	1.2	34.6	20	5	96	13	9	292	443	46.4	6.7	6.5	1.28	<50
B-5	MC87-H1-05	435109	6159573	5.300	19.59	2200	<5	<200	5	0.7	<20	<300	5	80	1000	10	1.53	44	0.19	10.3	<20	12	180	36.5	25	1040	1700	1870	26.4	29.4	7.19	<50
B-6	MC87-H1-06	432418	6168129	5.000	7.76	13000	<5	<200	<2	<0.2	<20	<600	17	180	2700	<8	2.58	160	1.2	20.1	<20	10	1300	215	360	2570	3570	360	8.4	26.1	4.81	<50
B-7	MC87-H1-07	425290	6162162	6.700	7.70	180000	<5	<200	<16	3	<20	500	19	270	3300	<5	3.82	78	0.92	33.8	<20	23	270	38.3	570	783	1020	66.3	10.1	16.4	1.9	<50
B-8	MC87-H1-08	434218	6160561	6.800	7.86	<39	<5	<400	<7	1.6	<20	<900	12	120	1300	<1	2.64	73	0.93	18.9	<30	12	160	73	260	505	828	96.1	13.2	27.3	4.81	<50
B-9	MC87-H1-09	412397	6162704	4.900	9.29	24000	<5	<200	<2	1.9	<20	1500	44	260	1800	4	6.86	16	0.83	34.3	30	16	140	26.1	1200	688	848	63.3	11.2	14.8	2.04	<50
B-10	MC87-H1-10	412309	6162481	8.200	14.86	<19	<5	<200	<4	1	<20	<300	11	300	500	7	2.52	16	0.37	32.9	100	21	150	34.1	110	478	688	69.8	8.6	17.2	2.54	<50
B-11	MC87-H1-11	412969	6171381	5.500	10.22	<36	<5	<200	<2	<0.9	<20	<900	<8	110	1900	16	3.36	60	0.37	21.4	<20	10	220	56.9	35	721	966	87.7	12	17.5	2.62	<50
B-12	MC87-H1-12	412742	6171390	6.700	5.34	INT	<5	INT	INT	<5.0	INT	INT	INT	INT	INT	INT	2.85	180	<0.26	15.1	INT	INT	1700	205	INT	5810	6600	468	46.2	18	6.91	<50
B-13	MC87-H1-13	419162	6155691	6.800	11.77	15000	<5	700	27	0.9	<20	<500	19	290	1200	<6	4.62	<1	0.47	24.6	<30	35	220	54.3	3200	727	1090	99.7	11.6	20	3.53	<50
B-14	MC87-H1-14	417068	6153910	6.000	3.26	<33	<5	<200	<5	<0.9	<20	INT	12	250	<800	9	3.91	<1	0.45	23.6	<30	27	250	68.9	240	515	824	106	17.4	34.3	4.48	<50
B-14	MC87-H1-14a	417068	6153910	6.000	3.26	60	<5	200	<2	0.8	<20	24000	1100	7600	<200	<3	37.9	<1	<0.05	39	<20	<1	1	2.2	<4	50	47	5.9	2.2	2.9	0.44	<50
B-15	MC87-H1-15	417083	6153646	7.800	7.80	INT	<5	600	22	<0.2	<30	INT	12	60	INT	10	1.78	400	0.49	18.9	<30	30	410	140	390	479	589	120	25.7	48.4	6.42	<50
B-16	MC87-H1-17	433348	6175678	5.400	7.92	INT	<5	300	<4	<4.4	<20	<500	<5	<10	7100	<2	0.77	89	INT	4.6	<20	<8	4200	577	INT	7420	8420	765	20.9	23.7	5.77	<50
B-17	MC87-H1-18	429281	6175315	6.200	4.19	<5	<5	<200	<9	<1.6	<20	<200	10	<100	8100	<1	1.05	<4	<4.6	9.1	<20	9	4200	607	INT	7280	8880	810	810	42.9	21.5	<50
B-18	MC87-H1-19	429227	6175106	7.000	6.44	<5	<5	INT	INT	INT	<20	<200	23	INT	5300	<20	INT	210	INT	3.9	INT	<9	4200	660	INT	711	8330	786	17	47.3	8.86	<50
B-19	MC87-H1-21	409630	6178610	5.900	3.72	<5	<5	<200	<2	<0.2	<20	900	<8	80	4900	<1	0.91	89	0.31	13.4	<20	<30	1900	187	INT	4590	6450	592	42.7	28	3.46	<50
B-20	MC87-H1-25	423375	6176950	7.900	5.56	INT	<5	700	380	INT	<20	INT	<17	130	INT	<3	0.94	160	INT	8.3	120	<11	5500	841	INT	10300	11800	1050	30.8	34.1	9.68	<50
B-21	MC87-H1-26	418250	6167660	5.100	6.02	<37	<5	<200	8	<0.9	<20	<900	11	60	<700	10	3.22	<1	0.16	20.8	30	15	170	99.6	400	620	678	81.8	11.2	17.3	2.87	<50

a - Denotes sample re-analysis

n/r - not run

Original field weight in kilograms, fraction weight is nonmagnetic fraction in grams.

INT - Indeterminate due to lack of sample.

-100+200 Fraction - 1987 RGS

Map No.	Sample Number	UTM Easting	UTM Northing	Original Field Wt.	Fraction 100 to 200	Au ppb	Ag ppm	Zn ppm	As ppm	Sb ppm	Mo ppm	Ni ppm	Co ppm	Cr ppm	Ba ppm	Ca %	Fe %	Hf ppm	Na %	Sc ppm	Se ppm	Ta ppm	Th ppm	U ppm	W ppm	La ppm	Ce ppm	Sm ppm	Eu ppm	Yb ppm	Lu ppm	Ir ppb
B-1	MC87-H1-01	420415	6157518	5.000	7.76	65	<5	<200	<2	<0.2	<30	<900	19	220	1000	7	4.59	58	1.1	42	<20	5	77	11.3	<4	467	686	45.4	10.3	8.5	1.56	<50
B-2	MC87-H1-02	429509	6156656	6.100	4.78	860	<5	<200	<7	<0.8	<20	<400	13	180	800	<6	3.27	120	0.92	30.5	<20	45	100	27.1	190	402	593	47.2	11.1	17	2.1	<50
B-3	MC87-H1-03	434071	6153362	5.700	4.42	3800	<5	<200	30	<1.7	<20	<500	15	240	3000	26	2.95	230	1.1	30.6	30	6	820	104	66	2430	3380	254	26.6	20	3.11	<50
B-4	MC87-H1-04	433263	6153514	5.400	11.80	190	<5	200	11	2.4	<20	800	18	390	3700	12	4.74	52	1.1	39.6	<20	6	210	36.3	18	683	1030	99.6	10	11	1.97	<50
B-5	MC87-H1-05	435109	6159573	5.300	10.74	INT	<5	<400	<20	<2.3	<20	INT	23	<80	INT	<20	1.44	440	0.23	14.6	80	25	780	136	INT	2240	2990	241	23.1	44.2	5.94	<50
B-6	MC87-H1-06	432418	6168129	5.000	8.05	460	<5	<300	<13	<1.6	<20	<1800	<14	<50	3000	<13	1.84	100	1.2	18	<20	<9	620	107	49	1410	1840	184	12.7	11.3	2.21	<50
B-7	MC87-H1-07	425290	6162162	8.700	6.15	160000	<5	<200	<17	<1.2	<20	<400	13	180	1300	10	2.04	160	0.87	28.1	40	20	330	54.2	270	1160	1550	100	17.4	35.4	3.04	<50
B-8	MC87-H1-08	434218	6160561	6.800	14.12	<19	<5	<200	<4	1	<20	<300	<5	100	700	10	1.56	88	1.2	14.4	<20	16	130	44.3	69	395	639	70.9	8.1	13.8	2.63	<50
B-9	MC87-H1-09	412397	6162704	4.900	9.93	13000	<5	<200	<2	1.4	<30	400	22	170	800	6	3.55	<1	1	25.1	<20	11	200	15.8	240	836	1100	64.5	8.3	16.1	1.49	<50
B-10	MC87-H1-10	412309	6162481	8.200	5.97	3000	<5	<200	<2	2	<20	<500	35	220	2100	<6	2.58	170	1.1	41.5	<20	33	630	64.4	260	2160	2490	155	17	32	2.97	<50
B-11	MC87-H1-11	412969	6171381	5.500	9.02	INT	<5	<200	<10	<1.2	<40	<1300	<11	<40	INT	<10	1.88	120	0.75	16	<60	13	320	60.7	27	1110	1530	123	9.2	18.1	2.4	<50
B-12	MC87-H1-12	412742	6171390	6.700	2.71	INT	<5	<200	INT	<0.2	<20	<200	<31	300	3600	INT	2.28	330	INT	12.4	<20	20	1900	318	INT	7380	9090	622	34.3	35.5	5.71	<50
B-12	MC87-H1-12a	412742	6171390	6.700	2.71	490	<5	1600	940	620	<30	26000	930	6100	<500	<1	32.6	<1	0.1	29.7	30	<3	1.3	3	<4	39	25	3.3	2.2	2.1	0.23	<50
B-13	MC87-H1-13	419162	6155691	6.800	4.18	10000	<5	200	34	<1.5	90	<200	14	250	1200	<7	3.26	130	<0.05	21.4	<20	33	470	96	2000	1800	2000	118	14	18.7	2.18	<50
B-14	MC87-H1-14	417068	6153910	6.000	1.91	<57	<5	<200	16	1.9	<20	<900	13	180	1600	INT	3.37	190	1	21.3	<20	30	370	88.6	320	1130	1090	112	15.5	31.6	6.54	<50
B-15	MC87-H1-15	417083	6153646	7.800	11.58	460	<5	<200	6	0.5	<20	<400	10	80	1400	14	1.85	260	2	16.2	<20	20	250	103	150	364	669	93.2	14.7	36.3	7.34	<50
B-16	MC87-H1-17	433348	6175678	5.400	4.42	2900	<5	<600	INT	INT	INT	<200	INT	INT	10000	INT	INT	<1	0.54	4.9	<20	INT	4200	496	INT	7550	8860	877	67.6	22.1	3.13	<50
B-17	MC87-H1-18	429281	6175315	6.200	6.08	<100	<5	<500	INT	<2.4	INT	<2800	<23	<100	<1000	<20	1.42	130	<0.05	7.2	<80	15	1100	174	49	2430	3040	280	INT	28.6	3.95	<50
B-18	MC87-H1-19	429227	6175108	7.000	4.24	210	<5	<200	<2	<0.2	INT	INT	9	INT	6500	INT	INT	110	0.99	3.8	<20	7	3300	457	100	6310	8170	831	18.7	37.4	8.25	<50
B-19	MC87-H1-21	409630	6178610	5.900	3.40	INT	<5	200	INT	INT	<20	<200	13	80	3500	<1	0.99	220	INT	13.9	<30	12	2200	267	INT	4950	7820	558	18.6	22.3	4.55	<50
B-20	MC87-H1-25	423375	6176950	7.900	8.32	470	<5	200	INT	<3.3	<20	INT	68	<90	3300	54	INT	180	0.95	4.1	40	<1	2400	362	INT	5420	7430	625	25.8	28.2	6.81	<50
B-21	MC87-H1-26	418250	6167660	5.100	3.67	<49	<5	<300	11	<1.2	<30	<2500	<13	<50	<1100	<11	1.75	130	0.24	18.7	<20	15	220	76.2	140	923	998	93.9	13.9	14.8	2.7	<50

a - denotes sample re-analysis

-200 Fraction - 1987 RGS

Map No.	Sample Number	Au ppb	Ag ppm	Zn ppm	As ppm	Sb ppm	Mo ppm	Ni ppm	Co ppm	Cr ppm	Ba ppm	Ca %	Fe %	Hf ppm	Na %	Sc ppm	Se ppm	Ta ppm	Th ppm	U ppm	W ppm	La ppm	Ce ppm	Sm ppm	Eu ppm	Yb ppm	Lu ppm	Ir ppb
B-1	MC87-H1-1	880	<5	400	<2	2.4	<20	<300	14	80	1100	4	3.07	66	1.2	25.1	<20	<3	28	4.1	<6	202	269	19	6.1	5.3	0.89	<50
B-2	MC87-H1-2	<25	<5	200	<2	<0.6	<20	<800	11	50	<600	<5	1.66	160	1.1	13.6	50	9	84	18.5	25	293	381	30.6	5.2	9.6	1.3	<50
B-3	MC87-H1-3	820	<5	<200	<2	<1.1	<30	<1000	18	70	<800	9	1.82	92	1.1	14.8	<20	6	170	31.6	<15	539	825	60	6.3	8	1.88	<50
B-4	MC87-H1-4	170	<5	<200	<2	1.2	<20	<300	18	90	1300	4	3.41	<1	1.1	21.2	<20	<4	140	21.5	<4	527	885	56.2	7.4	8.8	1.96	<50
B-5	MC87-H1-5	<5	<5	<300	<2	<0.8	<30	<200	13	100	1300	<8	1.5	540	1.4	17	<20	<5	440	120	55	985	1040	83.8	18	19	3.26	<50
B-6	MC87-H1-6	42	<5	<200	<2	1.8	<20	<200	9	140	1100	<8	1.91	130	1.5	10.4	<20	7	270	77.4	21	864	1570	162	11.5	13.5	2.99	<50
B-7	MC87-H1-7	24000	<5	<300	15	<1.5	<30	<1900	<17	140	1600	<23	2.24	220	2.3	16.2	<60	<14	280	54.3	54	1190	1170	93.4	9.8	12.1	2.32	<50
B-7	MC87-H1-7a	2000	170	4300	11000	70	<20	<600	10	60	800	<2	4.52	<3	0.11	12.5	<20	<1	5.7	5	<4	17	14	2.1	2.5	3.1	0.18	<50
B-8	MC87-H1-8	42	<5	<200	<2	<1.0	<20	<900	11	<10	<800	<7	1.59	210	1.4	13.4	<30	<5	220	54.2	25	700	960	83.6	8.6	14.1	2.62	<50
B-9	MC87-H1-9	6300	<5	<300	<2	<1.1	<30	<1500	<13	160	<1000	<10	1.97	39	1.7	15.8	<20	<7	240	12.5	97	854	1120	61.1	7.2	8.2	0.91	<50
B-11	MC87-H1-11	<32	<5	<200	54	2	<20	<200	<12	60	3700	<36	2.86	330	2.6	16.5	<20	<9	760	119	33	2980	3760	281	31.9	59.9	10.9	<50
B-13	MC87-H1-13	2300	<5	<200	9	<1.1	<20	<1200	<10	70	1900	<17	2.65	110	2.5	16.1	<20	20	170	24.6	200	768	963	57.5	7.3	13.2	3.02	<50
B-15	MC87-H1-15	330	<5	<200	<2	<0.5	<20	<700	8	<10	<400	<4	0.61	160	2	7.6	<20	<1	61	25.3	12	155	171	26.1	6.4	13.4	2.21	<50
B-16	MC87-H1-17	<5	<5	<200	<27	<2.7	<20	<1400	<17	<90	5900	<1	1.98	300	1.6	9.7	<80	51	1700	285	78	5220	6540	518	44.2	24	5.84	<50
B-17	MC87-H1-18	<57	<5	<400	<10	<1.4	<40	<2500	<17	<50	2800	<13	1.24	190	2	5.4	<20	<10	440	71.2	<15	1230	1440	145	9.6	19.9	4	<50
B-18	MC87-H1-19	1400	<5	<200	<16	<2.8	<20	1100	<14	<60	3700	<1	<0.77	180	3.1	4.8	<50	<11	850	128	INT	2580	3280	286	18	23.5	4.23	<50
B-19	MC87-H1-21	<98	<5	<200	<27	2.7	120	<200	<15	120	4000	INT	<0.88	350	2.6	2.3	<60	<13	1200	179	55	4120	5270	411	28.6	29.7	7.21	<50
B-20	MC87-H1-25	INT	<5	<400	<2	<0.2	<20	<200	<14	160	3100	INT	2.38	240	1.9	8	<20	<1	1100	170	INT	2650	3180	293	19.3	38.9	5.15	<50

a - denotes sample re-analysis

1988 RGS - BULK SAMPLES (-45+80 Sample Fraction, May 8, 1990)

Map No.	SAMPLE NUMBER	UTM Easting	UTM Northing	HMS Wt gm	SAMPLE WT. gm	Au ppb	Ba ppm	Ce ppm	Cr ppm	Eu ppm	Lu ppm	Sb ppm	Sc ppm	Sm ppm	Ta ppm	Th ppm	U ppm	W ppm	Y ppm	Zr ppm
B-22	MC88-H1-01	397526	6176309	20.59	500	82	770	380	3800	-2	0.8	6.2	67.1	27.0	6	48.0	8.6	9	-5	2400
B-23	MC88-H1-02	401509	6165060	24.74	500	190	150	1490	570	15	1.7	1.5	73.9	99.0	63	209.0	62.8	26	28	3100
B-24	MC88-H1-03	393190	6173564	17.75	350	-14	-100	96	1200	6	-0.5	2.2	82.2	11.0	2	5.6	1.2	-4	-5	-1100
B-25	MC88-H1-04	393258	6174198	58.90	380	35	-100	120	750	4	-0.5	2.0	68.1	12.0	2	2.8	-0.5	-8	-5	510
B-26	MC88-H1-05	384361	6175398	57.90	500	300	140	33	1700	-2	-0.5	1.5	98.5	5.3	2	2.5	-0.5	-8	-5	600
B-26	MC88-H1-05a	384361	6175398	-9.00		42	-100	23	1500	-2	-0.5	1.4	91.1	4.5	1	2.1	1.2	-5	-5	-500
B-27	MC88-H1-06	378916	6173602	96.80	550	-5	290	28	1700	-2	-0.5	0.8	111.0	4.3	-1	1.6	-0.5	-7	-5	-500
B-27	MC88-H1-06a	378916	6173602	-9.00		-11	160	-10	1500	-2	-0.5	1.1	97.8	4.2	-1	1.1	-0.5	-5	-5	-500
B-28	MC88-H1-07	380523	6169859	58.83	360	160	140	1260	940	10	0.8	2.5	74.0	77.9	25	205.0	40.0	160	13	1900
B-29	MC88-H1-08	380660	6169503	68.86	380	-5	-100	2790	-50	34	4.3	1.6	90.1	213.0	73	386.0	107.0	94	44	4000
B-29	MC88-H1-08a	380660	6169503	-9.00		-19	-200	2340	430	29	-0.5	0.9	87.7	144.0	67	371.0	85.0	87	44	4600
B-30	MC88-H1-09	387467	6171859	32.62	230	16	250	1440	840	9	0.6	4.3	63.1	72.3	21	202.0	34.0	339	12	1600
B-31	MC88-H1-10	382210	6171431	21.29	160	1870	-100	1310	860	10	0.8	5.0	67.2	59.7	17	171.0	24.0	236	13	970
B-32	MC88-H1-11	376214	6176922	106.05	500	-13	-100	-10	2300	2	-0.5	1.0	122.0	5.0	1	2.1	-0.5	-9	-5	-500
B-32	MC88-H1-11a	376214	6176922	-9.00		-12	-100	22	2200	-2	-0.5	0.9	119.0	4.9	-1	2.9	0.9	-13	-5	-500
B-32	MC88-H2-11	376214	6176922	152.12	550	-19	-240	31	2900	-2	-0.5	1.3	140.0	4.7	-1	1.9	1.8	-15	-5	-1000
B-32	MC88-H2-11a	376214	6176922	-9.00		-20	-100	-22	2800	3	-0.5	1.0	134.0	5.2	1	2.5	-0.5	-19	-5	-1000
B-32	MC88-H2-11b	376214	6176922	-9.00		31	-100	24	2700	-2	-0.5	1.2	125.0	4.6	-1	2.2	1.8	-18	-5	1400
B-33	MC88-H1-12	391133	6166983	14.70	250	-13	290	4640	-50	28	0.9	1.0	44.0	191.0	78	581.0	121.0	-21	36	4800
B-34	MC88-H1-13	393196	6180708	29.73	260	-14	-100	83	1200	-2	0.6	3.7	74.6	11.0	-1	3.6	-0.5	6	6	-1200
B-35	MC88-H1-14	390134	6186619	33.31	500	-18	590	82	1500	-5	0.7	3.3	66.2	10.0	2	5.5	-0.5	-8	-5	1900
B-36	MC88-H1-15	386442	6188159	104.44	650	-19	250	77	1500	2	-0.5	1.7	56.4	13.0	1	8.5	-0.5	-23	-5	-500
B-36	MC88-H1-15a	386442	6188159	-9.00		230	190	80	1900	3	-0.5	1.8	60.1	12.0	2	10.0	2.5	-250	-5	750
B-36	MC88-H2-15	386442	6188159	97.86	550	772	310	100	2400	4	0.8	2.4	83.4	11.0	2	12.0	2.7	-12	-5	-1100
B-36	MC88-H2-15a	386442	6188159	-9.00		-17	-100	78	2300	4	-0.5	2.1	85.5	11.0	2	8.8	1.6	-16	-5	1100
B-37	MC88-H1-16	390058	6186607	18.04	600	110	990	54	1200	-4	-0.5	4.2	60.6	10.0	-1	6.4	-0.5	32	7	-1400
B-38	MC88-H1-17	394806	6177307	37.46	610	-5	250	190	1000	4	-0.5	2.7	95.5	15.0	4	23.0	3.8	-7	-5	670
B-39	MC88-H1-18	381840	6188716	65.31	550	-5	110	34	1800	-2	-0.5	1.5	88.1	5.6	-1	1.9	-0.5	-10	-5	-500
B-40	MC88-H1-19	376714	6187107	97.96	750	-10	310	21	1400	3	-0.5	2.0	102.0	6.1	1	2.8	-0.5	-8	-5	-500
B-40	MC88-H1-19a	376714	6187107	-9.00		-11	250	30	1100	-2	-0.5	1.7	83.5	5.3	-1	2.5	0.8	-11	-5	-500
B-41	MC88-H1-20	388842	6164565	20.79	280	-19	-100	2690	450	47	-0.5	1.1	56.4	168.0	85	570.0	118.0	46	61	4800
B-42	MC88-H1-21	383236	6182322	20.23	500	250	-100	110	1400	4	0.7	2.9	66.8	14.0	2	5.6	2.6	-5	6	-500
B-43	MC88-H1-22	383057	6182210	40.90	370	-5	380	83	1600	3	-0.5	2.6	85.3	10.0	3	5.1	2.5	-7	6	980
B-44	MC88-H1-23	398704	6187338	49.35	300	-10	310	42	870	3	0.5	0.9	79.3	7.6	-1	2.0	-0.5	-9	-5	590
B-44	MC88-H2-23	398704	6187338	72.30	430	-11	260	32	730	3	0.7	0.8	77.4	7.5	-1	2.1	-0.5	-9	-5	-500
B-44	MC88-H2-23a	398704	6187338	-9.00		-12	240	33	630	-2	0.5	0.7	62.3	6.6	1	2.8	-0.5	-5	-5	-500
B-45	MC88-H1-24	397993	6183968	40.99	520	24	-100	270	3600	2	-0.5	2.6	87.8	19.0	6	38.0	6.9	-10	-5	1700
B-46	MC88-H1-25	398773	6184749	22.01	300	-16	-230	830	1700	-5	2.2	1.3	72.3	85.2	6	231.0	29.0	-7	12	-1400
B-47	MC88-H1-26	398773	6184749	68.86	550	-5	390	66	990	4	0.6	1.5	73.6	10.0	2	6.7	1.5	-7	-5	-500
B-47	MC88-H1-26a	400980	6192649	-9.00		-5	460	67	1000	3	-0.5	1.1	67.3	9.0	2	7.7	1.8	6	-5	-500
B-48	MC88-H1-27	402140	6188567	19.00	450	-13	-220	740	1000	-4	1.9	1.7	61.4	73.8	8	169.0	27.0	9	12	-1500

1988 RGS BULK SAMPLES
(-80+170 Fraction, May 8, 1990)

Map No.	Field Number	UTM Easting	UTM Northing	HMS Wt gm	SAMPLE WT. gm	Au ppb	Ba ppm	Ce ppm	Cr ppm	Eu ppm	Lu ppm	Sb ppm	Sc ppm	Sm ppm	Ta ppm	Th ppm	U ppm	W ppm	Y ppm	Zr ppm
B-22	MC88-H1-01	397526	6176309	28.37	705	552	740	360	3800	4	0.9	5.6	75.1	28.0	5	38.0	10.0	-6	8	1800
B-23	MC88-H1-02	401509	6165060	21.02	313	79	-230	1130	820	12	2.8	1.4	68.3	85.8	39	185.0	71.2	26	14	6800
B-24	MC88-H1-03	393190	6173564	10.59	83	150	-100	160	1300	3	-0.5	2.1	68.9	12.0	2	5.5	1.8	-5	-5	1200
B-25	MC88-H1-04	393258	6174198	4.83	87	24	-250	130	1500	-2	-0.5	1.7	64.0	10.0	2	8.3	3.5	-6	-5	-1200
B-26	MC88-H1-05	384361	6175398	21.12	192	97	-100	71	1300	-2	-0.5	1.5	90.0	8.1	2	6.5	1.6	7	-5	1600
B-27	MC88-H1-06	378916	6173602	30.86	171	96	-100	34	1600	-2	-0.5	1.5	90.8	5.7	1	2.9	-0.5	-6	-5	1500
B-28	MC88-H1-07	380523	6169859	30.70	133	1080	330	860	1800	9	-0.5	2.6	86.6	45.0	23	158.0	65.0	436	21	8500
B-29	MC88-H1-08	380660	6169503	17.05	102	34	-260	1230	640	12	2.1	1.2	70.2	101.0	33	238.0	142.0	339	28	18000
B-30	MC88-H1-09	387467	6171859	7.24	76	937	-260	770	1200	9	-0.5	3.1	48.0	44.0	13	137.0	53.6	304	-5	4200
B-31	MC88-H1-10	382210	6171431	4.62	58	1810	-300	720	1100	8	-0.5	3.3	51.0	36.0	11	103.0	38.0	190	-5	3900
B-32	MC88-H1-11	376214	6176922	44.86	225	250	-100	35	2800	-2	-0.5	1.1	124.0	6.3	2	5.1	2.2	-11	-5	-500
B-32	MC88-H2-11	376214	6176922	48.92	214	529	-100	35	2900	-2	-0.5	1.3	104.0	6.6	2	4.7	2.1	-11	-5	2000
B-33	MC88-H1-12	391133	6166983	8.11	87	1260	-260	2210	520	15	2.0	1.2	50.4	128.0	47	288.0	112.0	35	22	12000
B-34	MC88-H1-13	393196	6180708	9.47	70	28	-210	130	1500	-2	0.6	2.7	75.8	13.0	-1	5.7	3.2	-6	9	-1400
B-35	MC88-H1-14	390134	6186619	19.45	213	210	520	130	1900	-6	-0.5	3.5	67.7	13.0	2	8.2	-1.2	-10	-5	-2000
B-36	MC88-H1-15	386442	6188159	29.50	156	120	-260	110	2100	-5	0.6	2.7	67.9	15.0	2	12.0	2.8	-8	-5	-1600
B-36	MC88-H2-15	386442	6188159	24.79	145	46	230	120	2400	5	0.5	1.9	71.2	15.0	2	16.0	3.7	-8	-5	1200
B-37	MC88-H1-16	390058	6186607	5.97	275	24	1500	60	690	-2	-0.5	3.7	28.0	8.7	1	7.3	3.2	24	-5	-1300
B-38	MC88-H1-17	394806	6177307	22.92	230	15	-100	170	990	-2	0.7	2.0	72.9	15.0	2	16.0	3.8	-5	-5	-500
B-39	MC88-H1-18	381840	6188716	29.48	122	280	-100	32	2300	-2	0.7	1.5	87.3	6.0	1	3.9	-0.5	-6	-5	-1200
B-40	MC88-H1-19	376714	6187107	27.51	143	24	590	41	1400	-2	-0.5	2.1	85.0	5.9	1	2.7	1.4	-13	-5	-500
B-41	MC88-H1-20	388842	6164565	5.87	80	370	-300	2320	260	17	2.7	-0.2	54.1	165.0	39	450.0	106.0	28	16	11000
B-42	MC88-H1-21	383236	6182322	9.34	160	220	460	160	1400	4	0.9	2.7	55.2	16.0	2	6.8	3.7	-6	6	-1300
B-43	MC88-H1-22	383057	6182210	14.08	85	210	650	93	1900	-2	-0.5	2.3	60.6	10.0	3	5.6	3.0	-5	-5	1400
B-44	MC88-H1-23	398704	6187338	9.02	98	17	680	53	770	-2	-0.5	1.0	51.9	8.3	-1	1.7	1.0	-5	-5	-500
B-44	MC88-H2-23	398704	6187338	12.60	128	-18	570	48	670	-2	0.8	1.0	53.5	7.7	-1	-1.2	1.3	-6	-5	-1500
B-45	MC88-H1-24	397993	6183968	13.87	103	170	-260	310	2700	-2	1.0	2.4	57.7	21.0	5	36.0	7.7	17	-5	2400
B-46	MC88-H1-25	398773	6184749	6.42	71	-19	-100	2690	1500	11	-0.5	1.3	64.8	219.0	13	760.0	89.6	-15	37	2600
B-47	MC88-H1-26	400980	6192649	3.42	255	-17	700	75	1100	-4	0.7	1.1	37.0	8.5	1	11.0	3.1	-5	6	-1600
B-48	MC88-H1-27	402140	6188567	8.59	141	20	250	1440	950	7	-0.5	1.1	51.2	135.0	12	405.0	61.3	-11	25	2300

1988 RGS BULK SAMPLES (-170 Fraction, May 9, 1990)

Map No.	SAMPLE NUMBER	UTM Easting	UTM Northing	WT gm	SAMPLE WT gm.	Au ppb	Ba ppm	Ce ppm	Cr ppm	Eu ppm	Lu ppm	Sb ppm	Sc ppm	Sm ppm	Ta ppm	Th ppm	U ppm	W ppm	Y ppm	Zr ppm
B-22	MC88-H1-01	397526	6176309	7.46	306	350	1400	80	1000	-5	0.7	2.7	21.0	11.0	-1	17.0	6.7	6	-5	-1800
B-23	MC88-H1-02	401509	6165060	4.66	88	420	-380	510	270	-6	4.2	1.0	36.0	39.0	19	116.0	65.1	-6	20	6600
B-24	MC88-H1-03	393190	6173564	0.45	35	85	-500	-160	1400	-10	-2.5	1.3	56.0	13.0	-5	19.0	7.2	-10	-25	-5300
B-25	MC88-H1-04	393258	6174198	1.04	41	150	-500	130	970	-8	-0.5	2.2	60.1	11.0	2	3.9	4.1	-10	-5	-2800
B-26	MC88-H1-05	384361	6175398	4.79	107	470	-100	39	1100	-2	0.5	1.1	75.2	8.6	1	7.2	3.0	-4	-5	-1200
B-27	MC88-H1-06	378916	6173602	3.69	63	440	-370	-45	1600	-5	-0.5	1.4	63.1	6.2	2	3.5	3.1	-6	-5	-1800
B-28	MC88-H1-07	380523	6169859	7.24	51	2660	-250	580	750	6	6.4	2.0	56.2	35.0	15	129.0	98.9	231	26	17000
B-29	MC88-H1-08	380660	6169503	4.25	31	819	-380	580	-140	-7	11.0	1.3	58.8	51.0	17	174.0	173.0	242	47	27000
B-30	MC88-H1-09	387467	6171859	1.48	45	1200	-540	540	970	-9	2.3	2.6	48.0	35.0	10	116.0	71.4	130	17	8000
B-31	MC88-H1-10	382210	6171431	0.89	38	1050	1400	350	900	-10	-1.0	2.3	33.0	26.0	10	92.0	55.0	110	19	6400
B-32	MC88-H1-11	376214	6176922	2.64	105	562	580	61	3000	-4	1.0	1.2	46.0	6.7	-1	7.2	5.5	-6	-5	-1800
B-33	MC88-H2-11	376214	6176922	12.37	124	210	410	64	2300	-2	-0.5	1.0	61.5	6.6	1	5.8	3.8	-5	-5	-1200
B-34	MC88-H1-12	391133	6166983	1.43	48	949	-440	1180	-210	-13	4.8	1.3	41.0	82.7	40	278.0	185.0	29	36	30000
B-35	MC88-H1-13	393196	6180708	1.31	41	2630	-380	-73	1200	-7	-0.5	2.8	55.8	14.0	-1	6.6	3.2	14	13	3800
B-36	MC88-H1-14	390134	6186619	2.43	107	52	-320	130	1500	-4	0.8	1.8	47.0	14.0	2	16.0	7.9	-6	6	-2100
B-37	MC88-H1-15	386442	6188159	2.09	79	768	520	180	2100	5	0.9	1.9	41.0	18.0	-1	32.0	12.0	12	10	3100
B-38	MC88-H2-15	386442	6188159	1.05	62	320	-360	210	2200	-6	1.0	2.3	29.0	17.0	3	29.0	10.0	-9	-5	-2300
B-39	MC88-H1-16	390058	6186607	0.25	104	100	1200	-230	480	-10	-2.5	4.7	22.0	6.4	-5	-5.6	-2.5	-26	-25	-6400
B-40	MC88-H1-17	394806	6177307	2.11	114	60	-250	100	850	6	0.6	1.5	42.0	10.0	-1	11.0	5.0	-5	6	-2000
B-41	MC88-H1-18	381840	6188716	4.51	51	14	360	92	1900	-2	0.5	1.4	66.8	9.2	2	10.0	5.8	5	6	-1100
B-42	MC88-H1-19	376714	6187107	1.06	50	-24	1400	100	1700	-5	-0.5	3.6	38.0	6.5	2	5.8	4.3	-8	-5	-2200
B-43	MC88-H1-20	388842	6164565	1.36	30	500	-660	1940	-240	-15	6.4	1.2	55.8	115.0	23	472.0	171.0	40	60	25000
B-44	MC88-H1-21	383236	6182322	2.25	67	745	-280	170	1000	-5	1.0	2.1	46.0	19.0	3	13.0	6.9	-6	10	2500
B-45	MC88-H1-22	383057	6182210	1.55	38	682	-380	91	2200	-5	-0.5	2.0	37.0	8.2	3	10.0	7.3	-7	7	-2500
B-46	MC88-H1-23	398704	6187338	1.80	43	130	-380	-54	770	-5	0.7	1.0	48.0	10.0	-1	5.8	2.7	-7	-5	-1900
B-47	MC88-H2-23	398704	6187338	4.61	63	516	490	56	610	-2	0.7	1.0	54.9	8.7	1	3.9	1.9	-6	6	-1500
B-48	MC88-H1-24	397993	6183968	2.79	36	250	-260	250	2100	5	0.8	2.1	37.0	25.0	5	46.0	21.0	25	11	3300
B-49	MC88-H1-25	398773	6184749	1.72	26	2150	-690	3940	-360	-25	15.0	7.6	32.0	435.0	20	1320.0	212.0	-16	94	15000
B-50	MC88-H1-26	400980	6192649	1.29	147	1430	1100	98	420	-8	-0.5	0.8	22.0	7.4	-2	14.0	5.3	-10	-5	-3000
B-51	MC88-H1-27	402140	6188567	1.54	40	781	-580	3330	-290	-20	13.0	-0.6	40.0	326.0	9	990.0	169.0	-13	89	9500

APPENDIX IX
REGIONAL GEOCHEMICAL SURVEY; MOSS-MAT GEOCHEMISTRY FOR SAMPLES COLLECTED DURING THE 1989 FIELD SEASON

MAP No.	SAMPLE NUMBER	UTM Easting	UTM Northing	Au ppb	Ag ppm	Cu ppm	Pb ppm	Zn ppm	Ni ppm	Co ppm	As ppm	Mn ppm	Mo ppm	Fe %	U ppm	Th ppm	Sr ppm	Cd ppm	Sb ppm	Bi ppm	V ppm	Ca %	P %	La ppm	Cr ppm	Mg %	Ba ppm	Ti %	B ppm	Ge ppm	Se ppm	Te ppm	Al %	Na %	K %	W ppm	Hg ppb	LOI %
M-1	MC88-M1-01	397526	6176309	20	0.2	32	11	84	169	17	15.2	729	1	3.54	5	1	58	1	4.7	0.6	45	1.5	0.09	12	108	1.6	152	0.1	5	0.2	0.2	0.3	1	0	0.1	1	n	n
M-2	MC88-M2-01	397526	6176309	11	0.1	35	17	91	179	17	15.6	769	1	3.44	5	1	64	1	5.1	0.6	41	1.5	0.09	12	106	1.8	166	0.1	11	0.2	0.5	0.3	1	0	0.1	1	n	n
M-3	MC88-M1-02	401509	6165060	9	0.1	17	11	48	15	6	2.6	379	1	1.69	5	5	34	1	2.3	0.1	38	0.9	0.24	32	23	0.5	96	0.1	2	0.3	0.2	0.3	1.1	0	0.1	1	n	n
M-4	MC88-M1-03	393190	6173564	1	0.2	67	2	94	19	8	14.9	885	1	2.76	5	1	99	1	4.2	0.6	51	3.3	0.13	7	31	0.7	142	0.1	17	0.2	2.9	0.6	1.3	0	0.1	1	n	n
M-5	MC88-M1-04	393258	6174198	2	0.2	53	9	81	19	13	6.3	677	1	4.27	5	1	60	1	3.4	0.3	101	2.5	0.09	10	30	1	85	0.3	10	0.4	0.7	0.3	2.2	0	0.1	1	n	n
M-6	MC88-M1-05	384361	6175398	1	0.1	66	2	78	28	12	5.7	686	1	3.6	5	1	64	1	2.8	0.1	97	1.4	0.08	8	51	1.1	119	0.1	9	0.2	0.3	0.3	2.1	0	0.1	1	n	n
M-7	MC88-M1-06	378916	6173602	1	0.1	56	10	99	46	14	5.7	561	1	4	5	1	67	1	3.1	0.1	102	1.6	0.1	6	98	1.4	76	0.1	14	0.2	0.5	0.3	1.6	0	0.1	1	n	n
M-8	MC88-M1-07	380523	6169859	520	0.1	16	8	41	14	7	3	306	1	2.46	5	7	32	1	2.1	0.4	57	0.9	0.21	35	38	0.5	56	0.1	2	0.2	0.2	0.3	0.9	0	0.1	5	n	n
M-9	MC88-M1-08	380660	6169503	1	0.1	6	10	36	10	5	2	219	1	1.63	5	11	46	1	1.4	0.6	32	2	0.85	48	19	0.5	70	0.1	4	0.2	0.2	0.3	0.8	0	0.2	20	n	n
M-10	MC88-M1-09	387467	6171859	2	0.4	70	16	126	37	16	22.8	727	2	4.46	5	2	38	2	2.7	0.3	98	0.9	0.12	9	58	1.2	89	0.1	2	0.2	1.9	0.3	1.8	0	0.2	2	n	n
M-11	MC88-M1-10	382210	6171431	1090	0.1	17	12	70	18	8	6.2	342	1	3.71	8	9	56	1	1.4	0.5	75	1.7	0.63	46	38	0.6	111	0.1	7	0.2	0.2	0.3	1.2	0	0.2	22	n	n
M-12	MC88-M1-11	376214	6176922	1	0.1	52	13	84	40	11	5.2	406	1	2.96	5	1	84	1	2.9	0.3	80	1.8	0.1	6	68	1.1	66	0.1	20	0.2	0.8	0.5	1.4	0	0.1	1	n	n
M-13	MC88-M2-11	376214	6176922	1	0.1	54	3	80	42	11	5	431	1	3.07	5	1	82	1	2.4	0.4	84	1.7	0.08	5	72	1.1	57	0.1	15	0.5	1	0.6	1.4	0	0.1	1	n	n
M-14	MC88-M1-12	391133	6166983	187	0.1	11	4	60	10	6	2.7	486	1	2.72	5	4	81	1	1.1	0.2	45	2.2	1.01	68	18	0.4	146	0	2	0.2	0.2	0.3	0.9	0	0.2	2	n	n
M-15	MC88-M1-13	393196	6180708	47	0.3	54	15	96	35	13	15.7	631	1	3.74	5	1	51	1	4.7	0.4	81	1.3	0.08	8	43	1.1	68	0.2	7	0.4	1.7	0.3	1.7	0	0.1	1	n	n
M-16	MC88-M1-14	390134	6186619	42	0.2	37	14	88	37	10	7.9	850	1	2.96	5	1	51	1	2.5	0.1	61	1.8	0.08	6	46	0.8	97	0.1	10	0.2	0.4	0.3	1.1	0	0.1	1	n	n
M-17	MC88-M1-15	386442	6188159	31	0.2	32	7	51	38	13	4.7	571	1	4.02	5	1	30	1	1.8	0.1	102	1.3	0.05	6	60	0.9	66	0.2	10	0.3	0.2	0.5	1.5	0	0	1	n	n
M-18	MC88-M2-15	386442	6188159	21	0.2	31	7	53	42	14	5.3	506	1	5.65	5	1	29	1	1.6	0.1	144	1.3	0.06	7	81	0.9	53	0.2	9	0.2	0.2	0.3	1.4	0	0.1	1	n	n
M-19	MC88-M1-16	390058	6186607	15	0.1	31	6	92	36	10	11.7	1606	2	3.41	9	1	140	1	4.6	0.3	60	4.7	0.47	10	38	1	136	0.1	5	0.2	1.7	0.5	1	0	0.1	2	n	n
M-20	MC88-M1-17	394806	6177307	5	0.1	24	16	65	21	7	5.2	702	2	2.09	5	1	38	1	1.8	0.2	48	1.2	0.11	5	26	0.6	45	0.1	6	0.6	0.2	0.5	0.9	0	0.1	1	n	n
M-21	MC88-M1-18	381840	6188716	1	0.1	27	8	53	25	8	5	379	1	2.41	5	1	28	1	1.5	0.1	70	1.3	0.05	3	31	0.9	31	0.1	3	0.4	0.3	0.6	1.3	0	0.1	1	n	n
M-22	MC88-M1-19	376714	6187107	2	0.1	31	10	61	28	9	11.4	319	2	2.66	5	1	31	1	4.2	0.1	68	0.9	0.05	4	36	0.7	77	0.1	5	0.2	1.2	0.3	1	0	0	1	n	n
M-23	MC88-M1-20	388842	6164565	1	0.1	5	11	55	4	4	1.6	298	1	1.72	5	9	50	1	1	0.3	26	1.5	0.58	59	9	0.3	105	0	5	0.2	0.2	0.7	0.9	0	0.1	1	n	n
M-24	MC88-M1-21	383236	6182322	4	0.2	63	15	121	36	12	13.7	639	7	3.9	5	1	70	1	3.9	0.1	75	1.7	0.06	9	37	0.8	104	0.1	6	0.2	1.7	0.4	1.3	0	0.1	1	n	n
M-25	MC88-M1-22	383057	6182210	90	0.2	45	5	67	23	13	4.5	606	1	5.78	5	1	47	1	1.7	0.2	139	1.5	0.08	11	55	0.9	97	0.3	7	0.2	0.2	0.3	1.7	0	0.1	1	n	n
M-26	MC88-M1-23	398704	6187338	6	0.1	40	7	73	71	14	5.7	661	1	3.12	5	2	49	1	1	0.1	52	1.5	0.08	10	69	1.2	85	0.1	3	0.2	0.3	0.3	1.2	0	0.1	1	n	n
M-27	MC88-M2-23	398704	6187338	11	0.1	41	10	63	74	16	5.8	727	1	3.23	5	2	52	1	1.7	0.1	56	1.7	0.08	11	71	1.2	86	0.1	3	0.4	0.2	0.4	1.2	0	0.1	1	n	n
M-28	MC88-M1-24	397993	6183968	90	0.1	26	2	61	45	11	5.4	607	1	3.89	5	2	48	1	1.2	0.2	76	1.2	0.1	12	75	0.7	97	0.1	5	0.2	0.4	0.3	0.9	0	0.1	1	n	n
M-29	MC88-M1-25	398773	6184749	690	0.4	13	10	42	24	8	2.8	510	1	2.1	5	12	20	1	0.8	0.2	46	0.6	0.07	32	35	0.5	63	0.1	6	0.2	0.2	0.5	0.9	0	0.1	1	n	n
M-30	MC88-M1-26	400980	6192649	3	0.1	32	12	136	48	12	4.1	414	1	3.46	5	2	36	1	1.3	0.1	73	1.4	0.06	13	58	0.9	248	0.1	2	0.2	0.5	0.5	1.4	0	0.1	1	n	n
M-31	MC88-M1-27	402140	6188567	54	0.1	11	15	40	20	6	1.8	247	1	1.87	5	7	17	1	0.8	0.1	40	0.6	0.06	20	30	0.4	65	0.1	2	0.3	0.3	0.6	0.8	0	0.1	1	n	n
M-32	MC89-M1-01	391873	6201020	1	0.4	22	87	314	26	6	8	302	4	1.77	5	1	39	3	2	2	39	9.41	0.099	10	17	4.79	227	0	7	n	n	n	0.69	0	0.07	1	250	28.9
M-33	MC89-M1-02	389248	6203324	4	0.4	29	54	390	40	6	10	519	3	1.58	5	1	32	7	2	3	31	6.21	0.199	5	27	2.81	481	0	8	n	n	n	0.49	0	0.11	1	340	56.2
M-34	MC89-M1-03	391255	6203744	1	0.2	34	27	231	18	3	4	226	2	0.69	5	1	22	3	2	2	16	8.81	0.145	3	11	4.59	111	0	15	n	n	n	0.41	0	0.18	2	150	60.9
M-35	MC89-M1-04	404392	6217887	1	0.1	20	7	66	25	9	4	290	1	2.94	5	11	42	1	2	2	29	0.54	0.081	35	25	0.61	48	0.1	9	n	n	n	1.50	0	0.11	7	30	5.7
M-36	MC89-M1-05	389329	6209605	4	0.3	43	15	272	56	12	4	500	2	2.90	5	1	32	1	2	2	70	2.79	0.083	8	39	1.77	623	0.2	4	n	n	n	1.71	0	0.07	1	70	13.0
M-37	MC89-M1-06	388958	6209996	1	0.3	29	34	155	37	12	7	473	2	3.12	5	2	44	1	2	2	58	3.25	0.066	13	32	1.89	269	0.2	3	n	n	n	1.49	0	0.04	1	50	12.6
M-38	MC89-M1-07	388129	6209406	1	0.4	46	37	270	68	11	8	461	6	2.73	5	1	37	2	2	2	56	4.69	0.090	9	36	2.94	798	0.1	16	n	n	n	1.08	0	0.05	1	60	13.6
M-39	MC89-M1-08	387782	6208766	14	3.5	52	83	1005	262	21	12	787	4	1.85	5	1	45	6	5	2	38	6.12	0.219	9	22	3.00	665	0	4	n	n	n	0.63	0	0.21	1	350	44.0
M-40	MC89-M1-09	387766	6208614	4	2.8	34	75	852	200	19	12	705	4	1.52	5	1	43	4	3	2	30	8.92	0.218	6	12	4.46	532	0	6	n	n	n	0.41	0	0.09	1	260	40.3
M-41	MC89-M1-10	389688	6199065	3	0.3	80	10	109	51	16	2	837	1	4.02	5	1	24	1	2	2	99	1.79	0.056	9	55	1.47	452	0.3	3	n	n	n	2.59	0	0.04	1	50	13.0
M-42	MC89-M1-11	380507	6197109	1	0.1	56	5	69	30	16	3	567	1	7.53	5	1	36	1	2	2	201	1.90	0.066	6	66	1.23	72	0.3	18	n	n	n	2.20	0	0.03	1	90	4.5
M-43	MC89-M1-12	380864	6196642	10	0.2	66	4	101	48	18	9	674	2	5.66	5	1	34	1	2	2	137	1.71	0.061	7	61	1.23	139	0.3	10	n	n	n	2.21	0	0.04	1	180	9.7
M-44	MC89-M1-13	380639	6196304	1	0.2	90	2	93	29	17	7	687	1	4.78	5	1	87	1	2	2	118	1.97	0.073	10	53	1.41	69	0.2	9	n	n	n	2.79	0	0.06	1	70	16.0
M-45	MC89-M1-14	384710	6215571	2	0.2	32	19	311	44	12	2	684	2	2.69	5	1	30	2	2	2	66	2.46	0.103	11	39	1.57	632	0.2	19	n	n	n	1.41	0	0.07	1	40	9.8

MAP No.	SAMPLE NUMBER	UTM Easting	UTM Northing	Au ppb	Ag ppm	Cu ppm	Pb ppm	Zn ppm	Ni ppm	Co ppm	As ppm	Mn ppm	Mo ppm	Fe %	U ppm	Th ppm	Sr ppm	Cd ppm	Sb ppm	Bi ppm	V ppm	Ca %	P %	La ppm	Cr ppm	Mg %	Ba ppm	Ti %	B ppm	Ge ppm	Se ppm	Te ppm	Al %	Na %	K %	W ppm	Hg ppb	LOI %
*	MC89-M1-15	388190	6219452	1	0.1	18	10	63	20	10	2	350	1	2.48	5	6	49	1	2	2	12	0.74	0.074	41	15	0.35	129	0	2	n	n	n	0.85	0	0.10	1	20	10.5
M-47	MC89-M1-16	385066	6221158	7	0.8	53	46	349	71	11	11	737	6	2.87	5	1	59	2	2	3	33	4.98	0.104	13	24	2.92	1230	0	3	n	n	n	0.83	0	0.08	1	160	20.0
M-48	MC89-M1-17	382731	6219843	93	0.7	65	13	375	86	14	13	934	8	3.46	5	2	60	2	2	2	42	1.17	0.116	17	27	0.93	1373	0.1	2	n	n	n	1.00	0	0.07	1	90	8.0
M-49	MC89-M1-18	382657	6219921	2	0.4	52	23	408	111	13	9	728	8	2.85	5	1	49	2	2	3	38	1.12	0.090	12	28	0.81	1356	0	10	n	n	n	0.97	0	0.07	2	110	14.0
M-50	MC89-M1-19	399434	6216447	1	0.1	20	12	63	27	9	3	300	1	2.71	5	10	20	1	2	2	45	0.44	0.082	39	26	0.52	108	0.1	21	n	n	n	1.06	0	0.12	6	30	5.1
M-51	MC89-M1-20	399140	6213860	9	0.1	17	13	61	25	9	3	342	1	2.25	5	6	15	1	2	2	16	0.33	0.067	26	21	0.50	39	0	12	n	n	n	1.09	0	0.08	1	20	10.2
M-52	MC89-M1-21	396517	6215274	1	0.1	25	15	72	34	12	6	457	1	3.18	7	7	28	1	2	2	23	0.53	0.079	30	29	0.73	52	0	2	n	n	n	1.43	0	0.04	1	30	12.1
M-53	MC89-M1-22	392524	6216774	6	0.1	20	7	74	29	13	2	345	1	5.61	5	12	65	1	2	2	97	1.48	0.114	52	35	0.76	126	0	2	n	n	n	1.16	0	0.04	1	40	7.0
M-54	MC89-M1-23	389464	6218504	1	0.1	18	5	69	25	11	2	408	1	3.29	5	7	68	1	2	2	26	1.14	0.081	41	20	0.50	133	0	2	n	n	n	1.01	0	0.13	1	30	10.5
M-55	MC89-M1-24	385784	6220352	1	0.2	44	40	137	43	14	6	535	3	4.21	5	2	43	1	2	2	98	1.91	0.078	12	43	1.35	1164	0.2	6	n	n	n	1.55	0	0.06	2	60	8.5
M-56	MC89-M1-25	388177	6219439	1	0.1	19	20	57	23	10	2	355	1	2.66	6	6	49	1	2	2	14	0.74	0.077	40	16	0.38	160	0	5	n	n	n	0.96	0	0.11	1	40	10.8
M-57	MC89-M1-26	398791	6210613	1	0.1	21	7	63	42	12	2	488	1	2.52	5	6	22	1	2	2	20	0.59	0.054	32	22	0.51	51	0	4	n	n	n	1.22	0	0.07	1	50	12.4
M-58	MC89-M1-27	384821	6216459	1	0.1	20	9	56	24	10	5	441	1	2.45	5	5	41	1	2	2	17	0.80	0.107	29	16	0.42	154	0	5	n	n	n	0.76	0	0.14	1	30	14.8
M-59	MC89-M1-28	392296	6209759	1	0.1	31	24	135	45	17	9	4112	2	5.36	5	4	163	1	2	2	34	2.66	0.072	25	38	0.93	309	0.1	3	n	n	n	1.39	0	0.11	1	30	19.2
M-60	MC89-M1-29	392450	6209806	3	0.1	25	16	65	37	10	2	855	1	2.58	5	6	49	1	2	2	12	0.79	0.083	37	27	0.61	57	0	9	n	n	n	1.24	0	0.21	1	20	20.1
M-61	MC89-M1-30	392988	6208419	1	0.1	24	17	90	37	13	2	1087	1	3.21	5	7	72	1	2	2	23	1.79	0.078	39	29	0.97	110	0.1	2	n	n	n	1.11	0	0.19	1	40	12.3
M-62	MC89-M1-31	382867	6204985	1	0.1	67	9	83	51	17	2	680	1	4.03	5	1	18	1	2	2	118	2.38	0.054	5	74	1.52	221	0.4	2	n	n	n	2.99	0	0.06	1	50	12.2
M-63	MC89-M1-32	383801	6206208	2	0.1	60	9	88	35	15	5	671	1	3.44	5	1	25	1	2	2	104	2.11	0.078	4	52	1.29	143	0.4	2	n	n	n	2.59	0	0.11	1	40	22.1
M-64	MC89-M1-33	378814	6209195	2	0.1	44	16	71	34	17	2	1065	1	3.91	5	1	19	1	2	2	122	1.94	0.060	5	56	1.26	248	0.4	11	n	n	n	2.72	0	0.04	2	40	14.0
M-65	MC89-M1-34	375863	6208150	2	0.1	35	5	56	26	14	2	521	1	3.34	5	1	12	1	2	2	118	1.95	0.039	3	27	1.14	190	0.5	14	n	n	n	2.18	0	0.03	1	20	4.5
M-66	MC89-M1-35	376231	6210672	1	0.1	86	10	99	41	15	2	594	1	3.75	5	1	24	1	2	2	114	2.04	0.098	6	59	1.26	96	0.3	5	n	n	n	2.68	0	0.19	1	30	25.5
M-67	MC89-M1-36	376072	6210421	1	0.1	45	8	76	32	16	3	635	1	3.75	5	1	15	1	2	2	120	2.02	0.046	4	37	1.28	232	0.5	11	n	n	n	2.50	0	0.04	1	20	6.8
M-68	MC89-M1-37	375787	6220349	79	0.5	78	28	408	110	12	12	1083	6	2.55	5	1	77	2	2	2	25	1.32	0.086	10	21	0.87	1476	0	3	n	n	n	0.80	0	0.11	1	110	11.7
M-69	MC89-M1-38	405175	6206027	1	0.1	18	13	48	15	11	2	304	1	1.85	5	11	17	1	2	2	16	0.46	0.149	34	18	0.39	65	0.1	2	n	n	n	0.90	0	0.21	2	20	5.6
M-70	MC89-M1-39	405044	6205890	1	0.1	7	9	28	11	6	2	178	1	1.13	5	12	10	1	2	2	13	0.25	0.067	41	14	0.31	32	0.1	2	n	n	n	0.73	0	0.16	1	20	3.8
M-71	MC89-M1-49	397171	6208378	3	0.1	19	15	69	28	9	6	455	1	2.57	5	9	18	1	2	2	11	0.34	0.066	28	23	0.60	29	0	2	n	n	n	1.16	0	0.05	1	30	9.0
M-72	MC89-M1-51	389705	6201252	1	0.5	42	16	411	108	14	7	668	7	2.69	5	1	36	2	2	2	55	1.01	0.074	12	35	0.71	674	0.2	5	n	n	n	1.39	0	0.07	1	90	9.5
M-73	MC89-M1-52	397338	6197296	14	0.2	49	18	115	47	18	5	654	1	4.57	5	4	33	1	2	2	100	2.10	0.050	10	57	1.54	178	0.3	2	n	n	n	2.37	0	0.03	2	50	8.3
M-74	MC89-M1-53	395269	6205589	3	0.2	20	18	72	22	9	9	458	1	2.56	5	4	132	1	2	2	16	4.53	0.076	21	23	0.63	49	0	9	n	n	n	0.76	0	0.09	1	60	24.4
M-75	MC89-M1-54	376078	6215229	2	0.4	63	15	991	300	30	29	913	31	4.34	9	1	100	8	3	2	62	0.89	0.115	10	25	0.47	998	0.1	4	n	n	n	0.93	0	0.10	1	110	14.0
M-76	MC89-M1-55	375992	6215333	1	0.6	71	65	1043	275	16	20	598	18	3.18	5	1	71	6	6	2	49	0.98	0.098	11	28	0.63	1205	0.1	3	n	n	n	0.97	0	0.08	1	180	12.0
M-77	MC89-M1-56	384492	6215513	2	0.3	61	72	102	44	15	3	646	1	3.39	5	1	40	1	2	2	76	1.56	0.047	5	42	1.47	1247	0.3	2	n	n	n	1.87	0	0.04	1	60	7.6
M-78	MC89-M1-57	385502	6213669	1	0.5	51	35	491	58	12	9	619	3	2.54	5	1	30	3	2	2	54	2.23	0.081	9	46	1.53	724	0.1	4	n	n	n	1.28	0	0.08	1	120	14.6
M-79	MC89-M1-58	385905	6214053	2	0.5	38	49	704	54	12	7	1167	2	2.77	5	1	34	5	2	2	55	2.93	0.171	12	40	1.63	662	0.1	5	n	n	n	1.21	0	0.08	1	100	17.4
M-80	MC89-M1-59	384904	6218237	5	0.4	47	31	149	40	9	17	449	20	2.55	5	2	57	1	5	2	53	1.32	0.065	11	22	0.82	1052	0.1	2	n	n	n	0.62	0	0.06	2	70	7.9
M-81	MC89-M1-60	391617	6216135	1	0.1	22	19	89	35	12	5	441	1	3.41	5	8	56	1	2	2	24	0.95	0.057	42	26	0.67	118	0	4	n	n	n	1.20	0	0.06	1	30	8.8
M-82	MC89-M1-61	391508	6216341	1	0.1	21	20	85	26	12	3	343	1	4.41	5	13	81	1	2	2	58	1.93	0.129	51	30	0.80	147	0	2	n	n	n	1.09	0	0.10	1	40	7.8
M-83	MC89-M1-62	394896	6218558	1	0.1	18	10	49	18	14	2	270	1	1.81	5	7	18	1	2	2	19	0.30	0.063	41	18	0.42	57	0.1	2	n	n	n	0.97	0	0.17	2	20	5.7
M-84	MC89-M1-63	393354	6219983	1	0.1	16	9	56	16	12	2	210	1	1.53	5	5	18	1	2	2	15	0.26	0.057	36	16	0.37	47	0.1	2	n	n	n	0.87	0	0.23	8	10	10.6
M-85	MC89-M1-64	396582	6217829	1	0.1	19	16	48	20	8	2	288	1	2.34	5	11	20	1	2	2	39	0.41	0.098	40	23	0.48	69	0.1	2	n	n	n	0.96	0	0.15	3	30	4.2
M-86	MC89-M1-65	394987	6206499	1	0.1	14	20	78	16	8	2	343	1	2.06	5	2	49	1	2	2	13	3.76	0.081	17	20	2.11	71	0	3	n	n	n	0.73	0	0.07	1	40	21.3
M-87	MC89-M1-66	394635	6206673	1	0.1	20	20	66	24	11	8	358	1	3.02	5	6	136	1	2	2	18	6.38	0.066	26	23	0.97	44	0	2	n	n	n	0.80	0	0.04	1	20	15.6
M-88	MC89-M1-67	382255	6212150	1	0.2	64	2	63	40	19	2	635	1	3.77	5	1	15	1	2	2	100	1.72	0.048	3	48	1.61	104	0.4	2	n	n	n	2.40	0	0.03	1	30	7.2
M-89	MC89-M1-68	382200	6212190	1	0.1	101	7	77	69	21	4	694	1	4.18	5	1	16	1	2	2	108	1.81	0.070	3	67	1.89	106	0.3	2	n	n	n	2.66	0	0.06	1	50	17.5

MAP No.	SAMPLE NUMBER	UTM Easting	UTM Northing	Au ppb	Ag ppm	Cu ppm	Pb ppm	Zn ppm	Ni ppm	Co ppm	As ppm	Mn ppm	Mo ppm	Fe %	U ppm	Th ppm	Sr ppm	Cd ppm	Sb ppm	Bi ppm	V ppm	Ca %	P %	La ppm	Cr ppm	Mg %	Ba ppm	Ti %	B ppm	Ge ppm	Se ppm	Te ppm	Al %	Na %	K %	W ppm	Hg ppb	LOI %
M-90	MC89-M1-69	379207	6213700	3	0.6	73	8	161	72	13	11	721	4	2.69	5	1	47	1	2	2	65	1.33	0.086	8	91	0.82	1063	0.1	2	n	n	n	1.45	0	0.05	1	100	21.4
M-91	MC89-M1-70	379101	6213525	1	0.2	91	11	93	86	22	3	1143	1	4.43	5	1	21	1	2	2	101	1.41	0.047	6	62	1.81	252	0.3	2	n	n	n	2.54	0	0.03	2	50	3.6
M-92	*MC89-M1-71*	*377522*	*6214976*	*1*	*0.6*	*122*	*45*	*616*	*117*	*16*	15	*915*	*7*	*3.58*	5	2	62	7	2	2	26	0.42	0.076	14	21	0.46	1533	0	2	n	n	n	1.11	0	0.08	1	150	8.1
M-93	MC89-M1-72	377414	6214712	6	0.2	86	12	119	83	21	7	776	4	4.14	5	1	30	1	2	2	104	1.58	0.061	5	70	1.58	423	0.3	2	n	n	n	2.49	0	0.09	1	60	13.7
M-94	MC89-M1-73	376008	6214963	1	0.2	78	14	109	62	16	7	648	1	4.22	5	1	34	1	2	2	95	1.35	0.087	12	95	1.14	575	0.2	2	n	n	n	2.51	0	0.06	1	70	19.3
M-95	MC89-M1-74	376252	6215046	1	0.3	68	29	283	81	16	12	826	6	3.48	5	1	52	3	2	2	67	1.04	0.055	9	47	1.02	1427	0.2	2	n	n	n	1.49	0	0.04	1	110	8.5
M-96	MC89-M1-75	404591	6209094	1	0.1	11	4	39	15	7	2	203	1	1.28	5	9	15	1	2	2	14	0.35	0.104	37	15	0.29	151	0.1	11	n	n	n	0.73	0	0.20	1	20	9.0
M-97	MC89-M1-76	404450	6208538	1	0.1	17	11	65	20	9	2	219	1	1.79	50	7	20	1	2	2	18	0.36	0.092	30	20	0.42	47	0.1	2	n	n	n	0.98	0	0.21	1	20	8.2

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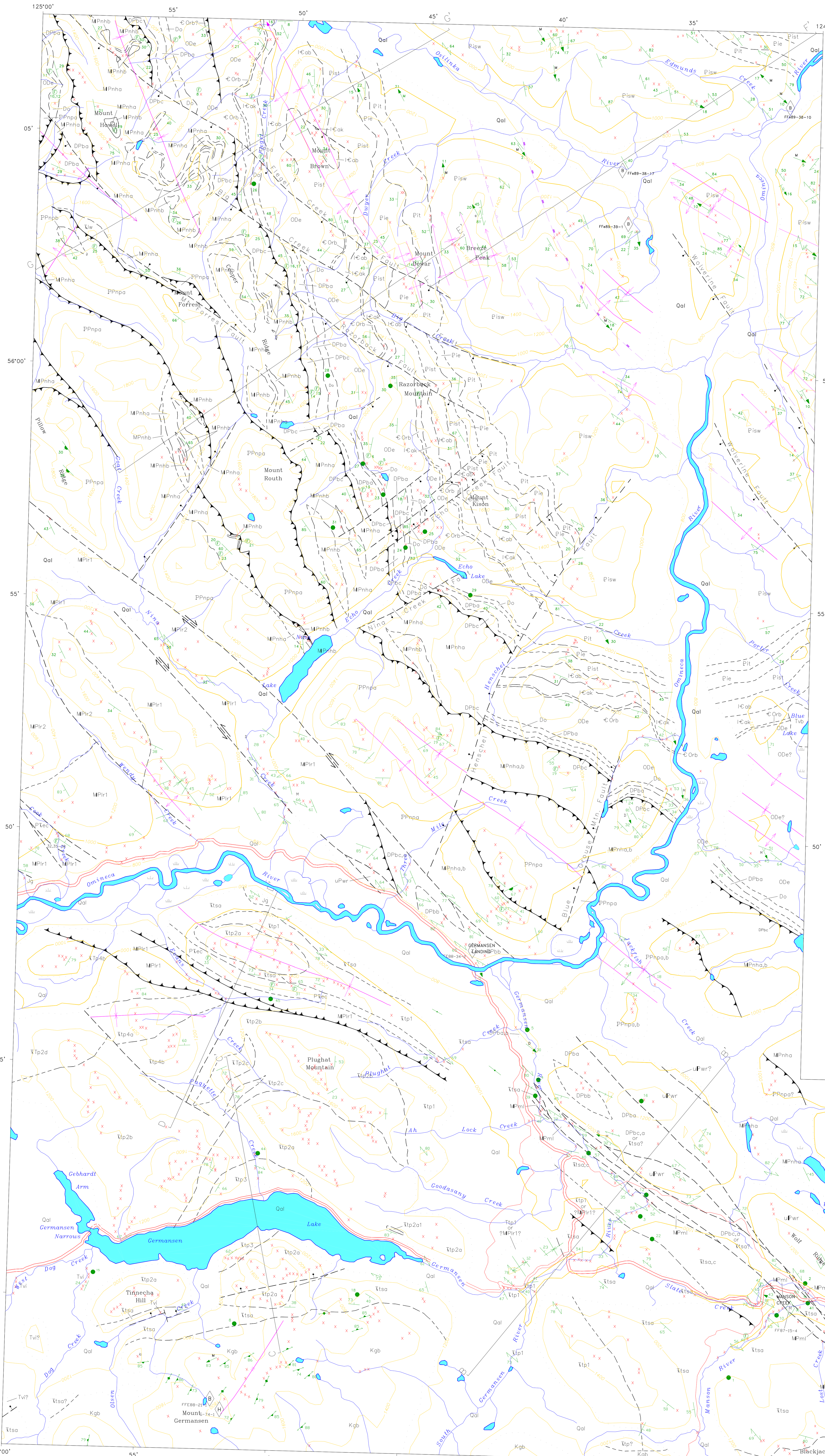


BC
Ministry of Energy, Mines and Petroleum Resources

BRITISH COLUMBIA GEOLOGICAL SURVEY

Geological Survey Branch

BULLETIN 91

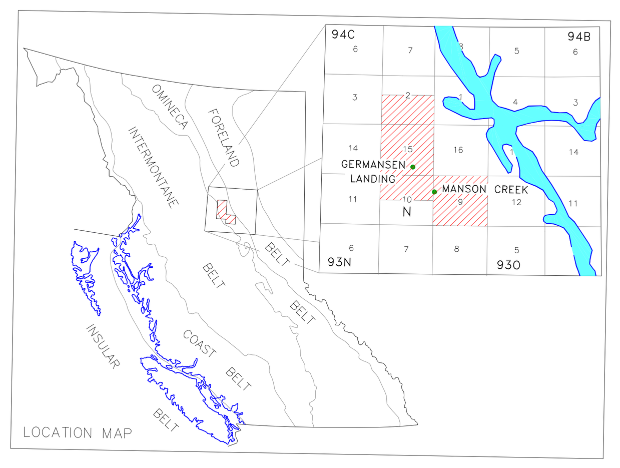
GEOLOGY OF THE GERMANSEN LANDING–MANSON CREEK AREA

NTS 93N/9, 10, 15; 94C/2

Geology by F. Ferri, D.M. Melville, (1987, 88, 89)

Scale 1:100 000

0 1 2 3 KILOMETRES



SYMBOLS

- Geological boundary (defined, approximate, assumed)
- Normal fault (defined, approximate, assumed)
- Thrust fault (defined, approximate, assumed)
- Strike–slip fault (approximate)
- Movement Indicator:
  - (Block moved away from viewer)
  - (Block moved towards viewer)
- Bedding (tops known, inclined, vertical)
  - (tops unknown, inclined, vertical)
- Pillows (tops known)
- F1 foliation (inclined, vertical)
- F2 foliation (inclined, vertical)
- F3 foliation (inclined, vertical)
- F4 foliation (inclined, vertical)
- Foliation in Germansen batholith (inclined, vertical)
- F1 minor fold axis
- F2 minor fold axis
- F3 minor fold axis
- F1 minor fold axis with S symmetry
- F1 minor fold axis with Z symmetry
- F1 minor fold axis with M symmetry
- F2 minor fold axis with S symmetry
- F2 minor fold axis with Z symmetry
- F3 minor fold axis with M symmetry
- Bedding–cleavage intersection (C)
- Mineral lineation (M)
- Deformed clast lineation (D)
- Vein (inclined, vertical)
- Drumloid feature
- Syncline
- Anticline
- Mineral isograd (biotite–garnet–staurolite–sillimanite) (symbol on high grade side)
- Fossil locality (F 1)
- Ultramafite occurrence
- Geochronology sample location & number (B–biotite, M–muscovite, H–hornblende, Z–uranium/lead, A–apatite) (FFe88–344 Z)
- Mineral occurrence (2)
- Cross–section line (A A')
- Isolated outcrop, station location
- Area of rock exposure
- Limit of Quaternary cover
- Contour interval: 200 metres (1000)
- Road, trail
- Topographic lineament

NOTES

Geology mapped by F. Ferri, D.M. Melville, G.A. Malensek and N.R. Swift during the summer of 1987; F. Ferri, R.L. Arksy & D.M. Melville during the summer of 1988; and F. Ferri, D.M. Melville, J. Whittles and M. Holmes during the summer of 1989. Geology was mapped at a scale of 1:20 000

REFERENCES

Ferri, F., Melville, D.M. Malensek, G.A. and Swift, N.R. (1988): Geology of the Manson Lakes Map Sheet, 93N/9; B.C. Ministry of Energy, Mines and Petroleum Resources, Open File 1988–12

Ferri, F., Melville, D.M. and Arksey, R.L. (1989): Geology of the Germanson Landing Area, 93N/10 and 93N/15; B.C. Ministry of Energy, Mines and Petroleum Resources, Open File 1989–12

Ferri, F. and Melville, D.M. (1990): Geology Between Nina Lake and Osilinka River, British Columbia, 93N/15 (North Half) and 94C/2 (South Half); B.C. Ministry of Energy, Mines and Petroleum Resources, Open File 1990–17.

TABLE OF MINERAL OCCURRENCES

Map Number	MINFILE Number	Commodities
1	093N 022	Ag, Pb, Zn, Au
2	093N 023	Au, Ag, Cu, Sb
3	093N 024	Au, Ag, Cu, Pb
4	093N 025	Au, Ag, Cu
5	093N 026	Cu, Ag
6	093N 027	Pb, Ag
7	093N 028	Pb, Ag
8	093N 029	Cu, Au, Ag
9	093N 030	Pb, W, Cu, Zn, Ag
10	093N 063	Ag, Pb, Zn
11	093N 117	Pb, Ag
12	093N 136	Pb, Ag, Au,
13	093N 136	Pb
14	093N 137	Pb, Zn, Ag, Ba, Au, Cu, Mo
15	093N 145	Cu, Ag, Zn, Sb
16	093N 144	Cu, Ag, Au
17	093N 197	Pb, Zn, Mo, Ag, Au
18	093N 202	Zn, Pb, Cu
19	093N 134	Au, Ag
20	093N 132	Au, Ag
21	093N 148	Pb
22	093N 198	Au
23	093N 130	Zn, Pb, Ba
24	093N 075	Zn, Pb, Ag, Ba
25	093N 076	Zn, Pb, Ag, Ba
26	094C 096	Zn, Pb, Ba
27	093N 114	Zn, Pb, Ge, Ag
28	093N 158	Pb, Zn
29	093N 172	Zn, Pb, Ag, Ba
30	093N 170	Pb, Zn, Ag
31	093N 011	Au, Ag, Cu, Zn
32	093N 012	Nb, Zr, Ti, U, Th
33	093N 174	Nb, Zr, Ti, U, Th
34	093N 201	Th, La, Ce, Nd, Y, Ta, Cu
35	093N 180	Cu
36	093N 118	Mo,Cu
37	093N 119	Mo,Cu
38	093N 133	Mo
39	093N 115	Asbestos
40	093N 116	Ni
41	093N 135	Cr
42	093N 087	Ba
43	093N 203	Cu
44	093N 153	Cu
45	093N 147	Cu

LEGEND

INTRUSIVE ROCKS

TERTIARY
- **Tvi** Sub–volcanic feldspar andesites, locally vesicular, fragmental; associated with monzonites to quartz monzonites, pink to biege, dikes and irregular bodies.

CRETACEOUS OR YOUNGER
WOLVERINE RANGE INTRUSIONS
- **KTwri** Garnet–muscovite–biotite granodiorite to granite and related pegmatite, beige to grey

CRETACEOUS
GERMANSEN BATHOLITH
- **Kg** (a)Biotite–muscovite granite to granodiorite, megacrystic, associated with garnet bearing pegmatites and aplite dikes (b)Foliated hornblende–biotite granodiorite, megacrystic associated with pegmatite and aplite dikes

JURASSIC OR YOUNGER
- **Jg** Hornblende–pyroxene gabbro, grey, massive, slight foliation

TRIASSIC OR JURASSIC
- **ŦJw** Wehrlite, dark grey to black, massive, slightly magnetic, minor serpentine and asbestos, gabbro, minor varicoloured chert

UPPER PALEOZOIC OR YOUNGER
WOLF RIDGE GABBRO
- **uPwr** Foliated biotite–hornblende–pyroxene gabbro, dark green to green, with related pegmatite

DEVONIAN TO MISSISSIPPIAN
- **DMc** Carbonatites; biotite and aegerine sovite; syenite; monzonite; foliated

VOLCANIC AND SEDIMENTARY ROCKS

QUATERNARY
- **Qal** Unconsolidated sands, silts, gravels; fluvial–glacial

BLUE LAKE VOLCANICS
- **Tvb** Pyroxene–phyric basalt, dark grey, massive or fragmental, local flows or dikes

MIDDLE TO LATE TRIASSIC
TAKLA GROUP
PLUGHAT MOUNTAIN SUCCESSION
- **Ŧtp4a** Basalt and agglomerate, maroon to dark green or grey, vesicular, typically aphanitic, locally augite phyric
- **Ŧtp4b** Agglomerate and tuff to tuffaceous siltstone, grey green to maroon, locally well bedded; minor basalt and agglomerate as in Ŧtp4a
- **Ŧtp3** Volcanic sandstone and conglomerate, dark grey to grey, massive to thickly bedded
- **Ŧtp2a** Aphanitic to augite and feldspar–phyric basalt to basaltic andesite, grey–green to maroon, massive flows, agglomerate, lapillistone and tuff, slightly magnetic, minor dark grey argillite and limestone (a1) and gabbro
- **Ŧtp2b** Agglomerate, lapillistone and tuff with lesser basalt to basaltic andesite flows, gabbro and argillite (a) as above
- **Ŧtp2c** Tuff, tuffaceous siltstone, grey to green, massive to well bedded
- **Ŧtp2d** Basalt and agglomerate, maroon to grey or brown, massive, augite–feldspar phyric, minor tuff
- **Ŧtp1** Tuff and agglomerate, lesser volcanic sandstone and conglomerate, grey to dark grey, massive to thickly bedded polymict, volcanic siltstone, argillite to calcareous argillite, and massive basalt

SLATE CREEK SUCCESSION
- **Ŧtsa** Argillite, slate, calcareous argillite, siliceous argillite, dark grey to grey, very thin to moderately bedded, lesser polymict volcanic sandstone, conglomerate and tuff, limestone, chert, massively bedded quartz–rich sandstone and siltstone at base
- **Ŧtsc** Massive and pillowed basalt, dark grey to green, may be a moderately foliated

PERMIAN TO TRIASSIC
EVANS CREEK LIMESTONE
- **PŦec** Grey limestone, massive with faint partings, finely recrystallized

NINA CREEK GROUP
PENNSYLVANIAN TO PERMIAN
PILLOW RIDGE SUCCESSION
- **PPnpa** Massive and pillowed basalt, dark grey to green, minor varicoloured chert, siliceous argillite and gabbro
- **PPnpb** Argillite, dark grey to grey, siliceous argillite, varicoloured chert (cream, grey, maroon, green), massive to moderately bedded

MISSISSIPPIAN TO PERMIAN
MOUNT HOWELL SUCCESSION
- **MPnha** Argillite, siliceous argillite, dark grey, grey to light grey, massive to poorly bedded, varicoloured chert (cream, grey, green, maroon) massive to moderately bedded, gabbro sills, basalt, wackes, quartz and quartz chert wackes, limestone, finely crystalline, minor quartz bearing tuffs
- **MPnhb** Gabbro, green to dark green, sill–like bodies

MANSON LAKES ULTRAMAFICS
- **MPml** Serpentine, dark green, massive with minor asbestos; talc–serpentine schist, dark to light green; mariposite–magnetite–quartz–serpentine–talc–ankerite schist, grey to brown

LAY RANGE ASSEMBLAGE
- **MPlr1** Tuff, tuffaceous siltstone, volcanic sandstone or conglomerate, blue grey–green, polymict, argillite and siltstone, grey–green to green
- **MPlr2** Agglomerate and lapilli tuff, grey to green and maroon, augite and feldspar phyric; lesser tuffaceous, siltstone, and argillite

LATE(?) DEVONIAN TO PERMIAN
BIG CREEK GROUP
- **DPbc** Argillite, black to dark grey, slightly siliceous, massive to poorly bedded, minor quartz wacke, limestone, finely crystalline
- **DPbb** GILLILAND TUFF: quartz and/or biotite, feldspar felsic tuff, minor argillite, grey
- **DPba** Shale, argillite, blue–grey to grey; minor quartz–chert sandstone, massively bedded

MIDDLE DEVONIAN
OTTER LAKES GROUP
- **Do** Dolomite, limestone, dark grey to grey, fetid, poorly bedded, locally fossiliferous; dolomite, grey, massive, finely crystalline

ORDOVICIAN TO EARLY DEVONIAN
ECHO LAKE GROUP
- **ODe** Upper Member: dolomite, limestone and sandy dolomite, grey, massively bedded, locally silicified, minor grey–brown argillite and dark grey to grey quartzite. Lower Member: limestone and dolomite, grey, massive to thinly bedded, algal laminae and oolites, locally silicified, minor dark grey argillite

MIDDLE CAMBRIAN TO ORDOVICIAN (?)
RAZORBACK GROUP
- **€Orb** Shale, slate, grey to dark grey; limestone, argillaceous, thin bedded, grey to black

EARLY CAMBRIAN
ATAN GROUP
MOUNT KISON LIMESTONE
- **€ak** Upper part: limestone, massive, to thickly bedded, grey, slightly argillaceous and dolomitic, may be oolitic Lower part: limestone, thinly bedded, platy, dark grey to grey

MOUNT BROWN QUARTZITE
- **€ab** Upper part: shale, siltstone, olive–green to grey, thin to moderately bedded; sandstone, beige to tan, moderately bedded; minor quartzite. Lower part: quartzite, massive to thickly bedded, white, grey, beige or maroon

PALEOZOIC(?) AND PROTEROZOIC
BOULDER CREEK GROUP
- **PPbc** Phyllite, slate, siltstone, schist, grey–green; sandstone, impure sandstone, grey–green, thin to moderately bedded; limestone or marble, minor amphibolite

LATE PROTEROZOIC
INGENIKA GROUP
STELKUZ FORMATION
- **Pist** Slate, siltstone, green to grey; sandstone and impure quartzite, grey to brown, planar bedded, massive to thickly bedded minor dolomitic limestone

ESPEE FORMATION
- **Pie** Limestone, locally dolomitic, grey, moderately to thinly bedded marble

TSAYDIZ FORMATION
- **Pit** Slate, phyllite, greenish grey to grey, interlayered with thinly bedded limestone to argillaceous limestone; minor siltstone, quartz and feldspathic wackes and marble

SWANNELL FORMATION
- **Pisw** Upper part: impure quartzite and sandstone, massively bedded, lesser siltstones, slates, phyllites and feldspathic wackes. Middle part: feldspathic wacke, massive, coarse grained, lesser slate, phyllite, quartz wacke and sandstone. Lower part: quartz and feldspathic wackes, thin to thickly bedded, lesser impure sandstones, siltstones, marble, slate and phyllite. Metamorphosed to garnet–staurolite and sillimanite bearing schists and gneisses; intruded by pegmatite and related granodiorite (KTwri) within sillimanite zone; micaceous meta–quartzite; quartz–mica schist meta–quartzite and minor amphibolite,
- **Pisq** Micaceous meta–quartzite; quartz–mica schist, meta–quartzite and minor amphibolite,
- **Pisp** Quartzo–feldspathic paragneiss, quartz–feldspar mica schist, micaceous meta–quartzite, calcsilicate and amphibolite gneiss
- **Pipi** Quartzo–feldspathic paragneiss and schist; minor amphibolite gneiss, calcsilicate gneiss; abundant granite and granite pegmatite
- **Pia** Quartzo–feldspathic paragneiss; amphibolite gneiss, calcsilicate gneiss; minor schist; abundant granite and granite pegmatite (a) marble, calcsilicote gneiss