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**Ministry of Employment and Investment**
Energy and Minerals Division
*Geological Survey Branch*



# GEOLOGY AND MINERAL DEPOSITS OF THE QUESNEL RIVER - HORSEFLY MAP AREA, CENTRAL QUESNEL TROUGH, BRITISH COLUMBIA

## NTS MAP SHEETS 93A/5, 6, 7, 11, 12, 13; 93B/9, 16; 93G/1; 93H/4

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Frontispiece. Quesnel River, view looking east (upstream) from the QR deposit towards Quesnel Forks.

# SUMMARY

The Quesnel and Horsefly rivers traverse the northwesterly trending axis of the central Quesnel belt, also known as the 'Quesnel Trough'. Since 1859 the region has been the site of significant placer gold production including some very large-scale mining operations. The identification of bedrock source areas for the placer gold and definition of the various mineral deposit types in this region are the main objectives of this field study. Recent economic interest has been concentrated on the Mount Polley (Cariboo-Bell) alkalic porphyry copper-gold deposit, the QR intrusion-related propylite-type gold deposit and the Frasergold and CPW (Spanish Mountain) auriferous quartz vein prospects in the black phyllite basal map unit. Recent road building related to ongoing logging in the area provides new bedrock exposures in this region of otherwise sparse outcrop.

Studies in the map area, all within 'Quesnel Terrane', confirm the presence of a regional synclinal structure formed within a Triassic continent-margin basin. It was infilled first with Triassic sediments and then Triassic to Jurassic volcanic rocks. Together these rocks constitute the Quesnel Trough. The basal lithologic units consist of mid-Triassic siliceous rocks to mainly younger pelitic, thinly bedded deposits with overlying, more massive volcaniclastic sediments. The younger epiclastic units pass upward or interfinger with Upper Triassic subaqueous volcanic deposits, mainly volcanic flow and breccia units. They are overlain, in turn, by subaqueous to subaerial Lower Jurassic volcanic flow and pyroclastic rocks and overlapping Lower to Middle Jurassic sedimentary assemblages. The volcanic rocks, and some Early Jurassic plutons, form the extensive magmatic edifice that defines the medial axis of the Quesnel island arc.

The older, submarine lavas, mainly olivine and pyroxene basalts of alkalic basalt to basaltic trachyandesite composition, are overlain by both subaqueous and subaerial, dark green-grey to maroon-purple feldspathic lavas and pyroclastic deposits of trachybasalt to trachyandesite composition, alternatively classified as rocks of the absarokite-shoshonite series or shoshonite association. Many of the lavas are characterized by analcite phenocrysts. Modal quartz does not occur in any of the arc rocks; the majority of chemical analyses reveal alkalic whole-rock compositions with characteristic normative nepheline.

The basal clastic rocks now form a continuous structurally complex black phyllite to metapelite unit along the eastern side of the map area. The rocks are well foliated at deeper structural levels but pass upward into weakly cleaved rocks. They are overlain by thick panels of the extensively block faulted volcanic successions. The basal sedimentary rocks are regionally metamorphosed to greenschist facies in the easternmost part of the map area. Metamorphic grade in the volcanic rocks is subgreenschist, consistent with burial metamorphism. Commonly there is extensive chloritization of mafic minerals; zeolite and calcite fill amygdules and occur in fractures in rocks throughout the region. Some zones of epidote, chlorite, tremolite, calcite and minor quartz represent locally developed propylitic alteration that can be related to nearby intrusive activity. Copper-gold and gold mineralization is associated with a number of the Early Jurassic diorite and zoned alkalic gabbro to syenite stocks that are intruded along the axis of the volcanic arc at intervals of about 11 kilometres.

The predominantly fine-grained clastic basin-fill rocks structurally overlie a thin, tectonically emplaced oceanic crustal slice, the Crooked amphibolite, part of the Slide Mountain Terrane. It defines the terrane boundary with the older metamorphic rocks of the Barkerville Subterrane (a subdivision of Kootenay Terrane) to the east. Middle Jurassic and (?) younger polylithic conglomerate lenses and thinly bedded, fine-grained clastic rocks are preserved in narrow fault-bounded wedges along the western terrane boundary of the Quesnel rocks with Cache Creek Terrane. In addition, a sinuous band of distinctive conglomerates of possible Cretaceous age and fluvial origin overlaps Quesnel arc rocks along Quesnel Lake and Quesnel River in the central part of the map area.

Eocene extensional faulting and magmatism disrupted the Quesnel Trough following a period of deep tropical weathering. Graben development, with attendant ash-flow eruptions and lacustrine deposits, characterizes this time period. Hydrothermal activity, possibly related to subvolcanic intrusions, produced tourmaline-sericite and propylitic alteration (for example, the Megabucks copper-gold prospect). Elsewhere incipient epithermal quartz-carbonate veining is evident. Mid-Miocene and younger basalts covered parts of the Eocene grabens and older arc rocks of Quesnel Terrane, and the tectonic boundary with Cache Creek rocks to the west, a high-angle fault. In places the basalt flows cap older Miocene fluvial systems that contain placer gold. Both preglacial and postglacial rivers flowing out of the metamorphic highlands to the east have transported additional gold. Perhaps more importantly, postglacial rivers and some of the smaller creeks have locally redistributed and concentrated gold from older placer deposits. The main bedrock sources for the placer gold appear to be in the eastern part of the study area where (?) Late Jurassic quartz veins occur in the basal black phyllite unit near the terrane boundary of Quesnellia and the high-grade metamorphic rocks of the Barkerville Terrane.

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# CHAPTER 1 INTRODUCTION

## PROJECT LOCATION AND OBJECTIVES

A geological mapping program in the Cariboo region of central British Columbia, the Quesnel Mineral Belt Project, was begun in 1985 and conducted over four succeeding field seasons. The main thrust was to remap and re-interpret the central Quesnel volcanic belt, also known as the Quesnel Trough, in the vicinity of Quesnel and Horsefly lakes and to the north and south of Quesnel and Horsefly rivers (Figure 1-1). A major undertaking was to investigate the economic potential for gold and copper-gold deposits along the volcanic-intrusive axis of the belt and study the newly discovered auriferous gold veins in the basal clastic unit.

The project was initially funded by the Canada/British Columbia Mineral Development Agreement 1985-1990 (MDA). In 1987 increased provincial funding enabled the project to expand along the trend of the Quesnel belt to both the northwest and southeast of the original mapping. Fieldwork was concluded in 1988.

This study was initiated and coordinated as a mineral deposits investigation by the senior author. He mapped mainly in the volcanic terrain in the southern part of the study area between the Horsefly River and Quesnel Lake. David G. Bailey was contracted seasonally during 1987 and 1988 to remap the central and northern portions of the Quesnel trough from the north end of Quesnel Lake and adjoining the Quesnel River to the northwest as far as the Cottonwood River. Mary Anne Bloodgood, supported by MDA funding in 1986 and as a staff geologist in 1987, studied the basal sedimentary facies of the Quesnel volcanic arc - the black phyllite map unit. She investigated the stratigraphy, structural setting and auriferous vein development in the Horsefly River headwaters, Mackay River and Spanish Mountain areas where the basal assemblage of fine-grained clastic rocks flanks the main Quesnel volcanic units along their eastern margin. Kirk Hancock mapped along side Panteleyev and summarized much of the information about placer deposits in the study area.

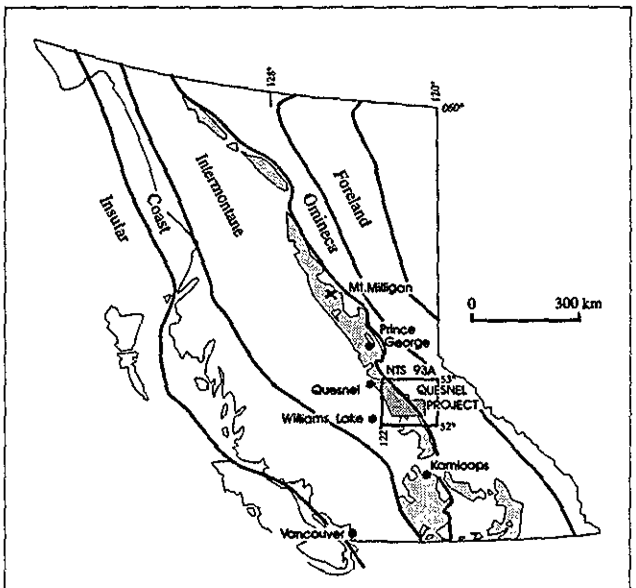



Figure 1-1. Cordilleran morphogeological belts after Wheeler and Gabrielse (1972) with rocks of of the Quesnel Terrane (shaded), after Wheeler *et al.* (1991), shown along the eastern margin of the Intermontane Belt. The central Quesnel Trough project area in mainly NTS 93A is indicated by the dark pattern.

Geological mapping was conducted by pace and compass traverses over most heights of land where outcrop potential was evident from study of aerial photographs. Examination of road cuts and the more deeply incised creek gullies was effective in locating otherwise scarce bedrock. Data were recorded on 1:20 000-scale black and white aerial photographs, more recent 1:15 000 coloured photographs or 1:20 000-scale planimetric maps. Mapping data and interpreted information were plotted on 1:50 000 topographic maps and presented on 1:50 000 and 1:100 000-scale compilation maps. Characteristic samples were taken from every map-unit to describe petrologic features and to determine the whole-rock and minor element chemical compositions of the volcanic and intrusive rocks. All macrofossils discovered were submitted to the Geological Survey of Canada for examination together with a number of collections from limestones and calcareous beds containing microfossils, mainly conodonts. Hydrothermally altered or unusual rocks were submitted for geochemical characterization as 'assay' samples.

Stratigraphic interpretation of the sparse and fault-disrupted volcanic outcrop data is difficult due to the similarity of lithologies but great lateral diversity in the fabric and textures of the predominantly pyroxene-phyric rocks. However, a few distinctive breccia and flow units containing analcite phenocrysts or feldspathic lavas provide readily identifiable marker units. Sedimentary units with rare fossil-bearing members are locally intercalated between some of the volcanic units and, where present, are invaluable as time-stratigraphic markers in the volcanic successions. Considerable assistance in geological interpretation in southern parts of the map-area is offered by 1968 federal/provincial 1:63 360 (1 inch to 1 mile) aeromagnetic maps 5239G (93A/6) and 1532G (93A/5). The 1989 1:250 000 aeromagnetic map of the northern part of the map-area (map 1952G, with four 1:50 000 component sheets) reveals only highly generalized map patterns.

## PROJECT SUMMARY AND PUBLICATIONS

This report, with its 1:100 000 geological compilation map, summarizes the work done in the central Quesnel belt between latitudes 52°15′ and 53°10′ north and longitudes

120°30′ and 122°25′ west. Mapping extends from the headwaters of the Horsefly River in the southeast to Cottonwood River in the northwest approximately 12 kilometres north of the town of Quesnel. The area mapped, centred roughly on the village of Likely, covers about 4600 square kilometres in a northwesterly-trending swath 26 to 60 kilometres wide and 120 kilometres long. The 1:50 000 map sheets completely or partially mapped are: NTS 93A/5, 6, 7, 11, 12, 13; 93B/9, 16 and small portions of 93G/1 and 93H/4 (Figure 1-1).

Sample collections with chemical analyses and petrologic data from 84 lithologic specimens, 20 macrofossil collections, 36 microfossil samples (6 producing conodonts), 3 palynomorph collections and 125 geochemical determinations (assays) are tabulated in appendices at the end of this report.

Published results of the project include:

- Open Files (Maps) - 1990-31, (Bailey, 1990); 1989-14, (Panteleyev and Hancock, 1989b); 1989-20, (Bailey, 1989b) and 1987-9, (Bloodgood, 1987b).
- Preliminary Maps - #67, (Bailey, 1988b).
- Papers - 1990-3, (Bloodgood, 1990).
- Geological Fieldwork Paper Series Contributions - Bailey and Archibald, 1990; Bailey, 1989a; Lu, 1989; Panteleyev and Hancock, 1989a; Bailey, 1988a; Bloodgood, 1988; Panteleyev, 1988; Bloodgood, 1987a; and Panteleyev, 1987.

## ACCESS

The area is readily accessible by road from the major population centres in the region, the towns of Quesnel in the north and Williams Lake in the south (Figure 1-2). Easiest access is from the Cariboo Highway (Highway 97) starting at 150 Mile House, 25 kilometres east of Williams Lake; there a paved all-weather road, the "Gold Rush Trail" joins the main highway. The road splits after 2 kilometres, into a southern branch that leads to the community of Horsefly, 55 kilometres away, and a northern branch that goes to the village of Likely, 80 kilometres distant. Alternate access to the headwaters of the Horsefly River in the southeastern part of the map area is from 100 Mile House. From there the settlement of Black Creek on the Horsefly River can be reached by this scenic route through a series of improved gravel roads that pass by Canim, Hendrix, Bosk and Crooked lakes. Entry into the central part of the project area and access to the Likely road near Beaver Creek can also be gained by way of the Gibraltar mine road - Tyee Lake connector road from McLeese Lake, 43 kilometres north of Williams Lake. The northernmost part of the map area is accessible from the Quesnel-Barkerville road (Highway 26) and a number of secondary roads along the Quesnel River.

In the project area, and generally throughout the central Quesnel Trough, there is a series of well-maintained gravel roads, a network of intermittently upgraded farm and ranch access roads and numerous unimproved logging roads. Local access is afforded by old logging roads in various states of disrepair, rough tracks, trails and various cattle walks that can be travelled on foot.

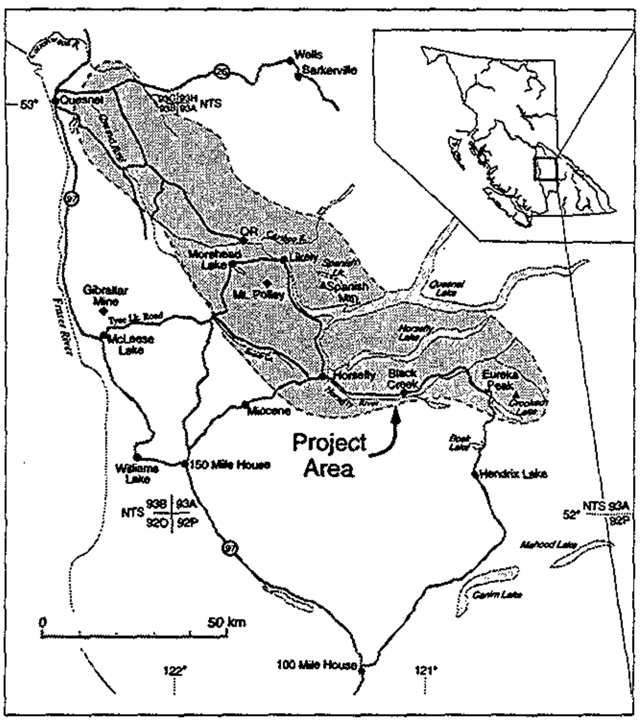



Figure 1-2. Location of project area, major lakes and rivers and main access routes.

## PHYSIOGRAPHY

The Quesnel Trough and the project area within it occupy the eastern part of the Intermontane morphogeological belt along its boundary with the Omineca Belt. The region is part of the Cariboo Plateau, the easternmost part of the larger region of Interior Plateaus (Mathews, 1986). The trough and the region to the east of it form the Quesnel Highland (Holland, 1964), a physiographic transition zone of hills, valleys and low mountains, that lies between the gently undulating Cariboo Plateau in the west and the higher and steeper sub-alpine and alpine terrain of the Cariboo Mountains, part of the Columbia Mountain ranges, in the east. The largest valleys are occupied by Quesnel and Horsefly lakes, both large and deep bodies of clean water that sustain important fish stocks. Numerous smaller lakes and ponds are found throughout the region.

The topography and physiography are expressions of the predominant underlying bedrock units. In the western plateau region, there are mainly flat-lying Tertiary volcanic flows of Early Miocene to Early Pliocene basalts and associated pyroclastic and sedimentary rocks of Mathews' (1989) Chilcotin Group. There is generally a thick cover of glaciogenic and fluvial deposits in the area or, rarely, small windows or uplifted fault blocks of the underlying Cache Creek Group. The area forms a plateau with a distinctive rolling topography of northwesterly trending undulations 10 to 25 kilometres across. The eastern margin of the basalts in the map area is marked by a prominent basalt 'rimrock' scarp along Beaver Creek valley. Vegetation varies from pine forest to scrubby hardwood stands, commonly with interspersed grasslands and marshy ponds. The central and main area of mapping interest, the Quesnel Trough, is a hilly, forested region underlain by Mesozoic volcanic and sedimentary rocks and some plutons (Photos 1-1 and 1-2). The higher hills and mountains along the eastern map boundary are composed mainly of sedimentary rocks of the Mesozoic basal clastic assemblage, their foliated metamorphosed equivalents and the underlying higher grade basement metamorphic rocks (Photo 1-3).

Evidence of glaciation is extensive and evident in the landforms. Large areas are covered by fluvioglacial deposits, till sheets, moraines with trains of large glacial erratics and ice-scoured, generally small, outcrop areas. Northwesterly glacial transport is consistent throughout the area with local zones showing more westerly ice-movement trends. Glacial striae have a pronounced northwesterly orientation with a dominant 305° ice-flow direction.

The overall northwesterly flowing drainage system established in the map area originates in the Cariboo Mountains. The largest river in the south is the Horsefly River and its tributaries. In the north the main rivers are the Cottonwood and Swift. The Horsefly River and outflow from Horsefly Lake drain into Quesnel Lake. Its outflow, the Quesnel River, and a northeast branch at Quesnel Forks, the Cariboo River, form the main river system in the centre of the study area and are a major tributary to the Fraser River at Quesnel. The dominantly northwest-southeast drainage pattern has a subsidiary system perpendicular to it, formed by many of the tributary creeks and secondary drainages.

Typical elevations of lakes and in the headwaters of the rivers in the Quesnel Highland, for example at Crooked Lake in the southeast part of the map area, are slightly more than 900 metres. The elevation at the confluence of the Quesnel and Fraser rivers in the northwest corner of the project area is about 500 metres. The undulating plateau in the west varies from 900 to 1100 metres in elevation. The central part of the map area, along the volcanic axis of the Quesnel Trough, is predominantly rolling hills with a few clustered heights of land rising gently to elevations around 1500 metres. The easternmost part of the area mapped is more rugged with a number of mountains close to 2000 metres in elevation; farther to the east the highest peaks are in excess of 2500 metres.

Outcrop in the extensively glaciated area is relatively scarce except along the eastern map boundary where the more severely deformed and metamorphosed rocks form highland areas, ridges and mountain peaks. Most of the area is underlain by volcanic rocks and topography is subdued; bedrock is exposed locally or where the generally shallow overburden has been disrupted by industrial activities, chiefly logging and road building. Outcrops are frequently found along ridge crests, commonly at the southeast end (the

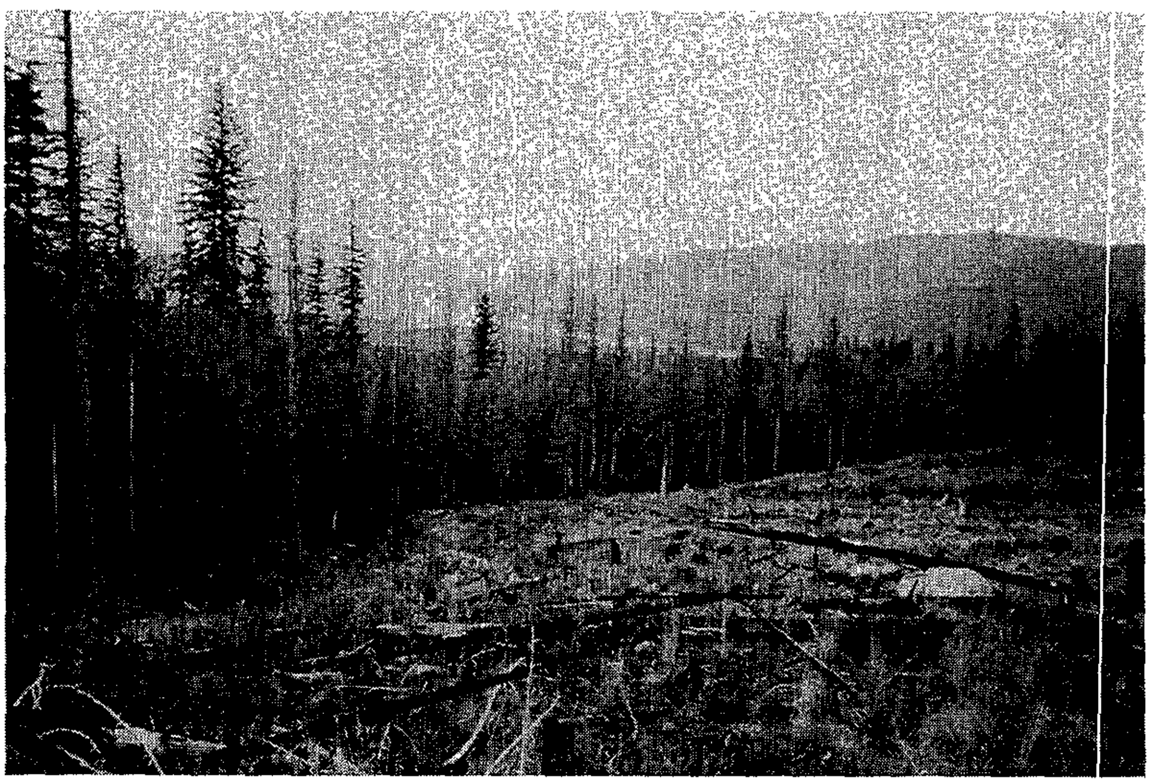


Photo 1-1. View of Quesnel Lake looking northwesterly towards Likely from the Shiko Lake property. The forested low hills with intervening broad valleys are typical of the region that is underlain by the Quesnel arc volcanic rocks.

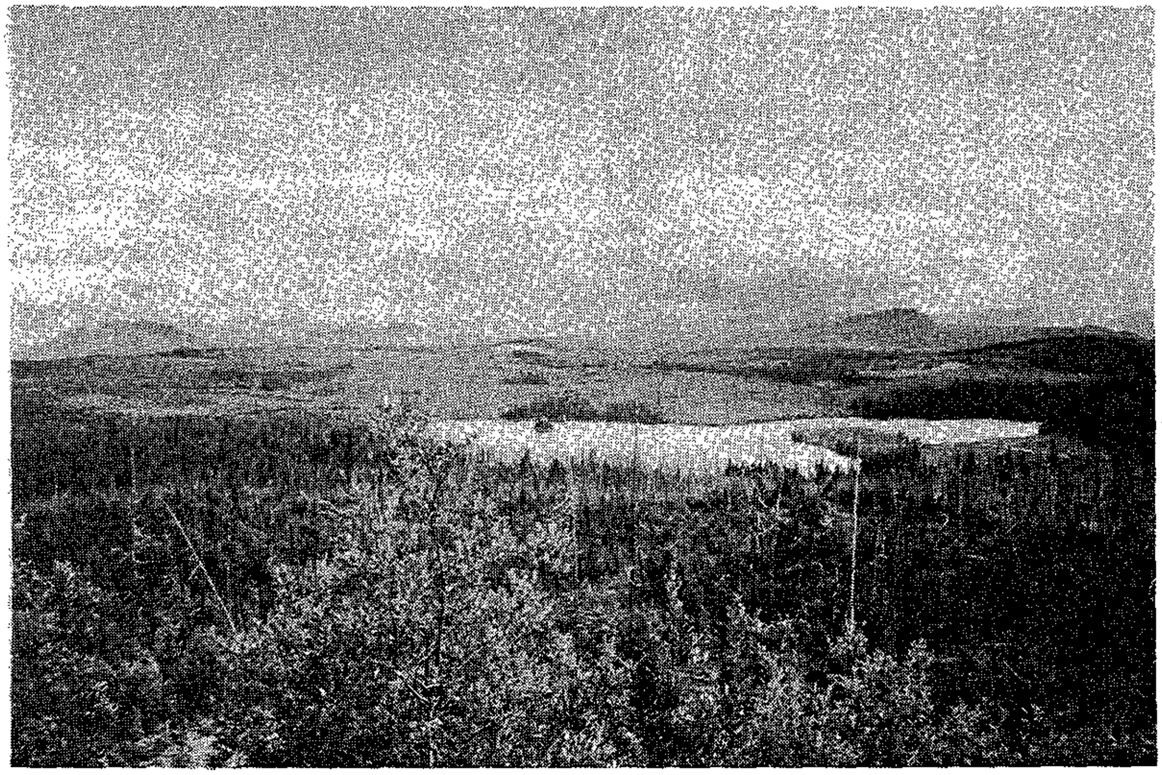


Photo 1-2. Niquidet Lake, between Horsefly and Quesnel lakes, looking eastward towards the Cariboo Mountains. The subdued topography is typical of the area of basin-fill Triassic sedimentary rocks of unit 1 that underlie the Quesnel arc volcanic deposits.

Photo 1-3. Rugged topography with bedded, metasedimentary Triassic rocks in the eastern part of the map area near the Quesnellia - Barkerville terrane boundary. View to east towards Eureka Peak, elevation 2426 metres.

up-ice or stoss side) of the glaciated ridges. Bedrock is also exposed in some of the more deeply incised river and creek gullies and locally along lake shores. Overall there is an extensive cover of glacial, fluvioglacial and fluvial deposits that support forest resources of good quality. Timber has been extensively harvested throughout much of the area and the cut blocks, especially the fire breaks along their perimeters, are places where bedrock is frequently exposed.

## PREVIOUS WORK

Triassic rocks near Kamloops to the south of the Quesnel area were first described by G.M. Dawson in 1877 (Dawson 1877, 1879). In 1887 Amos Bowman recognized the volcanic nature and Mesozoic age of rocks in the Quesnel River region. He referred to the volcano-sedimentary units as the "Quesnel River beds" (Bowman, 1889). Cockfield and Walker (1932) mapped a portion of the same belt to the west of the Quesnel Forks placer mining district. Their work supported Bowman's conclusions about the distribution of regional map units. Cockfield and Walker described the layered and intrusive units in more detail and noted the presence of syenites. With the use of faunal collections they resolved that Jurassic argillites are interbedded with the purplish brown volcanic successions in the Morehead Creek area.

The broad extent of Triassic (and some associated Jurassic) arc rocks as part of a volcanic belt that is virtually continuous throughout the Canadian Cordillera was documented in the 1960s, mainly by workers from the Geological Survey of Canada. The term 'Quesnel Trough' was first used by Roddick *et al.* in 1967. Comprehensive regional studies in the Quesnel River area during the late 1950s and 1960s (Tipper, 1959, 1978; Campbell, 1961, 1963; and Campbell and Campbell, 1970) are summarized by Campbell (1973, 1978) and discussed by Souther (1977). Campbell referred to the volcano-sedimentary units as the 'Quesnel River Group'.

A detailed geological description and definition of regional stratigraphy in the central part of this study area was done during the 1970s by Morton (1976) and Bailey (1976, 1978). Morton interpreted the volcanic assemblage in the Horsefly Lake area, designated by him as the 'Horsefly Group', to be a cyclical sequence of alkalic volcanics generated by crustal rifting. Bailey, on the other hand, considered that the rocks formed in an island arc, above a convergent plate margin. Bailey's mapping in the Morehead Lake area established a regional stratigraphy that serves as a geological mapping standard and reference framework for this project as well as other geological studies in the region. His stratigraphic succession is demonstrable and reliable in the map area and is generally applicable to other parts of the Quesnel trough.

Within the Quesnellia tectonostratigraphic terrane in north-central British Columbia, commonly referred to as the northern extension of the Quesnel Trough, the term 'Takla' or Takla Group has been applied to rocks identical to the Quesnel belt rocks, for example, Nelson *et al.* (1991, 1992). Equivalent rocks to the south, mainly between Kamloops and Princeton, are generally referred to as Nicola Group (Schau, 1970; Preto, 1977, 1979; Mortimer, 1987). The rocks mapped during this project in the central Quesnel Trough have been variously correlated with either Takla or Nicola rocks. Bailey (1978) pointed out the similarity of the Quesnel volcanic units with both the Nicola Group rocks to the south and the Takla Group rocks to the north but did not indicate any preferred correlation or inclusion of his Quesnel area map units with either group. He subsequently referred to them as Nicola Group (Bailey, 1988a). In this study we continue to correlate our map units with the Nicola Group simply to emphasize the association of these rocks with Quesnel Terrane. The term Takla leads to ambiguity because in northern British Columbia it has been used for rocks in both Quesnel and Stikine terranes.

The alkalic nature of the volcanic rocks in Quesnellia, and their related plutons, became evident during the 1970s largely from the work by Fox (1975) and near Princeton by Preto (1972, 1977, 1979). Similar rocks in the northern Quesnel Trough were described by Koo (1968), Meade (1977) and Garnett (1978). Detailed mapping and petrochemical studies of the alkalic rocks were done by Lefebure (1976), Morton (1976) and Bailey (1978). Mortimer (1986, 1987) has investigated the major and minor element petrochemistry of the volcanic rocks. He has discussed the large-scale correlations of the map units and concludes that chemically equivalent rocks extend far to the south in the United States. The relationship in the belt between alkalic volcanism, plutonism and related mineralization has been discussed by Barr *et al.* (1976), Hodgson *et al.* (1976) and Bailey and Hodgson (1979). In the northern part of the Quesnel Trough similar rocks in the Mount Milligan are (NTS 93K,93N) are discussed by Nelson *et al.* (1991, 1992, 1993) and Nelson and Bellefontaine (1996).

The boundary of the Intermontane - Omineca morphogeological belts or, alternatively, the Quesnellia - Barkerville terranes, has been the subject of a number of studies, mostly unpublished, concerned mainly with the tectonic evolution, structural development and metamorphic history of the region (Campbell, 1971; Montgomery, 1978; Fillipone, 1985; Elsby, 1985; Carye, 1986; Struik, 1986, 1988a; Bloodgood, 1987c; Rees, 1981, 1987; Radloff, 1989). Much of the work is summarized by Ross *et al.* (1985, 1989) and McMullin *et al.* (1990). To the east of the Quesnel belt, in the Cariboo Mountains of the Barkerville Subterrane, the Upper Proterozoic through Paleozoic stratigraphy, structures and metamorphic history have also been extensively studied (Sutherland Brown, 1963; Fletcher, 1972; Engi, 1984; Elsby, 1985 Getsinger, 1985; Montgomery, 1985; Garwin, 1987; Lewis, 1987). Major recent advances in understanding of the area have come from work during 1980 to 1986 by L.C. Struik of the Geological Survey of Canada, summarized in Struik (1986, 1987, 1988a,b). Two other comprehensive and insightful summaries and discussions are those of Rees (1987) and McMullin (1990). The major regional tectonostratigraphic units that make up the map area and the terminology of the terranes - Quesnellia, Stikinia, Cache Creek, Slide Mountain, Barkerville, Kootenay and others, are described by Monger *et al.* (1991).

Interest in the mineral potential of the area has been evident since 1859 when placer gold was discovered near the site of present-day Horsefly and elsewhere in the Quesnel River drainage system. The first reports on the economic potential of the district were prepared after a reconnaissance of the area by G.M. Dawson in 1894. A record of annual gold production and mining activity has been kept since 1874 and published in the Annual Report of the Minister of Mines. Reviews of the major placer mining operations at Cedar Creek were done by Johnston (1923), Quesnel Forks area by Cockfield and Walker (1932) and the Horsefly River and other areas by Lay (1939). Recent reviews of the geological settings and stratigraphy of gold placers in the Quesnel Trough and Cariboo mining district to the north are those of Levson and Giles (1991, 1993).

The first synopsis of lode mineral potential in the Quesnel Trough was by Campbell and Tipper (1970). Bedrock exploration in the area was active during the late 1960s and throughout the 1970s, mainly for copper and copper-gold deposits (Saleken and Simpson, 1984). During that time, the Cariboo-Bell (Mount Polley) porphyry copper-gold deposit was located (Hodgson *et al.*, 1976). Exploration activity peaked in the early 1980s after release of the 1980 Regional Geochemistry Survey (RGS) and recognition of the district's lode gold potential, as indicated by discovery of the volcanic-hosted, propylite-associated QR gold deposit (Fox *et al.*, 1986; Melling *et al.*; 1990; Fox and Cameron, 1995). Discovery and exploration of auriferous quartz vein deposits in the Spanish Lake and Mackay River areas focussed attention on the gold potential of the basal black phyllite units.

## ACKNOWLEDGMENTS

Discussions about the geology of the Nicola belt at the outset of this project and enlightening observations in the field were provided by Bill McMillan and Vic Preto. Ted Faulkner, Regional Geologist in Prince George, introduced the writers to the project area and a number of the main mineral deposits.

Macrofossils and microfossils submitted to them were expertly identified, respectively, by Howard Tipper and Mike Orchard of the Geological Survey of Canada. Terry Poulton and Tim Tozer provided consultations on certain fauna. Glen Rouse of The University of British Columbia identified palynomorphs. Bert Struik of the Geological Survey of Canada provided insights into many facets of regional and structural geology as did John Ross and Jeff Fillipone of The University of British Columbia. Specialized analyses by electron microprobe on gold grains were performed by John McKnight at The University of British Columbia and on pyroxene crystals by Mitch Mihalynuk at the University of Calgary. Potassium-argon radiometric dating was done by Joe Harakal at The University of British Columbia and Ar-Ar dating by Doug Archibald at Queens' University.

A number of exploration geologists, most notably Pete Fox and John Kerr, shared their knowledge about the project area and, in a number of cases, provided data and reports to the authors. Addition valuable information, discussions, assistance and hospitality were provided by Rob Cameron, Vin Campbell, Rudi Durfeld, Geoffrey Goodall, Charlie Greig and Bill Morton. A number of claim owners, prospectors and placer operators provided access to their properties, and in some cases, rock and mineral samples and tours of their operations. The visit with Lyle Shunter at his Black Creek placer mine and discussion about Beaver Valley placer creeks with the late Milt Lonneberg were especially informative. Land holders throughout the area were consistently cordial and helpful with information about local access, outcrop locations and placer mining history. Horsefly residents Susan and Bill Hall extended their hospitality at the Birch Bay Resort on Horsefly Lake. James Allard offered boat launching facilities at his family property on Horsefly Lake and provided site information and rock samples from a new quarry in the area.

Lu Jun of the Ministry of Metallurgical Industry, Hefei City, People's Republic of China, a visiting scholar funded in 1987/1988 by World University Services of Canada, conducted some field investigations ably assisted by Mike Fournier of the Ministry. The work within the central Quesnel belt in the vicinity of Cantin Creek was in an area of economic interest investigated by Pete Fox; the use of his data and maps is acknowledged. This work (Lu, 1989) has been incorporated in the regional 1:50 000 and 1:100 000 geology maps.

Ministry employees working on a seasonal basis as field and mapping assistants were: John Nicholson, Kari Marks, Larry Elgart, Giovanni Pagliuso, Mike Gartrell and Jan Hammack. Analytical work was done or expedited by the Analytical Sciences Laboratory, Geological Survey Branch. Shaun Pattenden assembled much of the sample and early analytical data. We acknowledge the assistance in data assembly and computer processing from colleagues Chris Ash, Wayne Jackaman, Ray Lett, Don MacIntyre, Aaron Pettipas and Steve Sibbick. Editorial comments about draft manuscripts, by John Newell and Brian Grant are incorporated in this report. The geological compilation maps were completed by Martin Taylor. A special mention is reserved for Victor Koyanagi who has generated most of the illustrations, tables, appendices and draft copies of the maps presented here.

# CHAPTER 2 REGIONAL GEOLOGY

## TECTONIC SUBDIVISIONS - BELTS, TERRANES AND TECTONIC ASSEMBLAGES

The Canadian Cordillera can be divided into five major longitudinal morphogeological **belts** of generally similar physiography and geology; from west to east these are the Insular, Coast, Intermontane, Omineca and Foreland belts (Wheeler and Gabrielse, 1972; *see* Figure 1-1). The belts are now interpreted to be made up of a number of geologic **terranes** representing crustal blocks of fundamentally contrasting histories (Monger *et al.*, 1991; Wheeler *et al.*, 1991). Terranes are characterized (Jones *et al.*, 1983; Keppie, 1988) by internally continuous geology, including stratigraphy, structure, fauna, metamorphism, igneous petrology, geophysical properties, paleomagnetic record and metallogeny. The terranes are commonly bounded by faults and melanges representing trench complexes or (collisional) suture zones. Neighbouring terranes may be far-travelled and exotic and therefore have distinctive geological records. Alternatively, if the terranes are similar they may be distinguished only by the presence of telescoped oceanic lithosphere along their boundaries. In most of the Cordillera, terrane and belt boundaries coincide but locally terranes transect the boundaries of belts.

Eleven allochthonous terranes in addition to the ancestral North American craton have been described in the Canadian Orogen (Monger *et al.*, 1982, 1991). Some of the terranes, or parts of them that are of uncertain origin with respect to North America, have been referred to as 'suspect terranes' (Coney *et al.*, 1980). The terranes have been assembled within a scenario of continent-margin amalgamation and accretion summarized by Monger (1993).

This study has investigated an area that lies along the eastern margin of the Intermontane Belt along its tectonic boundary with the Omineca Belt. The project area is almost entirely within Quesnellia (QN), sometimes alternatively referred to as Quesnel Terrane (Figure 2-1). The western terrane boundary of Quesnellia with Cache Creek (CC) rocks is marked by a zone of high-angle, strike-slip faulting that is probably the southern extension of the Pinchi fault system (Gabrielse, 1991). Along the eastern margin of the map area rocks of Quesnellia and a thin slice of underlying 'Crooked amphibolite', part of the Slide Mountain Terrane (SM), are structurally coupled and tectonically emplaced by the Eureka thrust onto the Barkerville Subterrane (KO$_B$) of the Omineca Belt (Struik, 1986, 1988a).

The predominantly Triassic and Early Jurassic volcanic arc and related volcaniclastic rocks that characterize Quesnellia overlie a thin, discontinuous slice of Crooked amphibolite (Campbell, 1971). Struik (1986, 1988a) regards the amphibolite as the basal unit of Quesnellia and considers the contact between Quesnel rocks and the amphibolite to be structural, as does Bloodgood (1988). On the other hand, Struik (1981, 1985a) refers to a depositional contact in some places. Also Rees (1987) suggests that the two map units have a depositional contact and were linked as a single composite terrane by the Late Triassic. He considers the amphibolite to be correlative with rocks of the Slide Mountain Terrane but refers to it as the 'Antler Formation' in order to supress the implication that it might be tectonically separated from Quesnellia. Basement for Quesnellia is probably rocks of the Harper Ranch (QN$_H$) Subterrane (Monger, 1977; Struik, 1986; Monger *et al.*, 1991). These are Devonian to Permian oceanic marginal basin or arc volcanics and sediments that locally contain mafic intrusions and alpine-type ultramafic rocks. No Harper Ranch rocks are known to crop out in the project area. Along the Eureka thrust, the eastern boundary of Quesnel Terrane, rocks of Quesnellia are superimposed on the intensly deformed, variably metamorphosed Proterozoic and Paleozoic pericratonic rocks of the Barkerville Subterrane (KO$_B$). The western part of the Intermontane Belt, Stikinia (ST), is separated

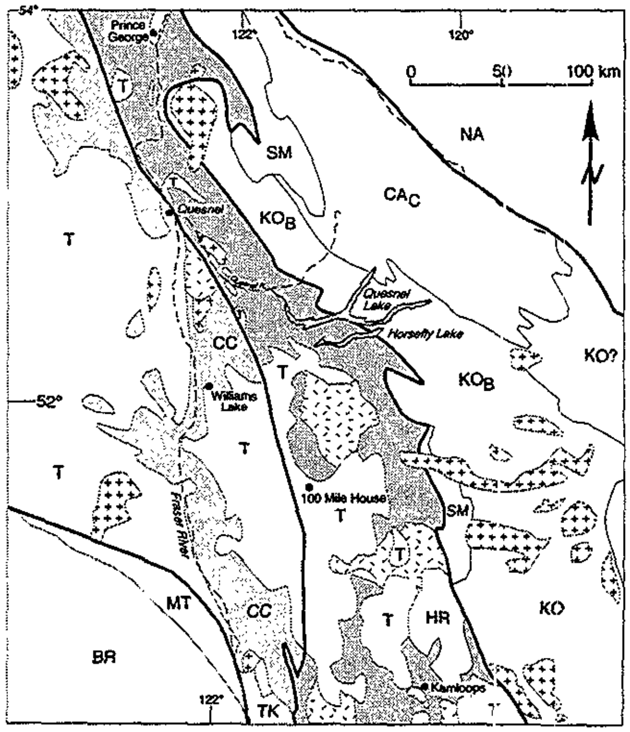



Figure 2-1. Tectonic assemblage map of the south-central part of British Columbia including Quesnel project area and surrounding region; tectonic assemblages are those of Wheeler and McFeeley (1991). Terranes: BR - Bridge River; CA$_C$ - Cariboo Subterrane, part of Cassiar; CC - Cache Creek; HR - Harper Ranch Subterrane; KO - Kootenay; KO$_B$ - Barkerville Subterrane; MT - Methow; NA - North America; SM - Slide Mountain. T - Tertiary overlap units; older (Jurassic) plutons - hatchured pattern; younger (Cretaceous) plutons - crossed pattern. Rocks of Quesnel Terrane are shown in dark grey pattern.

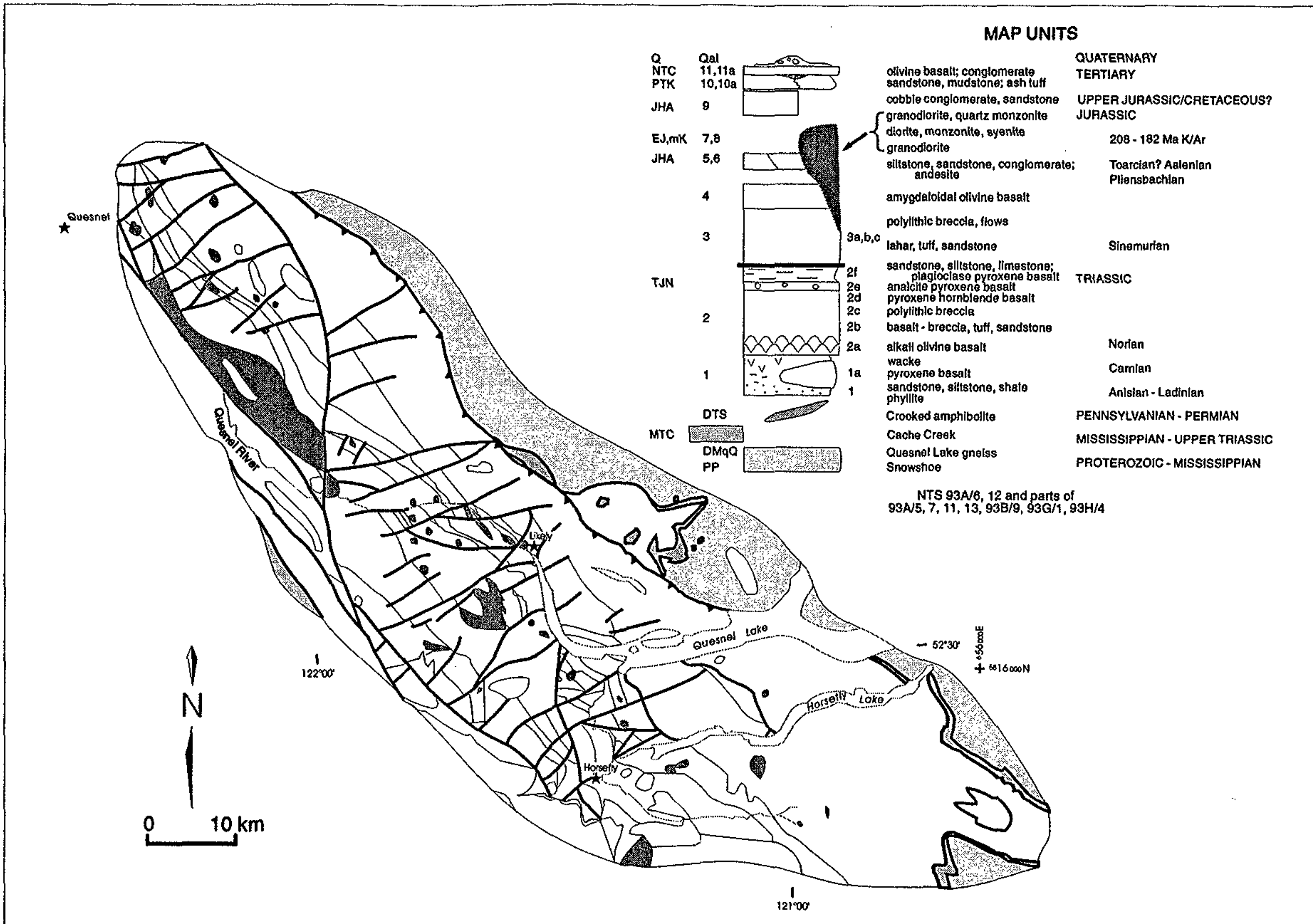



Figure 2-2. Generalized geological map of project area showing tectonic assemblages that border Quesnellia and major intrusive bodies within Quesnellia.

from Quesnellia by rocks of the Cache Creek Terrane (CC). It is composed of mainly Mississippian to Middle Triassic oceanic and island arc volcanics and sediments. The presence of accretionary prism mélange and alpine-type ultramafic assemblages, terrane boundaries along major faults and the presence of Tethyan fauna attest to the exotic and complex origin of Stikinia.

Terranes of the Intermontane Belt - Stikinia, Cache Creek and Quesnellia, collectively called (amalgamated) Superterrane I, were assembled by the Early Jurassic (Monger *et al.*, 1972, 1982; Monger, 1993). This conclusion is based largely on dated crosscutting plutons. Quesnellia and Slide Mountain terranes are tied by Late Triassic to Middle Jurassic overlap assemblages. The Stikinia and Quesnellia arc assemblages and Cache Creek oceanic mélange were accreted to terranes of North American affinity by latest Early to Middle Jurassic time, based on ages of magmatic emplacements (Monger *et al.*, 1982; Armstrong 1988; Oldow *et al.*, 1989).

The fundamental geologic components that make up the terranes are referred to as 'tectonic assemblages' (Wheeler and McFeely, 1991; Monger *et al.*, 1991). The assemblages represent rocks deposited in specific tectonic settings during certain periods of time and, therefore, are commonly bounded by unconformities or faults. They represent distinctive successions of stratified rocks and other characteristic lithologies, mainly coeval metamorphic, plutonic and ultramafic rocks. The assemblages are categorized in terms of their predominant depositional setting or position relative to the orogen, for example, island arc, back-arc, ocean basin or continent-margin foredeep clastic wedge or passive-margin sediment, and so forth. Tectonic assemblages are commonly named after their principal constituent formation, group or region in which the assemblage is best described.

The tectonic assemblage maps of Tipper *et al.* (1981) and Wheeler and McFeely (1991) outline the various assemblages of the Canadian Cordillera. The Quesnel Lake portion of the maps shows the four main tectonic assemblages in the project area as illustrated by Figure 2-2. The assemblage names and mnemonic codes used in the figure and in the following discussion are those of Wheeler and McFeely (1991). The principal assemblage in Quesnellia, the predominant unit in the project area, is the Triassic-Jurassic Nicola island arc - marginal basin sequence (TJN). The underlying rocks are the Crooked amphibolite, part of the Slide Mountain assemblage (DTS), a mylonitized mafic and ultramafic unit of oceanic marginal basin volcanic and sedimentary rocks. The Barkerville Subterrane to the east, a continental prism sequence, is made up of two units, the Snowshoe Group (PP) and Quesnel Lake gneiss (DMqQ). The Snowshoe rocks are Hadrynian (Upper Proterozoic) to Upper Devonian metasediments that are considered to be correlative in age with Eagle Bay rocks (PPEK) of the adjoining Kootenay Terrane to the south. The Quesnel Lake gneiss, found locally near Quesnel Lake within regions of predominantly Snowshoe rocks, is a Devonian to Mississippian intrusive unit (Mortensen *et al.*, 1987; Montgomery and Ross, 1989). Further to the east of the Barkerville Subterrane are Kaza and Cariboo Group rocks of the Upper Proterozoic to Carboniferous Cariboo Subterrane (CAc), a continental margin assemblage. To the west of Quesnellia and in a small part of the area mapped (see Figure 2-2) are Permian and (?) older limestone and Mississippian to Upper Triassic sedimentary rocks of the Cache Creek assemblage (MTC), an oceanic mélange. Two other minor map units in the northern part of the Quesnel Trough include small fault-bounded, fragments of tectonic assemblages. These are oceanic ultramafic rocks (DTuo), part of the Slide Mountain Group, exposed along a northern segment of the Eureka thrust, and a small wedge of Cambrian shale, sandstone and limestone (PCG)) by Dragon Lake near Quesnel, reported on by Tipper (1978) and Struik (1984b).

Some parts of the main tectonic assemblages in Quesnellia and the adjoining terranes are extensively overlapped by younger successions of sedimentary and volcanic rocks and intruded by post-accretionary plutons. Within the Quesnel Trough, near Quesnel and near its western margin along the Fraser River, these units include Lower and Middle Jurassic arc-derived clastic rocks (JHA). The rocks are considered (Wheeler and McFeely, 1991) to be equivalent to the Hall and Ashcroft formations of southeastern and southern Quesnellia. This unit in the Quesnel River area contains a number of undifferentiated clastic successions including rocks as young as Cretaceous. Subaerial volcanic rocks and the clastic aprons and lacustrine deposits derived from them include Paleogene Kamloops Group transtensional arc volcanics (PTK) and Neogene Chilcotin back-arc volcanics (NTC). Locally Neogene Fraser alluvial sediments are exposed through a regionally widespread cover of Quaternary deposits (Q).

Intrusive rocks in Quesnellia include pre-accretionary and accretionary Early Jurassic plutons and also some mid-Cretaceous post-accretionary stocks (Wheeler and McFeely, 1991, Armstrong, 1988 and Woodsworth *et al.*, 1991). Early Jurassic intrusions (214 - 182 Ma) include both calkalkaline plutons that are equated with intrusions of the Guichon Creek batholith (EJgG) as well as high-level alkaline stocks similar to the Copper Mountain suite (EJyCM). Some other unclassified intrusions form suites of dioritic (EJd) and granodioritic (EJg) stocks. Post-accretionary intrusions (130 - 87 Ma) are equivalent to the Bayonne granitic suite (mKgB) as well as some additional unclassified granodioritic intrusions (mKg). Tertiary plutonic rocks have not been discovered in the project area, although Eocene alkalic volcanic rocks and lamprophyric dikes are known to occur (this study).

The terminology used for the Mesozoic volcanic arc rocks in Quesnellia has been inconsistent. It has created difficulties in correlating the rocks in the central Quesnel Trough with similar rocks in other areas, even though all these rocks occur in the same terrane. The rocks in the project area have, at various times, been given their own group names, for example, Quesnel River Group (Tipper, 1959, 1978; Campbell, 1978) and Horsefly Group (Morton, 1976). The volcanic arc rocks have been commonly referred to as Nicola Group because of their similarity with rocks to the south (Bailey, 1978; Bloodgood, 1990). Alternatively, comparisons with similar rocks and stratigraphy to the north permit a valid correlation with the Takla Group (Tipper, 1978; Rees, 1987). Much recent work in the northern Quesnel trough refers to the Triassic-Jurassic arc assemblages there as Takla, for example, Nelson and Bellefontaine, (1995) and Ferri *et al.* (1992). Comparisons can also be made with the similar but somewhat younger rocks near Rossland in southern Quesnellia, referred to as the Rossland Group (Höy and Andrew, 1988).

Nomenclature applied in the Quesnel Lake area from 1971 to 1990 by various workers has been summarized by McMullin (1990, page 47). The basal sedimentary unit has been referred to by the following terms: pelite; black pelite; graphitic pelite; Quesnel River Group; black phyllite; phyllite; black shale, slate, argillite and so forth; graphitic phyllites and argillites; Eureka quarzite and Crooked Lake phyllite; Nicola Group; Quesnel River or Nicola Group; and Slocan - King Salmon assemblage. The upper, volcanic unit has been referred to as: Quesnel River Group; Horsefly Group; Takla Group; Nicola Group; possibly Takla or Nicola Group; Takla - Nicola assemblage and simply 'volcanic rocks'. Ages are stated to be: Triassic; Upper Triassic; Middle - Upper Triassic; Middle to Upper (?) Triassic; Upper Triassic - Lower Jurassic; Triassic - Jurassic and Jurassic.

The usage for all the Triassic-Jurassic volcanic arc and related rocks in Quesnellia currently preferred and advocated (Gabrielse and Yorath, 1991; Wheeler and McFeeley, 1991) is **Nicola** Group. The term Takla Group possibly should be discarded except for informal, regional usage in the northern Quesnel Trough. The term Stuhini should be reserved for the similar (some would say identical) Triassic-Jurassic, alkalic volcanic arc rocks of Stikinia.

## REGIONAL MAP UNITS AND MAP PATTERNS

### *BARKERVILLE TERRANE (KOB)*

#### SNOWSHOE GROUP (PP) AND QUESNEL LAKE GNEISS (DMqQ)

Pericratonic pelitic and psammitic metasedimentary rocks of the Snowshoe Group and intrusive Quesnel Lake gneiss are exposed in the northern and eastern parts of the project area. Snowshoe rocks are Late Proterozoic (Hadrynian) to mid-Paleozoic (Devono-Mississippian ?) in age. The successions consist mainly of moderately to thinly interbedded gritty siliciclastic and pelitic metasediments (Struik, 1988a). Metamorphic grade ranges from greenschist to amphibolite facies. The rocks are commonly finely foliated due to strong deformation and dynamic recrystallization, especially near lithologic contacts and the top of the unit. Major lithologies include pelitic to semipelitic (quartzose) schist, micaceous quartzite, feldspathic schist, metasiltite and phyllite with lesser grit, calcareous phyllite, micritic limestone, marble, calcsilicate, amphibolite and amphibolitic gneiss (McMullin, 1990). The rocks resemble, in part, the Paleozoic Eagle Bay assemblage of the Adams Plateau - Clearwater area (Schiarizza and Preto, 1987) and have also been correlated with the Lower Paleozoic Lardeau Group and the Carboniferous Milford Group of the Kootenay Arc (Struik, 1986).

Quesnel Lake gneiss (DMqQ) forms tabular to sill-like (Fletcher, 1972) intrusive bodies generally about 2 to 4 kilometres in width and up to 60 kilometres long (Montgomery, 1985; Rees, 1987). A number of bodies of the megacrystic quartz-feldspar augen gneiss have been mapped adjacent to the Barkerville - Quesnel terrane boundary (Rees, 1987). The gneiss along this boundary has a well developed mylonitic fabric in places and is mechanically intercalated with Crooked amphibolite. Rees recognized two major phases of deformation in this unit.

Quesnel Lake gneiss shows considerable variation in composition from diorite to granite to syenite. Two major varieties of granitoid orthogneiss within the Snowshoe Group metasediments are described on the basis of mineralogy and grain size. The main variety is characterized by pale outcrops composed of potassium feldspar megacrystic rocks with a mafic-poor groundmass of quartz, feldspars and white mica. Four distinct lithologies are described (Montgomery and Ross, 1989) from the larger intrusive bodies: a micaceous quartz-feldspar±hornblende gneiss, a pinkish pyroxene-hornblende-feldspar gneiss, and rarer dark green amphibolite and garnetiferous syenitic gneisses. The second type of gneiss is found to the south of Quesnel Lake. It is a more homogeneous, medium-grained, streaked black-grey-white gneiss to fine-grained schistose rock. It forms a discrete map unit in the Boss Mountain and Mount Perseus areas but is thought to be related to the main gneiss unit (Mortensen *et al.*, 1987). Ross and co-workers (1985) indicate that emplacement of this orthogneiss preceded or was contemporaneous with first-phase deformation.

The emplacement age of the gneisses is interpreted to be Late Devonian to middle Mississippian based on U-Pb dating (Mortensen *et al.*, 1987). Geochronological data for all the gneisses in the district have been tabulated by Rees (1987, pages 36-41). Dates range from 752 to 106 Ma for various minerals dated by different radiometric methods. The data suggest a long and complex tectonic history for Quesnel Lake gneiss with a Late Devonian or early Mississippian intrusive age, Middle Jurassic metamorphism and later, possibly mid-Cretaceous, igneous resetting.

### *CACHE CREEK TERRANE (CC)*

#### CACHE CREEK GROUP (MTC)

Cache Creek rocks are found in only a very small part of the project area to the west of Beaver Creek, north and south of the Likely - Tyee Lake road junction (NTS 93A/5). The Cache Creek Group is the main assemblage underlying the plateau region to the west of the Quesnel map area but is extensively covered by Tertiary strata and younger surficial deposits. The older bedrocks are poorly exposed through the deep cover of Tertiary and younger rocks. Major rock exposure consists of limestone that forms a number of large bluffs within an overall poorly exposed succession of Mississippian to Upper Triassic (probably Pennsylvanian and/or Permian) argillite, siltstone, chert and greenstone (Campbell, 1978). The limestone is a grey to pale grey weathering major unit in a Permian and possibly older succession that includes minor greenstone, chert and argillite.

## *SLIDE MOUNTAIN TERRANE (SM)*

### CROOKED AMPHIBOLITE (PART OF DTS)

The Crooked amphibolite, a name proposed by Struik (1985a), forms a thin, recessive map unit that effectively marks the boundary between the Barkerville and Quesnel terranes. The amphibolite in much of the map area is about 250 metres thick; locally it is only a few metres in thickness or discontinuous (Rees, 1987). In the western part of the project area it is up to 800 metres thick and in some places, for example, the hinge zone of major folds to the south of Quesnel Lake, it reaches 1200 metres in thickness (Carye, 1986; Bloodgood, 1987b).

The Crooked amphibolite is correlative on the basis of some lithologic similarities and mainly structural position with rocks of the Antler Formation, part of the Slide Mountain Group (Campbell, 1971; Campbell, 1978). Struik (1987) considers it to be the sheared and metamorphosed equivalent of the Antler Formation and, therefore, Mississippian to Permian in age. Crooked amphibolite is distinguished from other metamorphic rocks by its shear fabric, highly strained contacts, mechanical imbrication, mylonitic fabric and abundance of amphibolite. Rees (1987) describes three major (schistose) constituent rock types: greenstone, metagabbro and meta-ultramafite. In the Eureka Peak area map units consist of coarse-grained hornblende schist, talc-chlorite schist and actinolite schist. Along strike, north of Quesnel Lake, there are units of mafic metavolcanics, amphibolite, chlorite schist, serpentinite and ultramafic rocks; pillow lavas are present locally. Chemical analyses are interpreted by Rees to indicate subalkalic tholeiitic compositions of basalts formed on an ocean floor.

If the Crooked amphibolite is equivalent to the Antler Formation and is part of the Slide Mountain Terrane, it is separated from the underlying Barkerville Terrane along a thrust fault (Campbell, 1971). The fault, or more generally a wide zone of mylonitization, has been termed the Quesnel Lake shear zone (Brown and Rees, 1981; Rees, 1987) or Eureka thrust (Struik, 1985a). Crooked amphibolite and the overlying rocks of Quesnellia are structurally coupled and emplaced tectonically onto Barkerville Terrane. The upper amphibolite contact has been described by various authors to be a sedimentary, albeit tectonized, contact. Alternatively it is interpreted, at least locally, to be a depositional contact (Rees, 1987), possibly a disconformity. Whether this contact between Quesnellia rocks and Crooked amphibolite is depositional (Rees, 1987), structural (most authors) or unconformable (McMullin, 1990) remains uncertain. For convenience in mapping and map representation, Crooked amphibolite is generally considered to be part of Quesnellia and is regarded to be the base of the terrane (Struik, 1986; Rees, 1987; Bloodgood, 1990).

## *QUESNELLIA (QUESNEL) TERRANE (QN)*

### HARPER RANCH SUBTERRANE (DTH)

The Harper Ranch Group (Monger, 1977) or assemblage is considered to underlie the Mesozoic strata of Quesnellia in southern British Columbia (Read and Okulitch, 1977). The Devonian to Permian, possibly arc-related, assemblage consists of highly folded and faulted clastic and volcaniclastic units and carbonate bodies which include chert, argillite, basalt and associated ultramafic rocks (Monger *et al.*, 1991). No Harper Ranch rocks are known to crop out in the project area; the nearest exposures underlying Nicola rocks are approximately 130 kilometres southeast of Horsefly, near Kamloops. Similar rocks, possibly correlative with Harper Ranch rocks, underlie the Takla volcanics in the Lay Range in the northern Quesnel belt (Nelson and Bellefontaine, 1996).

### NICOLA GROUP (TJN) a.k.a. QUESNEL RIVER, HORSEFLY OR TAKLA GROUP

Two fundamental lithostratigraphic subdivisions of the Quesnel Terrane are evident: a basal, dominantly fine-grained metasedimentary unit and an overlying dominantly volcanic arc assemblage (Figure 2-3). The Middle to Late Triassic sedimentary rocks form a broad, continuous map unit along the northern one-third to one-half of the Quesnel project area. They also occur in a series of fault blocks along the southwestern terrane boundary. The observed thickness of the sedimentary unit is estimated by Rees (1987) to be about 2500 metres; Bloodgood (1990) suggests thicknesses of 2500 to 4000 metres from her work in the Spanish Lake and Eureka Peak areas. The overlying Late Triassic to Early Jurassic volcanic rocks occupy the central and southern parts of the northwesterly trending belt and outline the Quesnel magmatic arc. Volcanic deposits overlying eruptive centres in the central part of the map area are in the order of 6.5 kilometres thick in addition to the 2.5 kilometres of sedimentary rocks for a total thickness of 9 kilometres (Rees, 1987). We estimate a thickness of 7 kilometres for the sedimentary-volcanic arc succession.

The basal unit of dominantly black phyllitic rocks overlies Crooked amphibolite along a variably tectonized depositional contact or unconformity. Locally, as in the Spanish Lake area, the contact is folded and imbricated by a number of thrusts. Bloodgood subdivided the monotonous metasediment succession of black graphitic phyllites and slates into nine lithologic subdivisions. Contacts between the lithologic units appear to be gradational but the package

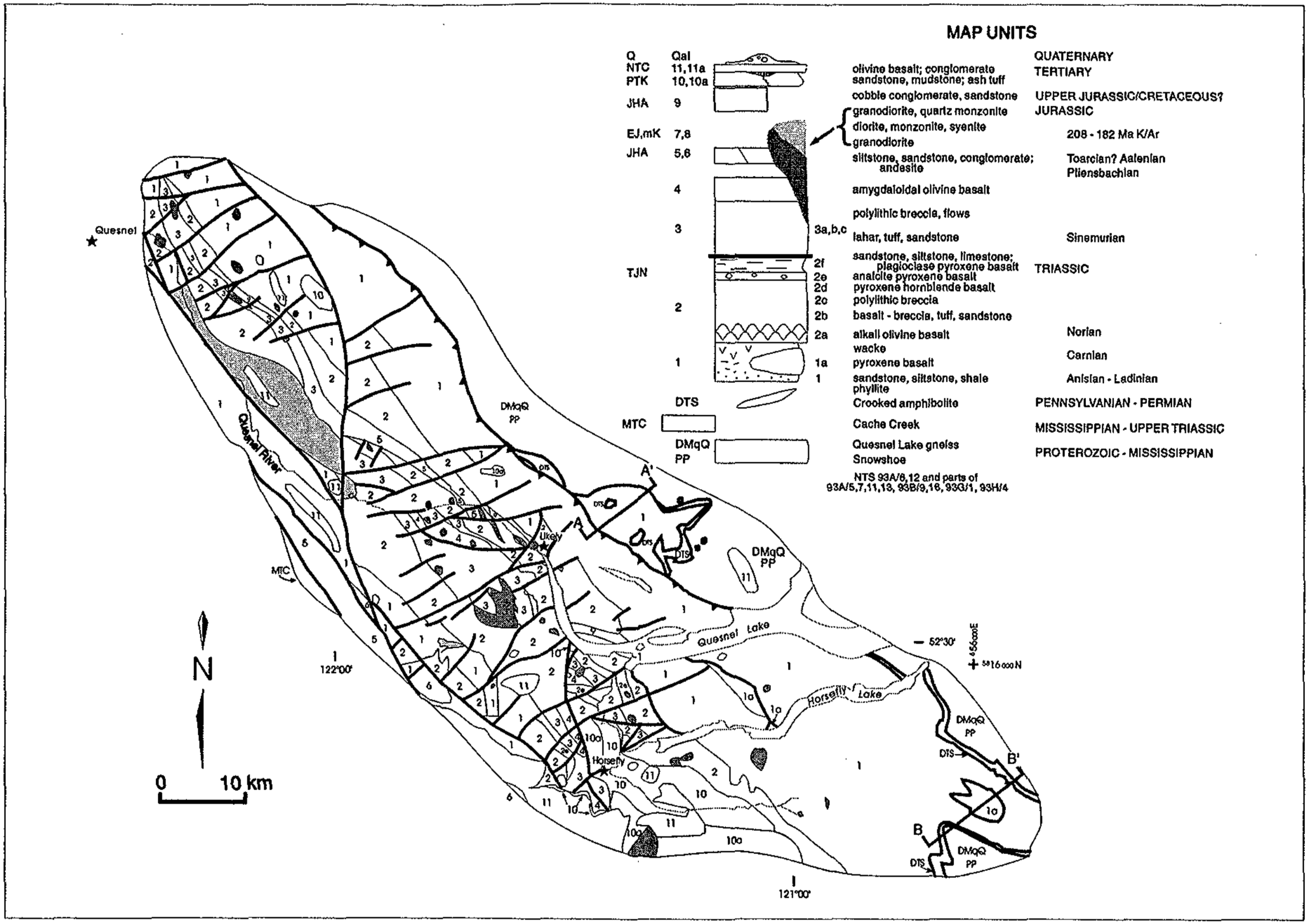



Figure 2-3. Generalized geological map of project area showing stratigraphic subdivisions and major intrusions of Quesnel Terrane and adjoining tectonic assemblages.

is strongly tectonized internally and not all the units are present throughout the study area. At deeper structural levels the rocks are moderately to strongly metamorphosed and are well cleaved with penetrative phyllitic to slaty foliation. More commonly they are weakly metamorphosed and display only a spaced cleavage and widely spaced fracturing. Lithologic variations along strike are of regional extent and probably reflect changes in sedimentation during evolution of the low-energy, stagnant Quesnel basin, but may be in part structural. There was some volcanic activity during latest stages of sedimentation. Volcanic rocks and successions with dominantly volcaniclastic components are present in some younger parts of the map unit. The age of this unit, based mainly on conodonts and some macrofossils, is Middle to Late Triassic (Anisian to Carnian and Norian).

The overlying volcanic rocks outline a northwesterly trending belt of subaqueous and lesser subaerial volcanic rocks 5 to 25 kilometres wide. They were deposited along a series of coalescing volcanic-intrusive centres that define the Quesnel island arc of predominantly alkalic basalts. A grossly consistent stratigraphy is evident throughout the length of the volcanic belt in the project area. It is very similar to that in the northern Quesnel Trough some 325 to 425 kilometres to the northwest, described by Nelson and Bellefontaine (1996). In addition, the alkalic volcanic rocks are lithologically and petrologically similar to some of the distinctive Nicola volcanics of southern Quesnellia (Preto, 1977; Mortimer, 1987).

The oldest and most widespread volcanic rocks are alkalic basalts. They are dark green and grey, olivine and pyroxene-bearing flows, pillow basalt, breccia and tuff deposited in probably relatively deep marine settings. The younger volcanic rocks of this map unit are dark green to maroon, rarely vesicular flows, tuff, volcaniclastic sandstone and breccias. Younger and possibly coeval flows include amphibole-bearing and analcite-bearing pyroxene basalt. The presence of pyroxene basalt flows and breccia containing euhedral analcite phenocrysts up to 2 centimetres in diameter provides a useful marker unit. Sedimentary rocks within and mainly near the top of the basaltic succession consist of generally thin members of dark grey to green, pyroxene-rich sandstone and siltstone, calcareous sandstone and graded grey to green sandstone. Many of these rocks are calcareous and occur together with small lenses of massive grey limestone. Limestone also occurs as bioclastic matrix in a reef-derived basalt breccia. Locally, a thin, distinctive maroon sandstone marks the top of this volcanic unit.

The basal contact, where it is exposed on the shore of Quesnel Lake, is a depositional contact between the volcanics and the basinal sediments. Along the southern contact near Beaver Creek, the volcanics interfinger with the sediments. Where the contact is visible there is no suggestion of faulting or any type of tectonic disruption. The age at the top of the unit is defined by conodonts and macrofossils and ranges from Carnian to Norian.

Overlying the main basaltic unit, probably above an angular unconformity, is an upper volcanic unit of basaltic and more differentiated feldspathic rocks and a variety of grey, green and purple-maroon-red volcaniclastic rocks derived from them. Volcanic breccias predominate as thick lenses of polylithologic subaqueous, shallow water "slump" or subaerial debris-flow and possibly laharic deposits. Flows, crystal and crystal-lithic tuff, volcanic-source sandstone and conglomerate are also present. The coarse breccias grade laterally outward into conglomerate and finer grained volcaniclastic rocks. This sequence and the presence of intrusive clasts can be used to outline eruptive volcanic centres. A number of volcanic centres are cored, or are inferred to be underlain, by high-level intrusive bodies. The presence of felsic volcanics and polylithologic breccias with felsic volcanic and intrusive clasts characterizes this map unit and provides a basis for distinguishing it from the underlying, less variable basaltic volcanics.

The age of the upper volcanic unit is Early Jurassic. The Sinemurian ammonite *Badouxia canadensis* and bivalve *Weyla* occur extensively throughout this unit. A younger, late Lower Jurassic age is inferred for the upper parts of the succession by stratigraphic relationships and from radiometric dating by Bailey and Archibald (1990) and earlier workers (see radiometric dating, Figure 4-3; Appendix F).

The last volcanic events in the arc deposited maroon analcite and olivine-bearing basalt. These rocks are exposed in a limited area that extends from the Quesnel River south towards Horsefly. The basalt was erupted subaerially and forms massive flows that pass upward into vesicular brecciated flow tops. The age of the rocks is uncertain. The distribution and outcrop pattern suggest an unconformable relationship with the underlying Sinemurian volcanic rocks and an age probably older than the nearby Pliensbachian sedimentary strata.

### *SEDIMENTARY OVERLAP UNITS (JHA)*

Sedimentary rocks were deposited in a post-volcanic basin that developed along the flanks and partially overlapped the volcanic arc. The predominantly dark grey siltstones and sandstones are similar to those of the basal black phyllite unit but contain syngenetic or diagenetic pyrite, suggesting an euxenic depositional environment. North of Likely these rocks are in fault contact with older volcanic rocks; elsewhere contacts are not exposed. A Pliensbachian age is indicated by fauna from similar rocks to the west of the map area.

Other conglomeratic rocks to the west and south of the arc volcanics are characterized by their grey and maroon colour, polylithologic character and presence of granitic clasts. This conglomerate and associated thin-bedded siltstone and sandstone beds overlap both Cache Creek and Quesnellia rocks in the northern part of the project area and farther to the south near Granite Mountain (Tipper, 1978). It is also exposed in narrow, fault-bounded blocks and wedges along the western side of the Quesnel Trough. This unit is Aalenian and possibly Bajocian in age on the basis of (limited) faunal evidence.

Another polylithologic conglomerate forms a thin belt with a sinuous map pattern along the north shore of Quesnel Lake and Quesnel River. It consists of well rounded and sorted clasts of numerous lithologies, mainly metamorphic rocks. The conglomerate has a distinctive orange-weathering carbonate matrix and displays fining-upwards sequences of conglomerate, sandstone and mudstone typical of fluvial or estuarine environments. A similar rock type farther to the south in the Beaver Creek valley, collected by R.B.Campbell, is said to contain Cretaceous (Albian) pollen (H.W. Tipper, written communication, 1993).

### *TERTIARY AND NEOGENE TO QUATERNARY COVER ROCKS (PTK, NTC, Q)*

Tertiary rocks are poorly exposed in the region and consist of a variety of intermediate to felsic flows, ash flows, crystal and lithic tuffs and epiclastic lacustrine beds. They unconformably overlie granitic rocks to the southeast of Horsefly and occur in a postulated graben to the west and north. They overlie or interfinger with sedimentary rocks that are exposed along the upper reaches of the Horsefly River. The Horsefly River beds comprise a sequence of lacustrine, varved, flaggy, pale-coloured fine-grained tuffaceous mudstones and clayey siltstones in which Eocene fossil fish have been found (Wilson, 1976, 1977a, b). Radiometric dating of the volcanic rocks and pollen from the sediments determine a Middle Eocene age for this unit.

A discrete unit of alkali plateau basalt subaerial flows covers some of the map area. The basalts appear to be deposited over parts of the plateau region both as a thin cover at a present elevation of 850 metres and as local valley-fill deposits near Horsefly River and Beaver Creek. The flows locally overlie a thin unit of palagonitic (bentonitic) tephra, breccia and conglomerate. A number of the valley-fill deposits cover fluvial and channel-gravel deposits. A Middle Miocene age is determined for most of the flow units but the presence of younger flows is documented by detailed studies and radiometric dating (Mathews, 1989).

### *INTRUSIVE SUITES (EJgG, EJyCM, EJd, EJg, mKgB, mKg)*

Two intrusive suites are represented in the study area, those associated with Early Jurassic volcanism and those related to a period of younger, probably Cretaceous magmatism. The older intrusions, with the exception of the quartz-bearing rocks of the large Takomkane batholith south of Horsefly, are generally small stocks of alkalic composition and are devoid of modal quartz. They mainly form small high-level intrusive bodies that are emplaced at approximately 9 to 13 kilometre intervals along the axis of the volcanic arc. They represent subvolcanic intrusions formed in, or near, eruptive centres. A few intrusions of various sizes and diorite to syenodiorite composition also occur in the basal sedimentary rocks in the northern part of the map area.

The alkalic rocks are subdivided according to composition and texture into three groups: a dominant pyroxene-bearing diorite, lesser monzonite and syenite with minor gabbro, pyroxenite and peridotite; syenite with megacrystic texture and large orthoclase phenocrysts; and a markedly silica-undersaturated syenite characterized by modal nepheline, sanidine and sodic amphibole. All three rock groups lack modal quartz and have normative nepheline compositions. A number of the alkalic stocks host porphyry copper-gold deposits, for example Mount Polley (Cariboo-Bell), Shiko Lake, Kwun Lake and Cantin Creek. The QR (Quesnel River) stock is associated with a significant volcanic-hosted gold deposit. Radiometric dates indicate Early Jurassic cooling ages (*see* Chapter 4).

A small number of stocks and dikes of leucocratic granodiorite, quartz monzonite and granite occur in the map area and contain some copper and molybdenum. They are thought to be equivalent to the Naver plutonic suite to the north, on the basis of their similarity in appearance and Cretaceous age.

## LITHOLOGIC - STRUCTURAL PATTERNS

The synclinal aspect of the Quesnel Trough, truly a trough in both a depositional and structural sense, is demonstrated by the basal sedimentary unit. In the east the rocks dip and face southwesterly overall, and in the west they dip and face or become younger to the northeast. The general structural model evident for the Quesnel Trough is that of a

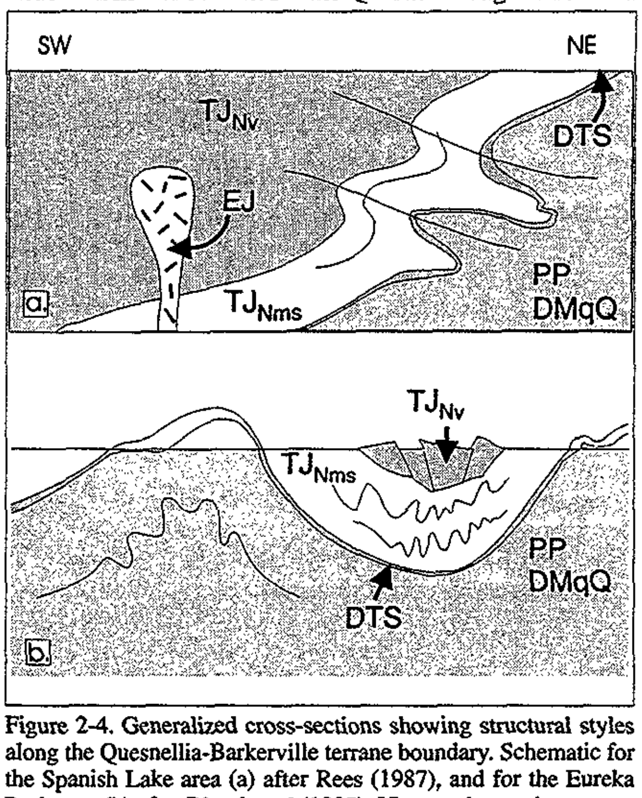



Figure 2-4. Generalized cross-sections showing structural styles along the Quesnellia-Barkerville terrane boundary. Schematic for the Spanish Lake area (a) after Rees (1987), and for the Eureka Peak area (b) after Bloodgood (1987). View to the northwest; see Figure 2-3 for locations. PP Snowshoe Group, DMqQ Quesnel Lake gneiss, DTS Crooked amphibolite, TJNv Nicola Group volcanics, THNms Nicola Group metasedimentary rocks, EJ intrusive rocks.

synclinorium with tightly folded rocks at deeper structural levels having well-developed penetrative cleavage. Upper parts display open, upright folds with less well developed cleavage. In the uppermost, volcanic portion of the belt, compression and deformation in the structurally massive volcanic units is accommodated by block faulting.

Regional map-unit contacts and structural trends are outlined by the major tectonic contact along the Barkerville-Quesnellia terrane boundary marked by the Crooked amphibolite. The structural patterns to the north, near Spanish Lake, are shown schematically by Rees (1987) and to the south, near Eureka Peak, by Bloodgood (1990; Figure 2-4). They describe large-scale, second phase, Jurassic fold structures of the Quesnel belt sedimentary units and Crooked amphibolite structurally coupled together with Snowshoe metamorphic rocks that outline the regional map patterns. In the Eureka Peak area the folds range from upright to overturned and recumbant structures and tend to be isoclinal to tight at depth and more open at higher structural levels. In the Spanish Lake area large second phase folds define recumbant, southwesterly verging structures with complicated map patterns.

# CHAPTER 3 GEOLOGY OF THE CENTRAL QUESNEL BELT

## MAP UNIT LITHOLOGIES AND STRATIGRAPHY

The Quesnel belt consists of two fundamental elements - a basal fine-grained sedimentary unit that represents a basin-fill succession (Unit 1) and an overlying volcanic arc subaqueous to lesser subaerial assemblage (Units 2, 3 and 4) (Figure 3-1). The sedimentary-volcanic arc succession has been estimated to have a thickness of 7 or 9 kilometres (Bailey, 1978 and Rees, 1987, respectively). This two-fold lithologic distinction of major map units corresponds to the (sedimentary) Rainbow Creek - Inzana Lake Formations and (volcanic) Witch Lake - Chuchi Lake Formations of Nelson *et al.* (1991) and Nelson and Bellefontaine (in preparation) in the Mount Milligan - Nation Lakes areas of the northern Quesnel Trough (NTS 93K, 93N). The same two-fold sedimentary-volcanic distinction is also evident somewhat farther to the north in the Uslika Lake area (Ferri *et al.*, 1992).

The geometric definition of the Quesnel Trough is provided by Unit 1 - the basin-fill rocks commonly referred to as the 'black phyllite unit'. In the eastern part of the map area the rocks dip toward the southwest; in the western part, they dip to the northeast. This Middle to Late Triassic succession has been subdivided into nine map units and described in detail by Bloodgood (1990). In this report eight of her subunits are included in unit 1; the ninth is considered to be equivalent to unit 1A - a volcanic and volcaniclastic unit within the upper part of the basin-fill succession. These clastic rocks are weakly metamorphosed and weakly to strongly deformed at deeper structural levels.

The main Late Triassic to Early Jurassic volcanic assemblage occupies the central, northwesterly trending elongate axis of the volcanic-sedimentary belt. It comprises

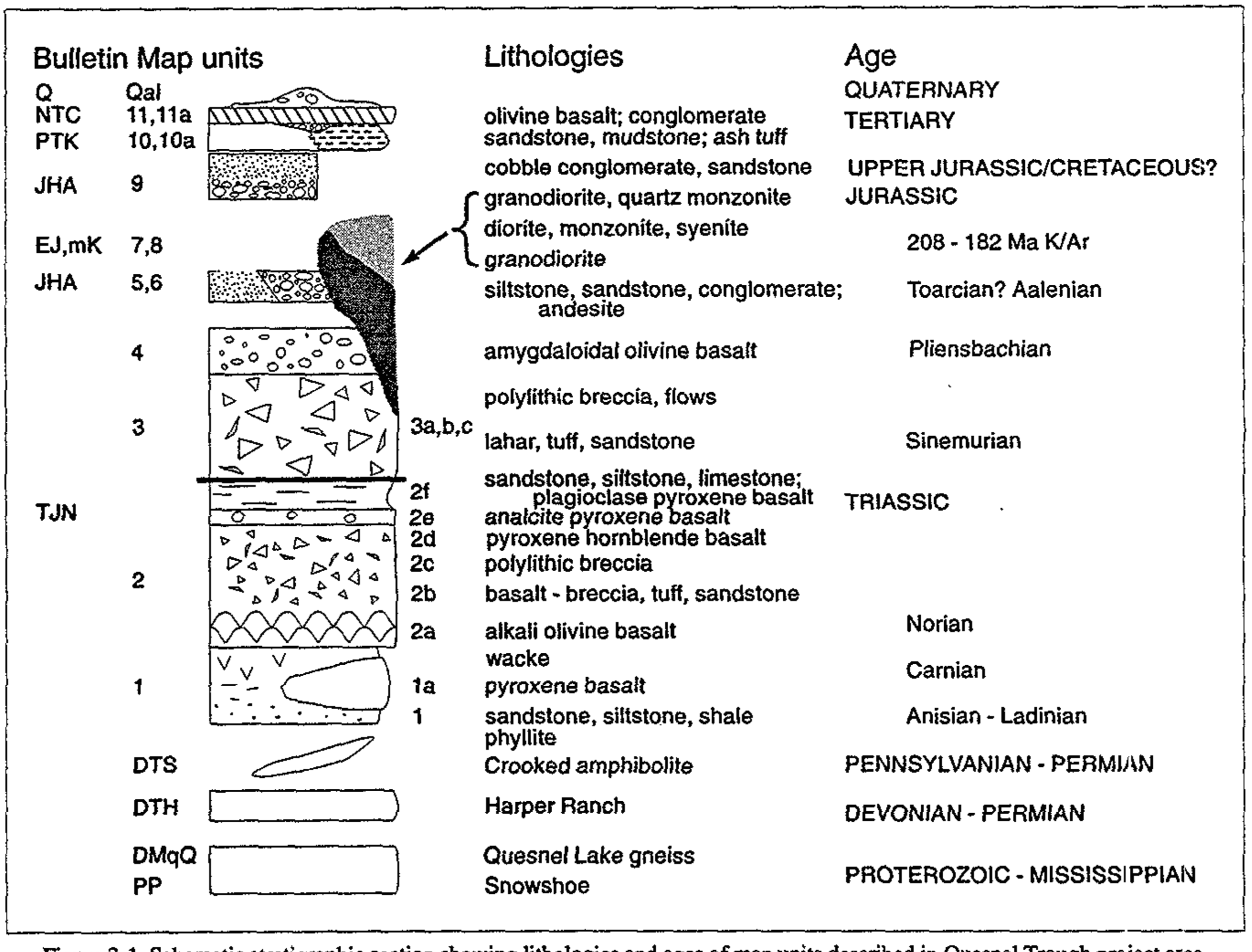



Figure 3-1. Schematic stratigraphic section showing lithologies and ages of map units described in Quesnel Trough project area.

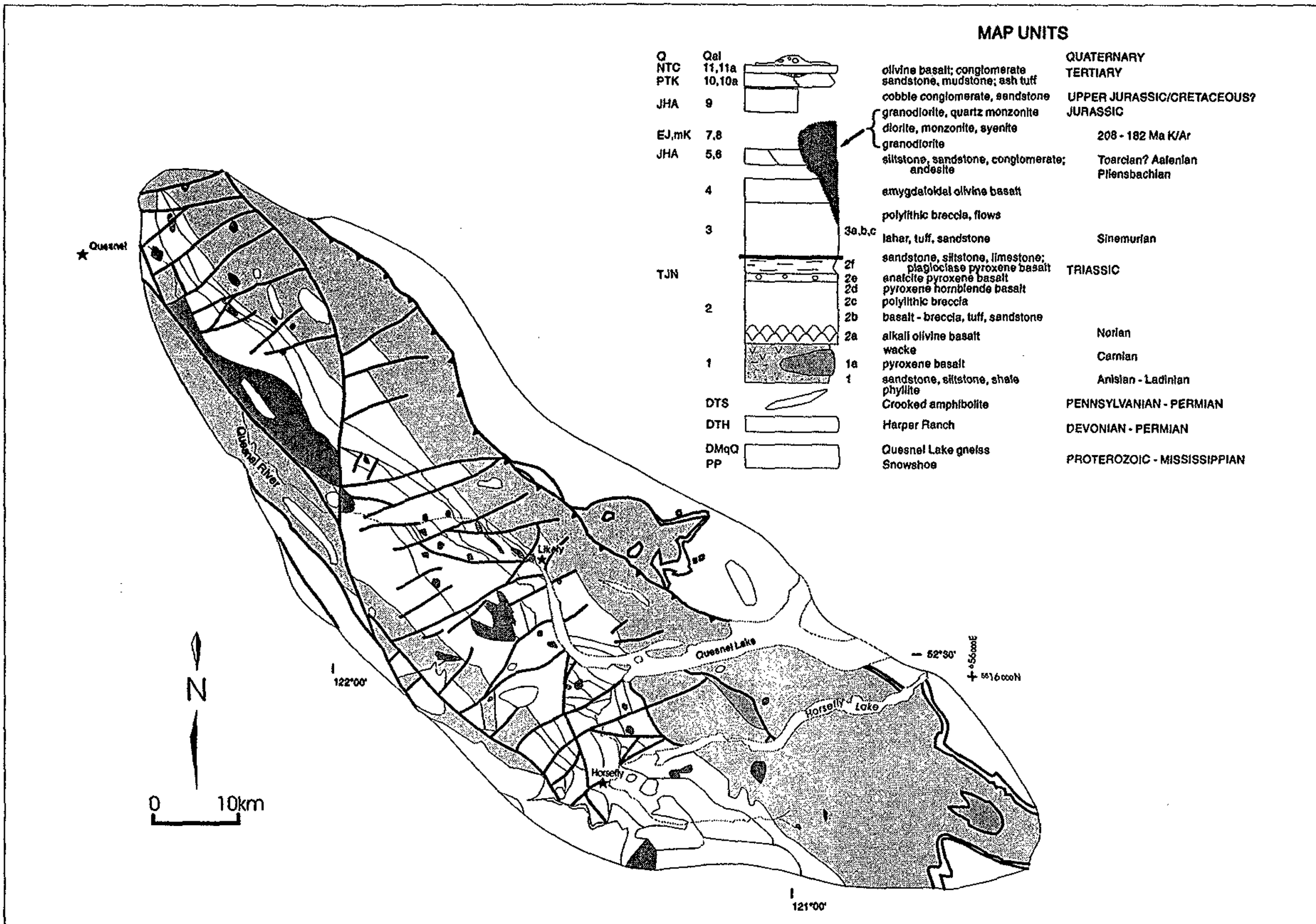



Figure 3-2. Generalized geological map of the Quesnel Trough project area showing units 1 and 1a - metasedimentary rocks.

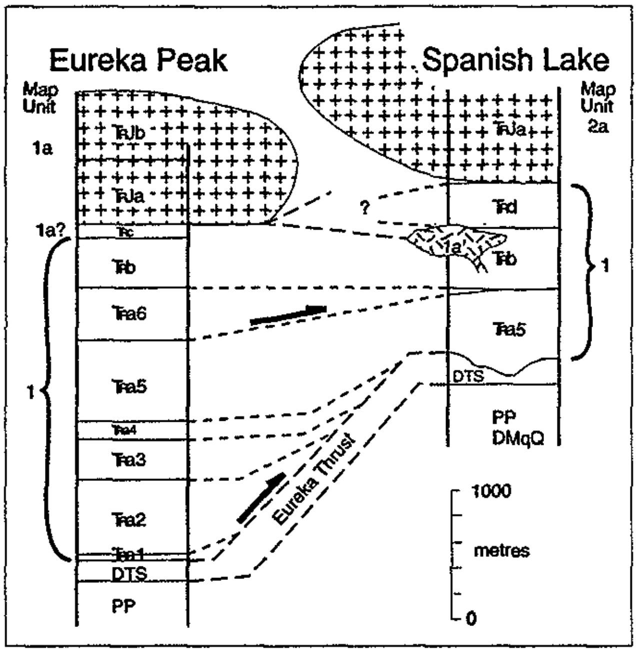



Figure 3-3. Schematic section and stratigraphic subdivisions after Bloodgood (1990) illustrate correlations between the Eureka Peak and Spanish Lake areas. Unit designations outside stratigraphic columns correspond to map units in this report.

three main map units - a main volcanic edifice of basaltic flows, breccia and flanking volcanic-source detritus (unit 2), an upper, more differentiated pyroclastic and volcaniclastic unit (unit 3), and a small flow unit of subaerial basalt (unit 4). The volcanic-sedimentary arc rocks are overlain by various successions of late Early Jurassic rocks (units 5 and 6) and younger, possibly Cretaceous, coarse clastic deposits (unit 9). Subvolcanic alkalic intrusive rocks (unit 7) that are coeval with the youngest periods of arc volcanism intrude along the medial axis of the volcanic belt. Other cogenetic intrusions appear to be emplaced at deeper levels and are exposed to the east of the volcanic belt in the sedimentary rocks of the basal clastic unit. A few quartz-bearing Early Jurassic (unit 7A) and Cretaceous (unit 8) intrusive bodies are also present in the map area. Tertiary volcanic and sedimentary rocks (units 10 and 11) cover much of the map area. Quaternary cover is extensive, mainly as lodgement till, ablation moraine and fluvioglacial deposits (unit Qal).

The map units of the Triassic - Jurassic Quesnel Trough and the overlying younger rocks are discussed in some detail below. Lithologic descriptions are, in large part, summaries of the extensive petrologic descriptions, chemical analyses and modal and normative determinations of Morton (1976) and Bailey (1978). Generalized distributions of the 11 bedrock units are illustrated on Figures 3-2 to 3-8 and 3-10, and shown in detail on the accompanying 1:100 000 map (Map 1, in pocket). The older rocks of the neighbouring Crooked amphibolite and adjacent terranes were not studied in the course of this project and are not discussed in any further detail. The extensive studies by other authors of these and the metamorphic rocks of the adjacent Barkerville terrane are listed in Chapter 1 in the section dealing with previous work.

## SEDIMENTARY BASIN FILL, BACK-ARC OR MARGINAL BASIN DEPOSITS - UNITS 1 AND 1a

We consider all Mesozoic sedimentary units that overlie the Crooked amphibolite and that underlie or interfinger with the Quesnel arc volcanics to be part of unit 1. Spatially restricted volcanic deposits and proximal volcaniclastic components derived from them occur near the top, but within unit 1 are shown as unit 1a. The nine subdivisions of our unit 1 are shown by Bloodgood (1990) as units Tra1 to Tra6, Trb, Trc and Trd. Our volcanic and volcaniclastic unit 1a includes Bloodgood's units TrJa, TrJb, probably Trc and possibly even some or all the volcanic members in the Eureka Peak area of her unit Trb. Her (volcanic) units TrJa and TrJb in the Spanish Peak area are included in our unit 2a but the volcanic portion of her unit Trb may be equivalent to our unit 1a.

### *METASEDIMENTARY ROCKS (PHYLLITES) - UNIT 1*

The stratigraphic succession and map units described by Bloodgood (1990, pages 6-11) are described below. The sedimentary units collectively constitute unit 1 of this report; her volcanic members are part of our map units 1a or 2a, as discussed above (Figures 3-1, 3-2 and 3-3).

#### UNIT Tra1 - MICACEOUS QUARTZITE

This is the basal unit of the metasedimentary assemblage that overlies Crooked amphibolite. The micaceous quartzite implies that the rocks are continent-margin deposits rather than deep ocean basin fill or fore-arc deposits.

The unit crops out along the limbs of the Eureka Peak syncline. It varies in thickness from 10 to 150 metres, either as a result of sedimentary deposition or structural thickening due to imbrication and/or folding. Bedding is well defined by pale grey, laminated quartzite beds 0.5 to 6 centimetres thick. A bedding-parallel schistosity is defined by planar alignment of rusty weathering muscovite. The contact of the micaceous quartzite with the underlying Crooked amphibolite is sharp, although both concordant and discordant relationships have been documented. The contact is imbricated near Crooked Lake. No correlative unit has been recognized in the Spanish Lake area.

#### UNIT Tra2 - MICACEOUS BLACK PHYLLITE AND TUFF

Siliceous dark grey to black, graphitic phyllite has a well developed phyllitic foliation with characteristic silvery fresh surfaces. Bedding is rarely seen. Where present it is defined by thin, rusty to dark grey quartzite or siltstone beds up to 20 centimetres in thickness and discontinuous tuffaceous lenses. Small porphyroblasts of chalky weathering

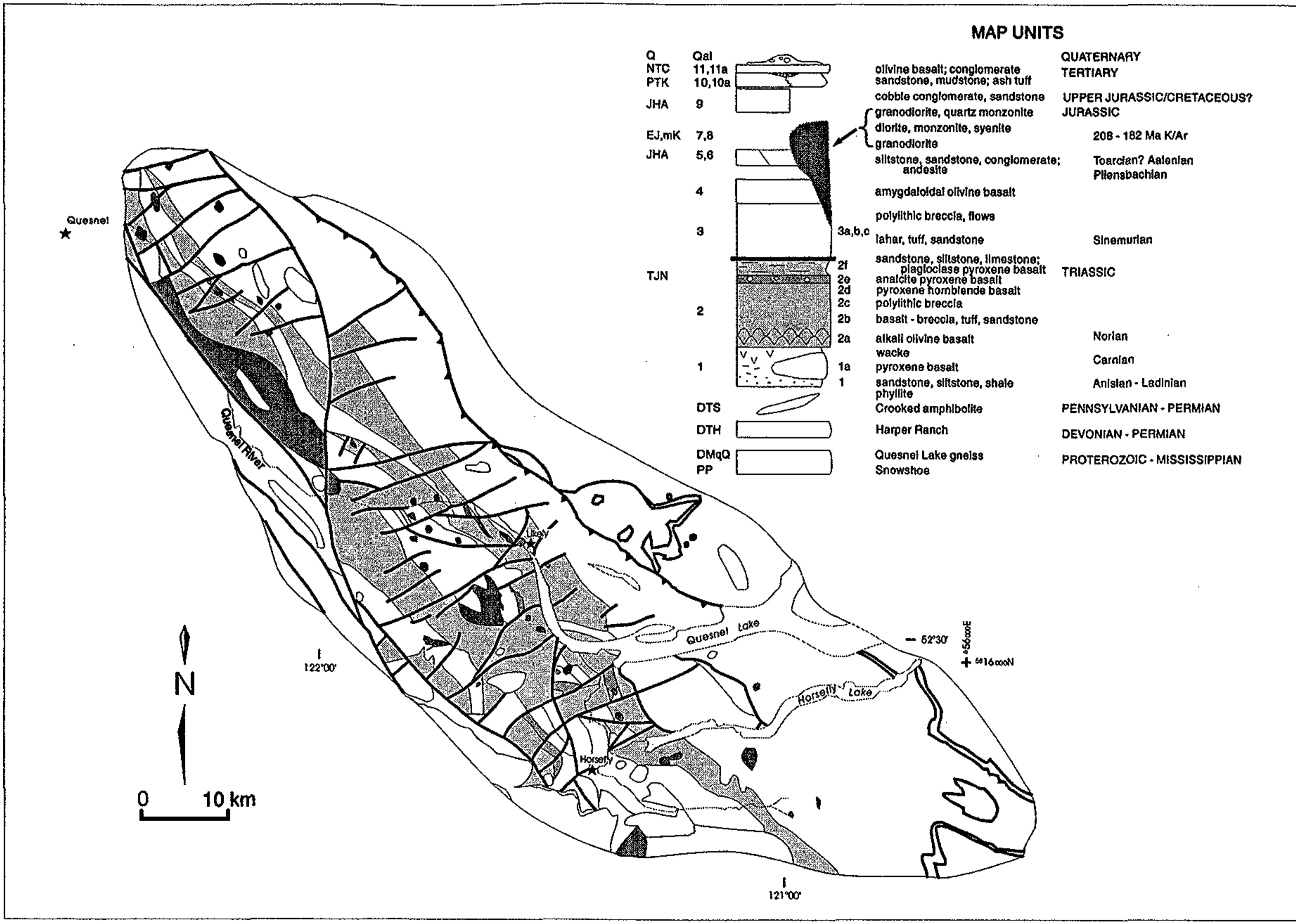



Figure 3-4. Generalized geological map showing unit 2 - basalts.

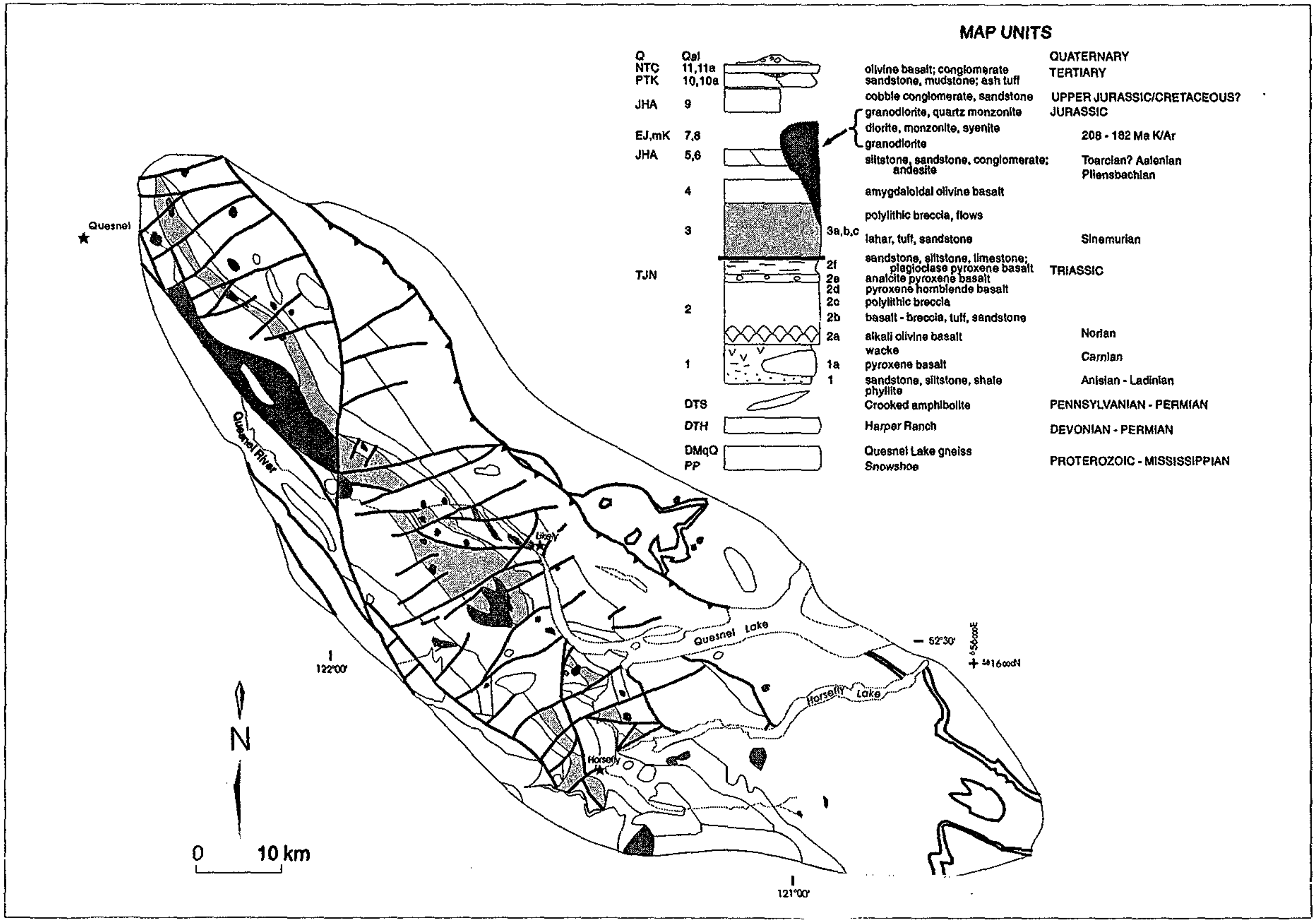



Figure 3-5. Generalized geological map showing unit 3 - 'felsic breccia'.

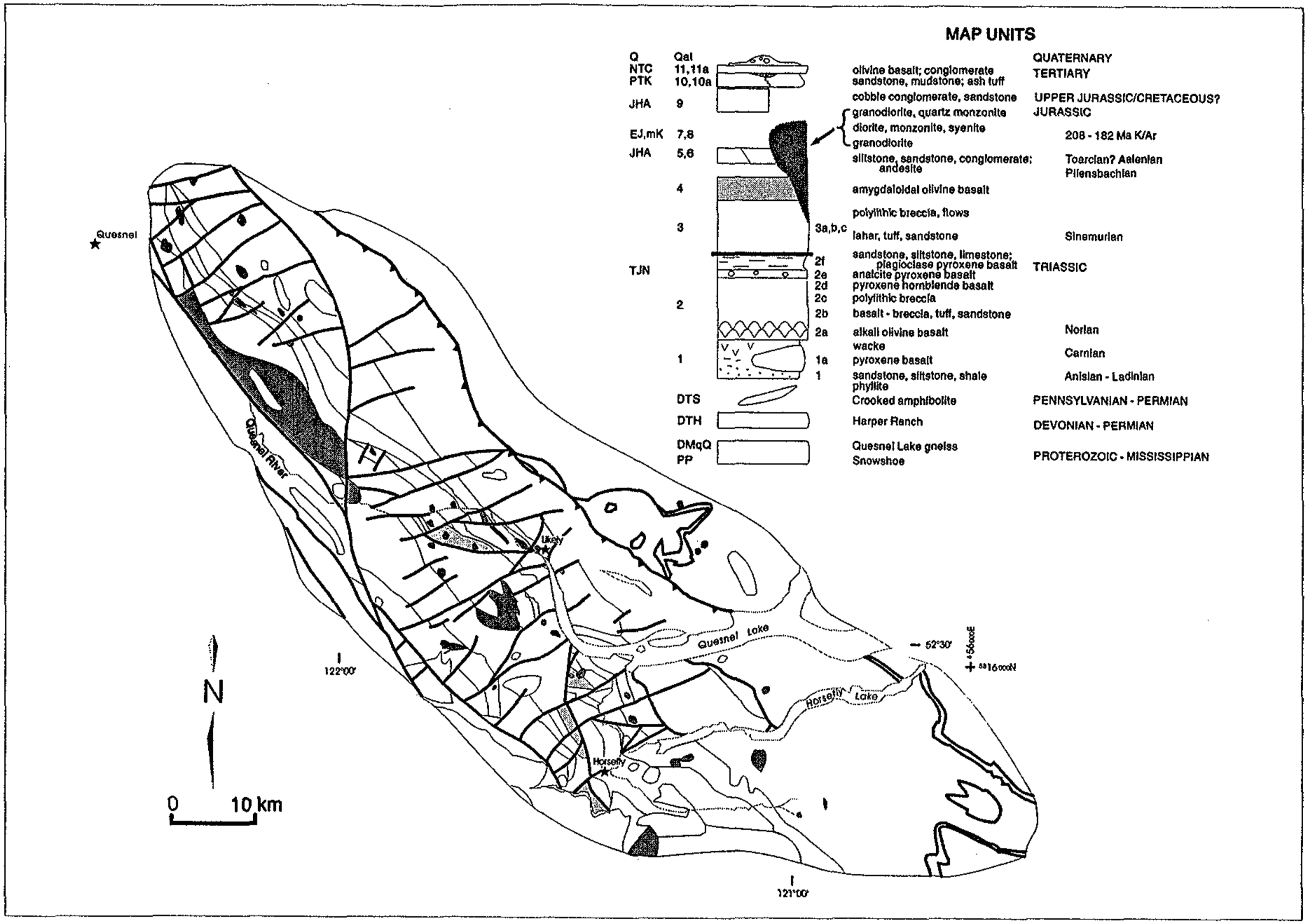



Figure 3-6. Generalized geological map showing unit 4 - subaerial basalt.

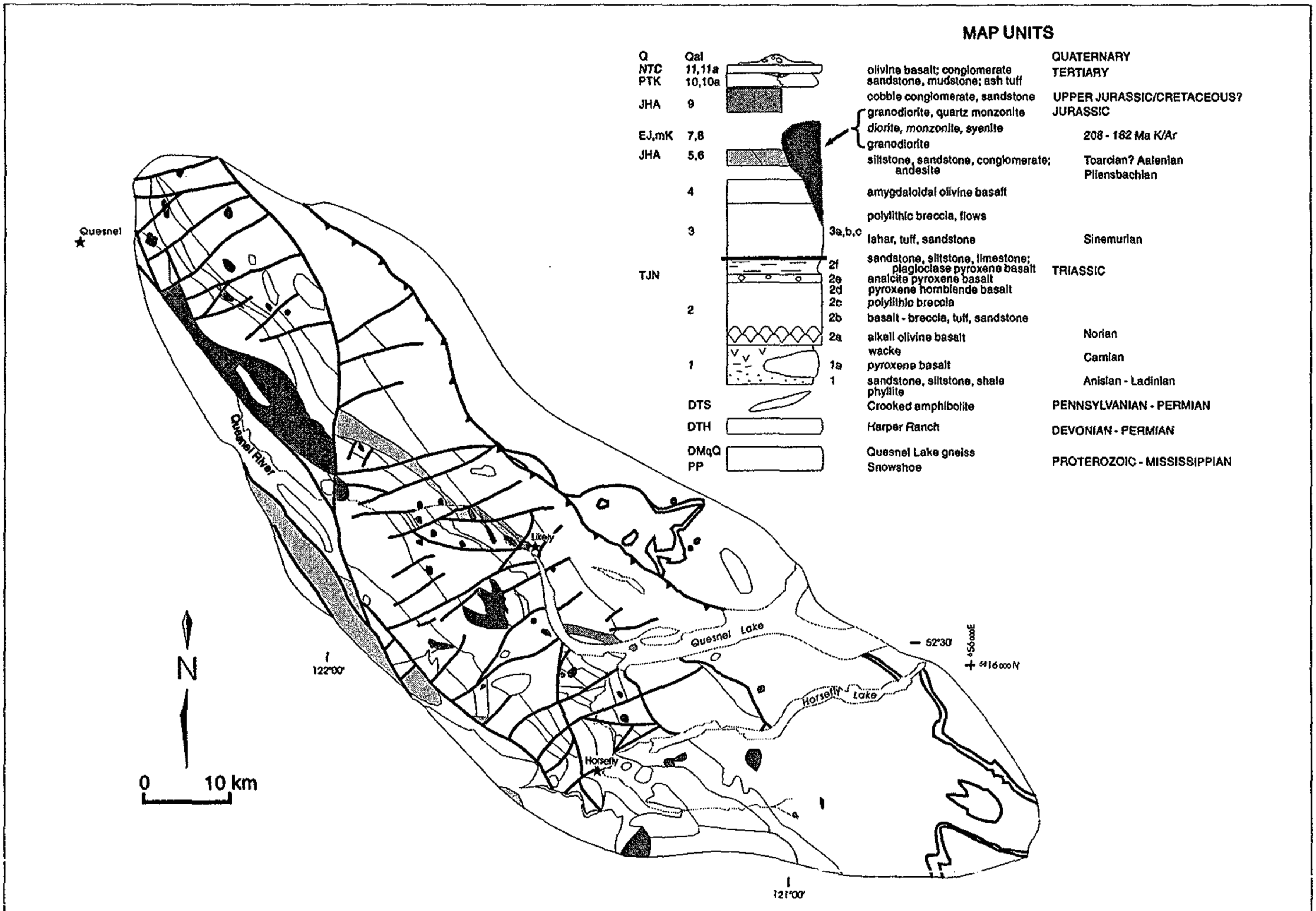



Figure 3-7. Generalized geological map showing units 5, 6 and 9 - overlap units.

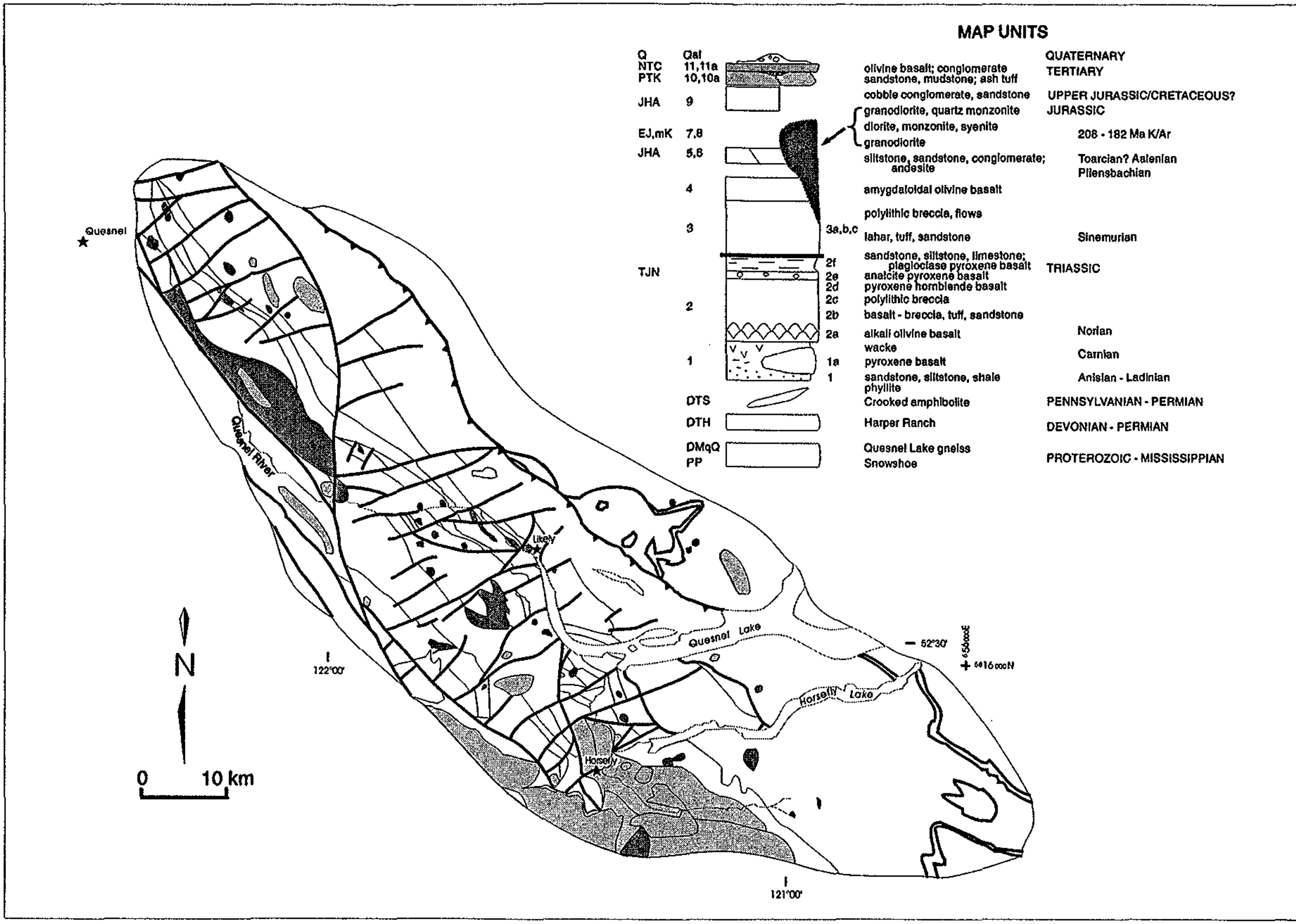



Figure 3.8. Generalized geological map showing units 10 and 11 - Tertiary rocks.

plagioclase occur throughout the unit. On the south limb of the Eureka Peak syncline porphyroblasts of garnet up to 0.5 centimetre in size are abundant within 10 metres of the base of the unit. The contact with the underlying micaceous quarzite is not exposed but may be faulted, judging from the noticeable break in slope and the discordant contact relationship observed on the north limb of the Eureka Peak syncline. No lithological equivalent to this unit in the Eureka Peak area has been recognized in the Spanish Lake area.

### UNIT Tra3 - PHYLLITIC SILTSTONE

This unit contains interbedded pale to dark grey silty slates and lesser phyllitic siltstone and minor siliceous limestone. Bedding is well defined by fine banding, thin beds of laminated quartz sandstone and minor interbeds of siliceous limestone. Well-developed cleavage is defined by a planar, slaty parting. Narrow bedding-parallel quartz veinlets occur throughout. This unit has not been recognized outside the Eureka Peak area.

### UNIT Tra4 - LAMINATED PHYLLITE AND PORPHYROBLASTIC PHYLLITE

Finely laminated grey phyllite is intergradational with the underlying and overlying units. Bedding is outlined by pale grey to rusty weathering quartz sandstone beds commonly 1 to 3 millimetres but up to 1 centimetre in thickness. A well-developed phyllitic foliation is accentuated by graphitic material. Porphyroblasts of garnet, plagioclase and chloritoid occur in these rocks on the south limb of the Eureka Peak syncline; chloritoid is associated with ankerite on the north limb. Bedding-parallel quartz lenses, up to 2 metres in thickness and several metres in length, are present. They are most evident along the north limb of the Eureka Peak syncline, most notably in the Frasergold property area. No stratigraphically equivalent units have been recognized in the Spanish Lake area.

### UNIT Tra5 - SILTY SLATES

The porphyroblastic phyllite unit (Tra4) grades upward into coarser grained, dark grey to black-weathering silty slates with interbedded dark grey quartzose sandstone. Bedding is shown by dark grey, dull quartz sandstone beds, most commonly 10 to 12 centimetres in thickness. Thinner, pale layers of laminated quartz sandstone are interbedded throughout the unit. Pale weathering quartzite and pale grey to green-weathering tuffs form discontinuous lenses. Silty slates have well developed planar slaty parting. In outcrop they are rusty weathering to locally speckled with limonite, probably due to the presence of fine-grained siderite or authigenic iron sulphide minerals. These rocks are the basal map unit and the dominant rock type in the Spanish Lake area.

### UNIT Tra6 - GRAPHITIC BLACK PHYLLITES

This unit forms a sequence of grey, graphitic phyllites that grade upward through black phyllite, grey silty phyllites and an upper succession of graphitic phyllite. There are minor interbedded quartz sandstone and limestone beds. Bedding is defined invariably by prominent pale, laminated quartz siltstone beds that rarely exceed 2 centimetres in thickness. The rocks are exposed south of Horsefly Lake, on the south limb of the Eureka Peak syncline and in small synclinal cores north of Spanish Lake.

### UNIT Trb - BANDED SLATES AND TUFFS

Unit Trb, the uppermost phyllitic unit in the metasedimentary succession, contains a significant volcanic component. Where volcanic rocks, or their eroded products, are the dominant lithology, the successions are included in unit 1a in this study. Unit Trb crops out continuously along both the northern and southern limbs of the Eureka Peak syncline, and underlies much of the western part of the basal sedimentary belt along Horsefly River, between Horsefly and Quesnel lakes and northwest of Quesnel Lake. The contact with the underlying rocks, at least locally in the area north of Quesnel Lake, is interpreted to be a fault.

In the Eureka Peak - Horsefly River area, and probably generally throughout the belt, there is a progressive increase in volcanic components at higher stratigraphic levels in this unit. Dark green to black phyllite with interbedded grey to green tuffs comprise the lowermost 50 metres of the succession. Siliceous, banded aquagene tuffs become more abundant stratigraphically upwards and are interbedded with grey to black banded slates, massive pale quartz sandstone and minor limestone. The uppermost part of the unit consists of fissile graphitic phyllites interbedded with tuffs, and locally with dark brown to black argillaceous limestone and minor quartzose sandstone beds. The phyllites within this section are recessive, black and sooty in outcrop. Locally they are strongly silicified, but throughout the region they are typically rusty weathering and pyritiferous.

North of Quesnel Lake, in the Spanish Lake area, black slaty to phyllitic, rusty weathering metsediments are interbedded with gritty, dark brown to black-weathering grey limestone. Conodonts from the limestone are Middle Triassic in age (Anisian to Ladinian); east of Spanish Mountain the rocks have yielded conodonts of Anisian and probable Anisian age (GSC Locations C-117649 and C-117645, M.J. Orchard, analyst). Struik (1986, 1988a) has suggested that imbrication has taken place within this map unit, on the basis of these conodont ages.

The volcanic component includes discontinuous lenses of banded tuff, volcanic conglomerate, flow breccia, pillow lava and a few dikes. The banded tuffs in the Spanish Lake area are lithologically identical to the banded aquagene tuffs in the Eureka Peak area but the Spanish Lake succession also includes volcanic conglomerate, breccia and flows as discontinous lenses up to several kilometres in strike length. The volcanic rocks appear to be identical to the pyroxene-bearing flows of the overlying, volcanic unit in the Eureka Peak area and in the main Quesnel volcanic belt to the south and west. The volcanic rocks in unit Trc are now known to be chemically distinct from the main volcanic arc rocks (see

Chapter 5 - Petrochemistry). They are now considered to be a discrete subunit within the sedimentary succession, referred to in this study as unit 1a.

## UNIT Trc - VOLCANICLASTIC BRECCIA

This breccia unit crops out to the west of Eureka Peak where it overlies the tuff-phyllite sequence of unit Trb. It consists of dark grey, angular clasts in a paler grey matrix. Chloritization is extensive and readily evident in a cleavage defined by well developed chloritic parting. Both the lower and upper contacts with unit Trb and the overlying volcanics are faults. We consider this unit to be an intraformational breccia, as first suggested by Campbell (1971), and part of unit 1a.

## UNIT Trd - VOLCANIC SANDSTONE AND WACKE

North of Quesnel Lake unit Trb is overlain by this unit of coarse-grained, dark green volcanic sandstones and wackes with interbedded siltstone, sandstone and minor argillite. The argillaceous sediments are interbedded in beds 3 millimetres to 2 centimetres thick with dominant green sandstone and wacke and give rise to a compositionally defined, colour-banded sequence, parallel to bedding. A rough fracture cleavage parallel to the bedding is locally developed but no penetrative cleavage is recognized.

## UNITS TrJa AND TrJb - MASSIVE FLOWS, AGGLOMERATE, TUFFS, PILLOW BASALTS AND MAFIC DIKES; MASSIVE PORPHYRYTIC FLOWS, BRECCIA AND TUFF

A succession of mafic volcanic rocks 300 metres thick, referred to as 'Nicola Group metavolcanics' by Bloodgood (1990), forms a klippe that occupies the core of the Eureka Peak syncline. She correlated these rocks with the pyroxene-bearing volcanics of unit 2, but we now regard them as part of unit 1a, largely on the basis of their petrology and chemical compositions, as described in Chapter 5.

Lithologies described by Bloodgood (1990) in the Eureka Peak area include crystal-lithic tuff, basalt pillow lava, flows, flow breccia and volcanic breccia and minor limestone. The tuffs form the basal member of the volcanic sequence 5 to 20 metres thick, but locally they attain a thickness of up to 50 metres. The tuff forms massive, homogeneous, rarely banded, pale grey to green-buff-weathering outcrops. Volcanic lithic clasts and mafic epidote-chlorite-altered crystals up to 3 millimetres in size are contained in a fine-grained matrix. Pyrite cubes up to 1 centimetre across have been observed and millimetre-sized cubes are common in narrow pyritic beds. A unit of pillow basalt up to 10 metres thick overlies the tuff. The pillow lavas are pale grey to green weathering but dark on fresh surfaces. Pillow structures are flattened with dimensions of 60 by 30 by 60 centimetres. A thick sequence of porphyritic basalt flows, flow breccias and volcanic breccias forms the main part of the volcanic unit. Individual flow units are 15 to 30 metres thick and are characterized by a brecciated rubbly base, homogeneous, massive centre and coarser porphyryitic top. Outcrops are pale green to grey but commonly are rusty weathering and crumbly or yellowish green in areas of extensive epidote alteration. The coarser porphyritic flows contain black and green mafic phenocrysts, commonly 2 to 5 millimetres in size but up to 2 centimetres in length.. The pyroxene crystals are stubby, subhedral and extensively altered to chlorite. Amphibole crystals are euhedral, acicular to prismatic in form, and little altered.

## VOLCANIC AND EPICLASTIC ROCKS - UNIT 1a

Hornblende pyroxene basalt flows, breccia, related volcaniclastic deposits and conglomerate comprise this subunit. Pyroxene-bearing hornblende porphyry members also form small intrusive bodies and intrusive breccias within it.

Unit 1a has been defined (this study) as a discrete volcanic subunit within the predominantly sedimentary unit 1. It is found at Horn Bluff on Horsefly Lake and in the thin belt of volcanic rocks between Horsefly Lake and Quesnel Lake, centred around Viewland Mountain. There unit 1a on the east side of the volcanic belt is in contact with sedimentary rocks of unit 1 along a steeply eastward-dipping reverse fault. Unit 1a includes rocks of Bloodgood's units Trc, TrJa and TrJb from the volcanic klippe in the Eureka Peak area, discussed above, and possibly her unit Trd in the Spanish Lake area. The volcanic rocks of unit 1a are not considered to be part of the overlying unit 2 because these volcanic rocks form a succession near the top, but entirely within, sedimentary unit 1. Mapping in the Viewland Peak area reveals that the apron of volcaniclastic rocks and conglomerate that surrounds the pyroxene amphibole basalt interfingers with the sedimentary rocks of unit 1. In addition, petrochemical differences are evident between the volcanic rocks of units 1a and 2. The chemical distinctions offer the most persuasive evidence for subdividing these volcanic units, as discussed in Chapter 5. Northwest of Likely to the Cottonwood River, unit 1 has not been subdivided, although Bailey (1978, 1990) noted that volcaniclastic sandstone, conglomerate and basaltic breccia are locally dominant lithologies near the top of the sedimentary succession.

Petrologic descriptions by Bloodgood (1987a) of volcanic rocks in the Eureka Peak area offer more detail about primary and metamorphic mineralogy. She describes the volcanic rocks to consist of primary phenocrysts clinopyroxene, hornblende and plagioclase with a groundmass of similar composition and tremolite/actinolite, clinozoisite, epidote, sericite, chlorite, biotite, carbonate and quartz, some of which is a metamorphic or alteration assemblage. The clinopyroxene, with or without hornblende, is the dominant phenocryst type in the basal part of the volcanic assemblage; amphibole is more abundant in the higher stratigraphic units. The mafic minerals comprise from 20 to 50% of the rocks. Plagioclase, both as phenocrysts and groundmass, accounts for up to 35% of the rock but varies in abundance proportionally with hornblende. Clinopyroxene phenocrysts are dominantly euhedral to subhedral and vary in size from 0.01 to 3 millimetres. Hornblende occurs as euhedral to subhedral, twinned, tabular crystals from less than 1 millimetre to 1 centimetre in size. Plagioclase is variably saussuritized, but where compositions can be determined, it is andesine, approximately $An_{44-46}$. Twinning is generally preserved with common albite and less common Carsbad twinning. Mafic grains are commonly rimmed by actinolite and biotite or completely replaced by chlorite and calcite. Accessory minerals include apatite, sphene and opaque minerals. The flow textures are hypidiomorphic granular to glomeroporphyritic and variably vesicular.

Pyroxene-bearing hornblende porphyry dikes and subvolcanic syenodiorite breccia cap the peak of Viewland Mountain. The porphyries, together with a number of small plugs, indicate the region was the site of subvolcanic intrusive activity in the Quesnel sedimentary basin during periods of early volcanism.

## VOLCANIC SUCCESSIONS OF THE QUESNEL ARC

The volcanic deposits of the Quesnel belt island arc succession are subdivided into three major map units (units 2, 3 and 4). The two most voluminous volcanic assemblages, units 2 and 3, are further broken down into subunits. Although the volcanic rocks generally form lithologically similar prisms, wedges or lens-like deposits, a stratigraphic succession can be resolved mainly from the superposition of units, some paleontological data (discussed in the following chapter) and radiometric dating of crosscutting intrusions. The present subdivisions are similar to those defined by Bailey (1978). They extensively revise and largely invalidate the stratigraphy used by Morton (1976). In general, the volcanic succession consists of subaqueous pyroxene-phyric basalt flows and breccias (unit 2), an overlying sequence of pyroclastic and debris-flow (laharic ?) deposits (unit 3) and an upper unit of subaerial analcite-bearing olivine basalt flows (unit 4). Shallow-water sedimentary rocks (parts of units 2 and 3) overlap and flank the volcanic accumulations.

### *BASALTS - UNIT 2*

This major map unit (Figure 3-4) is made up of a succession of alkali olivine basalt, alkali basalt, hornblende-bearing basalt and analcite-bearing units in the upper part of the assemblage. The volcanic rocks are typically dark-coloured, clinopyroxene-phyric basalts in which the flows near the base of the succession contain olivine and those near the top have analcite. The map units can be followed throughout the length of the central Quesnel belt. Major variations in appearance are due to differences in depositional environments, rock textures and fabric in the subaqueous, mainly flow and breccia deposits. Bailey (1978) estimates a thickness of 3100 metres for the volcanic succession. The units established are:

- 2a - Green and grey pyroxene-phyric alkali olvine and alkali basalt flows, breccia, minor pillow basalt
- 2b - Grey and maroon pyroxene-phyric alkali basalt flows and breccia, minor basaltic tuff and maroon sandstone
- 2c - Polylithic grey and maroon mafic breccia
- 2d - Greenish grey and maroon hornblende-bearing pyroxene basalt
- 2e - Greenish grey and maroon analcite-bearing pyroxene basalt flows, breccia and minor tuffs
- 2f - Dark grey to brown mafic siltstone, sandstone, calcareous sandstone; grey limestone and limestone breccia; grey to greenish grey sandstone

Each map unit has one or more dominant rock types; photomicrographs of the typical rocks are shown on Photos 3-3, and 3-4. The appearance of outcrops and rock fabric is shown on Photo 3-4. Phenocrysts of diopsidic augite composition are characteristic of all the basalts and the pyroxene displays very little compositional variation between the units (Appendix A). The rock types as described mainly by Morton (1976) and Bailey (1978) are as follows:

#### ALKALI OLIVINE PYROXENE BASALT (UNIT 2a)

This basalt overlies or interfingers with sedimentary rocks of unit 1 and forms sequences of massive to brecciated flows and lesser pillow basalt. The flow rocks are massive aphanitic to porphyritic, commonly with brecciated, amygdaloidal tops. They are interbedded with basaltic clastic rocks, mudstone, calcareous mudstone and limestone lenses and breccia.

Phenocrysts and other grains discernible by eye make up from 30 to 75% of the rock and comprise clinopyroxene (diopsidic augite), olivine, plagioclase and magnetite. Average phenocryst content of typical rocks is 30% clinopyroxene, 1 to 8% olivine, 20% plagioclase and 1 to 4% magnetite. The amounts and grain size of plagioclase phenocrysts vary widely between 5 and 40%; most of the plagioclase is contained in the matrix as microlites. The matrix contains small grains of plagioclase and clinopyroxene, devitrified glass and lesser olivine, magnetite and accessory apatite, calcite and alteration minerals.

The clinopyroxene is green diopsidic augite. It is generally euhedral, between 2 and 10 millimetres and up to 1 centimetre long, but with considerable variation in size. Pyroxene grains commonly display simple twinning and optical zoning but little compositional variation. Analyses of pyroxene (Bailey, 1978; Appendix A) indicate an average composition of $Ca_{0.9}(Mg,FeO)_{0.9}(Al,Si)_2O_6$. The pyroxenes have constant calcium content, relatively high alumina between 4 and 5% and an average magnesium to iron ratio in molecular percent Mg:Fe of 3.3:1. Olivine grains average 0.5 millimetre in diameter but some grains and aggregates are 2 to 7 millimetres in size and occasionally reach 2 centimetres. The olivine crystals, now waxy green pseudomorphs, are recognized by their relict, euhedral shape. They are now virtually all compeletely replaced by chlorite, serpentine, carbonate, magnetite, iddingsite and other alteration minerals. Plagioclase phenocrysts occur as euhedral laths that are commonly aligned. The plagioclase is extensively saussuritized but where compositions could be determined optically, the plagioclase is labradorite (An50-58) according to Bailey (1978) and An70-75 in cores and An58-65 in rims according to Morton (1976). Magnetite is abundant in all the basaltic rocks where it occurs both as an alteration product of olivine and pyroxene and also as discrete, euhedral grains. Grains of magnetite are reported to contain up to 5.5% $TiO_2$ (Bailey, 1978). Nepheline and orthoclase characterize the normative mineralogy of these rocks but only Morton (1976) reports small amounts of modal nepheline in volcanic rocks from the Horsefly area.

## ALKALI (PYROXENE) BASALT (UNIT 2b AND CLASTS WITHIN UNIT 2c; UNIT 2c)

Pyroxene basalts, the most extensive type of basalt in the area, are similar in chemical composition to alkali olivine basalt, but differ by the absence of olivine and the presence of more abundant modal plagioclase. These rocks overlie and interfinger with alkali olivine basalt of unit 2a. The rocks form flows, flow breccias and minor tuffs.

Phenocrysts are mainly pyroxene and plagioclase; the absence of olivine is characteristic of this rock type. Clinopyroxene grains up to 6 millimetres in length comprise from 10 to 35% of the rock; plagioclase ($An_{42-65}$) as tabular to lath-shaped, 1 to 4-millimetre crystals forms up to 25%. In some units the plagioclase occurs as seriate, felted trachytoid microlites that are interstitial to the larger pyroxene grains. The matrix is grey, green and reddish brown and consists of intergranular to subophitic plagioclase and pyroxene with accessory magnetite, apatite and patchy alteration assemblages of hematite, limonite, epidote and chlorite. Morton (1976) describes spherulitic textures in amygdaloidal flows that he interprets indicate the presence of devitrified glass. Morton also reports the presence of minor olivine and analcite in the matrix, an observation that was not substantiated by this study.

Alkalic basalts from mainly unit 2b are the main lithologic and compositional clast type in the overlying breccias of unit 2c. Less common members within unit 2c are mafic lapilli tuff, lithic basaltic tuff, pyroxene crystal wacke and tuffaceous wacke. These rocks are part of a maroon to grey polylithologic breccia unit that is distinguished from overlying breccias of unit 3 by the sparseness or absence of felsic clasts.

## HORNBLENDE PYROXENE BASALT (UNITS 2a/2d AND 2d)

Green and grey basalts near the base of unit 2, possibly stratigraphically correlative with units 2a and 2b, contain green hornblende phenocrysts in addition to the usual diopsidic augite. The rocks form flow and breccia units along the eastern side of the volcanic belt near the Quesnel River. In these rocks 5 to 10% hornblende forms euhedral grains up to 3 millimetres in length. Plagioclase occurs as grains of roughly similar size and abundance. Plagioclase compositions range from $An_{54}$ in crystal cores to $An_{42}$ near the grain edges. Locally the unit is predominantly pyroxene grain wacke.

## ANALCITE-BEARING PYROXENE BASALT (UNIT 2e)

Flow and breccia units of dark green and maroon analcite-bearing pyroxene basalt crop out in central parts of the volcanic belt. The green basalts have a characteristic coarsely crystalline porphyritic fabric that is emphasized by the presence of large white to buff analcite crystals. The rock has been described as "bird-dropping rock" because of the white splotchy appearance. The phenocrysts make up about 65% of the rock; on average 25% is analcite and the rest is equal amounts of plagioclase and clinopyroxene. In some thicker flows, analcite occurs only in the upper part; the base is pyroxene basalt. The analcites are commonly about 1 centimetre across but some exceptional rocks contain crystals up to 3 centimetres in diameter. Some of the larger analcite grains are petal-shaped, composite aggregates of lobate, rounded crystals. Also present are laths of plagioclase up to 11 millimetres in length and grains of pyroxene 2 to 3 millimetres in size when equigranular and 5 millimetres long when present as laths. Feldspar phenocrysts are generally strongly altered (saussuritized). In the rare samples in which compositions can be determined optically, feldspars appear to range in composition from bytownite to labradorite An77-64 in the early formed, strongly zoned largest crystals. In the more abundant and ubiquitous smaller laths, feldspars are labradorite/andesine An54-47. Microlites in which compositions could be determined from a few samples from northeast of Horsefly, range from An30 to An23 and from Beaver Creek area An55 (Coates, 1960). Pyroxene compositions determined optically by Coates are classed as augite in the idiomorphic phenocrysts. In adddition, he describes a distinctive grass-green pyroxene in poikilitic masses of pyroxene-feldspar-iron oxide to be aegerine-augite on the basis of its strong dispersion and large extinction angle. Coates considered this to be a local reaction product (possibly with seawater).

Microprobe analyses (Appendix A) suggest typical diopsidic augite compositions. The pyroxene grains are weakly zoned from core to rim, with a variation of about 3 mol% in iron offset by an antithetic decrease in magnesium. The phenocrysts are contained in a pale grey weathering homogenous groundmass that constitutes about 35% of the rock. The marix is aphanitic or composed largely of plagioclase microlites and fine-grained orthoclase, pyroxene and magnetite. Accessory and minor alteration minerals include apatite, calcite, chlorite, rare biotite and iron oxides. The original presence of olivine is suggested by rare relict crystals now replaced by antigorite and iddingsite. Some flows contain amygdules filled with zeolite (thomsonite according to Coates, 1960) and calcite.

A second type of flow unit consists of maroon basalt in which the analcites are pink to brown in colour and are both euhedral and rounded. Pyroxene typically occurs as small phenocrysts or is present in minor amounts as minute grains in the groundmass. These rocks also contain analcite in the groundmass as irregular, interstitial grains together with a turbid mass of very fine grained plagioclase microlites and orthoclase (?), pyroxene, magnetite, calcite, chlorite, opaque dusty material and other minor alteration products. In some members the groundmass is aphanitic and commonly has the appearance of devitrified glass. Lithic-crystal tuffs with diagnostic pink to brown analcite crystals, and maroon to reddish brown laharic deposits with analcite-bearing clasts, are also present but less common. Flows are interbedded locally with analcite-bearing coarse breccia members, lapilli, crystal-lithic and crystal-vitric tuffs.

The analcite phenocrysts appear to be a late crystallizing mineral; whether primary or secondary is uncertain. Morton (1976), Bailey (1978) and, before them, Coates (1960) favour a primary origin for the following reasons. The phenocrysts, in many cases, are euhedral with sharp outlines and grain contacts. Euhedral analcite grains are present as clasts in crystal-vitric and crystal-lithic tuffs. The white grains are isotropic with no twinning evident, although pink crystals may display some twinning and weak birefringence. Small feldspar and pyroxene inclusions are aligned parallel to the trapezohedral faces within analcite crystals (ocellar texture). Although many analcite-bearing flows are amygdaloidal, analcite does not commonly fill vesicles. The crystals and their adjoining grains are not cracked or fractured as would be expected if expansion due to sodium replacement of potassium in primary leucite has taken place. Bailey's analysis of three analcite samples (Bailey, 1978, page 37 ) reveals no trace of residual $K_2O$ that would be probable if replacement of leucite had taken place. The average of the three chemical determinations, in weight percent, is: $SiO_2$ - 57.3, $Al_2O_3$ - 23.9 and $Na_2O$ - 9.7. In many rocks pyroxene crystals are relatively unaltered and "fresh-looking", a most unlikely situation if original leucite has been replaced totally by analcite. All this suggests a primary origin for the white-weathering, glassy when freshly broken, analcite phenocrysts, but a secondary origin for the pink and brown, weakly birefringent grains and the interstitial groundmass analcite is possible and probably likely.

A discussion of analcite in similar Nicola lavas by Mortimer (1987) leaves the problem of their origin unresolved. This long-standing debate about the primary versus secondary origins of analcite phenocrysts in igneous rocks has been reviewed (and perpetuated) by Karlsson and Clayton (1991). Their conclusions from stable isotope and microprobe studies favour a secondary origin. Their data offer persuasive arguments that despite their euhedral, pristine appearance, the analcite crystals have undergone extensive low-temperature subsolidus isotopic exchange (with meteoric waters) or formed from pre-existing leucite crystals.

## SEDIMENTARY SUCCESSIONS CAPPING UNIT 2 (UNIT 2f)

At the top of unit 2 is a thin succession of sedimentary rocks, unit 2f, a consolidation of three sedimentary subunits termed 2f, 2g and 2h by Bailey (1990). The rocks are dominantly dark grey to brown mafic, pyroxene-rich sandstone and siltstone, greenish grey and brown coarse sandstone and grey medium-grained sandstone and siltstone. In places these rocks form flaggy, fetid and pyritiferous beds containing broken shells and other faunal debris. The rocks are commonly associated with calcareous siltstone and sandstone and thin, massive micritic and, locally, coarsely crystalline limestone beds.

A discontinuous unit of the red to maroon basic sandstone in the Morehead Lake area, described by Bailey (1978), was considered by him to occur at the top of unit 2. The sandstone is derived from the erosion of the underlying basalts and is composed of 50% pyroxene grains and plagioclase, analcite, magnetite, calcite and clay minerals. This rock contains Triassic (Norian) fauna. A sandstone of similar composition, but dark green in colour and bearing shell debris of possible Early Jurassic age, is exposed north of Shiko Lake. The rocks there are overlain by felsic volcanic rocks and sedimentary beds with diagnostic Early Jurassic (Sinemurian) fauna. These sedimentary units might well form an unconformable succession at the top of the basalt unit and the basal members of the overlying, more oxidized volcaniclastic unit, unit 3.

The top of unit 2 on the western side of the central axis of the Quesnel belt, from near Gavin Lake to south of the Quesnel - Barkerville highway, is also marked by lenses of discontinuous grey limestone which, on the basis of its conodont fauna, is of Norian age (H.W. Tipper, personal communication, 1989). Limestone does not appear to have developed at a similar stratigraphic level to the east of the central axis of the belt. Instead, highly calcareous volcaniclastic sedimentary rocks occupy this stratigraphic position. Bailey (1978) included both the limestone and the calcareous sediments within unit 3 and thus, by inference, considered them to be of Early Jurassic age. However, later mapping (Bailey, 1987, 1988) clearly shows these rocks form the uppermost part of unit 2 and are Triassic.

## PLAGIOCLASE-LATH PYROXENE-PHYRIC BASALT (UNIT 2g)

This is a minor unit in the Shiko Lake area that overlies pyroxene-rich wackes of probable Early Jurassic age. It both underlies and interfingers with polylithologic felsic breccias. These rocks were characterized and analyzed as unit 2g because of their basaltic nature but are probably correlative with rocks of unit 3. The major rock type is a plagioclase pyroxene basalt with a distinctive porphyritic texture resulting from the presence of large euhedral pyroxene crystals and plagioclase laths. About 25% of the rock consists of 4 to 9-millimetre sized, euhedral, generally equant clinopyroxene crystals and 15% is laths of plagioclase 4 to 6 millimetres long. Plagioclase ranging in size from microlites to 3-millimetre laths forms an additional 15% of the rock. The presence of this finer grained plagioclase in the microcrystalline to aphanitic groundmass imparts a seriate feldspar texture to the overall trachytic-textured rock. The associated breccias comprise lapilli to ash-tuff sized polylithic clasts. Many of the clasts appear to be fine-grained microdiorite to diorite/monzonite or latite and are contained in a milled matrix of similar composition. This suggests a subvolcanic source or flow-dome breccia close to a volcanic vent. In Beaver Creek valley the predominantly conglomeratic rocks of this unit contain abundant feldspathic clasts and rare granitic cobbles. Small limestone lenses within the assemblage hold Triassic conodonts. The limestones and enclosing clastic rocks could be part of an olistostrome and the map unit might be considerably younger, possibly equivalent to unit 3, or even younger, rocks.

## POLYLITHIC 'FELSIC' BRECCIAS - UNIT 3

Rocks of unit 3 form a heterogeneous sequence of basaltic and intermediate composition ('felsic') coarse volcaniclastic rocks, lesser flows and conglomerate. There are well-defined lenses of sedimentary and tuffaceous rocks within the subaqueous shallow-water succession and more limited pyroclastic rocks deposited under ephemeral subaerial conditions. The map unit occupies the upper part of the volcanic arc assemblage along the central axis of the Quesnel belt (Figure 3-5). The thickest accumulations of these volcanic rocks, including flow-dome complexes and possibly intrusive breccias, outline centres of eruptive volcanism and subvolcanic intrusive emplacement along the belt. Bailey (1978) has calculated an aggregate thickness of 2160 metres for this unit.

Unit 3 has been subdivided in the Morehead Lake area and the region to the north of the Quesnel River by Bailey (1990, and earlier reports) into three subunits - 3a, 3b and 3c. These units, from lower to upper, are: a polylithologic breccia, a heterogeneous assemblage of tuff, sediment and breccia and a tuffaceous sediment and minor felsic breccia. In the Horsefly area farther to the south, no stratigraphic subdivisions were established in the generally massive, unstratified and unsorted breccia and flanking conlgomerate deposits (Panteleyev and Hancock, 1989a, and earlier discussions). We now consider the plagioclase-lath pyroxene-phyric basalt flow and breccia in the Shiko Lake area, previously referred to as unit 2g (Panteleyev and Hancock, 1988a,) to be correlative in age, if not composition, with the oldest parts of unit 3.

The rocks of unit 3 are generally pink to pale brown weathering and leucocratic in appearance. They contain more abundant feldspars, notably alkali feldspar, than the underlying pyroxene basalts of unit 2 and, therefore, appear to be more felsic in composition. Both orthoclase (perthite as clasts and in breccia fragments) and intermediate plagioclase (albitic composition according to Bailey, 1978) and andesine (according to Morton, 1976) are present. The rocks are predominantly breccias deposited as autobrecciated subaqueous slump and subaerial laharic (debris-flow) units. Flows and pyroclastic breccia and tuff are present but less common. The breccias are polylithologic with a wide variety of rock types, including intrusive rocks. The deposits are poorly sorted and generally lack stratification. Their pale grey, maroon, red and purplish to violet colour suggests that they are more oxidized than the underlying basalt units, consistent with their shallow-water to partly subaerial origin. The volcanic rocks are flanked by aprons of reworked breccias, epiclastic sedimentary rocks (wackes) and conglomerate derived from the volcanics.

Compositions of the breccias vary widely depending on the composition of the dominant lithic clasts derived from the underlying strata and local flows and pyroclastic eruptions. Locally, small amounts of monolithologic trachytic or fine-grained, equigranular and porphyritic breccia and tuff suggest deposition in and around volcanic dome deposits. Trachytoid latite to trachyte and equigranular, fine-grained diorite to porphyritic syenite clasts consist mainly of plagioclase and diopside to diopsidic augite phenocrysts and intergranular orthoclase. Most clasts and the rock matrix are generally too altered to optically determine modal mineralogy and mineral compositions with accuracy. Alteration minerals are chlorite, epidote, calcite, clay minerals and zeolite (laumontite). Where analcite is present as an erratic constituent in clasts and matrix of some volcanic members it differs from that in unit 2, mainly in form. The analcite grains in this unit are generally less than 2 millimetres in size and round to irregular in shape. They are most likely to occur in the more altered rocks, suggestive of a secondary origin.

The top of the unit consists of lenses of maroon sandstone, calcareous sandstone, conglomerate and massive, pale grey limestone. Near Morehead Lake there is a thin, marine fining-upward clastic sequence of grey calcareous sandstone, minor conglomerate and carbonaceous mudstone and argillite. A few kilometres to the north of these rocks are interbedded sandstone, siltstone and mudstone cropping out along Morehead Creek. On the basis of stratigraphic position and composition, the Morehead Lake section is considered to be correlative with that near Morehead Creek. In this latter section Lower Jurassic macrofossils, including the Sinemurian index ammonite *Badouxia canadensis* (Frebold), have been recognized, while at the Morhead Lake locality an Early Jurassic age is apparent by the presence of *Weyla sp.*

## SUBAERIAL BASALT - UNIT 4

This unit is a distinctive dark purple to maroon, vesicular and amygdaloidal, analcite and olivine-bearing pyroxene basalt flow and breccia assemblage. Its limited distribution in small segments of the central arc suggests that it was deposited in a rift zone or elongate fault-bounded trough along the medial axis of the volcanic belt (Figure 3-6). There is little lithologic variation in this unit. Flows and flow

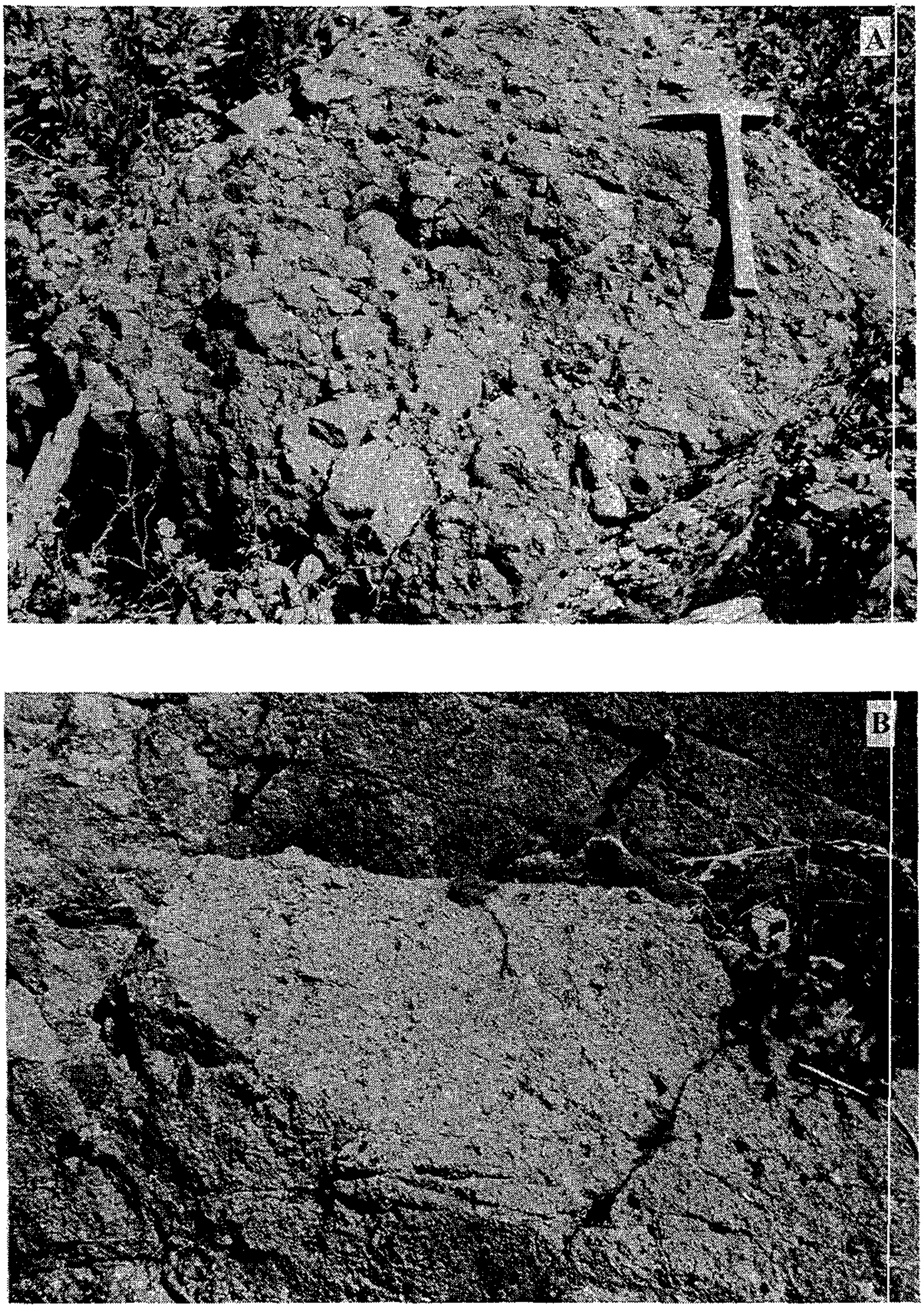



Photo 3-1. Typical outcrop appearance and fabric in basaltic units. A. Volcanic breccia of clast-supported, momomictic pyroxene phyric basalt typical of unit 2. B. Lithic crystal ash to lapilli tuff containing some cognate euhderal crystals and broken grains of analcite.

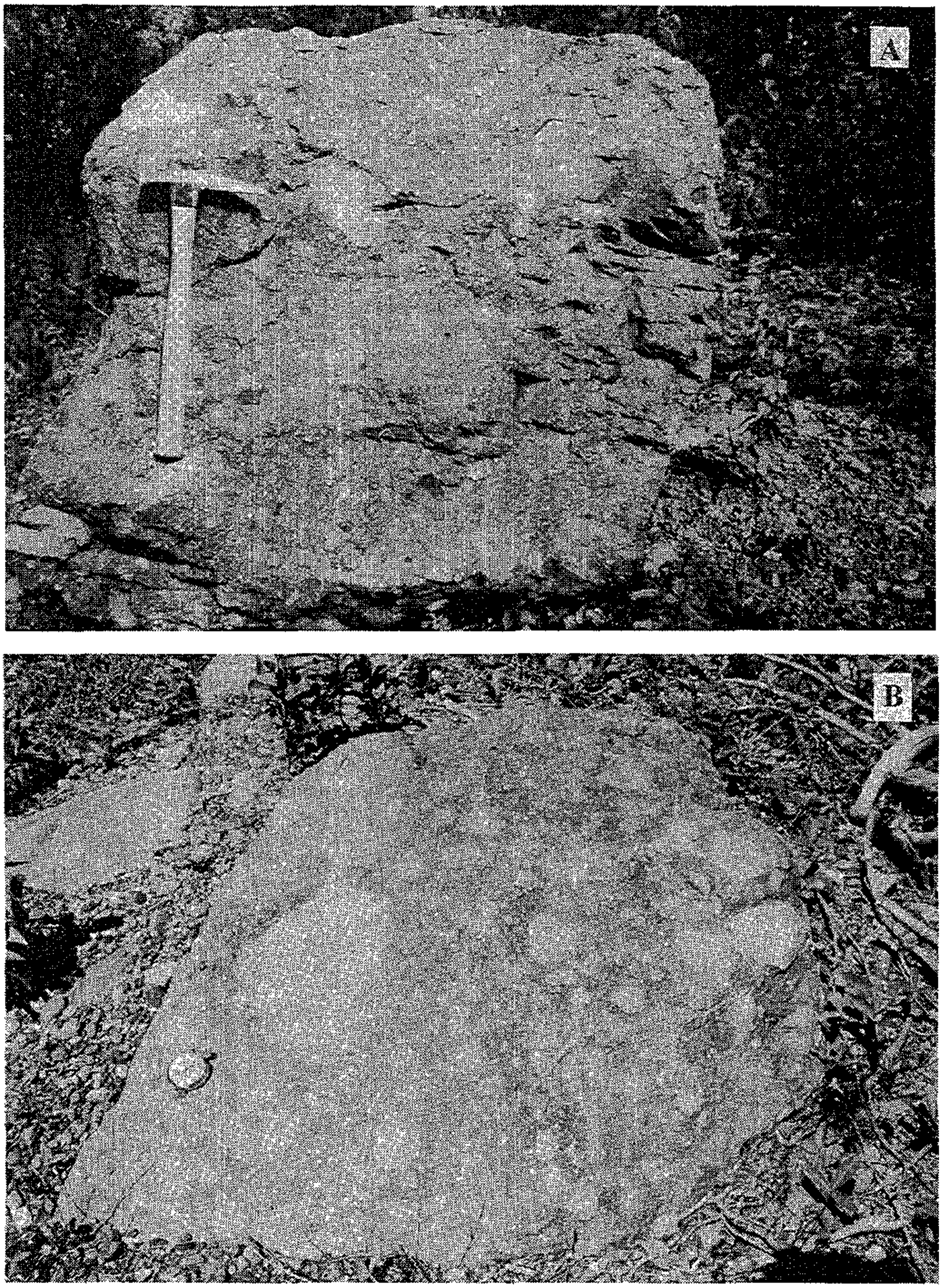



Photo 3-2. Typical outcrop appearance and fabric in 'felsic' shoshonitic basaltic rocks. A. Volcanic breccia with lithic ash matrix containing a wide variety of clasts including many from underlying volcanic units. B. Breccia with reddish, sand to mud-sized granular matrix and some clasts with reaction rims, suggesting laharic deposition. Clasts are dominantly pink, fine-grained and analcite-phyric, 'felsic' volcanics.

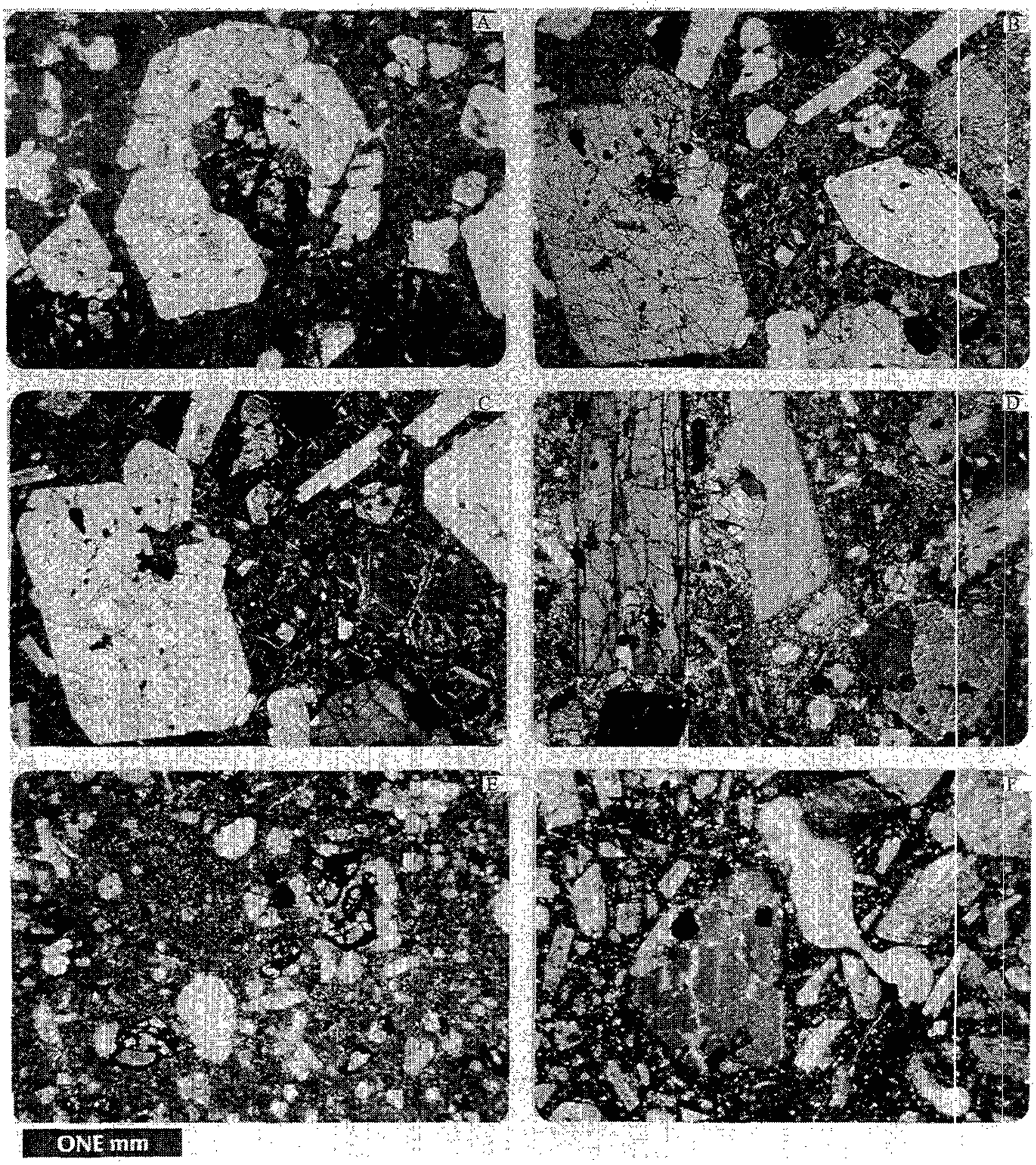



Photo 3-3. Photomicrographs of unit 2 basalts. A. Olivine grains altered to magentite, carbonate and iddingsite (?) partially enclosed by diopsidic augite. B. Alkali olivine basalt. Euhedral olivine phenocrysts completely replaced by serpentine and magnetite, plane polarized light. C. Same as B., crossed nicols. D. Hornblende-bearing alkali basalt, crossed nicols. E and F. Alkali basalt with calcite. Bar scale is 1 mm; scale is the same on all photographs.

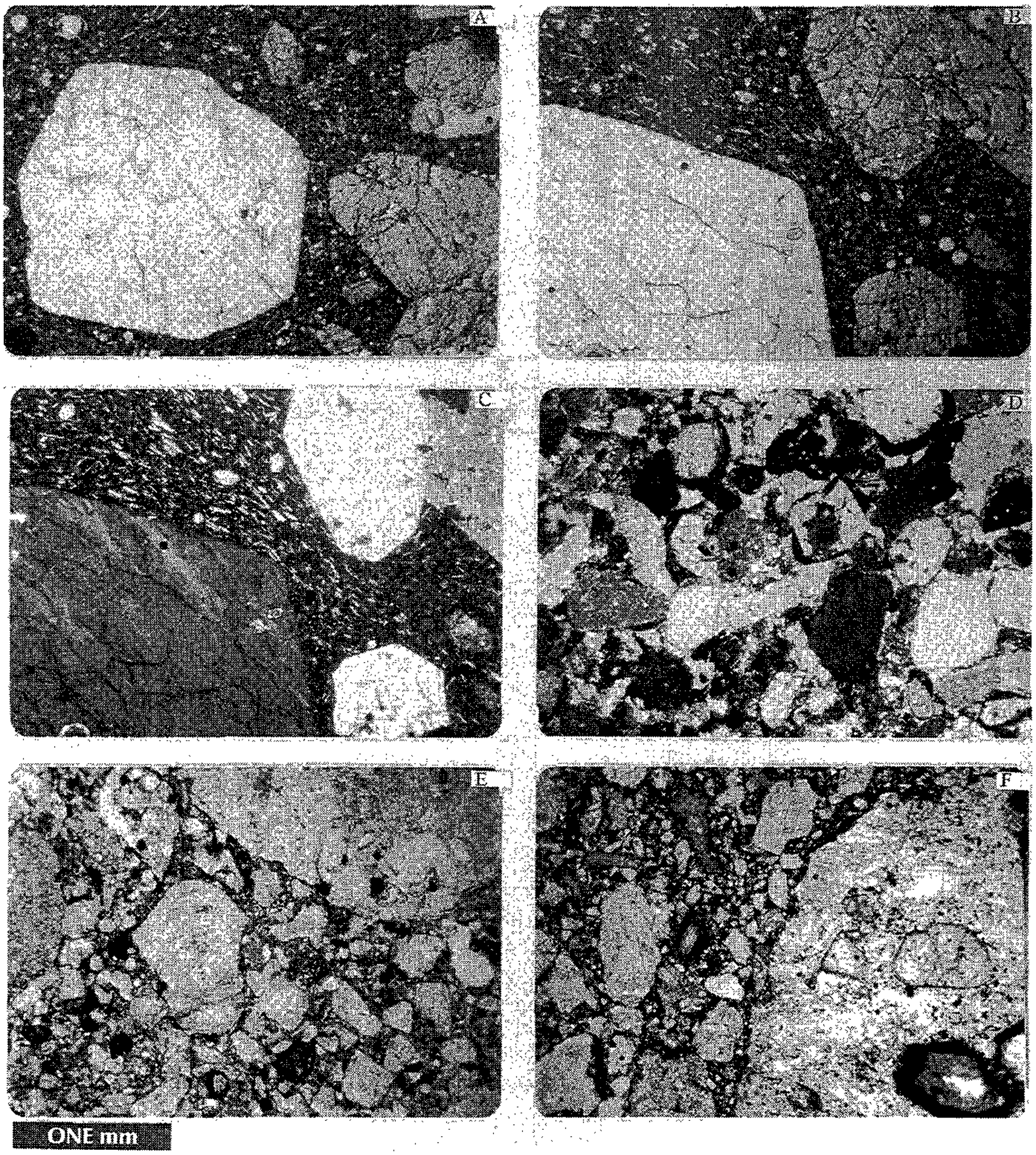



Photo 3-4. Photomicrographs of analcite basalt of unit 2e, sandstone and felsic breccias of unit 3. A. Large analcite grain and diopsidic augite in groundmass of plagioclase microlites, analcite and devitrified glass, plane polarized light. B. 'Primary' analcite phenocrysts with sharp, unaltered contacts with rock groundmass. Note lack of evidence for replacement, plane polarized light. C. Same as B., crossed nicols. D. Mafic sandstone composed of rounded grains of clinopyroxene, feldspar and magentite in matrix of calcite and clay minerals, crossed nicols. E. and F. Polylithologic felsic breccia. Bar scale is 1 mm.

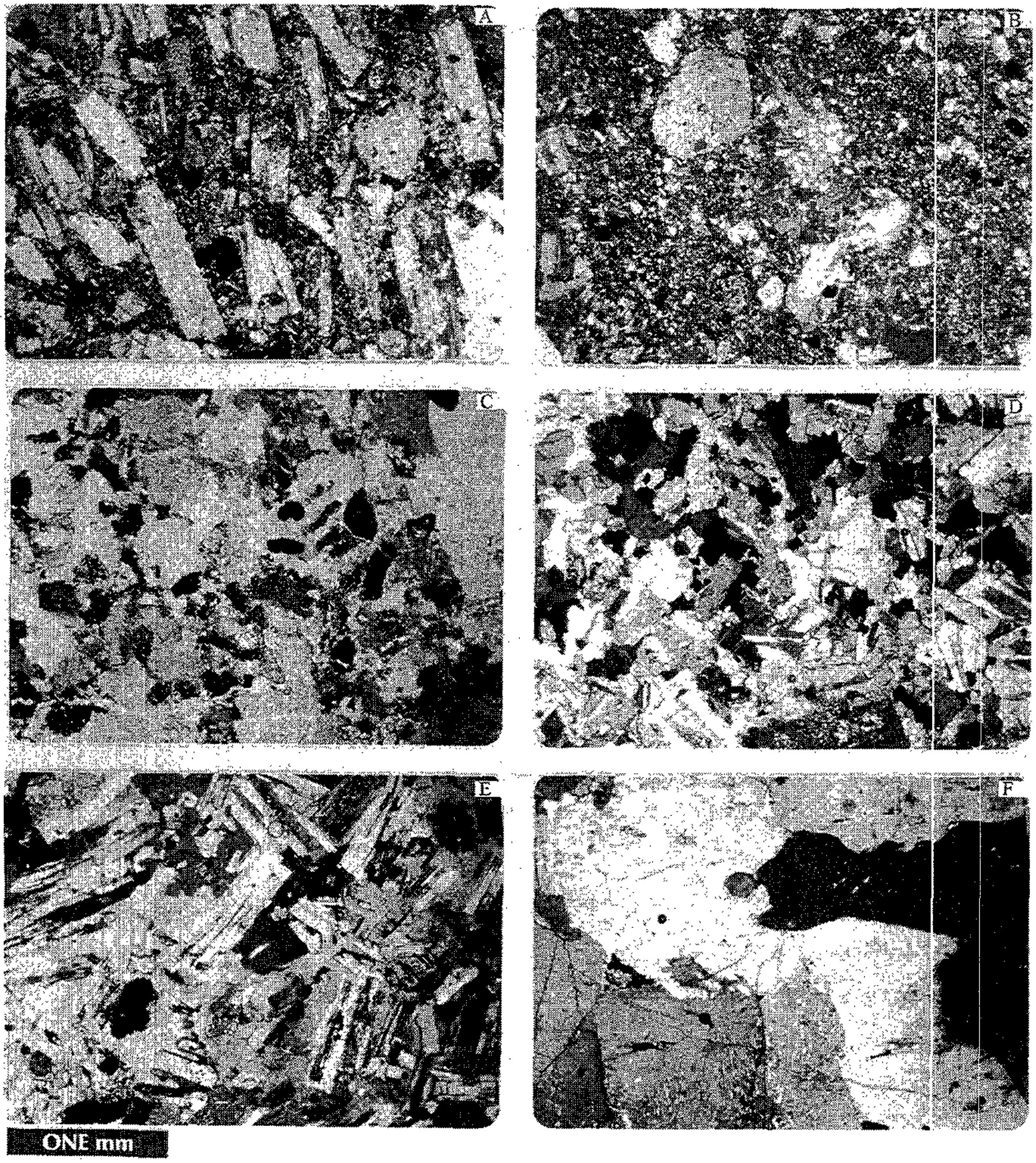



Photo 3-5. Photomicrographs of felsic rocks of unit 3 and intrusive rocks of unit 7. A. Trachytic felsic flow, crossed nicols. Plagioclase is slightly altered; potassium feldspar is almost completely replaced by calcite. B. Felsic crystal tuff, crossed nicols. C. Calcareous sandstone, crossed nicols. D. Hornblende and clinopyroxene-bearing monzonite, crossed nicols. E. Monzonite adjacent to Cariboo-Bell (Mt. Polley) copper deposit with orthoclase 'flooding' of matrix and replacement of plagioclase, crossed nicols. F. Nepheline syenite from the Bootjack stock, crossed nicols. Potassium feldspar has perthitic texture; nepheline is isotropic (black). Bar scale is 1 mm; scale is the same on all photographs.

breccias of fairly uniform composition dominate, with minor units of laharic breccia. A maximum exposed thickness of 620 metres is estimated by Bailey (1978).

The basalt contains varying amounts and sizes of phenocrysts of pyroxene and plagioclase and smaller grains of analcite and relict olivine. Grains are euhedral to subhedral in shape and average 3 millimetres in diameter. Some display marked green pleochroism and simple twinning and optical but not compositional zoning. Pyroxene is diopsidic augite in composition and chemically indistinguishable from pyroxenes of unit 2 (Appendix A). Plagioclase forms euhedral laths and anhedral blebs. The grains are extensively replaced by sericite, clay minerals and zeolite. Plagioclase compositions range from $An_{48}$ to $An_{42}$ and, thus, are about 10 molecular% more albitic than feldspars in the alkali olvine basalts of unit 2a. No olivine remains, but idiomorphic relict grains about 0.3 millimetre in diameter are replaced by alteration minerals, mainly magnetite and iddingsite. The olivine is commonly enclosed by pyroxene grains. It forms about 10% of the rock but may constitute up to about 50%. The analcite occurs as euhedral phenocrysts averaging 0.5 millimetre in size and also as small grains in the groundmass. It is generally pink in colour but lacks the twinning seen in the maroon to red analcite-bearing rocks of unit 2e. Other minerals commonly present are magnetite, calcite and zeolite; the latter two minerals are locally abundant in vugs and veinlets. Zeolite minerals identified by x-ray diffraction are thompsonite, scolecite and analcime. The groundmass is hematitic and extensively altered. Where grains can be recognized, they are analcite, magnetite and, in some cases, felted aggregates of plagioclase microlites.

## OVERLAP UNITS

Sedimentary units in the Quesnel belt are found in two northwesterly trending belts (Figure 3-7). The clastic detritus, at least the coarsest part, is derived largely from the volcanic arc. The two sequences are distinguished on the basis of age and, to a lesser extent, lithologic type and provenance of clasts in congomerate.

### *CLASTIC OVERLAP DEPOSITS - UNIT 5*

The older, Early Jurassic sequence, unit 5, was deposited as volcanic-source epiclastic deposits. The rocks overlap the volcanic arc rocks and flank them in fault-bounded troughs or a postvolcanic marginal basin. This unit forms a sequence of dark to medium grey, thin-bedded, fine-grained calcareous sandstone and siltstone along the eastern side of the volcanic arc. The rocks are similar in composition and appearance to rocks of unit 1 as well as the flaggy beds of pyritic siltstone and sandstone of unit 2f. The sedimentary rocks of this unit are best exposed along the banks of the Quesnel River to the northwest of the village of Likely. There, in the south bank of the river, the beds are overlain by basalts of unit 2 along a shallow, west-dipping thrust fault.

### *CLASTIC ROCKS IN FAULT BLOCKS - UNIT 6*

A younger sequence of Middle Jurassic age, unit 6, consists of polylithic conglomerate as well as bedded successions of finer grained clastic rocks that are similar to rocks of unit 5. This unit is characterized and distinguished from the older clastic unit by the presence of a variety of clasts derived from the underlying volcanic arc, continental and oceanic provenance as well as the presence of quartz and rare granitic detritus. The map unit is poorly exposed along the fault-bounded western margin of the Quesnel arc, near the boundary of the map area. Thin-bedded fine-grained sediments in the Beaver Creek area contain Aalenian fauna (Poulton and Tipper, 1991). Coarse clastic sedimentary units of uncertain age include grey and maroon polylithic conglomerate with granitic clasts and quartzose sandstone. A Bajocian age for these rocks is suggested, based on observations outside the map area (H.W. Tipper, personal communications, 1987, 1992). Some of the isolated conglomerate outcrops in the Beaver Creek valley contain Cache Creek chert, limestone, greenstone and argillite and are, therefore, derived largely from western source areas. These rocks also contain rare clasts of granitic and quartz-bearing dike rocks and quartz-bearing sandstone. Other conglomerates and associated clastic rocks contain abundant basaltic detritus and are derived from the Quesnel volcanic arc. The age of some of these conglomerates is uncertain; they might be as young as Cretaceous and equivalent to rocks of unit 9.

## CONTINENTAL CLASTIC AND VOLCANIC DEPOSITS

### *FLUVIAL DEPOSITS - UNIT 9*

Conglomerate with abundant rounded cobbles and boulders of chert, quartzite, other metamorphic and sedimentary rocks, various volcanic lithologies, some ultramafic detritus, rare granitic clasts and white to grey (vein) quartz clasts occurs as narrow sinuous belts of overlapping clastic deposits on the northern flank of the volcanic belt in the Quesnel Lake and Quesnel River areas. The conglomerate is readily identified by its rounded polylithic clasts and calcareous sandy matrix. Commonly the carbonate forms an orange-weathering, fine-grained interstitial matrix such as that seen in the rocks of Cariboo Island in Quesnel Lake. Elsewhere, for example, the Rose Gulch area, orange-weathering carbonate occurs in veinlets of sparry dolomitic calcite. This carbonate cementation and vein filling appears to be due to the action of late thermal fluids or groundwater.

McMullin (1990) has described the conglomerate near Likely as well as the lithologically similar rocks near Cottonwood River at the northeast corner of the map area. The latter may be equivalent to the Likely site but are probably Jurassic in age and possibly equivalent to rocks of unit 6. Lithologically similar rocks also occur in small fault blocks in the Beaver Creek valley. There the conglomerate unconformably overlies volcanic rocks of unit 2 at Antoine Creek, above a thin layer of hematitic red sand and soil derived from the volcanic rocks. At Rose Gulch, near Quesnel Forks, there is a rhythmic sequence of fining-upward conglomerate, sandstone and thin-bedded siltstone, some of which contains dolomitic veinlets. The mudstone commonly contains leaf impressions of monocotyledons (Bailey, 1978) and similar rocks on the south side of the Quesnel River contain nondiagnostic carbonaceous plant trash.

Provenance of many of the clasts in the conglomerate is the eastern metamorphic belt of the Barkerville Terrane and, to a lesser extent, oceanic rocks of the Slide Mountain Terrane (McMullin, 1990). The age of the map unit is possibly Albian, or younger, (H.W. Tipper, personal communication, 1992), if the rocks are equivalent to the conglomerate in Beaver Creek valley at Antoine Creek. This age is based on unreported data from palynology samples collected by R.B. Campbell and examined by D.C. McGregor (H.W. Tipper, written communication, 1993, Report F1-12-1967-DCM). These coarse clastic deposits are suggested by Tipper to represent ancient fluviatile systems of possible Cretaceous age that had their origins in an Omineca highland following uplift in the Toarcian. Alternatively, all or part of the channel-fill conglomerate unit may be Tertiary. Certainly Quesnellia arc and cover rocks have been repeatedly eroded.

## *TERTIARY SUCCESSIONS - UNIT 10*

Tertiary felsic and sedimentary rocks in the map area (Figure 3.8) are Middle Eocene in age according to both fossil and radiometric data. The rocks can be observed in places, to overlie rusty basaltic Nicola rocks along a lateritic-looking soil horizon that marks the unconformity. This deep weathering in the basalts suggests there was considerable tropical weathering at the start, or during, the Eocene. The Eocene rocks have been subdivided into sedimentary and volcanic subunits:

### LACUSTRINE SEDIMENTS - UNIT 10

Pale grey to tan and yellow, thin-bedded to varved lacustrine deposits of clay, silt and fine-grained sandstone with some tuffaceuous component are found along the Horsefly River, near the mouth of Hazeltine Creek at Quesnel Lake and along Victoria Creek, north of Quesnel River. The well-bedded succession contains abundant plant debris and floral imprints. Abundant palynomorphs confirm a Middle Eocene age of deposition. Rarely, fossil fish and insects can be found. Wilson (1977a,b) regards the Horsefly River locality near Horsefly village, locally referred to as 'The Steps', as one of the type localities in Canada for Eocene fossil fish.

### VOLCANIC FLOWS, ASH FLOWS AND CRYSTAL ASH TUFFS - UNIT 10a

Two main lithologic types are recognized. A single exposure on a knoll to the west of the Horsefly River consists of platy, fine-grained homogeneous to porphyritic, grey to brown biotite-phyric sanidine-bearing latitic flows (unit 10a). The rocks consists of about 15% plagioclase crystals and pale yellow and honey-coloured dolomite grains up to 2 millimetres in size. Rare grains and crystal aggregates of glassy sanidine up to 4 millimetres in size are also present. Biotite flakes up to 2 millimetres across form about 3 to 5% of the rock. This rock type is present as clasts and is the source of the abundant biotite grains in the pebble conglomerate at the base of unit 10 where it is exposed along the Horsefly River at the historic Hobson placer mining site. A Middle Eocene radiometric date has been obtained from the biotite contained in the flow rocks. A biotite-bearing lamprophyre dike of similar age (unit 10c) that cuts rocks of unit 1 in the Beaver Creek valley is probably a feeder for the flows. Tertiary dikes are rarely seen in the map area.

To the north of Quesnel Forks, near the confluence of the Quesnel and Cariboo Rivers, biotite-bearing volcanic rocks are exposed which, although superficially resembling the breccias and tuffs of unit 3, are probably correlative with the similar biotite-bearing rocks near Horsefly.

The second volcanic lithology consists of pale grey to brown, commonly iron stained, and mauve to purple plagioclase-phyric crystal ash-flow tuffs (unit 10b). Small lithic clasts are commonly present but are generally less than 5% in abundance. The rocks are usually compacted with blocky fracturing outcrops. Locally, there is faint, indistinct layering defined by a weakly developed foliation that is imparted by plagioclase crystal alignment. Some outcrops, notably those with foliated rocks, display slabby to platy fracturing. Plagioclase crystals less than 1 millimetre up to 5 millimetres across make up about 50% of the rock. The plagioclase crystals are euhedral and blocky to tabular in shape and have well developed albite and Carlsbad/albite twinning. The composition is oligoclase $An_{27-29}$. Mafic minerals, originally probably amphibole, are completely replaced by calcite, epidote, dusty hematite and other opaque minerals. Magnetite grains are extensively to completely altered to maghemite. Grains of rounded, resorbed quartz occur sporadically throughout the rock. The quartz and small, cloudy grains of interstitial orthoclase form less than 15% of this rock. The ash tuffs overlie Middle Eocene sedimentary beds at Hazeltine Creek. Elsewhere, for example the Megabuck property to the south of Horsefly village, feldspathic ash flows occur together and possibly interfinger with fine-grained tuffs and tuffaceous sedimentary rocks. The tuffaceous sediments are variably purple to green and grey in colour. Some beds and successions contain large clots and spherules of fine-grained epidote. These subaqueous tuffs probably grade laterally and interfinger with the lacustrine sediments of unit 10.

## *NEOGENE PLATEAU BASALTS AND MIOCENE FLUVIAL CHANNEL DEPOSITS - UNITs 11 AND 11a*

Dark grey to black and maroon alkali olivine basalt subaerial flows and tephra cover much of the southwest part of the map-area (Figure 3-8). The rocks are typical of the

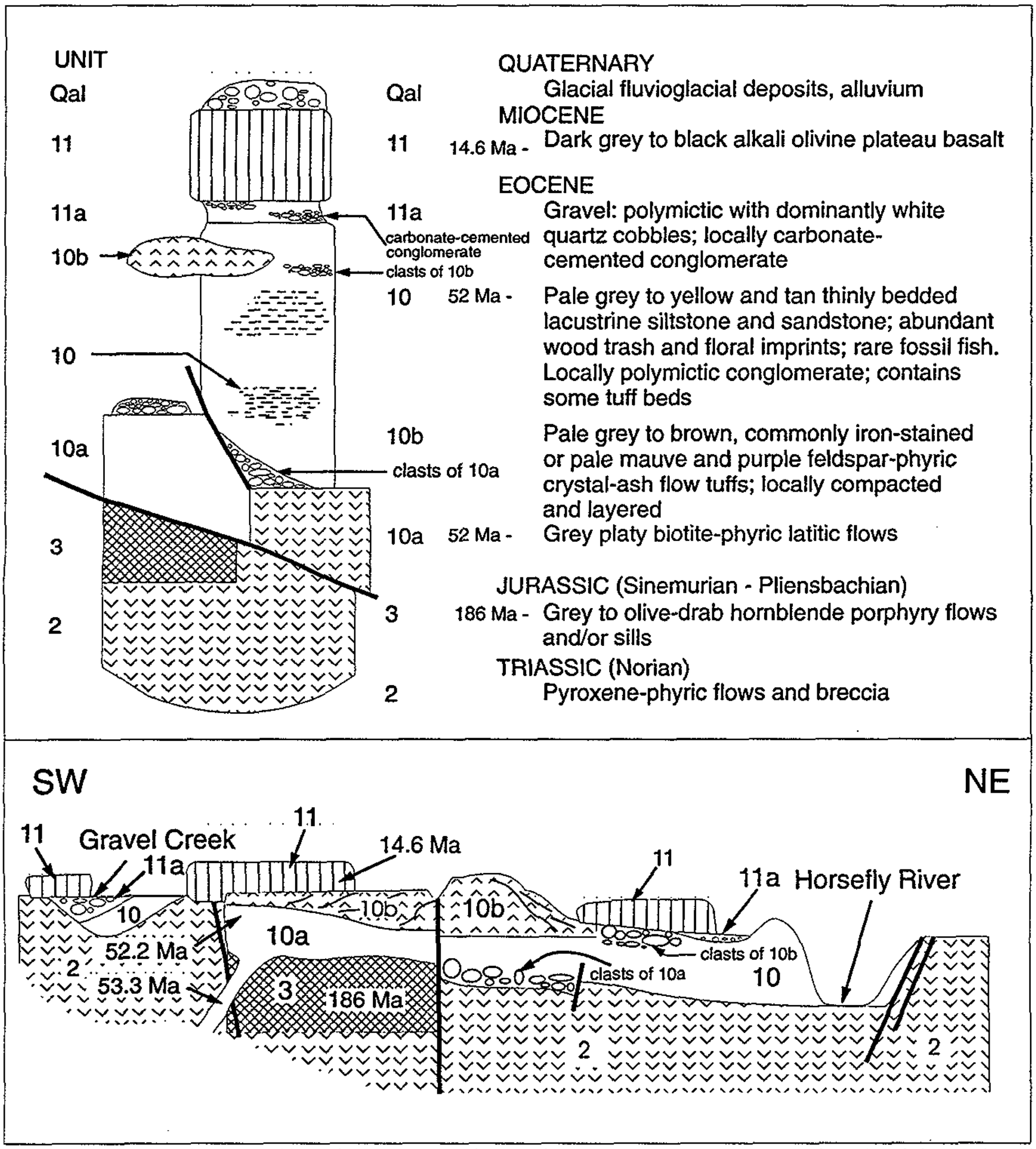



Figure 3-9. Diagrammatic stratigraphic section and cross-section showing Tertiary and Quaternary map units and the Miocene channel (auriferous) gravel deposits.

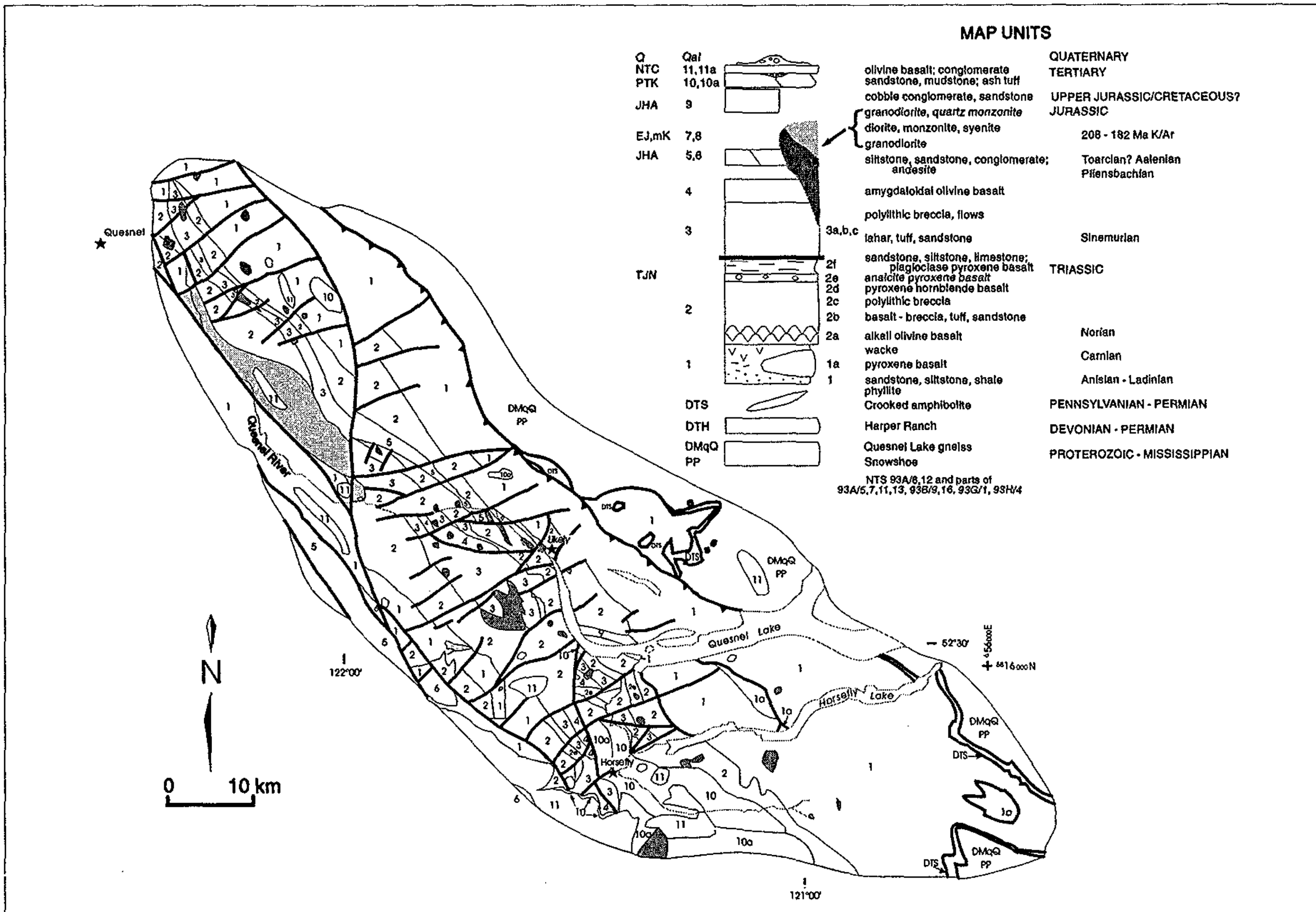



Figure 3-10. Generalized geological map showing units 7 and 8 - intrusive rocks.

widespread plateau basalts, termed Chilcotin Group volcanics by Mathews (1989), that cover much of south-central British Columbia. Commonly flows display well formed columnar joints. They give rise to flat-topped outliers and rimrock scarps that are the eroded remnants of previously more extensive plateau basalt flows. At least two ages of flows are present in the map area according to Mathews (1989): a 14 to 16 Ma series and a 7 to 9 Ma flow series. A younger series of flows, 1 to 3 million years in age, has not been recognized in the map area. In places the flows contain ultramfic, orthopyroxene-bearing xenoliths. Locally, the base of the basalt unit has a bentonitic palagonite ash and tephra layer with abundant basaltic scoria.

A conglomerate unit underlies the basalt flows in a number of gravel-filled river channels. It is shown as unit 11a (Figure 3-9). The gravels consist of a distinctive white quartz cobble congomerate that placer miners in the area refer to as the Miocene (placer gold) channel. The white quartz clasts appear to be derived from coarsely crystalline vein quartz. At its base, at least in the Horsefly River valley in the historic Hobson placer mine, the gravel is cemented with calcite. It forms a resistant conglomerate in which adits and other underground openings were drvien that permitted extensive underground mining of the auriferous gravels.

### *QUATERNARY DEPOSITS - UNIT Qal*

A durable blanket of one or more tills, local ablation moraine and widespread fluvioglacial deposits with an extensive thin cover of colluvium and other overburden is present throughout much of the map area. Drumlins and crag-and-tail features that indicate northwesterly ice-flow directions are common on the plateau. Fluvioglacial deposits and some thick accumulations of glacial silt are found in the major valleys occupied by Beaver Creek and the Horsefly and Quesnel rivers.

## INTRUSIVE SUITES

Two groupings of intrusive rocks are evident, based on the age and compositions of the major intrusions (Figure 3-10). An older, latest Triassic to Early Jurassic alkalic suite (unit 7) is coeval with some of the younger arc volcanism. These rocks represent the most common type of intrusions found in the project area. A single pluton of quartz-bearing granodiorite in the southern part of the map area, part of the Takomkane batholith, is evidently also Early Jurassic in age (Campbell, 1978). It represents a separate, calcalkalic magma type that is distinct from the main group of silica-undersaturated alkalic dioritic magmas. The stock is included in the Early Jurassic unit 7 as a silica-saturated subdivision (unit 7A) on the basis of its similar age. The younger suite of intrusions (unit 8) are calkalkaline, quartz-bearing stocks of probable Cretaceous age.

Morton (1976) described the intrusive rocks in the Horsefly area in detail and classified many rock types according to their compositions. He subdivided the intrusive bodies according to their size into major plutons and related smaller stocks and plugs, domes, dikes, sills and intrusive breccias, all within a complicated three-cycle sequence of intrusive-extrusive magmatism. He places olivine and alkali gabbros, syenodiorite, monzonite and dikes of syenite and trachyte in the oldest magmatic cycle, and assigns nepheline-bearing syenodiorite, monzonite and their related dikes as well as analcite-bearing olivine teschenite, teschenite, tephrite, phonolite and other dikes to the two younger cycles. His proposed intrusive scheme has not been substantiated by this investigation but some of his rock descriptions and petrological data are incorporated here.

### *ALKALIC GABBRO-DIORITE-SYENITE - UNIT 7*

Stocks ranging from diorite to syenite in composition intrude sedimentary rocks of units 1 and 1a and the older volcanics of unit 2. They appear to be coeval and cogenetic with the alkalic volcanics of unit 3. A number of the dioritic bodies are composite stocks or are zoned due to differentiation into monzonite and syenite phases. The intrusions are assigned to unit 7 on the basis of their alkalic compositions and Early Jurassic ages (see following chapter). The K-Ar radiometric dates from the stocks, including some samples of hydrothermal minerals, range from 208 to 182 Ma. A mean age of 195 Ma (Early Jurassic) is obtained from ten of the most recent K-Ar radiometric determinations (*see* Table 4-1). More recent U-Pb dating indicates intrusive ages of approximately 202 Ma (Ghosh, 1993; 1994).

Unit 7 has not been subdivided in this study but can be readily split into subunits that are differentiated on the basis of composition and texture. For example, Bailey (1990) describes three subunits he designated as units 7a, b, c. These are: 7a - pyroxene-bearing diorite, monzonite and syenite with lesser gabbro, clinopyroxenite and peridotite; 7b - syenite with characteristic large othoclase phenocrysts and megacrystic texture; and 7c - nepheline-bearing syenite, in part orbicular. All the rocks contain normative nepheline and lack modal quartz.

The most abundant intrusive rock type is fine to medium-grained, equigranular to weakly porphyritic syenodiorite and less commonly diorite. The syenodiorite is grey in colour and composed mainly of fine to medium-grained plagioclase, orthoclase and clinopyroxene. Crystal size generally ranges from 0.5 to 1.5 millimetres. The rock contains, on average, 50% plagioclase of andesine composition (An34-52), 15% diopsidic augite and up to 25% anhedral, poikilitic orthoclase as the main groundmass component. Hornblende occurs in variable amounts together with accessory magnetite (up to 5%), apatite and sphene. Biotite is present, generally as a replacement of clinopyroxene; some of the pyroxene is rimmed by aegerine or aegerine augite (Bailey, 1978). Other alteration minerals are sericite, calcite and chlorite. Monzonite has the same mineralogy but has an orthoclase content of about 35% and, in places, abundant biotite. The rock is usually pale grey to pink in colour. Syenite contains abundant microperthite and orthoclase of which much, if not most, appears to be a secondary replacement of groundmass and plagioclase phenocrysts. Plagioclase compositions range from oligoclase to albite (An22-6). Both Schink (1974) and Morton (1976) report the presence of small amounts of fluorite in syenite. Gabbro is a minor component of the Polley and Lemon Lake stocks (Hodgson *et al.*, 1976; Morton, 1976) and both gabbro and serpentinized peridotite form parts of the Cantin Creek intrusions (Lu, 1989; P.E. Fox, personal communication, 1987).

A number of the stocks, even the smaller ones, are zoned. Some display symmetrical zoning with gradational changes from cores of monzonite or syenite to a rim of diorite, for example, the QR stock. The dioritic rims contain more abundant mafic minerals and magnetite than the centres of intrusions and consequently have a strong magnetic signature. Other intrusions, probably the higher level subvolcanic stocks, are commonly composite. They have intrusive (and possibly metasomatic) internal contacts, for example the Bullion Pit stock. In the composite stocks, the various constituent map units may display irregular shapes and geometries.

Coarser grained to megacrystic variants of mainly monzonite and syenite are present, usually as minor components of a number of the stocks. At both the Polley and Shiko Lake stocks there are small zones or pods of pegmatitic syenite. Lamprophyric dikes and irregular zones of granophyric syenite that contain coarse flakes of biotite and long, thin hornblende needles are also found within the stocks. Pegmatitic, orbicular and granophyric textures are found locally in stocks of nepheline syenite such as the Bootjack Lake and Mouse Mountain stocks. The coarsest grained parts of the intrusive bodies are the core regions; grain size typically diminishes outwards into very fine grained, more mafic-rich border zones. The coarser grained rocks contain nepheline, orthoclase, aegerine augite and less abundant biotite, hornblende, albite and magnetite. Pseudoleucite and analcite are present in places, commonly as cores of the orbicular structures surrounded by nepheline, orthoclase and mafic minerals.

The plutons are emplaced along the central axis of the volcanic arc or, less commonly, are to the east of it in the sedimentary rocks of underlying units 1 and 1a. There is a frequency of intrusive emplacement at approximately 11-kilometre intervals along the volcanic belt. The intrusions appear to coincide with centres of eruptive volcanism and arc construction. Intrusive lithologies that outline the intrusive-extrusive centres are present as clasts in vent and proximal breccias as well as in the surrounding laharic and slump deposits. The plutons intruded at higher stratigraphic levels, as a generalization, appear to be more irregular in shape, have late dikes and are associated with proximal volcanics that are more differentiated felsic magmas with hydrous mafic minerals hornblende and biotite. Some of the intrusions have associated pegmatites and intrusion or hydrothermal breccias. A number of the subvolcanic stocks display some evidence of deuteric or other types of associated hydrothermal alteration and copper mineralization. The plutons in the sedimentary rocks of the underlying basin-fill assemblage, and presumably at greater depths, tend to have thin 'dry-looking' thermal aureoles (hornfels) with little evidence of deuteric alteration within the stock, or hydrothermal products in the country rocks.

The largest pluton, comprised of a number of intrusive phases (Hodgson *et al.* 1976, Bailey, 1978), is the Mount Polley stock. It is a high-level composite stock made up of a laccolith-like series of sills, dikes and intrusion breccias (Fraser, 1994). It is possibly the highest level pluton exposed in the Quesnel belt and coincides with the largest accumulations of felsic volcanic deposits of unit 3. Note that the term 'high-level' is a relative term. On the basis of intrusive morphology, Sutherland Brown (1976) estimated the emplacement of the Mount Polley stock at a depth of about a kilometre. Sillitoe (1989), in his discussions of young island arcs in the southwest Pacific and their intrusion-related deposits, considers 0.5 to 1-kilometre emplacement depths to be 'shallow'. In any case, the Mount Polley stock has been emplaced in an epizonal environment and has ample evidence of high-level, subvolcanic intrusive phenomena such as extensive brecciation and related hydrothermal activity. Other stocks in the Quesnel belt, especially those intruding lower stratigraphic units and those with regular, cylindrical shapes and steep, sharp contacts, appear to be deeper intrusions. For example, Schink (1974) suggested a 6.5-kilometre, or deeper, depth of emplacement for the Shiko Lake stock on the basis of geological mapping evidence.

A hornblende-bearing syenodiorite intrusive breccia exposed on the peak of Viewland Mountain was sampled for radiometric dating. It produced one of the older K-Ar dates in the map area - 203 million years. Morton (1976, pages 37-40) describes the breccia as an intrusive monzodiorite breccia composed mainly of rounded fine-grained syendiorite clasts and minor clasts of other lithologies. He reports that this rock type occupies a 500 by 400- metre area near the peak of the mountain. The dated sample in this study is also from the Viewland Mountain peak area, presumably from the same outcrop examined by Morton, but is from a clast of monolithologic breccia of hornblende porphyry. The breccia forms a body, a 100 but less than 200 metres across, that caps the peak of the mountain. On the slopes below the peak the breccia is underlain by pyroxene basalts of unit 1a. The porphyry contains about 40% hornblende laths 1 to 2 millimetres in length or as rare glomeroporphyritic grains up to 4 millimetres across. Smaller phenocrysts and microlites in the plagioclase crystal groundmass account for about 50% of the rock volume. Plagioclase composition is labradorite (An58-70). The rock is weakly altered and contains minor chlorite, calcite and epidote.

## *QUARTZ DIORITE/GRANODIORITE - UNIT 7A*

Other Late Triassic to Early Jurassic plutons include the granodiorite, quartz monzonite and quartz diorite intrusions of the Takomkane batholith that crop out to the south of Horsefly village (Campbell, 1978) and in the adjoining Bonaparte Lake map area to the south (Campbell and Tipper, 1971). The rocks a few kilometres south of Horsefly are grey medium-grained, equigranular to weakly porphyritic quartz diorite. Plagioclase grains up to 5 millimetres in size constitute about 55% of the rock. The fine granular groundmass is made up of approximately 15% quartz, 10% hornblende and roughly the same amount of orthoclase. Epidote, chlorite and calcite extensively replace the hornblende. At the Megabuck property these rocks are hydrothermally altered and cut by quartz veinlets. The altered rocks contain epidote, sulphide minerals, magnetite, and locally clay minerals, sericite and black tourmaline.

A second intrusion, possibly belonging to this subunit, is a crumbly and rusty weathering, medium-grained quartz diorite exposed in a single road cut 2.5 kilometres to the northwest of Shiko Lake.

## *QUARTZ MONZONITE/ALASKITE - UNIT 8*

Quartz-bearing rocks with calcalkaline compositions form stocks of medium to coarse-grained granodiorite, quartz monzonite and minor alaskite. These rocks occur in the large Nyland Lake stock, the smaller Gavin Lake stock and dike complex and a number of small, unnamed quartz-bearing dikes 7 kilometres to the southeast of Gavin Lake. The rocks are most commonly pale grey, medium-grained quartz monzonite which in places ranges from fine-grained quartz monzonite to porphyritic alaskite. They are considered to be of Cretaceous age (Bailey, 1978) and possibly equivalent to the Naver Plutonic Suite of the northern Quesnel Trough.

# CHAPTER 4

# AGE OF MAP UNITS - PALEONTOLOGY AND GEOCHRONOLOGY

The ages and correlations of lithologies were established by studies of macrofossils and microfossils from sedimentary rocks and radiometric dates from igneous rocks (Figure 4-1). Thirty-six samples from beds of limestone and silty limestone to calcareous siltstone were collected for conodont extraction. The samples were dissolved in acetic acid; the sieved, dried residue was examined and conodonts were identified by M.J. Orchard, Geological Survey of Canada. Three samples taken for palynology were examined and reported on by G.E. Rouse of the University of British Columbia. Twenty sites in which macrofossils were discovered were sampled and the collections submitted to H.W. Tipper for study or referral to T.P. Poulton and E.T. Tozer, all with the Geological Survey of Canada. Two of the fossil sites located to the south of Quesnel Lake (C-117285 and C-117286) were resampled by Tipper and later reported on to the authors. All site locations and other data are given in Appendices B, C, D and E. Radiometric dating on mineral separates of hornblende and biotite was performed at the University of British Columbia Geochronology Laboratory. Thirteen new K-Ar age determinations from rocks of the various intrusive and volcanic units are reported in Table 4-1 and shown on Figure 4-2.

## MICROFOSSILS

### *CONODONTS*

Six samples, all from unit 1, yielded conodonts. Key taxa identified are: *Chiosella timorensis* of early Anisian age, *Neogondolella constricta* of late Anisian-early Ladinian age, *Metapolygnathus ex gr. nodosus* of late Carnian age, and *Epigondolella sp.* of Norian age (Orchard, in Appendices B, C). In addition, a number of the samples contained ramiform elements and indeterminate ichthyoliths, shell fragments, worm tubes and a single, nondiagnostic

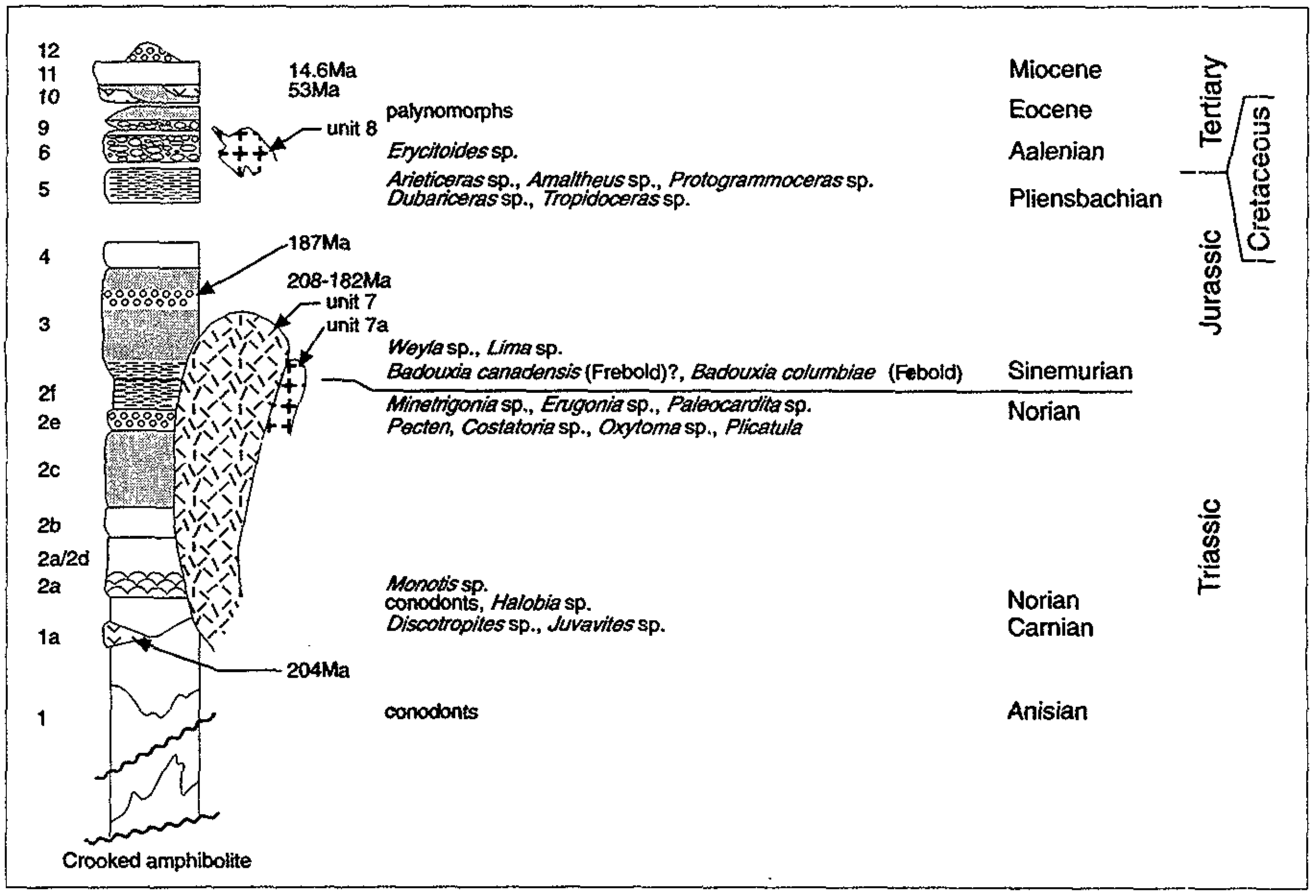



Figure 4-1. Central Quesnel belt time-stratigraphic units with diagnostic fossils and radiometric ages.

**TABLE 4-1**
**RADIOMETRIC AGE DETERMINATIONS;**
**POTASSIUM-ARGON ANALYTICAL DATA, THIS STUDY AND OTHERS**

| Sample Number | Location (UTM) | Lithology | Material Analysed | % K | $Ar^{40*}$ ($10^{-10}$) (moles/g) | $Ar^{40*}$ / Total $Ar^{40}$ | Apparent Age (Ma) |
|---|---|---|---|---|---|---|---|
| 1. 88AP4/8-12 | 629000<br>5802300 | Horsefly Mountain stock<br>diorite | hornblende | 0.918 | 3.507 | 94.3 | 208±6 |
| 2. 88AP25/1-76 | 624800<br>5810200 | Viewland Mountain breccia<br>hornblende porphyry clast | hornblende | 1.01 | 3.792 | 90.7 | 204±7 |
| 3. DB-87-2 | 591300<br>5819650 | Bootjack stock<br>nepheline syenite | hornblende | $^{40}Ar/^{39}Ar$ plateau age (Bailey and Archibald, 1990) | | | 203.1 ±2.0 |
| 4. 85AP21/2-120 | 581450<br>5835300 | QR stock<br>diorite | biotite<br>(chloritized) | 3.95 | 14.565 | 95.2 | 201±7 |
| 5. 85AP7/2-63 | 603750<br>5812800 | Shiko stock<br>hornblende porphyry dike | hornblende | 0.828 | 2.067 | 91.8 | 196±7 |
| 6. 85AP8/1-64 | 603550<br>5813000 | Shiko stock<br>monzonite core zone | biotite | 4.67 | 16.408 | 86.7 | 192±10 |
| 7. 85AP8/1-64 | 603550<br>5813000 | Shiko stock<br>monzonite core zone | biotite | 4.94 | 16.408 | 86.7 | 182±6 |
| 8. 85AP8/9-71 | 591900<br>5831900 | Bullion Pit stock<br>diorite | biotite | 5.4 | 19.037 | 87.7 | 193±7 |
| 9. | 617600<br>5860750 | Lemon Lake stock<br>monzodiorite | no analytical data, 187±Ma age reported by Pilcher and McDougall (1976); age recalculated with new constants | | | | 192 |
| 10. | 592050<br>5822850 | Mount Polley stock<br>Cariboo-Bell deposit | hydrothermal biotite (Hodgson *et al.,* 1976) reported as 184±7 Ma; recalculated using constants from Steiger and Jäger (1977) | | | | 188±7 |
| 11. DB88-03 | 546800<br>5881500 | Cottonwood River stock<br>pyroxene hornblende gabbro | hornblende | 1.98 | 6.776 | 91.2 | 187±7 |
| 12. 87AP6/3-16 | 605670<br>5799080 | Unit 3<br>hornblende porphyry flow or dike | hornblende | 0.642 ±0.240 | 2.181 | 97.2 | 186±7 |
| 13. 86AP20/6-64 | 611250<br>5806000 | Kwun stock<br>biotite monzonite | biotite | 5.00 | 16.932 | 89.8 | 185±6 |
| 14. 88AP11/5-36 | 581500<br>5811000 | Unit 10C<br>biotite lamprophyre dike | biotite | 6.08 | 5.702 | 72.6 | 53.3±1.7 |
| 15. 87AP3/1-4 | 603440<br>5799080 | Unit 10A<br>biotite trachyandesite flow | biotite | 7.250 ±0.020 | 6.662 | 93.2 | 52.2±1.8 |
| 16. 87AP18/8-44 | 601710<br>5797170 | Unit 11<br>plateau basalt | whole rock | 0.722 ±0.008 | 0.1838 | 33.4 | 14.6±0.5 |
| 17. 87MAB35632 | 610300<br>5831525 | Frasergold quartz vein | sericite | 872±0.10 | 23.759 | 91.3 | 151±5 |

*Sample numbers refer to Figure 4-3; locations are shown on Figure 4-2.*

*% K determined by the Analytical Laboratory, British Columbia Ministry of Energy, Mines and Petroleum Resources, Victoria.*
*Ar determination and age calculation by J.E. Harakal, The University of British Columbia, except where noted. * denotes radiogenic Ar.*
*Constants:* $^{40}K_{\lambda\varepsilon}=0.581x10^{-10}yr^{-1}$; $^{40}K_{\lambda\varepsilon}=4.962x10^{-10}yr^{-1}$; $^{40}K/K=0.01167$ *atom per cent; errors are 1* $\sigma$

*U-Pb dates for the Mount Polley and Bootjack stocks reported by J.K. Mortensen, written communication (1994), from ongoing studies at the Mineral Deposit Research Unit (MDRU), The University of British Columbia; 201.7±0.4, 203.4±6.0, 202.7±7.1 (zircon); 200.8±1.8 (titanite isochron)*

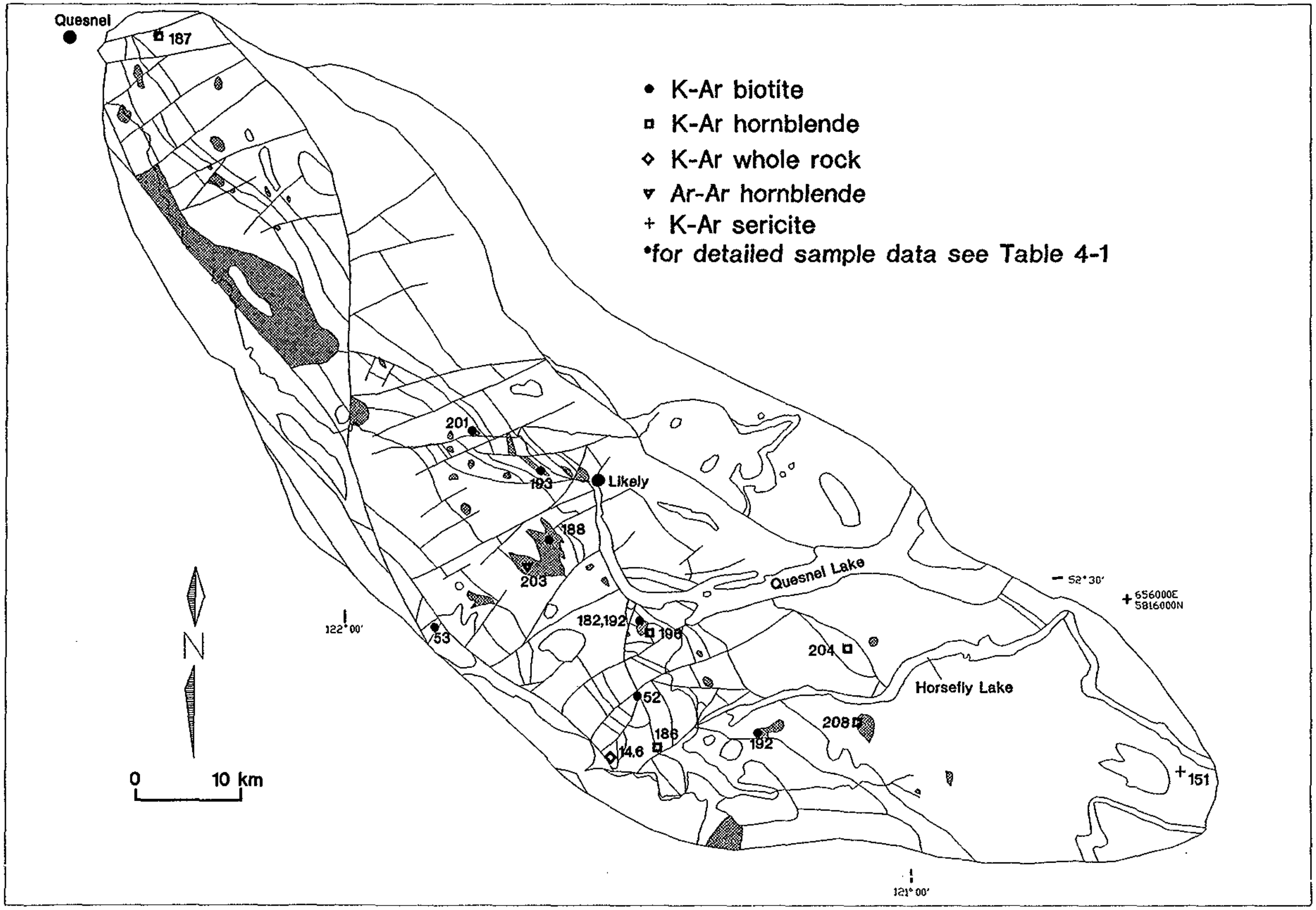



Figure 4-2. Generalized geological map with radiometric dating sample sites; this project, age in Ma.

formaniferid (Appendices B, C). Three samples from unit 2a were barren.

The presence of Middle Triassic (Anisian) fauna in rocks overlying younger rocks near Spanish Lake is interpeted by Struik (1986, 1988a) to be due to thrusting within the metasedimentary succession of unit 1. Bloodgood's work in the area supports Struik's interpretation for the Spanish Lake area but the existence of similar relationships throughout the region is not demonstrable.

The colour and preservation state of the conodonts, as indicated by the colour alteration index (CAI) of Epstein *et al.* (1977), shows a consistent relationship with stratigraphic position and increasing metamorphic grade within the metasedimentary succession (*see* Chapter 6). The least metamorphosed, subgreenschist, zeolite to prehnite-pumpellyite grade volcanic rocks of the central Quesnel belt have a CAI of 2.5 to 3.5 in the contained Norian sediments. The underlying sedimentary rocks have CAI from 3.5 to 4.5 at the top of the succession (unit 1) and 4.5 to 5.5 in the deeper and structurally more disrupted older parts of the Quesnel belt.

### *PALYNOMORPHS*

Three samples from the Tertiary, lacustrine, varved sedimentary beds of unit 10 were submitted for palynological analysis. They include two from the area of waterfalls on the Horsefly River known as The Steps, 7 kilometres downstream from Horsefly village, and one from Hazeltine Creek near its mouth at Quesnel Lake. The samples were examined by G.E. Rouse at The University of British Columbia. He confirms the presence of a mid-Eocene assemblage of angiosperm pollen, conifer pollen, fungal spores, algal cysts and fern glochidia. Diagnostic palynomorphs are: *Pistillipollenites mcgregorii, Sabal granopollenites, Ailanthipites berryi, Granatisporites cotalus, Rhizophagites cerasiformis, Rhoipites retipillatus, Araliaceoipollenites granulatus, Pluricellaesporites, Multicellaesporites* -6, *Tetracellaesporites* sp., *Diporisporites* sp., and glochidia of the water fern *Azolla*. A list of all palynomorphs documented is given in Appendix D.

The overall assemblage represents a mixed mesophytic forest, similar to present forests of southeast North America and central China. Temperatures were warm, bordering on subtropical, and precipitation was much greater than present amounts. The presence of *Lejeunia* algal cysts confirms aquatic, probably lacustrine deposition. The Horsefly River - Hazeltine Creek assemblage of unit 10 is correlative with other mid-Eocene assemblages between 48 and 52 Ma in age, equivalent to rocks of the Kamloops Group. The Horsefly River sample site at The Steps also contains abundant fossil plants and lesser fish and insects.

## MACROFOSSILS

Extensive collections of fauna collected at various times in the Quesnel Lake area, notably from outcrops and placer mine workings on Morehead Creek and other nearby areas, are in the repository of the Geological Survey of Canada. Much of the site data and identifications are listed in Appendix E and have been utilized by Campbell (1978) in preparation of his Quesnel Lake 1:125 000 geological map. New collections and identifications from this project, and some older data, are contained in Appendix E and summarized on Figure 4-1; these data, and other information, are have been reported by H.W. Tipper (written communications, Report J1-1993-HWT, 1993, and older reports).

Unit 1, in addition to conodonts, contains beds near the top of the succession with *Halobia*. This fauna, and possibly *Monotis*, is also found in rocks of unit 2, mainly in small lenses of reefoid limestone and limestone-cemented basalt breccias. The top of the basalt succession is marked locally by fetid beds with a trigonid-bearing, rich shelly faunal accumulation. The Sinemurian rocks of unit 3 contain the diagnostic ammonites *Badouxia canadense* and *Badouxia columbiae* of the Early Jurassic, lower Sinemurian, Canadensis Zone, as well as the bibalve, *Weyla*. Badouxia has been referred to in some earlier reports as Psiloceras (Caloceras) canadense. The presence of both Pliensbachian and Aalenian clastic assemblages is documented by a number of ammonites including Arieticeras, Amaltheus and Erycitoides. Tertiary rocks and conglomerate of unit 9 of possible Cretaceous age commonly contain abundant wood debris and plant fragments, but none collected are diagnostic.

Palynormorphs, fossil fish and insects are characterisitic of the Middle Eocene varves of unit 10. The Horsefly River sample site at The Steps is also a type locality for Eocene fossil fish, including Amyzon aggregatum, and other fossil materials described by Wilson (1977a, b; 1984). The Amyzon was a fresh-water lake fish related to the living buffalo fishes and suckers. Fossil insects collected by R.B. Campbell (GSC Catalogue No. 20 and 22) and described by H.M.A. Rice (Report No. Misc. 1 60/61 HMAR, H.W. Tipper, written communication, 1993) contain a variety of well-preserved Diptera, Hymenoptera and Hemiptera similar to those from other Tertiary basins in the province. The most common species are Plecia pictipennis (Hanlirsch) (March fly) and Plecia similkameena Scudder, among others, all indicative of a tropical or semitropical climate.

## RADIOMETRIC DATES

The thirteen K-Ar ages, a single Ar-Ar date and other data generated by this study are listed in Table 4-1. Sample locations and the stratigraphic relationships of dated lithologic units are shown on Figures 4-2 and 4-3. Radiometric ages of the diorite to monzonite stocks range from 208 to 182 Ma (Norian/Hettangian to Toarcian) with a mean of 193 Ma (Pliensbachian), on the time scale of Harland *et al.* (1990). A mean age of 196 Ma (late Sinemurian) is obtained from the hornblende dates, and 190 Ma (late Pliensbachian) from the biotite analyses. Recent U-Pb dating using zircons (Ghosh, 1993; Mortensen, 1994) provide 4 dates around 202 Ma from the Mount Polley and Bootjack stocks that are

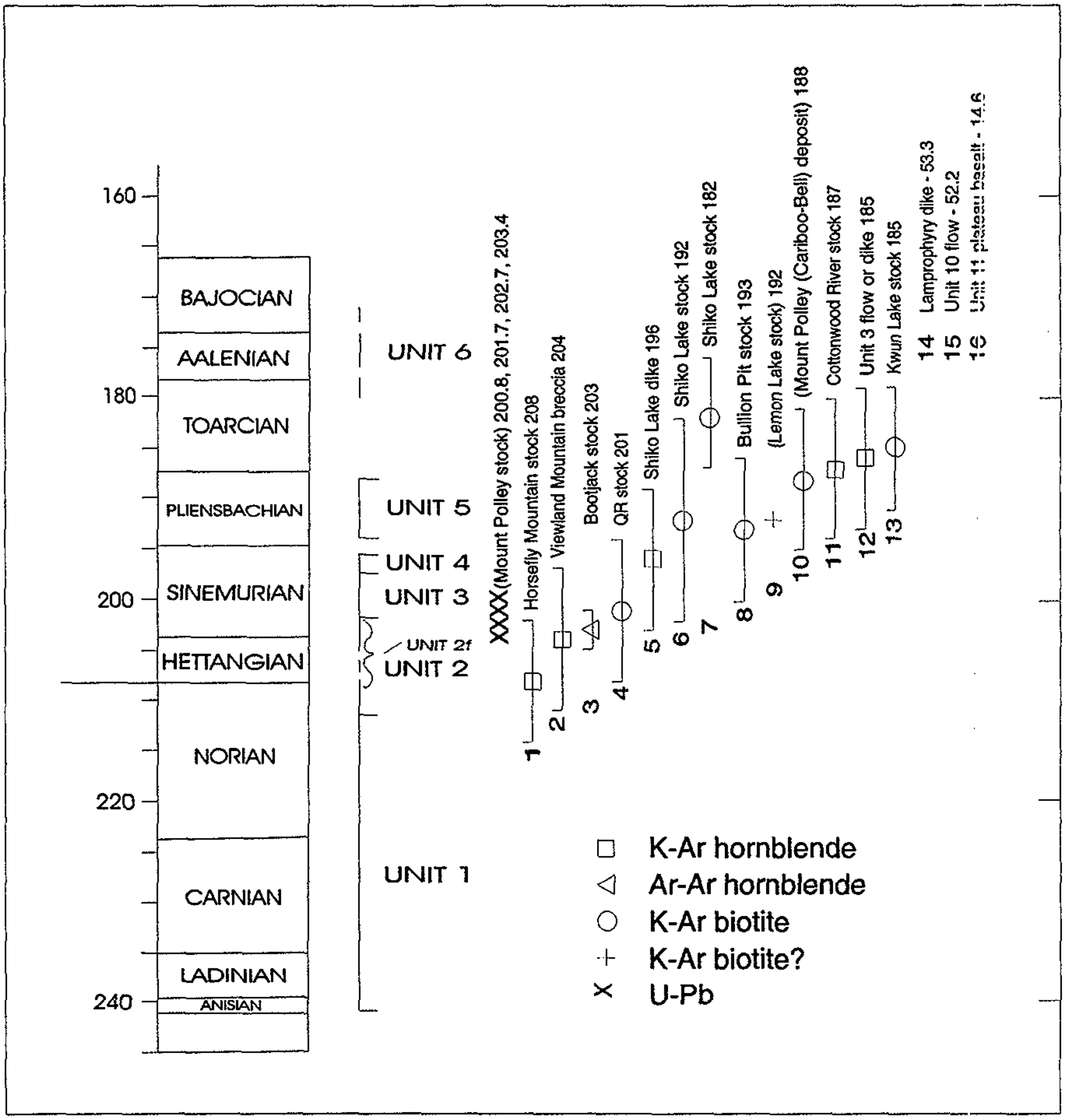



Figure 4-3. K-Ar radiometric ages and stratigraphic relationships of alkalic stocks and other dated rocks of the central Quesnel belt. Data in brackets from other studies; numbers refer to data in Table 4-1. Time scale is that of Harland *et al.* (1990).

considered to be the age of intrusion. These are close to the 203 Ma Ar-Ar date of the Bootjack stock reported by Bailey and Archibald (1990). An interpretation of these data is that the age of intrusive emplacement was around 200 Ma and the younger dates represent a loss of argon due to thermal effects, probably during late deuteric activity or hydrothermal alteration. The only volcanic arc rock dated is a weakly zeolitized hornblende porphyry of uncertain flow, dike or subvolcanic plug origin; its 186 Ma age is compatible with its correlation with unit 3.

Mid-Tertiary magmatic activity is confirmed by the 52 Ma date of biotite from latite flows of unit 10a. These rocks have provided the distincitive biotite-bearing clasts and biotite flakes in basal beds of the Eocene lacustrine sedimentary unit. A dike of 53 Ma biotite-bearing 'lamprophyre' that intrudes unit 1 attests to the more widespread presence of Tertiary rocks in the map area. They are probably a manifestation of the widespread, regional extension that took place in central British Columbia during Eocene time.

Miocene and younger volcanic rocks referred to by Mathews (1988) as the Chilcotin Group occur in three groupings according to their age: 14 to 16, 6 to 9 and 1 to 3 Ma. The older rocks form extensive flat-lying flows that cover extensive areas of the interior plateau; the two younger groups of flows fill valleys. The oldest group is represented in the map area by 14.6 Ma basalt flows. The dated rocks overlie thin units of Tertiary sediments (unit 10) and a Miocene channel-filling gravel (unit 11a) at Gravel Creek. Similar basalt flows capping auriferous Miocene gravels occur a short distance away in China Cabin and Moffat creeks. The dated sample is from the same outcrop as specimens with a 12.1 Ma age reported by Mathews (1988). An identical 14.6 Ma age was obtained by him from similar flows at Miocene, 16.5 kilometres to the west. The presence of younger flows near Opheim Lake and MacIntosh Creek, 33 kilometres northwest and 26.5 kilometres south of the dated Gravel Creek site is documented by Mathews. He reports dates of 7.5 and 8.7 Ma, respectively, from those two localities. Rocks of the youngest suite have not been recognized in our map area.

## STRATIGRAPHIC SUMMARY AND FACIES RELATIONSHIPS

The oldest exposed rocks of Quesnellia in the central Quesnel belt are Middle to Upper Triassic sedimentary rocks of unit 1, which from their composition (Bloodgood 1987) and from that of accompanying tholeiitiic basalts with MORB-like character, were probably deposited in a back-arc, or marginal basin, developed by crustal rifting adjacent to the Triassic margin of continental North America. This sedimentary assemblage which underlies the eastern part of the central Quesnel belt, is also exposed near the western margin of the belt, suggesting that the volcanic arc which formed during Late Triassic - Early Jurassic times is underlain across its width by sedimentary rocks of unit 1. Carnian epiclastic sedimentation was accompanied by the onset of mafic alkalic volcanism (unit 2) which continued into the Norian stage. Eruptive locii were possibly controlled by extensional (listric normal?) faults which developed subparallel to the margins of the belt. Early mafic volcanism occurred under relatively deep-water marine conditions but, with time, the volcanic pile grew to the point where late mafic volcanic products were deposited in shallow water and, in part, probably subaerially.

By late Norian time mafic volcanism had ceased and a period of erosion of the volcanic piles began and was accompanied by epiclastic sedimentation and the development of limestone reefs in intervolcano basins. In Morehead Creek a section of mudstone, siltstone and sandstone contains a Norian Trigoniid fauna in strata which underlie Badouxia beds of Sinemurian age. Elsewhere in the central Quesnel belt, however, the uppermost Norian and Hettangian appears to be marked by a hiatus in volcanism and sedimentation which, in places, may be represented by a slight angular unconformity. A similar relationship exists between Triassic mafic volcanic rocks and overlying, more felsic, volcanic rocks of Early Jurassic age elsewhere in Quesnellia (Nelson *et al.* 1993; Nelson and Bellefontaine, 1996) and in Stikinia (Monger, *et al.*, 1978); Logan and Koyanagi, 1994).

Earliest Jurassic volcanism (unit 3) probably began during the Sinemurian and, unlike Late Triassic volcanism, occurred from discrete volcanic centres. Products of Early Jurassic volcanism are trachyandesitic to latitic in composition and were erupted mainly as breccias. Monolithic breccias were deposited close to vent areas whereas polylithic breccias are distal with clasts of the same composition as the surrounding volcanic rocks as well as those of previously deposited underlying rocks. The degree of reworking of the clasts, and the proportion of underlying rocks, increases away from the vent areas, suggesting most polylithic breccias formed as the result of slumping down the sides of the largely submarine Lower Jurassic volcanoes.

Following the eruption and deposition of volcanic rocks of unit 3, a brief period of mafic volcanism recurred (unit 4) and produced alkali olivine basalt flows of limited extent and apparent subaerial origin. While there is no direct evidence of these rocks being younger than Sinemurian, indirect evidence suggests a Pliensbachian age.

Comagmatic and, in part, coeval with Early Jurassic volcanism are a number of dioritic stocks and many small intermediate to felsic intrusions which formed in the vent areas of the volcanoes from which unit 3 volcanic rocks erupted. Cooling ages of these intrusions (Table 4-1) indicate that emplacement began during uppermost Hettangian time but with successively younger phases being emplaced from Sinemurian through to possibly the Toarcian stage of the latest Lower Jurassic, well after volcanism had ceased in the belt.

A period of epiclastic sedimentation within restricted basins followed the cessation of volcanism in the central Quesnel belt. These sedimentary rocks, dominantly siltstone and fine-grained sandstone and containing a Middle Jurassic fauna, formed an overlap assemblage which now is preserved in the eastern and western parts of the belt.

Further sedimentation in lacustrine settings and volcanism occurred during a period of Eocene crustal extension, and which was followed by the widespread eruption of plateau basalts of Miocene and, locally, younger age.

# CHAPTER 5 PETROCHEMISTRY

## INTRODUCTION

Representative samples of igneous rocks, 84 in all, were analyzed for major oxide and minor element compositions by standard, commercially available, combined x-ray fluorescence, atomic absorption spectophotommetry and neutron activation techniques in order to characterize their chemical compositions. The sample suite consists of 59 of the least altered looking rocks collected during this study from the various, mainly volcanic, map units. The remaining data represent suitable samples from previous studies in the map area, including twenty-two analyses by Bailey (1978) and three by Morton (1976). The loss on ignition (LOI) from these samples is generally in the order of 3%, or less. In addition, 29 analyses by Bloodgood (1987) from rocks of unit 1a have been included in this study. The data are presented in Appendices F to L. The analytical data are summarized as average values for the various map units in Tables 5-1, 5-2 and 5-3. All the analytical data are documented in the appendices, including: sample locations and descriptions (Appendix F); major oxide and minor element analyses (Appendices G, I, J); replicate analyses (Appendix H); comparison of analyzed and calculated ferrous-ferric values (Appendix L); and calculated CIPW norms (Appendix K). The data can be compared with, or expanded to include, an additional 38 analyses by Bailey (1978) and 43 analyses reported by Morton (1976). Further comparisons can be made with similar rocks in British Columbia, the Nicola volcanics to the south (Preto, 1979) and Takla rocks to the north (Barrie, 1993; Nelson and Bellefontaine, 1996). Comparable Triassic - Jurassic volcanic arc rocks elsewhere in the North American Cordillera are discussed by Mortimer (1986, 1987).

Variations in composition between samples are evident; their range within map units is indicated by the standard deviations of mean values, as shown in Tables 5-1, 5-2 and 5-3. Differences are generally greater between map units than between samples of the same unit. This allows the recognition of map units and their correlation on the basis of composition. Differences are regular and continuous between the map units, as shown on various variation diagrams, and are consistent with processes of magmatic differentiation and crystal fractionation. The post-depositional oxidation and related changes from ferrous to ferric iron are considered to be consistent throughout the region. The manner in which ferrous/ferric ratios were established is discussed below. The effects of local metasomatism, mainly by potassium and sodium, are not evident in thin section or in staining tests and are, hopefully, negligable in the selected least-altered samples. Nonetheless it is possible that some sodium was introduced by the interaction between the island arc rocks and seawater.

The major oxide data are regarded as high quality and appear to be reliable and reproducible. Analytical results compared by paired replicate analyses and the precision of major oxide analyses quoted by the Geological Survey Branch Analytical Laboratory are shown in Appendix H. Minor element analyses, on the other hand, show much variability due to both differences between samples from the same map unit and inherent problems with analytical accuracy and precision. Minor element data used and recorded in Table 5-2 are the mean arithmetic values that represent a composite of various numbers and types of analyses from different laboratories. In general, elements with consistent concentrations in the samples analyzed by x-ray flourescence methods (XRF - barium, strontium, rubidium, yttrium, titanium, vanadium and probably zirconium) have sufficient accuracy and precision to adequately demonstrate major differences between the map units. Elements determined by instrumentation neutron activation (INAA - rare earth and some large-ion lithophile elements, scandium and terbium) should be regarded as approximate, especially because no comparisons to higher precision atomic absorption or x-ray fluorescence analyses have been made. Analytical results for niobium, neodinium, tantalum and probably uranium and thorium are suspect, as are any values near the analytical detection limits of the elements (shown in Table 5-2).

## CHEMICAL COMPOSITIONS, DIFFERENTIATION TRENDS, CIPW NORMS AND PETROCHEMCIAL CLASSIFICATIONS

### *PETROCHEMICAL VARIATION*

Analytical data (Appendices G to I) were assembled in dBase file format and processed by computer to produce various calculations and plots. The data for the various map units are summarized in Tables 5-1 and 5-2 as mean values, with standard deviations. Most plots shown on figures use unit-mean values to illustrate chemical trends and relationships in a simpified manner; a few plots utilize all analytical values in order to show the scatter and more detail of the data distribution. The computer program used to initially reduce and study the data is the *GSB* petrochemical program developed within the Geological Survey Branch by D.G. MacIntyre. Final calculations and graphic output is from *NEWPET*, a petrochemical shareware program developed 1987 to 1991 by Daryl Clark, Memorial University of Newfoundland.

Crystal-liquid fractionation processes in Quesnel basaltic arc magmas can be illustrated by any number of Harker-type variation diagrams that depict fractionation indices (Cox *et al.*, 1979). Bailey (1978) effectively utilized the

## TABLE 5-1
## AVERAGE MAJOR OXIDE COMPOSITIONS

| MAP UNIT | *N | $SiO_2$ | $TiO_2$ | $Al_2O_3$ | FeO_T | MnO | MgO | CaO | $Na_2O$ | $K_2O$ | $P_2O_5$ | FeO | $Fe_2O_3$ | LOI | Total | $CO_2$ | K (ppm) | DIF INDEX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1A | 1 | 46.92 | 0.75 | 16.64 | 8.39 | 0.18 | 5.68 | 13.06 | 1.76 | 1.32 | 0.22 | 5.52 | 2.25 | 5.28 | 100.20 | 1.81 | 10958 | 24.1 |
| 2A | 13 | 47.70 | 0.66 | 13.17 | 10.47 | 0.19 | 7.70 | 11.23 | 2.54 | 2.09 | 0.34 | 7.48 | 2.16 | 3.43 | 99.52 | 0.64 | 17350 | 32.7 |
| 2A | SD | 1.26 | 0.11 | 2.53 | 1.19 | 0.02 | 2.33 | 2.37 | 1.28 | 1.52 | 0.12 | 1.08 | 0.11 | 0.94 | --- | 0.81 | — | --- |
| 2A/2D | 5 | 50.33 | 0.73 | 15.99 | 9.88 | 0.17 | 5.62 | 8.05 | 3.33 | 2.07 | 0.31 | 6.88 | 2.23 | 3.00 | 99.48 | 0.32 | 17184 | 42.2 |
| 2A/2D | SD | 1.21 | 0.12 | 0.31 | 1.22 | 0.02 | 0.46 | 0.66 | 0.32 | 0.56 | 0.04 | 1.07 | 0.12 | 0.06 | --- | 0.14 | — | --- |
| 2B | 16 | 47.51 | 0.70 | 13.04 | 11.27 | 0.20 | 7.47 | 10.29 | 2.97 | 2.61 | 0.57 | 8.08 | 2.20 | 3.24 | 99.87 | 0.30 | 21667 | 37.2 |
| 2B | SD | 1.10 | 0.08 | 1.75 | 1.27 | 0.03 | 1.77 | 1.99 | 1.15 | 1.51 | 0.10 | 1.03 | 0.08 | 0.83 | --- | 0.35 | --- | --- |
| 2C | 5 | 49.03 | 0.78 | 16.59 | 10.12 | 0.21 | 5.02 | 8.60 | 4.02 | 2.55 | 0.47 | 6.92 | 2.28 | 2.95 | 100.34 | 0.22 | 21169 | 45.6 |
| 2C | SD | 2.06 | 0.14 | 1.88 | 1.12 | 0.03 | 1.79 | 2.43 | 1.32 | 1.55 | 0.07 | 1.03 | 0.14 | 0.99 | --- | 0.30 | --- | --- |
| 2D | 4 | 48.05 | 0.73 | 12.51 | 11.83 | 0.22 | 9.25 | 10.41 | 2.78 | 1.85 | 0.39 | 8.51 | 2.23 | 2.83 | 100.85 | 0.02 | 15358 | 32.8 |
| 2D | SD | 1.61 | 0.18 | 3.14 | 1.71 | 0.02 | 3.08 | 2.98 | 1.17 | 1.00 | 0.13 | 1.31 | 0.18 | 1.40 | --- | 0.03 | --- | --- |
| 2E | 4 | 48.36 | 0.74 | 15.71 | 9.72 | 0.21 | 4.77 | 7.33 | 4.09 | 3.40 | 0.53 | 6.96 | 2.13 | 4.66 | 99.52 | 0.24 | 28225 | 51.1 |
| 2E | SD | 2.57 | 0.08 | 2.29 | 2.05 | 0.02 | 1.54 | 2.95 | 1.03 | 1.55 | 0.10 | 1.97 | 0.08 | 1.37 | --- | 0.16 | --- | --- |
| 2G | 3 | 52.55 | 0.65 | 16.76 | 8.37 | 0.19 | 4.68 | 7.42 | 3.72 | 2.27 | 0.35 | 5.60 | 2.15 | 2.45 | 99.41 | 0.04 | 18844 | 46.6 |
| 2G | SD | 3.90 | 0.11 | 0.54 | 1.37 | 0.05 | 0.79 | 3.27 | 1.21 | 1.83 | 0.19 | 1.15 | 0.11 | 0.23 | --- | 0.06 | --- | --- |
| 3 | 3 | 53.92 | 0.65 | 17.39 | 7.20 | 0.19 | 2.26 | 5.76 | 5.09 | 3.44 | 0.34 | 4.54 | 2.15 | 3.32 | 99.56 | 0.99 | 28557 | 64.2 |
| 3 | SD | 4.56 | 0.17 | 1.14 | 1.75 | 0.05 | 1.25 | 2.35 | 2.07 | 1.22 | 0.09 | 1.48 | 0.17 | 0.75 | --- | 0.46 | — | --- |
| 3A | 9 | 50.82 | 0.82 | 17.36 | 9.94 | 0.22 | 3.81 | 7.05 | 4.65 | 2.97 | 0.40 | 6.29 | 2.32 | 3.04 | 101.08 | 0.07 | 24655 | 53.9 |
| 3A | SD | 3.26 | 0.13 | 2.02 | 1.61 | 0.02 | 1.11 | 1.71 | 0.76 | 0.91 | 0.12 | 1.33 | 0.13 | 1.13 | --- | 0.00 | --- | --- |
| 3B | 2 | 48.80 | 0.85 | 18.45 | 10.59 | 0.18 | 4.29 | 7.67 | 3.14 | 3.60 | 0.30 | 7.17 | 2.35 | 3.37 | 101.24 | 0.16 | 29885 | 46.1 |
| 3B | SD | 2.40 | 0.04 | 0.07 | 1.70 | 0.09 | 1.08 | 1.48 | 1.64 | 0.46 | 0.01 | 1.58 | 0.04 | 0.70 | --- | 0.00 | --- | --- |
| 4 | 3 | 48.93 | 0.83 | 15.92 | 11.64 | 0.20 | 4.78 | 8.08 | 4.42 | 2.17 | 0.48 | 8.22 | 2.33 | 3.51 | 100.96 | 0.16 | 18014 | 46.7 |
| 4 | SD | 1.31 | 0.11 | 1.50 | 1.04 | 0.03 | 0.89 | 0.28 | 0.42 | 1.17 | 0.08 | 0.82 | 0.11 | 0.50 | --- | 0.00 | --- | --- |
| 7 | 10 | 51.00 | 0.79 | 16.05 | 9.56 | 0.18 | 5.24 | 9.26 | 3.01 | 2.60 | 0.37 | 6.52 | 2.29 | 1.78 | 99.84 | 0.25 | 21584 | 42.0 |
| 7 | SD | 2.80 | 0.19 | 2.57 | 1.70 | 0.04 | 2.30 | 1.83 | 0.74 | 0.61 | 0.08 | 1.43 | 0.19 | 0.71 | --- | 0.34 | --- | --- |
| 8 | 2 | 57.01 | 0.84 | 15.34 | 7.78 | 0.13 | 4.33 | 5.48 | 4.41 | 1.29 | 0.18 | 4.90 | 2.33 | 2.98 | 99.77 | 0.65 | 10709 | 54.7 |
| 8 | SD | 3.85 | 0.29 | 2.00 | 2.68 | 0.01 | 0.70 | 0.60 | 0.50 | 1.29 | 0.06 | 2.16 | 0.29 | 0.06 | --- | 0.69 | --- | --- |
| 10 | 2 | 54.91 | 0.71 | 14.71 | 5.57 | 0.15 | 3.29 | 6.32 | 3.43 | 3.30 | 0.48 | 3.03 | 2.21 | 6.49 | 99.36 | 4.65 | 27395 | 59.8 |
| 10 | SD | 5.20 | 0.42 | 4.01 | 0.37 | 0.06 | 3.03 | 0.93 | 0.81 | 1.42 | 0.42 | 0.05 | 0.42 | 3.18 | --- | 4.07 | --- | — |
| 10C | 1 | 45.54 | 1.11 | 11.43 | 9.11 | 0.16 | 8.86 | 8.77 | 2.63 | 0.96 | 0.89 | 5.85 | 2.61 | 8.94 | 98.40 | 5.60 | 7969 | 31.4 |
| 11 | 1 | 48.55 | 2.04 | 13.06 | 12.71 | 0.17 | 8.43 | 8.92 | 2.91 | 0.77 | 0.33 | 8.25 | 3.54 | 1.88 | 99.77 | 1.71 | 6392 | 30.1 |
| MAB 1A | 29 | 49.84 | 0.68 | 13.78 | 11.23 | 0.19 | 9.65 | 10.43 | 2.10 | 1.73 | 0.35 | 8.14 | 2.18 | 0.00 | 99.98 | 0.00 | 14359 | 28.3 |
| MAB 1A | SD | 3.00 | 0.17 | 1.77 | 1.55 | 0.04 | 3.72 | 2.59 | 1.43 | 0.95 | 0.08 | 0.00 | 0.00 | 0.00 | --- | 0.00 | --- | --- |
| 2A to E | 47 | 48.14 | 0.70 | 13.95 | 10.70 | 0.20 | 7.00 | 9.89 | 3.08 | 2.40 | 0.45 | 7.60 | 2.20 | 3.33 | 99.84 | 0.36 | 19945 | 38.4 |
| 2A to E | SD | 1.58 | 0.11 | 2.13 | 1.33 | 0.03 | 1.93 | 2.30 | 1.14 | 1.40 | 0.12 | 1.15 | 0.11 | 0.93 | --- | 0.43 | --- | --- |
| 3/3A/3B | 14 | 51.20 | 0.79 | 17.52 | 9.19 | 0.21 | 3.55 | 6.86 | 4.53 | 3.16 | 0.37 | 6.04 | 2.29 | 3.15 | 100.53 | 0.99 | 26275 | 55.0 |
| 3/3A/3B | SD | 3.59 | 0.15 | 1.69 | 1.90 | 0.04 | 1.27 | 1.79 | 1.27 | 0.91 | 0.11 | 1.54 | 0.15 | 0.96 | --- | 0.46 | — | --- |

**N is number of analyses: SD refers to standard deviation; DIF INDEX refers to Thornton and Tuttle (1960) differentiation index.*
*84 analyses performed by Geological Survey Branch, Analytical Sciences Laboratory*

## TABLE 5-2
## AVERAGE MINOR ELEMENT COMPOSITIONS

| MAP UNIT | Ba | Ce | Cs | Cr | V | Co | Eu | Hf | La | Lu | Ni | Rb | Sm | Sc | Ta | Tb | Th | U | Yb | Sr | Y | Ti | $TiO_2$ | Nd | Nb | Zr | K | P | DIF INDEX |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1A* | 721 | — | — | 386 | 270 | — | --- | --- | — | — | 141 | 31 | --- | --- | --- | --- | --- | — | 1 | 907 | 18.0 | 4091 | 0.7 | --- | 6.5 | 43 | 14248 | 1504 | 28.10 |
| 2A | 878 | 18 | 31.1 | 296 | 269 | 57 | 0.4 | 0.7 | 9 | 0.2 | 76 | 36 | 3 | 47.3 | 0.1 | 0.6 | 1.1 | 0.5 | 1 | 542 | 14.2 | 3917 | 0.7 | 10.0 | 9.6 | 61 | 17350 | 1484 | 34.00 |
| 2A/2D | 1008 | — | — | 82 | 255 | --- | --- | --- | --- | — | 29 | 32 | --- | --- | --- | --- | --- | --- | --- | 685 | 12.4 | 4373 | 0.7 | --- | 9.0 | 80 | 17184 | 1353 | 46.60 |
| 2B | 922 | 33 | 1.9 | 214 | 260 | 54 | 0.9 | 1.1 | 17 | 0.1 | 41 | 50 | 4 | 32.8 | 0.2 | 0.5 | 2.5 | 1.2 | 1 | 933 | 12.8 | 4237 | 0.7 | 20.0 | 10.4 | 62 | 21663 | 2488 | 37.20 |
| 2C | 865 | 60 | 0.1 | 10 | 195 | 33 | 0.2 | 3.0 | 25 | 0.1 | 9 | 51 | 5 | 10.0 | 2.3 | 0.1 | 2.1 | 1.5 | 1 | 1008 | 21.0 | 4672 | 0.8 | --- | 14.7 | 119 | 21165 | 2051 | 45.60 |
| 2D | 500 | 17 | 2.9 | 705 | 285 | 57 | 0.3 | 1.0 | 7 | 0.2 | 49 | 47 | 2 | 40.3 | 0.1 | — | 1.1 | 0.8 | 2 | 553 | 11.5 | 4399 | 0.7 | 9.0 | 4.5 | 77 | 15355 | 1702 | 32.80 |
| 2E | 1322 | 34 | 0.9 | 43 | 302 | 52 | 0.2 | 2.0 | 14 | 0.1 | 14 | 63 | 4 | 19.6 | 0.6 | 0.1 | 1.8 | 1.4 | 1 | 995 | 15.7 | 4434 | 0.7 | --- | 10.0 | 78 | 28220 | 2313 | 51.10 |
| 2G | 997 | 29 | 3.2 | 221 | 334 | 22 | 1.1 | 1.4 | 14 | 0.4 | 127 | 63 | 4 | 27.8 | 0.1 | 0.7 | 2.0 | 2.2 | 3 | 619 | 21.3 | 3933 | 0.7 | 13.0 | 5.0 | 80 | 18841 | 1527 | 46.60 |
| 3 | 1096 | --- | --- | 10 | 148 | --- | --- | --- | --- | --- | 6 | 56 | — | --- | 1.6 | --- | --- | 16.0 | 4 | 821 | 25.0 | 3917 | 0.8 | --- | 9.7 | 108 | 10707 | 786 | 54.70 |
| 3/3A/3B | 1298 | 34 | 1.0 | 9 | 146 | 30 | 0.2 | 0.2 | 8 | 0.1 | 12 | 56 | 4 | 9.5 | 1.1 | 0.1 | 1.7 | 11.0 | 3 | 751 | 26.3 | 4728 | 0.7 | --- | 9.8 | 114 | 28552 | 1484 | 64.20 |
| 3A | 1500 | 34 | 1.0 | 5 | 143 | 30 | 0.2 | 0.2 | 8 | 0.1 | 27 | 54 | 4 | 9.5 | 0.1 | 0.1 | 1.7 | 1.0 | 1 | 542 | 30.0 | 4918 | 0.8 | — | 10.0 | 132 | 26228 | 1484 | 55.00 |
| 3B | --- | --- | --- | --- | --- | --- | --- | --- | --- | — | --- | --- | --- | --- | --- | --- | --- | --- | — | --- | --- | 5091 | 0.8 | — | — | — | 24651 | 1746 | 53.10 |
| 4 | 1100 | 43 | 0.1 | 5 | 305 | 46 | 0.2 | 2.0 | 17 | 0.1 | 4 | 44 | 4 | 19.0 | 0.1 | 0.1 | 2.4 | 1.5 | 1 | 955 | 16.0 | 4951 | 0.9 | --- | 15.0 | 67 | 29880 | 1309 | 46.10 |
| 8 | 831 | --- | --- | 124 | 164 | --- | --- | --- | --- | --- | 25 | 21 | --- | --- | --- | --- | --- | — | --- | 427 | 23.0 | 5006 | 0.8 | --- | 12.5 | 120 | 18011 | 2095 | 46.70 |
| 7 | 1050 | 25 | 1.5 | 104 | 287 | 46 | 1.0 | 1.2 | 12 | 0.3 | 10 | 64 | 3 | 36.7 | 0.3 | 0.0 | 1.8 | 1.2 | 2 | 751 | 19.4 | 4863 | 0.8 | 13.0 | 5.0 | 66 | 21580 | 1615 | 42.00 |
| 10 | 2800 | — | --- | 170 | 138 | --- | --- | --- | --- | --- | 62 | 73 | — | --- | 1.1 | --- | --- | 16.5 | 5 | 903 | 22.5 | 4254 | 0.7 | --- | 9.0 | 161 | 27390 | 2095 | 59.80 |
| 10C | 5097 | — | — | 520 | 221 | — | --- | --- | — | — | 160 | 20 | --- | — | — | — | — | --- | --- | 1044 | 23.0 | 6655 | 1.1 | — | 9.0 | 164 | 7968 | 3884 | 30.10 |
| 11 | 190 | --- | 10.3 | 297 | 191 | --- | --- | --- | --- | — | 147 | 7 | --- | --- | 0.1 | — | — | 10.0 | 1 | 481 | 22.0 | 12219 | 2.0 | — | 15.0 | 124 | 6391 | 1440 | 31.40 |
| 2A-2E | 935 | 29 | 10.3 | 220 | 272 | 54 | 0.6 | 1.2 | 14 | 0.1 | 48 | 44 | 3 | 34.6 | 0.4 | 0.4 | 1.9 | 1.0 | 1 | 760 | 14.1 | 4240 | 0.7 | 13.8 | 9.9 | 71 | 19962 | 1961 | --- |

*84 analyses; DIF INDEX refers to Thornton and Tuttle, 1960 (major oxide) differentiation index.*
** Unit 1A includes 29 analyses reported by Bloodgood, 1987.*
*Analytical method, detection limit in brackets in ppm; values quoted by analytical laboratory, 1989.*
*XRF - Ba(10), Sr(5), Rb(10), Cr(10), Zr(20), Y(10), Nb(5), V(5), Ti(10),*
*INA - Ce(0.5), Cs(0.5), Eu(0.2), Hf(1), La(2), Lu(0.05), Sm(0.1), Sc(0.2), Ta(0.5), Tb(0.5), Th(0.2), U(0.2), Yb(2), Nd(5)*
*AA - Co(3), Ni(5)*
*XRF and AA analyses: Geological Survey Branch, Analytical Science Laboratory*
*INAA analyses: Bondar-Clegg & Company Ltd., Vancouver, 1988, and/or X-ray Assay Laboratories Ltd, Ontario, 1986*

## TABLE 5-3
## CIPW NORMS FOR MAP UNIT AVERAGE COMPOSITIONS

| | AVE | AVE | AVE | AVE | AVE | AVE | AVE | AVE | AVE | AVE | AVE | AVE | AVE | AVE | AVE | AVE | AVE | AVE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Map Unit | 1A | 2A | 2A/2D | 2B | 2C | 2D | 2E | 2G | 3 | 3A | 3B | 4 | 7 | 8 | 10a | 10b | 10c | 11 |
| OXIDES AS DETERMINED | | | | | | | | | | | | | | | | | | |
| $SiO_2$ | 49.78 | 47.70 | 50.33 | 47.51 | 49.03 | 48.06 | 48.36 | 52.55 | 53.92 | 50.82 | 48.80 | 48.93 | 51.00 | 57.01 | 51.23 | 58.59 | 45.54 | 48.55 |
| $TiO_2$ | 0.69 | 0.66 | 0.73 | 0.70 | 0.78 | 0.73 | 0.74 | 0.65 | 0.65 | 0.82 | 0.85 | 0.83 | 0.79 | 0.84 | 1.01 | 0.41 | 1.11 | 2.04 |
| $Al_2O_3$ | 13.73 | 13.17 | 15.99 | 13.04 | 16.59 | 12.51 | 15.71 | 16.76 | 17.39 | 17.36 | 18.45 | 15.92 | 16.05 | 15.34 | 11.87 | 17.54 | 11.43 | 13.06 |
| $Fe_2O_3$ | 11.23 | 2.16 | 2.23 | 2.20 | 2.28 | 2.23 | 2.24 | 2.15 | 2.15 | 2.32 | 2.35 | 2.33 | 2.29 | 2.34 | 2.51 | 1.91 | 2.61 | 3.54 |
| FeO | — | 7.48 | 6.88 | 8.08 | 6.92 | 8.51 | 6.87 | 5.60 | 4.54 | 6.29 | 7.18 | 8.22 | 6.52 | 4.90 | 2.99 | 3.06 | 5.85 | 8.25 |
| MnO | 0.19 | 0.19 | 0.17 | 0.20 | 0.21 | 0.22 | 0.21 | 0.19 | 0.19 | 0.22 | 0.19 | 0.20 | 0.18 | 0.13 | 0.11 | 0.19 | 0.16 | 0.17 |
| MgO | 9.55 | 7.70 | 5.62 | 7.47 | 5.02 | 9.25 | 4.77 | 4.68 | 2.26 | 3.81 | 4.29 | 4.78 | 5.24 | 4.34 | 5.43 | 1.15 | 8.86 | 8.43 |
| CaO | 10.52 | 11.23 | 8.05 | 10.29 | 8.60 | 10.41 | 7.33 | 7.42 | 5.76 | 7.05 | 7.67 | 8.08 | 9.26 | 5.48 | 6.97 | 5.66 | 8.77 | 8.92 |
| $Na_2O$ | 2.09 | 2.54 | 3.33 | 2.97 | 4.02 | 2.78 | 4.09 | 3.72 | 5.09 | 4.65 | 3.14 | 4.42 | 3.01 | 4.41 | 2.85 | 4.00 | 2.63 | 2.91 |
| $K_2O$ | 1.71 | 2.09 | 2.07 | 2.61 | 2.55 | 1.85 | 3.40 | 2.27 | 3.44 | 2.97 | 3.61 | 2.17 | 2.60 | 1.29 | 4.31 | 2.30 | 0.96 | 0.77 |
| $P_2O_5$ | 0.34 | 0.34 | 0.31 | 0.57 | 0.47 | 0.39 | 0.53 | 0.35 | 0.34 | 0.40 | 0.30 | 0.48 | 0.37 | 0.18 | 0.78 | 0.18 | 0.89 | 0.33 |
| $CO_2$ | 1.81 | 0.64 | 0.32 | 0.30 | 0.22 | 0.02 | 0.24 | 0.04 | 0.99 | 0.07 | 0.00 | 0.16 | 0.23 | 0.66 | 7.53 | 1.77 | 5.60 | 1.71 |
| LOI | 5.28 | 3.43 | 3.00 | 3.24 | 2.95 | 2.84 | 4.66 | 2.45 | 3.32 | 3.04 | 3.37 | 3.51 | 1.78 | 2.98 | 8.74 | 4.24 | 8.94 | 1.88 |
| Total | 99.89 | 98.70 | 98.71 | 98.88 | 99.43 | 99.77 | 98.91 | 98.79 | 99.06 | 99.75 | 100.18 | 99.87 | 99.08 | 99.20 | 98.80 | 99.23 | 97.75 | 98.85 |
| OXIDES RECALCULATED VOLATILE FREE | | | | | | | | | | | | | | | | | | |
| $SiO_2$ | 49.92 | 50.08 | 52.59 | 49.68 | 50.83 | 49.59 | 51.29 | 54.52 | 56.29 | 52.56 | 50.42 | 50.78 | 52.40 | 59.25 | 56.88 | 61.68 | 51.28 | 50.07 |
| $TiO_2$ | 0.69 | 0.69 | 0.76 | 0.73 | 0.81 | 0.76 | 0.79 | 0.68 | 0.69 | 0.85 | 0.88 | 0.86 | 0.81 | 0.87 | 1.12 | 0.43 | 1.25 | 2.10 |
| $Al_2O_3$ | 13.78 | 13.84 | 16.70 | 13.65 | 17.21 | 12.92 | 16.67 | 17.40 | 18.16 | 17.93 | 19.06 | 16.53 | 16.50 | 15.94 | 13.18 | 18.47 | 12.87 | 13.47 |
| $Fe_2O_3$ | 11.24 | 2.27 | 2.33 | 2.30 | 2.36 | 2.30 | 2.38 | 2.23 | 2.25 | 2.40 | 2.43 | 2.42 | 2.35 | 2.43 | 2.79 | 2.01 | 2.94 | 3.65 |
| FeO | ----- | 7.84 | 7.19 | 8.44 | 7.17 | 8.78 | 7.30 | 5.81 | 4.75 | 6.50 | 7.41 | 8.53 | 6.71 | 5.09 | 3.32 | 3.22 | 6.59 | 8.51 |
| MnO | 0.19 | 0.20 | 0.18 | 0.21 | 0.22 | 0.22 | 0.23 | 0.20 | 0.20 | 0.23 | 0.19 | 0.21 | 0.18 | 0.14 | 0.12 | 0.20 | 0.18 | 0.18 |
| MgO | 9.57 | 8.07 | 5.87 | 7.80 | 5.19 | 9.54 | 5.06 | 4.86 | 2.38 | 3.94 | 4.43 | 4.96 | 5.39 | 4.51 | 6.03 | 1.21 | 9.98 | 8.69 |
| CaO | 10.55 | 11.78 | 8.41 | 10.75 | 8.89 | 10.73 | 7.80 | 7.73 | 6.03 | 7.28 | 7.92 | 8.38 | 9.52 | 5.69 | 7.74 | 5.96 | 9.88 | 9.20 |
| $Na_2O$ | 2.09 | 2.67 | 3.47 | 3.10 | 4.18 | 2.86 | 4.35 | 3.85 | 5.31 | 4.81 | 3.25 | 4.58 | 3.09 | 4.58 | 3.16 | 4.21 | 2.96 | 3.00 |
| $K_2O$ | 1.72 | 2.19 | 2.16 | 2.74 | 2.64 | 1.92 | 3.60 | 2.36 | 3.60 | 3.08 | 3.73 | 2.26 | 2.67 | 1.35 | 4.79 | 2.42 | 1.08 | 0.79 |
| $P_2O_5$ | 0.35 | 0.36 | 0.33 | 0.60 | 0.49 | 0.40 | 0.56 | 0.37 | 0.35 | 0.42 | 0.31 | 0.50 | 0.38 | 0.19 | 0.87 | 0.19 | 1.00 | 0.34 |
| Total | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| CIPW NORM VOLATILE FREE | | | | | | | | | | | | | | | | | | |
| Q | 0.19 | 0.00 | 0.74 | 0.00 | 0.00 | 0.00 | 0.00 | 0.37 | 0.00 | 0.48 | 0.00 | 0.00 | 0.99 | 8.06 | 1.50 | 12.99 | 0.00 | 0.00 |
| or | 10.15 | 12.97 | 12.78 | 15.78 | 15.63 | 11.32 | 21.26 | 13.93 | 21.29 | 18.20 | 22.00 | 13.33 | 15.76 | 7.92 | 28.28 | 14.31 | 6.39 | 4.69 |
| ab | *15.73* | *16.41* | *27.49* | *15.10* | 23.89 | *14.74* | 21.74 | *32.55* | *39.50* | *27.85* | *20.25* | *26.98* | *23.11* | *38.73* | *26.77* | *35.62* | *25.05* | *25.38* |
| an | 23.12 | 19.29 | 23.61 | 15.21 | 20.42 | 16.75 | 15.38 | 23.25 | 15.10 | 18.43 | 26.45 | 17.90 | 23.29 | 19.00 | 7.64 | 24.35 | 18.64 | 20.94 |
| ne | 1.07 | 3.36 | 1.03 | 6.05 | 6.19 | 5.14 | 8.13 | 0.00 | 2.91 | 6.78 | 3.92 | 6.38 | 1.64 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| ac | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| di | 21.91 | 29.89 | 13.07 | 27.92 | 16.83 | 27.53 | 16.15 | 10.37 | 10.35 | 12.35 | 8.94 | 16.93 | 17.51 | 6.50 | 19.82 | 3.32 | 19.05 | 18.12 |
| lc | 0.00 | 0.00 | 0.00 | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| hy | 11.83 | 0.20 | 7.97 | 0.00 | 0.00 | 5.72 | 0.00 | 11.69 | 1.57 | 1.31 | 0.00 | 0.00 | 5.53 | 14.24 | 7.84 | 5.27 | 17.52 | 16.73 |
| ol | 9.85 | 12.47 | 7.76 | 13.53 | 10.96 | 13.16 | 11.13 | 2.51 | 3.92 | 8.42 | 12.58 | 12.23 | 6.37 | 0.00 | 0.00 | 0.00 | 4.41 | 4.07 |
| mt | 3.18 | 3.29 | 3.38 | 3.33 | 3.43 | 3.34 | 3.45 | 3.24 | 3.26 | 3.35 | 3.52 | 3.50 | 3.41 | 3.52 | 4.04 | 2.92 | 4.26 | 5.29 |
| il | 1.31 | 1.31 | 1.45 | 1.39 | 1.54 | 1.44 | 1.50 | 1.29 | 1.30 | 1.61 | 1.67 | 1.63 | 1.54 | 1.65 | 2.13 | 0.82 | 2.37 | 4.00 |
| ap | 0.81 | 0.84 | 0.76 | 1.40 | 1.13 | 0.93 | 1.32 | 0.85 | 0.82 | 0.97 | 0.73 | 1.15 | 0.89 | 0.43 | 2.02 | 0.44 | 2.34 | 0.79 |
| AN= | 61.92 | 58.13 | 46.59 | 54.69 | 49.22 | 53.71 | 41.77 | 42.23 | 31.92 | 41.61 | 58.15 | 40.85 | 51.06 | 32.29 | 22.19 | 40.60 | 42.67 | 45.21 |

**CIPW norms calculated by GSB program (Don MacIntyre 1992)*

***Averages (AVE)calculated for 84 analyses plus 29 analyses of unit 1A from Bloodgood, 1987*

****$Fe_2O_3$ values for unit 1A = $Fe_2O_3$ Total*

differentiation index (D.I.) of Thornton and Tuttle (1960) and we continue its use in this report. The differentiation index is expressed as: D.I. = normative $Q + Or + Ab + Ne + Ks + Lc$. Major oxide trends (Figure 5-1) show the least differentiated rocks are basalts of the oldest and youngest basalt units units 1a and 11. The main arc basalts, unit 2, show progressive evolution and increasing differentiation in magmas from earliest to the latest subunits 2a to 2g; the subaerial basalts of unit 4 and the coeval intrusive suite of diorite to syenite are similar. The most differentiated rocks are those of units 3, the younger quartz-bearing intrusions of unit 8 and the Eocene volcanics of unit 10. The differentiation trends of the major oxides are normal and consistent with fractional crystallization. Increases in differentiation index are largely due to increases in $K_2O$, $Na_2O$ and a decrease in CaO (with attendant decreases in FeO* and MgO). Potassium shows considerable variation, especially in the more felsic rocks. Silica, titanium and phosphorus have little variation. The sole exception to simple, continuous trends is alumina which appears to have a bimodal distribution. The two populations show little variation from concentrations either around 13% or 16 to 17%. The larger amounts of alumina are present in units 1a, 7 and the more differentiated subunits of unit 2 compared to rocks of units 2a, 2b, 2d, 10 and 11. The rocks with the greater alumina content tend to contain larger amounts of modal plagioclase and hornblende in addition to ubiquitous pyroxene. These chemical differences are evident in terms of silica saturation as indicated by calculated norm compositions, discussed below.

Minor element concentrations plotted against differentiation index (Figure 5-2) show similar distinctions between the map units. Similar behaviour is shown by barium, rubidium, strontium, yttrium and zirconium which rise in more differentiated rocks, and chromium together with nickel which decrease. Vanadium has two concentration levels -

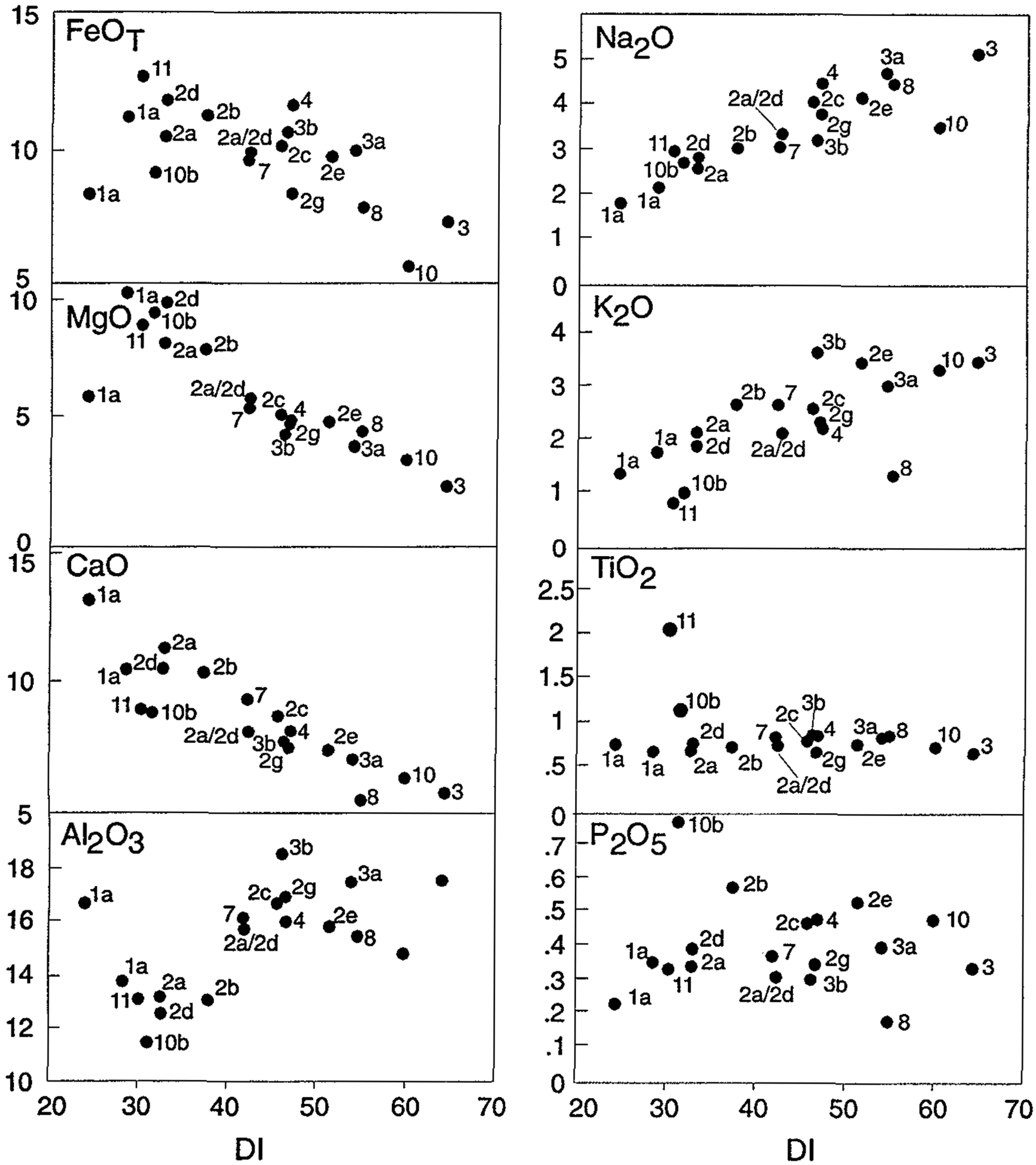



Figure 5-1. Differentiation index (D.I.) of Thornton and Tuttle (1960) with D.I. = normative *Q+Or+Ab+Ne+Ks+Lc* plotted against Quesnel map-unit average major oxide values.

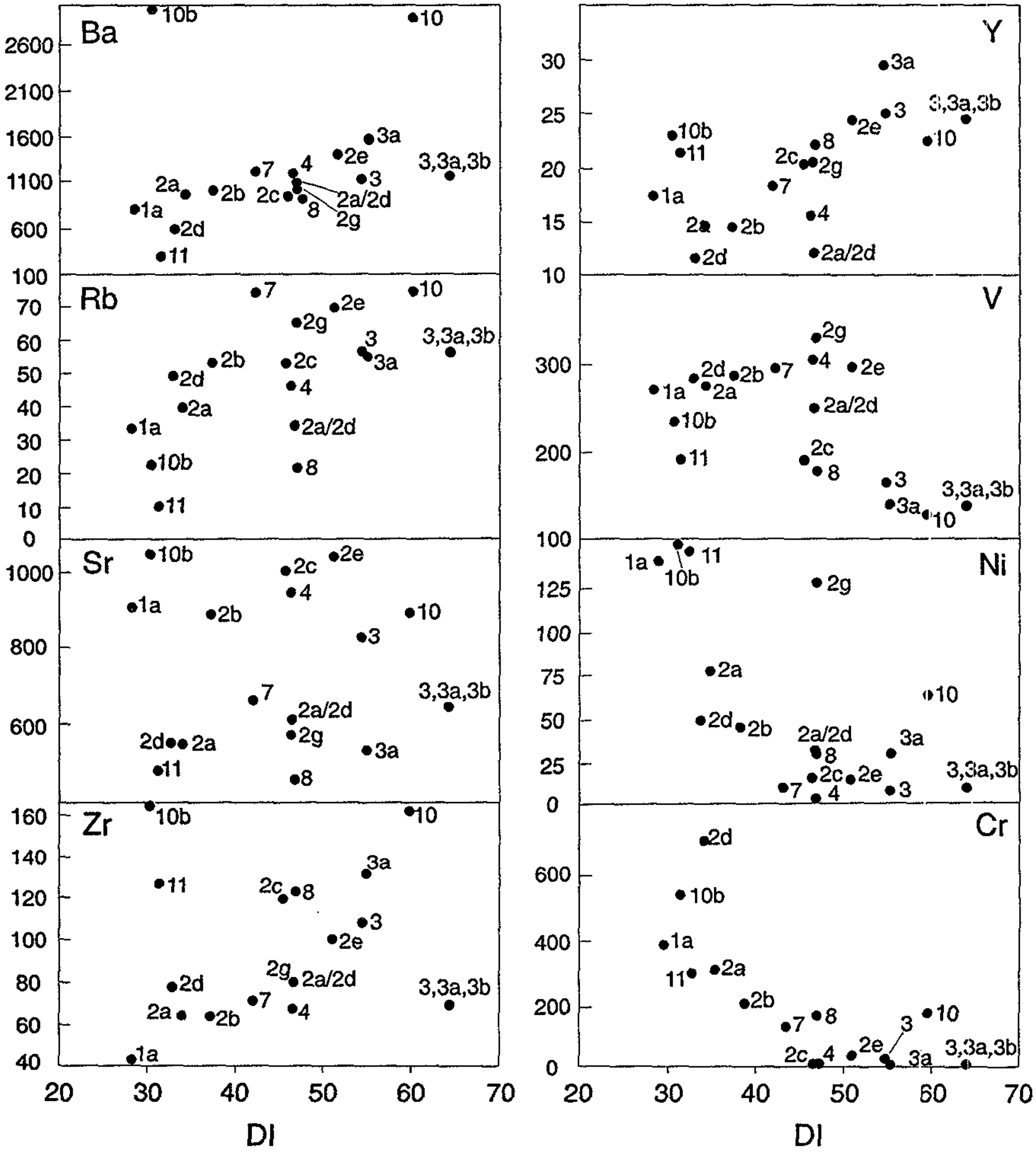



Figure 5-2. Differentiation index (D.I.) of Thornton and Tuttle (1960) with D.I. = normative *Q+Or+Ab+Ne+Ks+Lc* plotted against Quesnel Map-unit average minor element values.

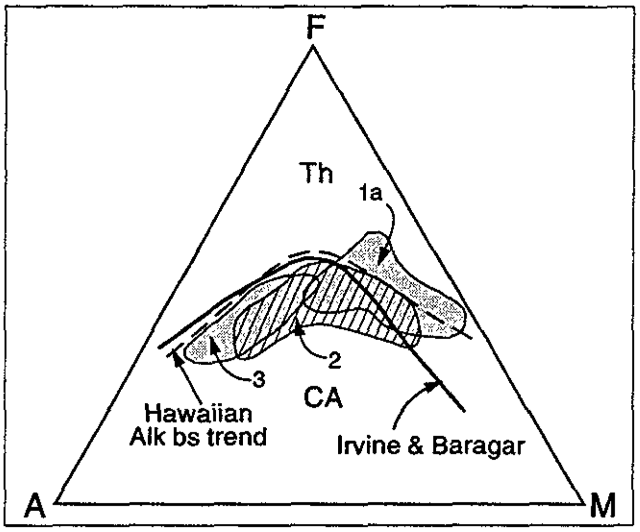



Figure 5-3. AFM diagram showing fields for Quesnel units 1a, 2 and 3. Basalts of the Quesnel island arc are calcalkaline. The oldest basalts of unit 1a appear to be transitional from tholeiitic (subalkaline) to calcalkaline. Boundaries and differentiation trends are from Irvine and Baragar (1971).

either 150 ppm or around 275 ppm. Differences between map units are recognizable according to their minor element abundances. The main arc basaltic units 2, 3 and 4 are similar but their minor element concentrations are distinct from those of units 1a, 10 and 11. The oldest basalts of unit 1a contain the smallest amounts of most minor elements except for yttrium and nickel which have relatively high concentrations. The Eocene biotite-bearing flows of unit 10 are markedly enriched in barium, strontium, rubidium, zirconium, chromium and nickel. The Miocene plateau basalts are depleted in barium, strontium, rubidium and vanadium but are enriched in yttrium, zirconium and nickel.

The AFM diagram (Figure 5-3) shows some separation of fields for volcanic rocks of the major map units 1a, 2 and 3. All rocks in unit 3 and most in unit 2 are calkalkaline rather than tholeiitic in character; rocks of unit 4 overlap these fields and are not shown in the figure. The compositions of the volcanic rocks shown on Figure 5-3 are mimmicked by the data of Bailey (1978) and Morton (1976) from similar rocks in the study area but their data are not shown on the figure. Rocks of unit 1a appear to be transitional tholeiitic rocks that follow a primitive Hawaiian basalt fractionation trend. Some of the magnesium and iron in these rocks might have increased due to metasomatism associated with chlorite alteration (Bloodgood, 1987). Overall, the distinction between unit 1a and the other arc rocks shown in the AFM diagram and in other discriminant plots (*see* discussion below) seems fundamentally valid. The sample of Miocene plateau basalt is the other lava type that falls in the tholeiitic field.

## CIPW NORMS

Calculated CIPW norms for typical rocks, as indicated by map unit average values, are shown in Table 5-3 and norms for all the analyzed rocks are listed in Appendix M.

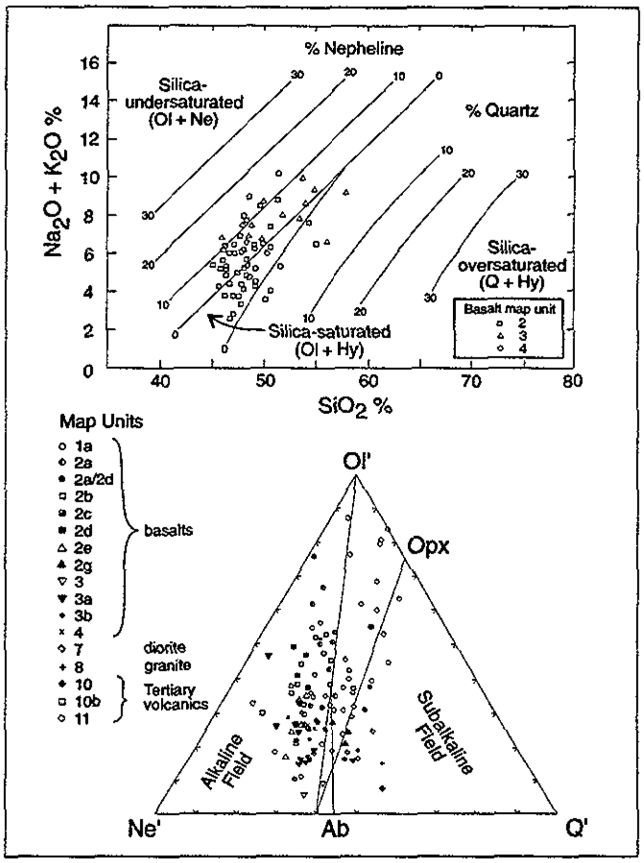



Figure 5-4. Normative compositions, CIPW norms for all analyzed Quesnel samples. A. - Composition of basalts on alkali-silica plot with idealized norm compositions of Cox *et al.* (1979). Quesnel rocks are dominantly silica undersaturated with normative *Ol+Ne*. B. - Normative *Ne'-Ol'-Q'* indicating predominantly alkaline compositions for Quesnel basalts.

A vast majority of the rocks are silica undersaturated; 60 of the 84 rock analyses provide normative olivine and nepheline. Of the remainder, five are silica saturated with normative hypersthene and olivine and the remaining five samples are silica oversaturated with normative quartz and hypersthene. The undersaturated rocks contain up to 14.7% normative nepheline and as much as 18% olivine; three of the samples have a small amount of normative leucite. These basaltic rocks are alkali basalts in the sense of Yoder and Tilley (1962). The ten alkalic intrusive rocks analyzed are evenly divided between silica undersaturated and (slightly) silica-saturated rocks. The Eocene volcanic rocks are silica over-saturated according to their norms, as would be expected for these quartz-bearing rocks. The Miocene tholeiitic basaltic rocks are silica saturated and have normative hypersthene and olivine. The relationships showing alkali-silica ratios of the analyzed sample suite compared with predicted, ideal normative character and degree of silica saturation are shown on Figure 5-4a. A plot of normative *Ne'-Ol'-Q'* places the majority of Quesnel arc volcanic and intrusive rocks in the alkaline field (*see* Figure 5-4b). Only a few samples from units 1 and 2g fall in the subalkaline field; it is occupied by the rocks of unit 1a and the younger rocks of units 8, 10 and 11.

The oxidation state of iron in the analyzed rocks and used in the normative calculations was assigned a standard oxidation state using the convention of Irvine and Baragar (1971). According to their convention the iron reported from the laboratory as $Fe_2O_3$ ($FeO^*$ or $FeO_T$) was considered to be approximately $Fe_2O_3 = TiO_2 + 1.5$ with $FeO^* = FeO + Fe_2O_3^*$ 0.8998 and $Fe_2O_3^* = Fe_2O_3 + FeO^*$ 1.11135. The convention used resulted in an overall $Fe_2O_3/FeO$ for the data set of about 0.31. This is fairly close to the empirical value of about 0.39 determined by Morton (1976) and the 0.35 value used universally by Bailey (1978). The value used appears to be appropriate or still possibly slightly too oxidized, based on the distribution of compositions in the ideal normative alkali-silica saturation figure (Figure 5-4a). A less oxidized value would make the sample suite appear even more silica undersaturated. Ferric/ferrous ratios determined in this study from twelve analyses of typical Quesnel arc rocks (Appendix N) indicate a greater degree of oxidation than the calculated values used and those of Morton and Bailey. The measured $Fe_2O_3/FeO$ is approximately 0.8 for the Triassic-Jurassic volcanic and intrusive rocks of the Quesnel belt. This highly oxidized assemblage is thought to represent post-depositional oxidation of rocks in the volanic belt.

## ALKALINITY: ALKALIC BASALTS AND SHOSHONITES - TERMINOLOGY FOR QUESNEL ARC ROCKS

Alkaline rocks may be defined (Fitton and Upton, 1987, page ix) as those with higher concentrations of alkalis than can be accommodated by feldspar alone. The excess is taken up in felspathoids, sodic pyroxene, sodic amphibole and other alkali-rich phases. The rocks are undersaturated in silica and alumina with respect to alkalis and will have nepheline and/or acmite (or leucite) in their norms. More commonly, alkaline rocks are defined simply in terms of their alkali and silica content. The analcite-bearing, nepheline-normative basaltic arc rocks of the central Quesnel belt qualify according to both of these criteria.

Total alkalis-silica diagrams (TAS), one of the simplest yet most effective indicators of chemical associations and the basis for a number of classifications, show all data and unit average values on Figure 5-5. The compositions reveal a pronounced alkaline character with the exception of unit 1a and the plateau basalt of unit 11 which are subalkaline. According to the TAS diagram and classifications of Zanettin (1984) and Le Bas *et al.* (1986) the Quesnel basaltic rocks are mainly basalt, basaltic trachyandesite and trachyandesite. Less commonly present are the more basic and alkali-enriched variants. They range in composition from picrobasalt to basaltic andesite and basalt trachyandesite or include tephrite (normative olivine percent) and basanite (normative olivine 10%) and their more differentiated types - phonotephrite and tephriphonolite. Alternatively, according to the classification of Cox *et al.* (1979) the (alkaline) basaltic volcanic rocks, if considered 'normal', that is, non-

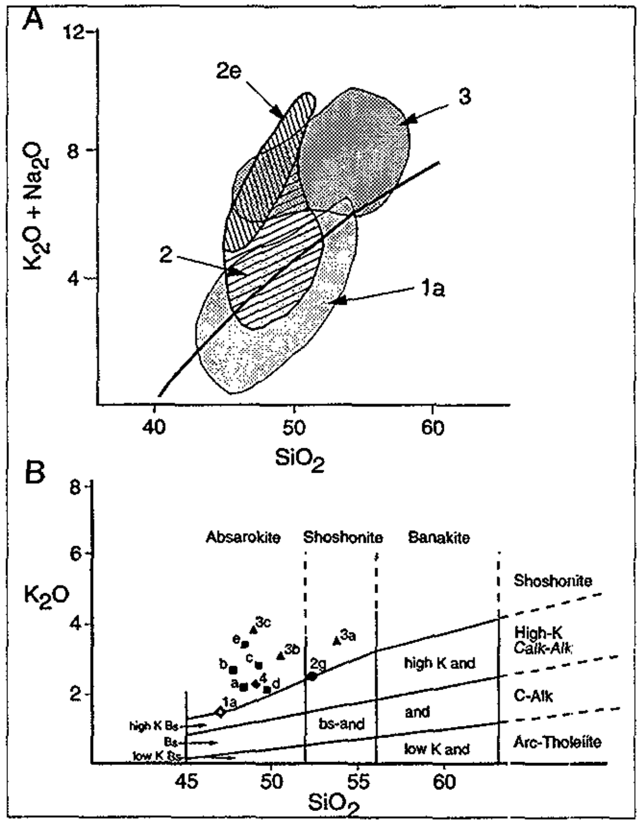



Figure 5-5. Classification of Quesnel basalts on the basis of total alkalis, potassium and silica contents. A.- Total alkali-silica (TAS) plot with boundary of Irvine and Baragar (1971) showing predominance of alkalic compositions. Fields encompass all analyses from units 1a, 2 and 3; unit 4 analyses are contained within the field for unit 2. B. Potassic alkalic rock classification of *Peccerillo and Taylor (1976) showing dominant shoshonite series* affiliation of Quesnel arc basalts. Map-unit average values plotted; fields encompassing all analyses from units 2 and 3 are shown.

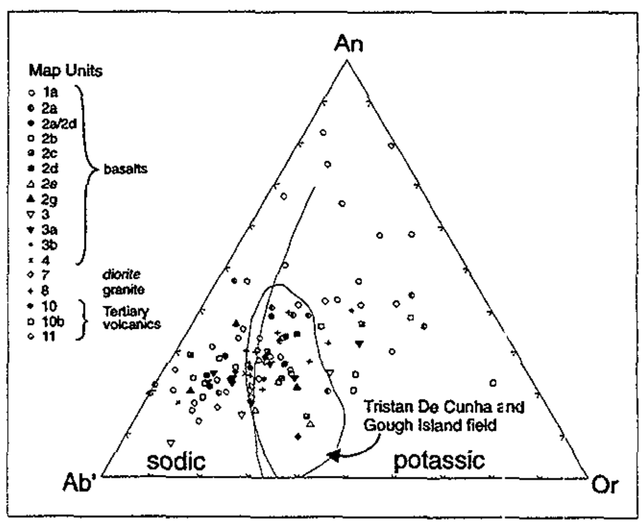



Figure 5-6. Normative *Ab'-An-Or* plot for Quesnel map-area rocks; *Ab' = Ab+5/3*Ne. According to this plot, Quesnel rocks are evenly divided between sodic and potassic suites.

potassic rocks, are a suite of basalt-hawaiite-mugearite to trachybasalt, with lesser trachyandesite, benmorite and phonolitic tephrite (Figure 5-5). However, the rocks fall in the field of potassic alkaline rocks according to a number of conventional discrimination diagrams such as the Ab'-An-Or (Figure 5-6) and $K_2O/Na_2O$ versus $SiO_2$ (Figure 5-8). Therefore the classification and terminology using schemes for alkalic potassic rocks are appropriate as discussed below.

The basaltic rocks have a relatively high content of alkali metal oxides and (most) are clearly alkaline or 'alkalic', silica-undersaturated rocks of mafic composition. The younger, analcite-bearing rocks of unit 4 and some of the unit 2 and 3 subunits are strongly sodium-enriched compared to the other basaltic units. The overall potassium to sodium ratio reveals that the rocks are more sodic than potassic. Nevertheless they lie in the 'potassic' field on normative Ab'-An-Or plots as shown by Bailey (1976) and this study (Figure 5-6). A similar alkaline potassic designation is given the sample suite according to the alkali ratio classification scheme of de Rosen-Spence (1992). If the $K_2O$ versus $SiO_2$ variation diagram for potassic rocks of Peccerillo and Taylor (1976) is used, the Quesnel arc volcanics are part of the shoshonite series, (*see* Figure 5-5b).

The term 'shoshonite' originates from rock types referred to by Iddings (1895) as the absarokite-shoshonite-banakite series. The terminology was re-established and redefined by Joplin (1968, and references therein) as the shoshonite magma series and later as the shoshonite association. The shoshonite association consists of assemblages of alkaline rocks of mafic to intermediate aspect. Chemical characteristics of the shoshonitic association according to Morrison (1980) with modifications by Mutschler *et al.* (1987), Gill and Whelan (1989), Rickwood (1989) and Mutschler and Mooney (1993) are:

- basaltic members are nearly silica saturated and can contain up to 5% normative quartz or nepheline
- high total alkalis ($Na_2O + K_2O$), generally >5%;

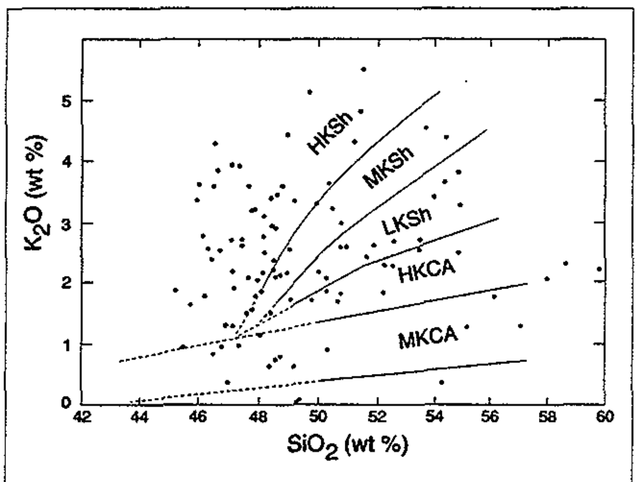



Figure 5-7. $K_2O$ versus $SiO_2$ plots of Gill (1981). Quesnel basalts range from calcalkaline to shoshonitic compositions. H = high, M = medium, L = low, K = potassium, Sh = shoshonite and CA = calcalkaline.

- high potassium with 1.8% $K_2O$ at 50% $SiO_2$ and 2.5% $K_2O$ at 53% $SiO_2$ and $K_2O/Na_2O$ values >0.6% at 50% $SiO_2$ and >1.0 at 55% $SiO_2$
- steep positive slope on $K_2O$ versus $SiO_2$ at <57% $SiO_2$ but zero or negative slope at 57% $SiO_2$
- high but variable $Al_2O_3$, commonly 14 to 19 %
- low iron enrichment (flat trend on AFM)
- low $TiO_2$ (<1.3 %, commonly <1.0 %)
- high $Fe_2O_3/FeO$ (>0.5)
- enrichment in Ba, Sr, Rb, Pb, light rare-earth elements (LREE), in accord with high potassium; also commonly high copper, platinum group elements, phosphorus and, locally, carbon dioxide and fluorine.

Under the shoshonite series classification, the rocks of units 2 and 4 are mainly absarokites and those of unit 3 are absarokite to shoshonite. The rocks of units 1a, and the Tertiary units 10 and 11 are calcalkaline to high-potassium calcalkaline series (Figure 5-5b). The similar scheme of Gill (1981) utilized by Gill and Whelan (1989) provides further subdivisions into medium and high-potassium calcalkaline (MK and HK CA) and low, medium and high-potassium shoshonite fields (LK, MK and HK Sh; *see* Figure 5-7). A further distinction can be made within the shoshonite suite on the basis of potassium and sodium contents; the most basic alkaline rocks with elevated sodium content in the Quesnel arc (Figure 5-8) can be referred to as 'tristanites' according to de Rosen-Spence (1992).

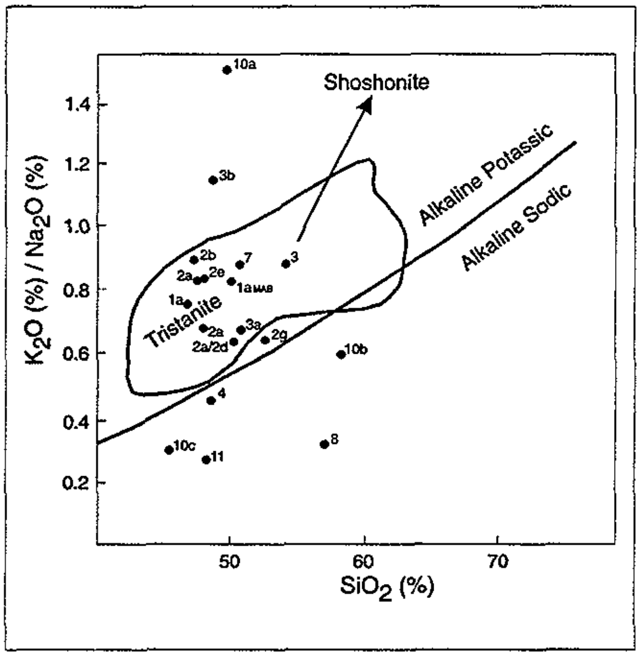



Figure 5-8. Alkaline sodic and alkaline potassic suites, diagram of de Rosen-Spence (1992). Field of alkaline potassic rocks of 'tristanite' association of Gough Island, Tristan da Cunha shaded. Shoshonitic suites have larger $K_2O/Na_2O$ and commonly plot outside this diagram. Quesnel map unit average values are shown; the rocks are relatively sodium-rich basalts of the alkaline potassic association.

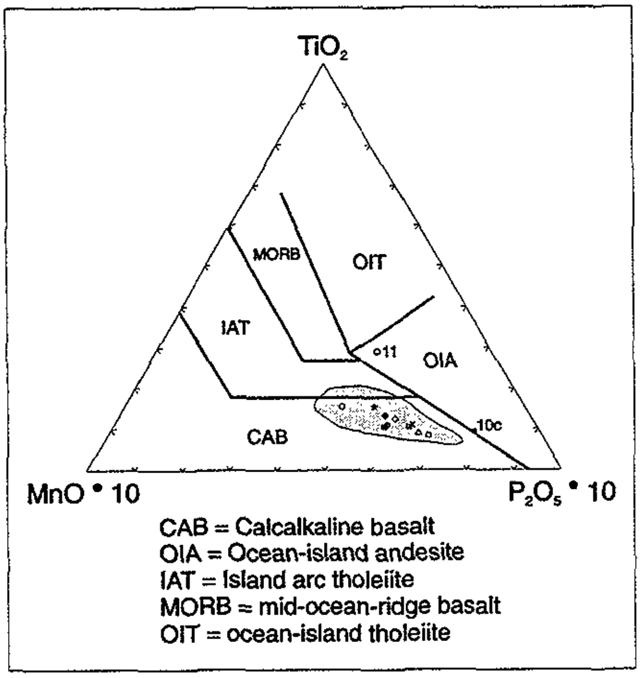



Figure 5-9. Ternary plot of minor oxide analyses with fields for various tectonic settings after Mullen (1983). Quesnel map-unit average values plotted; shaded field shows spread for all analyzed samples.

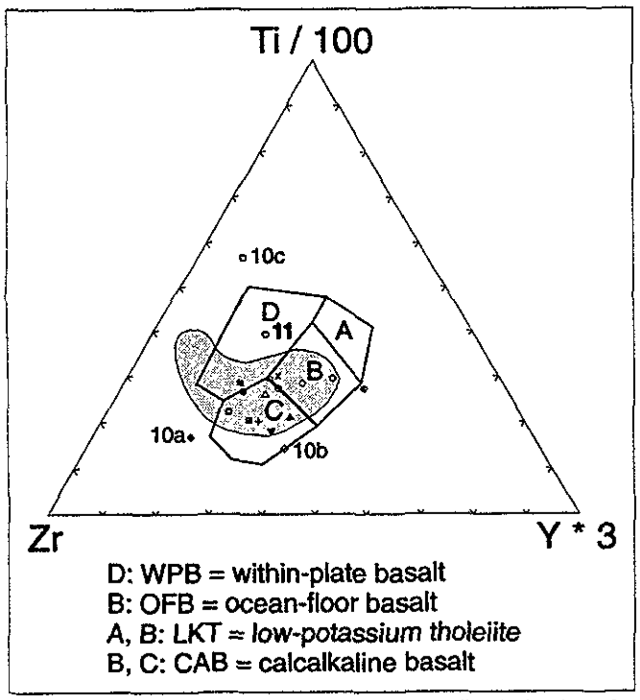



Figure 5-10. Ternary minor element tectonic discrimination plot after Pearce and Cann (1973). Quesnel map unit avaerage values plotted; shaded area shows spread for all analyzed samples.

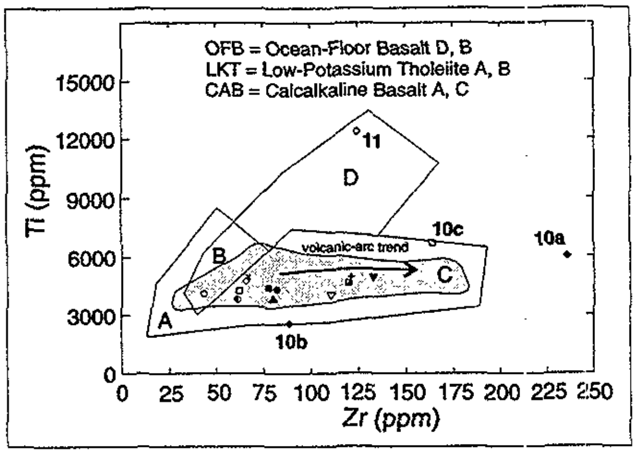



Figure 5-11. Ti/Zr minor element discrimination plot for various tectonic settings after Pearce and Cann (1973). Quesnel map unit average values plotted.

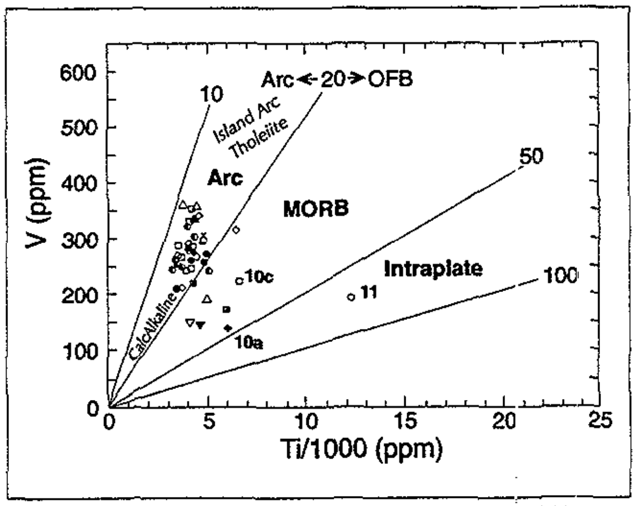



Figure 5-12. V/Ti minor element discrimination plot of Shervais (1982). Data for all analyzed Quesnel samples.

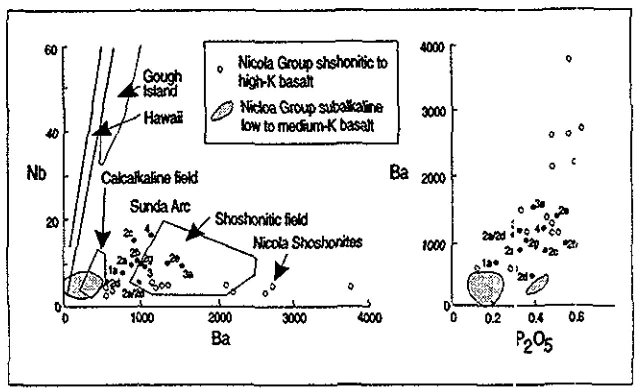



Figure 5-13. Comparison of some minor element contents of Quesnel and equivalent Nicola Group basalts; figure modifed from Mortimer (1987). Quesnel map-unit average values plotted.

## MULTI-ELEMENT VARIATION AND MINOR ELEMENT DISCRIMINATION DIAGRAMS

Multi-element discrimination diagrams pioneered by Pearce and Cann (1973), Miyashiro (1975), Floyd and Winchester (1975), Pearce (1982) and others, are commonly used to identify the tectonic setting or interpret the origin of basaltic magma. More importantly, minor element diagrams, especially plots of elemental ratios and normalized multi-element plots (Pearce, 1983, Hawkesworth and Norry, 1983) can provide an effective basis for comparison between similar rock suites. These plots can show significant contrasts not always evident from major oxide and other analyses. The application, use and effectiveness of discrimination diagrams has been reviewed extensively by Erdman (1985).

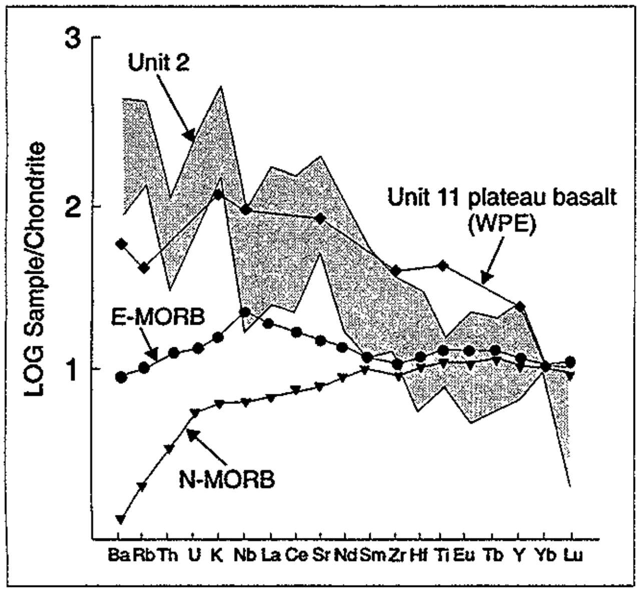



Figure 5-14. Chondrite-normalized extended minor element plot (bulk earth normalized diagram or 'BEND' plot of Erdman, 1985). Ranges of values for basalt units 2a to 2e are shown as 'unit 2' in the shaded area.

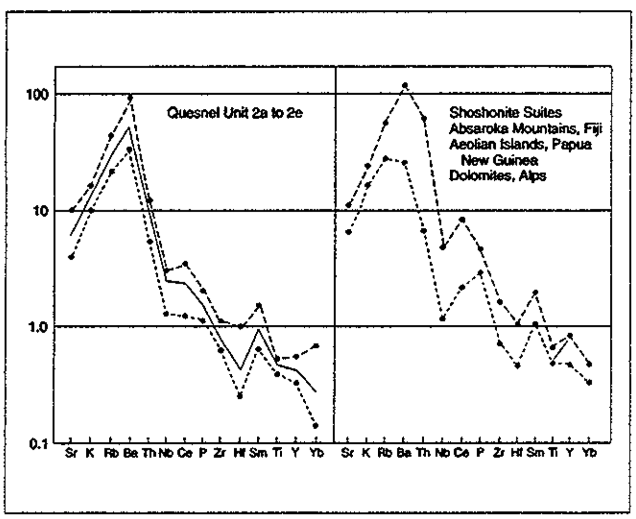



Figure 5-15. Chondrite-normalized minor element plot for high-potassium calcalkaline and shoshonitic lavas from southern Italy compared to Quesnel basalts, after Ellam *et al.* (1989).

In this study, geological mapping of the Quesnel volcanic rocks has led us, and others before us, to the interpretation that they were deposited in a (calc)alkaline volcanic island arc. It is, therefore, reassuring that at least some of the discrimination diagrams support this conclusion. A problem frequently encountered is that the use of the minor element discriminant diagrams requires analytical accuracy and detection limits that are simply not provided by commercially available, large-volume standard analytical facilities. A number of the effective diagrams are illustrated on Figures 5-9 to 5-16 as examples.

The most reliable data are from the suite of immobile minor elements - titanium, yttrium, zirconium, as well as vanadium, and the minor element oxides MnO, $TiO_2$ and $P_2O_5$. Plots (Figures 5-9 to 5-12) clustering of the Quesnel basalts into fields for calcalkaline arc rocks; the transitional tholeiites of unit 1a in many cases can be distinguished as their analyses plot outside the main basalt unit clusters. The Eocene and Miocene volcanics generally fall in fields separate from the other rocks and are distinct.

Comparison of the minor element contents of basalts with studies by Mortimer (1987) of the similar Nicola rocks from southern British Columbia reveals a similarity between the Quesnel basaltic units and the high-potassium calcalkaline to shoshonitic rocks of his map unit 1 (Figure 5-13). Quesnel basalts have barium and vanadium contents that are distinct from calcalkaline rocks and are intermediate between the subalkaline low to medium-potassium rocks and the enriched shoshonites of the Nicola Group. All the Quesnel basalts and Nicola unit 1 rocks appear to be depleted in niobium compared to Hawaiian lavas and

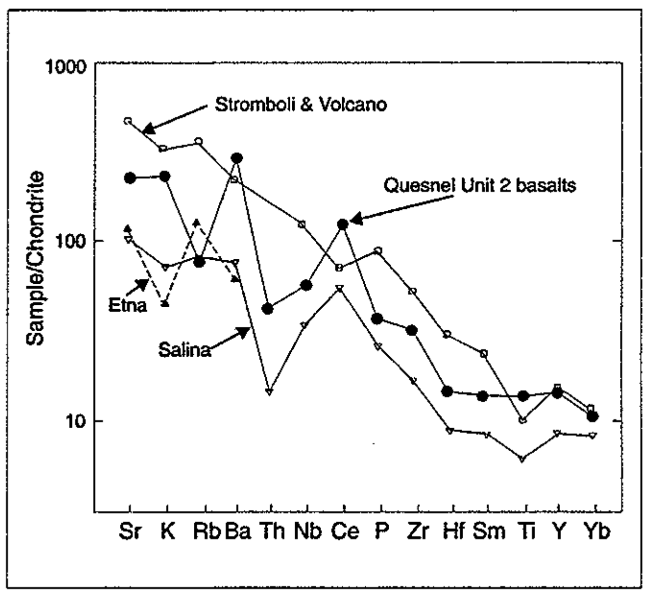



Figure 5-16. MORB-normalized trace element plots of island arc and other typical suites of the shoshonitic association after Sloman (1989) compared to Quesnel arc basalts. Range and median values for Quesnel basalts of units 2a to 2e are shown.

shoshonites from the Gough Islands. A number of similar bivariant plots with various combinations of barium, chromium, zirconium, vanadium, yttrium and $P_2O_5$ were used by Mortimer to produce the same subdivision of the Nicola rocks as the niobium-barium ratio and $Ba/P_2O_5$ diagrams shown on Figure 5-13.

The alkaline nature and shoshonitic association of Quesnel basalts are possibly best demonstrated by extended rare earth diagrams, or 'spidergrams'. These utilize mid-ocean-ridge basalt (MORB) and mantle or chondrite-normalized multi-element analyses as described by Pearce (1983) and discussed by Rock (1987). The alkalic rocks are strongly enriched in the incompatible or large-ion lithophile elements (LILE) and slightly elevated in the light rare-earth elements (REE) compared to the high field-strength elements (HFSE). The slope and pattern of the chondrite-normalized or bulk-earth normalized diagram (the 'BEND' plot of Erdman, 1985, shown on Figure 5-14) shows the expected alkalic pattern for the Quesnel arc basalts. It contrasts with the classical concave-upward curve of the within-plate basalt (WPB) pattern for plateau basalt of unit 11 and the reference curves for N-MORB and E-MORB.

A comparison of chemical compositions can be made with subduction zone, mantle-source alkalic mafic magmas of southern Italy which have typical enrichment of LILE over REE with negative nobium anomalies (Ellam *et al.* 1989), as portrayed on Figure 5-15. The Quesnel rocks on this diagram occupy positions intermediate between the mafic members of low to high-potassium calcalkaline Etna and Salina lavas and the low to high-potassium calcalkaline to potassic (shoshonitic association) lava of Stromboli and Volcano.

A comparison using MORB-normalized extended element plots provides similar diagrams as the chondrite-normalized data. Data from typical shoshonite suites from the Absaroka Mountains, Fiji, Aeolian Islands, Papua New Guinea and Italian Dolomites are all associated with destructive plate margins (Sloman, 1989) and are shown on Figure 5-16 alongside Quesnel data. The similarity in patterns and element concentrations between the basalts from the various shoshonite suites shown and the Quesnel basalts of unit 2 is striking. Quesnel rocks in units 3 and 4 display similar patterns but there is insufficient data to adequately detail their element distributions.

## DISCUSSION

The magmatic rocks of the Mesozoic Quesnel volcanic belt, at least the major elements of the volcanic arc, are an assemblage of predominantly alkalic olivine basalt, alkalic basalt to trachyandesite and genetically related intrusions. The rocks are characterized by silica-undersaturated, nepheline and olivine normative mafic compositions; they contain, on average, 3 to 14% normative olivine and up to almost 15% normative nepheline. The lower to lower-middle part of the stratigraphy is characterized by silica-saturated or nearly saturated rocks. They are recognized mineralogically by the presence of modal hornblende, greater than average amounts of plagioclase and are characterized chemically by normative hypersthene and quartz. The silica content in these rocks is close to saturatation and typical norm compositions have around 10% olivine with only a little quartz or nepheline. The oldest parts of the arc, represented by the transitional subalkaline (tholeiitic) to calcalkaline rocks of unit 1a. The silica-saturated rocks are interspersed with undersaturated rocks in the upper parts of unit 2 and ultimately are overlain by analcite-bearing basalts. Possibly the volcanic belt represents a sequence from tholeiitic-like basalts through to alkalic basalts (units 1a and 2) and then a second sequence (units 3 and 4), repeating the first but under more hydrous conditions.

The basaltic rocks are enriched in both potassium and sodium but the abundance of sodium generally exceeds that of potassium. Sodium-rich compositions are indicated mineralogically by the presence of modal analcite. Chemical compositions plotted on various major oxide variation diagrams and minor element discrimination plots clearly show the high-potassium calcalkaline to strongly alkaline, potassic character of the rocks in units 2, 3 and 4, the main volcanic arc constituents. Exceptions are the oldest volcanic deposits of unit 1a; these rocks are primitive Hawaiian-type lavas transitional between tholeiite and calcalkaline compositions. They are interpreted to have originated in a marginal basin or back-arc setting at the onset of (early) continent-margin rifting (Bloodgood, 1987). The analyses from this map unit show a large amount of scatter on various chemical plots. The rocks appear to have undergone some magnesium metasomatism that is indicated by an abundance of magnesian chlorite.

Classification of rocks in the upper part of the Quesnel arc as shoshonites or part of a shoshonite suite is largely, but not totally, compatible with the original definitions and usage of the term 'shoshonite association' by Joplin (1968). Shoshonite terminology is permissible under the expanded and less restrictive, widely applied recent usage of Morrison (1980), Mutschler and Mooney (1993) and others. The Quesnel volcanics comply in most aspects with these more liberal classification requirements for the use of the term shoshonite. The main differences between Quesnel arc shoshonites and those from elsewhere are that the Quesnel rocks have sodium in excess of potassium and are strongly undersaturated with respect to silica, rather than close to silica saturation.

Our preference, at least for field usage, is to use descriptive names and mineralogical modifiers, for example, analcite-bearing pyroxene basalt or pyroxene amphibole trachyandesite, feldspar-phyric amphibole pyroxene basalt, and so forth. Simple petrochemical terminology would apply the TAS classification based on major oxide analysis - basalt, trachybasalt, basalt trachyandesite, trachyandesite with unusual compositional variants picrobasalt or basaltic andesite and tephrite, basanite and phonotephrite and tephriphonolite. Use of the more restrictive and specific class or series terms 'shoshonite, shoshonite suite or shoshonite association' would require the utilization of other petrochemical data such as rare earth and other minor element discrimination plots, studies or ferrous/ferric ratios, and so forth. Classification of the rocks as shoshonites draws attention to the petrologic affiliation of the Quesnel arc rocks with similar alkaline rocks in destructive plate boundary subduction zone settings elsewhere around the world, notably the young volcanic island arcs of the southwest Pacific.

Alkali basalts of the shosonitic association in the Quesnel belt are volcanic products of subduction-related island arc magmatism. These relatively rare arc rocks in this convergent plate margin setting, compared to commonly present calcalkaline suites, are characterized by the abundance of potassium, barium, strontium, rubidium and $P_2O_5$, and the lack of enrichment in notably niobium, zirconium and titanium as well as yttrium, ytterbium and other high field-strength elements. The magma generation in this type of oceanic island arc setting is evidently a result of melting of the asthenosphere in the deepest parts of the subducted slab above deep Wadati-Benioff subduction zones. Alkalic magmatism is probably the result of combined petrogenetic processes including source enrichment from the subducted slab, partial melting of a (? repeatedly) metasomatised, LILE-enriched, depleted mantle wedge and fractional crystallization. This type of magma genesis for alkalic rocks with nepheline normative, potassium and LILE-enriched basalts, including shoshonites, as slab melts of metasomatised mantle wedge-material is proposed by Bailey *et al.* (1989) for rocks in the Kurile arc that are similar to the Quesnel belt volcanics. The magma generation in the Kuriles, and in other arcs, takes place in a tectonic regime that permits upwelling of enriched lithosphere, probably in zones of localized rifting of ocean basin lithosphere that allows hybridized mantle uplift and decompression melting to produce the distinctive alkalic magmas (McInnes and Cameron, 1994). Comparable basic alkalic rocks in intra-oceanic arcs with similar tectonic settings occur in Fiji, Lihir and the Marianas. In contrast, other alkalic arcs, have different compositions with low K/Na ratios and enrichment in niobium and zirconium; these arcs may represent intraplate settings.

Mixed source or process magmatism is evident and can be intermittent and repetitive; shoshonites are commonly interlayered with transitional (high-K to calcalkalic lavas). This is evidence for complicated tectonic regimes and a great diversity of petrogenetic processes. Assimilation of sediment and continental lithosphere is a possibility in the generation of some alkaline magma but this is not evident in the Quesnel island arc environment where low initial strontium isotope values indicate primitive magma sources without siginificant crustal contribution (Beddoe-Stevens and Lambert, 1981; Preto *et al.*, 1979). Other mechanisms for alkalic magma generation are arc-continent collision, as in the Papua New Guinea Highlands and Greece, again not applicable in the case of the Quesnel arc. This contrast is also evident for the Aeolian potassic lavas of southern Italy and rocks of the Roman region and Sunda-Banda arc, as reviewed by Nelson and Bellefontaine (1996), where mantle-source alkaline lava results from a continental crust contribution, similar to the shoshonites of the western United States of America.

Shoshonites commonly postdate the cessation of subduction. One of the main settings is the late stages of arc evolution near arc termini (Jakes and White, 1972). This may be applicable for Mortimer's unit 1 rocks in Nicola volcanics to the south where one of the three volcanic units is shoshonitic, but not applicable to Quesnel where shoshonites are present througout the entire volcanic succession. Similarly, arc reversals or 'flipping over' of subduction direction with alkalic rocks (and copper-gold deposits), as discussed by Solomon (1990) and espoused by Spence (1985), are not applicable to the Quesnel belt because there is no mapping evidence for any changes in polarity of the arc with time. Arc rifting along deep-seated crustal-scale structures as in Fiji (Gill and Whelan, 1989), and possibly along transforms, might be an applicable mechanism if modern examples of lineaments and segmentation in southwest Pacific arcs are considered. This type of tectonic setting involving transform-related extension during transcurent faults has been proposed for the segmentation of the northern Quesnel Takla arc by Paterson (1977) to produce a series of interconnected volcanic edifices with intervening basins. A similar tectonic setting with regional strike-slip faulting and related Triassic alkalic magmatism is described in the Dolomites of northern Italy by Sloman (1989), but the volcanism is not equivalent to that in the Quesnel belt due to the degree of older continental crust involvement.

In the Quesnel belt the alkalic basalts of shoshonitic association occur throughout the stratigraphic succession of the volcanic arc. The presence of alkalic rocks of shoshonite association is a widespread phenomenon throughout the northern Nicola Group volcanics and is a product of long-lived volcanism (Norian to Sinemurian and possibly Pliensbachian). The magma generation, therefore cannot simply be related to late or post-subduction, 'arc-reversal' events associated with some type of LILE-enriched lithosphere upwelling during short-term extension (or transtension). There is considerable similarity in the tectonic setting with the active subduction-related alkalic submarine magmatism in a 350-kilometre segment of the northern Marianas arc - a nascent shoshonite arc within a larger belt of low-potassium basaltic magmas (Stern *et al.*, 1988). Possibly the Quesnel arc-building shoshonitic magmatism represents a similar, subduction-related compressive volcanism that was reinitiated after earlier continental-margin back-arc rifting produced enriched lithosphere along a steeply dipping length of the convergent plate margin.

The shoshonitic volcanics of Quesnellia are a suite of alkalic basic rocks relatively rare worldwide, but they constitute a significant part of a 500-kilometre long belt in the eastern Intermontane region of the Cordillera. Analagous alkalic rocks in island chains of roughly the same dimensions as the Quesnel belt occur in the Tabar-Lihir-Targa-Feni arc, Papua New Guinuea, and the adjoining New Britain arc, as described by McInnis and Cameron (1994). The typical silica-undersaturated rocks of high-potassium calcalkaline magma series nepheline-normative magmatism are unusual for island arcs and are more characteristic of continental rifts or intraplate hot spots. The Cordilleran alkalic arc rocks appear to be the products of a combination of complex tectonic events and magmatic processes, possibly indicating unusual chemical compositions in the mantle-wedge source region or subducting plate edge-effects in a primitive oceanic arc setting. There are identical, time-equivalent rocks in the adjoining terrane, Stikinia, in the so-called Stuhini volcanics (Logan and Koyanagi, 1994; Brown *et al.*, in preparation). The relationship of these two similar arcs in different terranes is discussed by Nelson and Mihalynuk (1993). The alkalic arc volcanics are similar to a number of other primitive intra-oceanic island arcs with alkalic basalt and andesite compositions but are chemically distinct from still other shoshonitic arcs built on continental basement or involving continent-margin interactions during subduction. In the Quesnel belt, as elswhere in shoshonitic terranes, there is a persistent presence of economically important copper-gold and gold deposits (Muller and Groves, 1993; Mutschler and Mooney, 1993.

# CHAPTER 6 STRUCTURE

## REGIONAL DEFORMATION AND FOLDING

The structures of the central Quesnel belt were initially produced during accretion of Quesnellia arc rocks and the underlying Crooked amphibolite with rocks of the North American continental prism. This event is interpreted by Nixon *et al.* (1993) to have taken place from 186 to 180 Ma, the Toarcian epoch. Subsequent tectonic activity resulted in a number of overlapping and dominating phases of deformation accompanied by a metamorphic culmination that followed tectonic crustal thickening. Folds are most evident in Quesnellia in both the thick sedimentary successions of unit 1 and the thin sedimentary units interbedded with the basaltic volcanic rocks of unit 2. The volcanic rocks are extensively block faulted but the massive appearance of the volcanic assemblages does not readily allow the definition of folds and the resolution of fold patterns within the volcanic units.

Numerous studies of structures and metamorphism have been conducted in the high-grade metamorphic rocks of the Barkerville Terrane to the east of the Quesnel belt (see discussion of previous work, Chapter 1). The structural relationships between Quesnel and Barkerville terranes have been discussed by Ross *et al.* (1985); Rees (1987) and Struik (1988a), among others, and summarized by McMullin (1990). Structures within Nicola rocks and the structural development of Quesnellia have been the topics addressed by Carye (1985) and Bloodgood (1987c, 1990).

Previous workers have identified from two to five phases of folding and Elsby (1985) even suggested that normal faulting represents a sixth phase of regional deformation. In the eastern part of the Quesnel Terrane, Rees (1987) has described five deformational episodes which he relates to the development of the arc, its subsequent accretion with cratonic North America and to later tectonism involving perictatonic and cratonic rocks of the Omineca belt as well as allocthonous Quesnellia. We have adopted Rees' convention of describing the sequence of regional deformational events by the letter D, with $D_1$ for the earliest to $D_5$ for the latest event. In the specific areas of our study we use the term F, for example $F_1$ and $F_2$, to describe the relative sequence of events recognized. Thus the earliest period of deformation we recognize in the Quesnel belt is designated $F_1$, followed by $F_2$ but this sequence can correspond to and begin with any of the regional events, most likely either $D_2$ or $D_3$. The complicated and not altogether consistent scenario described by different investigators has been summarized by McMullin (1990) and is outlined below.

McMullin considered that five phases of deformation can be recognized in the Quesnel Lake area, mainly in the well stratified metasedimentary successions of the Barkerville Terrane which is not part of Quesnellia. The first four phases produced coaxial folds with northwesterly trending axes and variably dipping axial planes. These folds are overprinted by northeasterly striking folds with vertical axial planes. McMullin's phase one structures are present only in rocks of Barkerville Terrane and possibly the Crooked amphibolite, the basal oceanic rocks on which Quesnellia evolved. He considered that the oldest structures in Quesnellia formed during the second phase of regional deformation, producing tight to isoclinal folds with a well developed axial planar fabric. The attitudes of these folds are affected by later deformation, but generally fold axes trend to the northwest. Rees (1987) suggested that these folds have northeasterly to easterly vergance. In Quesnellia and the Barkerville Terrane this second phase of folding is synmetamorhphic in that metamorphic mineral growth is synchronous with, or slightly postdates, development of the axial planar foliation.

The third phase of regional deformation recognized by McMullin, $D_2$ in Quesnellia, generated upright to semi-recumbant, westward-verging 'backfolds' that he considered to be responsible for the major map-scale features in the area described in this report. He states that fold axes trend northwesterly and that axial planes generally dip steeply to the northeast. A second cleavage is a nonpenetrative crenulation that is indistinguishable from the older cleavage. At higher structural levels the rocks have either a crenulation or spaced fracture cleavage. Some metamorphic mineral growth is evident with this deformation but the events are generally postmetamorphic; metamorphic mineral isograds were folded during this deformation. Late deformation with possibly two separate, possibly conjugate fold systems, is described by McMullin. The late deformation produced

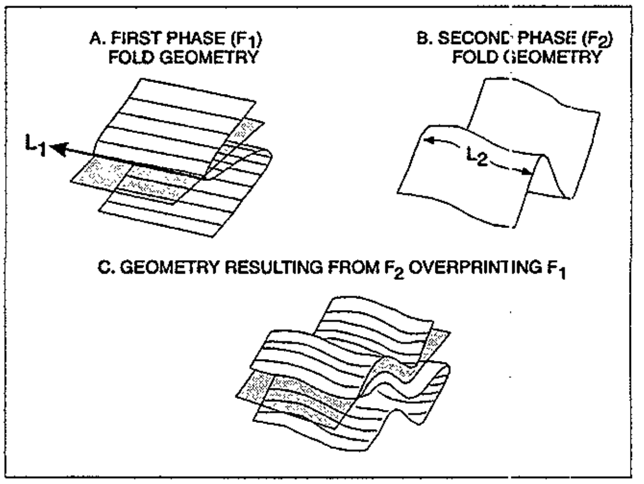



Figure 6-1. Schematic illustration of the geometric relationships between $F_1$ and $F_2$ folding. Recumbant first phase structures are overprinted by doubly plunging second phase fold sets, resulting in the development of relaying antiform-synform pairs.

open small-scale buckles and warps. In one system upright axial planes of folds with poorly developed fracture cleavage trend north or northwest. The youngest fold axes trend northeastward. The late deformation postdates peak metamorphism and some retrogression is evident.

Most investigators in the Quesnel Trough recognized two major, consecutive, and probably protracted phases of deformation (Rees, 1987; Bloodgood, 1987a; and Bailey, 1990). A schematic illustration of the relationships between $F_1$ and $F_2$ is shown on Figure 6-1. A third postmetamorphic, late structural event is usually described or is implicit. The first deformation coincides with the tectonic emplacement of Quesnel Terrane onto Barkerville Terrane. Kinematic indicators from high-strain zones and mylonites suggest northeastward or eastward sense of shear (Rees, 1987). The second deformation phase coupled Quesnellia and Barkerville terranes into large-scale, southwesterly verging subrecumbent folds that are outlined by the Z-shaped terrane boundary. Evidence for a late (third) phase of deformation is taken to be open folds or warps with no axial planar foliation. Structures related to the late events are subtle. Rees related northwest-trending warps to this event but McMullin describes late, north and northwest-trending structures and Bailey documents northeasterly trending fold axes. One area with good outcrop evidence for superimposed fold axes with divergent trends is available on the north bank of the Quesnel River near Likely. There thin-bedded sedimentary rocks of unit 5 exhibit interference structures resulting from the superimposition of northwesterly trending, moderately northwest-plunging, isoclinal folds on northeasterly trending open to tight folds with gently southwest-plunging minor fold axes.

## FAULTING

Faulting of three types and discrete periods is evident: thrust faulting that coincides with accretion outlines the major crustal structures and defines the terrane and major map unit boundaries; high-angle to listric normal faults that either follow the northwesterly trend of stratigraphic units or are transverse to them and strike easterly to northeasterly; and late strike-slip movements along the western terrane boundary and related extensional faulting within the associated transtensional basins.

The major, early low-angle thrust fault in the map area is the Eureka thrust, a boundary fault between the Crooked amphibolite of Quesnellia and the underlying rocks of Barkerville Terrane . This and similar structures in Barkerville rocks to the north are the Pundata and Pleasant Valley thrusts described by Struik (1983, 1988b). Brown and Rees (1981) and Rees (1987) refer to the Eureka thrust as the Quesnel Lake shear zone. Struik (1988a) also suggests, on the basis of stratigraphic repetition, that is evident from conodont studies, that one, and probably more, thrusts are internally present in the Quesnel basal sedimentary unit. In the volcanic map units low-angle faulting is difficult to document but evidence for it is available in a number of places where detailed studies have been done. For example, during periods of low water flow in the Quesnel River near Likely, a flat-lying, sinous fault and 1-metre wide shear zone mark the contact between older hangingwall basaltic rocks of unit 2 and footwall sedimentary rocks of unit 5. Also at the QR deposit, 13 kilometres northwest of Likely, interpretation of drill core by Fox *et al.* (1986) proposes that one or more reverse fault structures such as Wally's fault are present. They are cut by younger, steeply dipping normal faults.

Northeasterly and northwesterly-striking normal faults are rarely seen in outcrop but are interpreted from outcrop distribution and patterns of map units and their aeromagnetic expression. A case for early, east-side-down, normal fault structures that trend along the axis of the volcanic belt has been made by Bailey (1978). The faults outline the trends and form contacts of many of the volcanic units and appear to have controlled the distribution of eruptive centres. Reactivation of these high-angle extensional faults postdates thrusting but is no later than Cretaceous as granitic rocks of this age do not appear to be cut by them.

A third set of faults is present as a number of major, strike-slip structures along the poorly exposed terrane boundary of the western Quesnel belt with Cache Creek rocks. Narrow belts of Middle Jurassic and younger clastic deposits are preserved along the fault zones. These faults are part of the Pinchi and Fraser fault systems; a subsidiary fault system along the Quesnel River, its location only inferred, is informally named the Quesnel fault. A fault in the north-central part of the map area, the Chiaz fault (Bailey, 1988a), forms an arcuate structure that extends to the north of the Quesnel fault. It is defined largely by aeromagnetic and induced polarization surveys. This fault has dextrally displaced Cretaceous granite by up to 4 kilometres and has a west-side-up throw of at least 5 kilometres. Extensional faulting in the Quesnel central volcanic belt during the mid-Tertiary is possibly also related to the large-scale strike-slip faulting. The structural extension has produced a number of small, north to northwesterly trending grabens that are probably transtensional basins. They were sites of Eocene sedimentation and volcanism.

## DETAILED STRUCTURAL STUDIES IN THE EUREKA PEAK AND SPANISH LAKE AREAS

Bloodgood conducted a number of structurally focused, detailed studies in the black phyllite succession of unit 1 in two regions within the map area near Eureka Peak and Spanish Lake (Bloodgood, 1987a, 1988, 1990). She recognized overprinting relationships of structural elements that indicate two distinct deformational episodes produced folds within the rocks of the Quesnel Terrane. Her conclusions (Bloodgood, 1990, pages 15-27) are summarized below.

First phase folds ($F_1$) are tight to isoclinal, eastwardly verging structures characterized by a penetrative slaty cleavage and mineral elongation lineation. In the Eureka Peak area, a structural transition is observed, characterized by

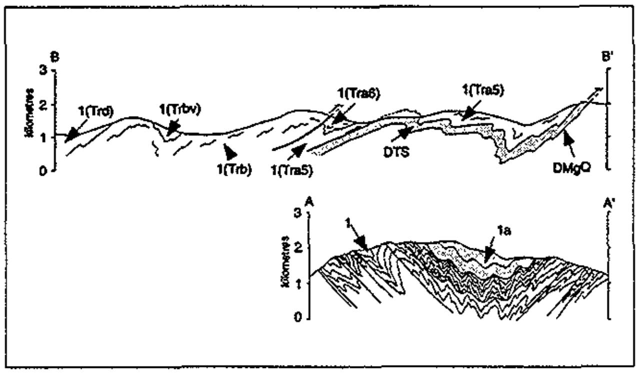



Figure 6-2. Schematic structural cross-sections - A. Spanish Lake and, B. Eureka Peak areas; locations indicated on Figure 2-3. Map units of Bloodgood (1990) in brackets.

tight to isoclinal folding at lower structural levels, gradually becoming more open and upright at higher structural levels. No regional-scale $F_1$ structures were recognized in the Eureka Peak area. This contrasts with the Spanish Lake area where vergence of $F_1$ structures indicates an $F_1$ nappe to the north of Spanish Lake (Figure 6-2).

A nonpenetrative spaced cleavage is developed parallel to the axial plane of second phase ($F_2$) folds. The $F_2$ folds are manifest as doubly plunging, open and upright buckle folds which deform $F_1$ and fold the tectonic boundary into the form of the Eureka Peak syncline. In the Spanish Lake area, $F_2$ folds commonly have a box-fold geometry and the axial planar cleavage is developed in a conjugate orientation.

## *PHASE 1 STRUCTURES*

Phase one structures are a penetrative slaty cleavage ($S_1$), the lineation defined by the intersection of bedding on the slaty cleavage ($L_1$) and a mineral lineation. The slaty to phyllitic cleavage occurs as closely spaced planes that define a penetrative fabric. It is marked by a fine micaceous or graphitic parting in the metasediments and a chloritic parting in the volcanic rocks. The cleavage is axial planar to both mesoscopic and microscopic folds, strikes northwesterly, and dips variably to the northeast and southwest. A planar parting defines the cleavage in the more siliceous or slaty sediments and a more closely spaced, anastamosing micaceous to graphitic foliation occurs in the finer grained sediments. The penetrative cleavage is most strongly developed in argillaceous sediments and is poorly developed or absent in coarser grained rocks, notably the overlying metavolcanic suite.

Intersection lineations defined by the intersection of bedding with one of the cleavage planes, and mineral elongation intersections, plunge northwest or southeast at shallow to moderate angles, parallel to mesoscopic fold axes. Mineral elongation lineations are defined primarily by elongate quartz grains and quartz rods.

A dark coloration along cleavage planes outlines cleavage stripes. In thin section this striping appears to be due to the concentration of insoluble material along the cleavage planes, suggestive of extensive dissolution along the cleavage surface. The material remoblilized by pressure solution processes may be present as the small quartz veins within hinges of folds and as quartz veinlets that are parallel and subparallel to bedding.

In the Eureka Peak area, first phase slaty cleavage shows a consistent variation in orientation from the limb to the hinge regions of the Eureka Peak syncline. At lower structural levels and on the limb of the syncline, $F_1$ folds are tight to isoclinal. The axial plane cleavage is gently to moderately inclined to the northwest. In contrast, at higher structural levels within the volcanic succession, and in the hinge regions of the syncline, $S_1$ is more steeply inclined and folds are open and upright. The change in orientation of the cleavage, and the transition in fold style is a consequence of greater flattening strains along the limb of the syncline and the distance away from the volcanic-sedimentary lithologic contact. The deformation is most intense in the phyllites which have accomodated a greater proportion of the strain than the more competent volcanics. All $F_1$ folds are easterly verging, outcrop-scale structures with maximum observed limb lengths of about 10 metres; no regional-scale structures are recognized. The structures all show the effects of subsequent deformation. The slaty cleavage is deformed and cut by a spaced or crenulation cleavage ($S_2$) and mineral lineations are commonly bent around the $F_2$ fold hinges.

In the Spanish Lake area, fine colour laminations and thin grey to white siliceous siltstone interbeds clearly outline bedding folds. There is also a widespread, well developed, penetrative slaty cleavage and bedding-cleavage intersection lineation. $F_1$ folds, both as mesoscopic and microscopic scale structures, are tight to overturned with gently to moderately inclined $S_1$ planes. Vergence of $F_1$ structures is believed to be eastward but the structures are largely obscured by $F_2$ overprinting. The sense of symmetry on mesoscopic folds indicates the presence of a macroscopic $F_1$ antiform. As no closure is seen, the area may lie on the upper limb of a large $F_1$ nappe structure (Figure 6-2).

## *PHASE 2 STRUCTURES*

Phase two deformation ($D_2$ in Quesnellia, the regional D3 of McMullin, 1990) established the regional map pattern. Structures associated with this deformation are a nonpenetrative, spaced or crenulation cleavage and bedding-cleavage or cleavage intersection lineations. All earlier structures, including the Eureka thrust, are refolded but the distinction between the two phases is difficult to recognize unless unequivocal overprinting relationships of the essentially coaxial structures are evident. The structural elements associated with $F_2$ are nearly coplanar and colinear with those of $F_1$. As a result, the development of $F_2$ mesoscopic folds is not always obvious. Evidence in outcrop at lower structural levels is the overprint tightening of $F_1$ folds with an increased ratio of amplitude to wavelength. As a result of similar orientation, the $F_1$ structures usually appear only slightly modified by $F_2$ although refolding is evident locally.


Photo 6-1. *Second phase overprint of first phase isoclinal fold. A penetrative slaty cleavage ($S_1$) is well developed axial planar to the first* phase structure, which is overprinted by a spaced second cleavage ($S_2$). Local refolding by $F_2$ has occurred along the limb of $F_1$.

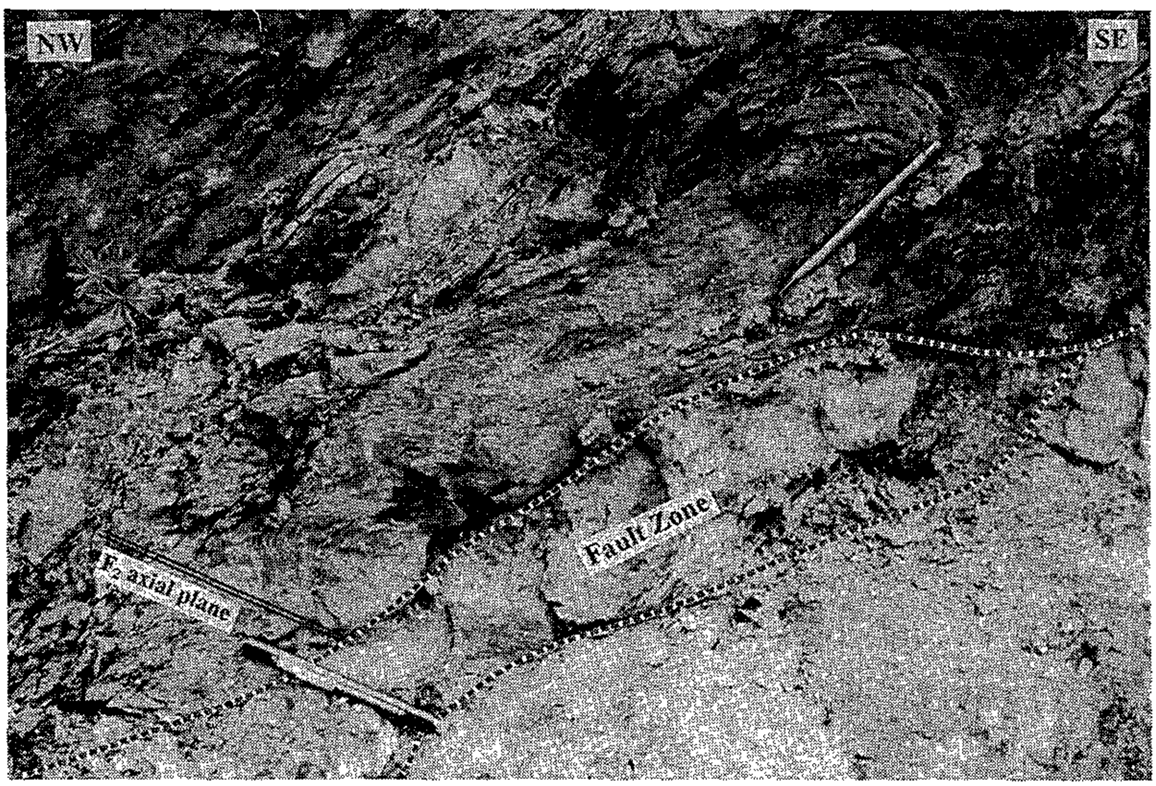



Photo 6-2. Imbrication along the contact between the Crooked amphibolite and the Triassic black phyllites. An imbricate slice of the Triassic metasediments lies in the hangingwall of the fault. Quartz veins are prominent close to the fault zone, which is overprinted by southwesterly dipping $F_2$ crenulations.

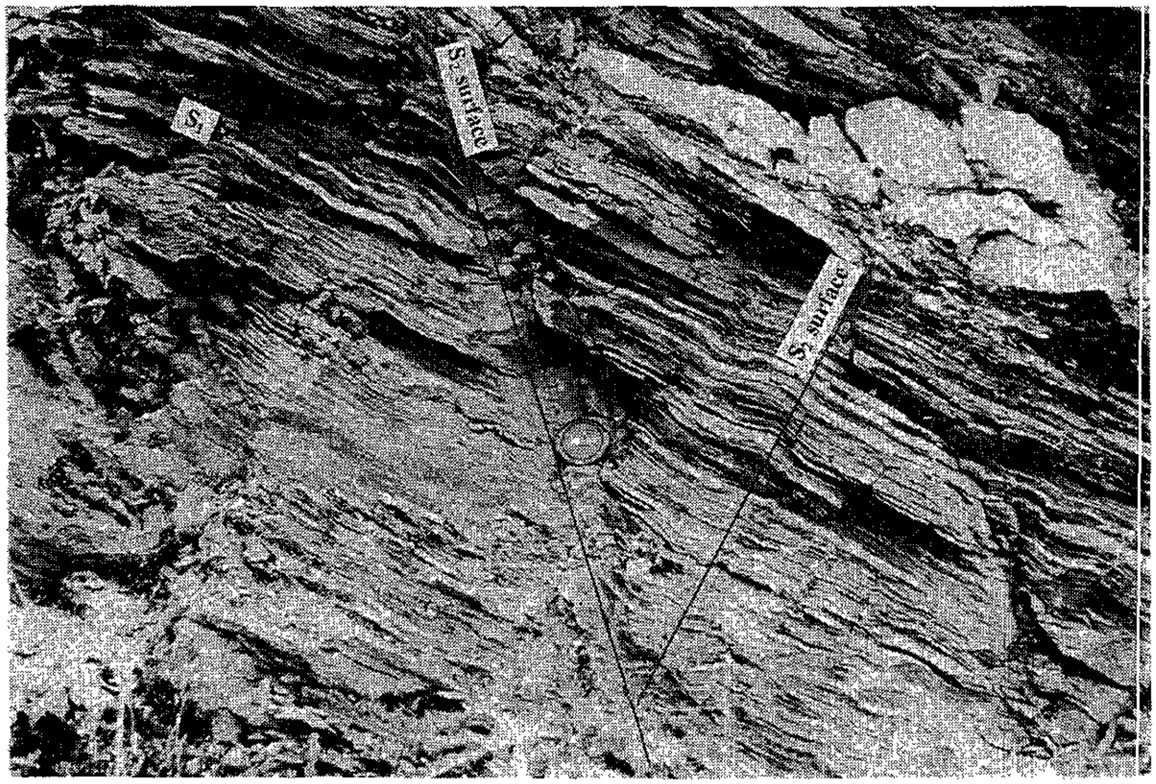



Photo 6-3. Second phase folding of the gently inclined bedding has a conjugate kink-type geometry. The quartz vein in the upper right is parallel to both bedding and the slaty cleavage ($S_0$ and $S_1$, respectively).


Photo 6-4. Plan view of a slaty cleavage surface ($S_1$) deformed by $F_2$. Overprinting of the $F_2$ fold geometry gives rise to the relaying antiformal culminations and synformal depressions. $L_1$ is deformed about the $F_2$ fold axis, which is parallel to the pen. The development of this feature is schematically illustrated in Figure 6-1.

The $S_2$ spaced cleavage strikes northwest and dips moderately to steeply to the northeast and southwest. This is a nonpenetrative cleavage within both the metasediments and the metavolcanic rocks. Cleavage spacing varies with lithology and position on mesoscopic structures. The more closely spaced individual cleavage planes vary from 1 to 15 millimetres apart. Cleavage in the Nicola volcanic rocks is weakly developed and, where present, is best developed near the hinges of folds rather than on the limbs. Throughout the volcanic members, the cleavage dips steeply to the northeast or southwest. It is defined by a chloritic parting and the spacing varies from 1 to 3 millimetres in the fine-grained tuffs to 3 to 4 centimetres in the coarser grained rocks.

In the Spanish Lake area, second phase defomation ($D_2$) refolds earlier structures, bedding and slaty cleavage ($S_1$). $F_2$ folds are open and upright and are accompanied by an axial planar nonpenetrative spaced cleavage. The folds are generally southwesterly verging, trend northwest (280° to 310°), and dip moderately to steeply to the northeast or, gently to moderately southwest. Local small-scale crenulations of $S_1$ are associated with $F_2$ deformation. Well displayed $F_2$ structures locally have a characterisitic box-fold geometry. There the $S_2$ cleavage forms conjugate sets, axial planar to the fold structures, and this cleavage commonly defines kink-band boundaries. Linear structures associated with $F_2$ deformation are $S_0/S_2$ or $S_1/S_2$ intersection lineations. These structures are doubly plunging, inclined to the northwest and southeast.

Second phase structures in the Spanish Lake area establish the geometry of the tectonic boundary and map pattern. To the north the $F_1/F_2$ interference structures determine the outcrop pattern of the Crooked amphibolite. The steeply dipping $F_2$ axial plane and doubly plunging fold axis imposed upon a gently dipping $F_1$ axial surface results in the development of a series of antiformal culminations and synformal depressions along the trend of the fold axis. The deepest structural levels are thus exposed where an $F_2$ antiform overprints an $F_1$ antiform. This relationship is evident in the map area where Crooked amphibolite is exposed along the coincident antiformal axis. To the north of this axial trace higher structural levels are preserved within lobate synformal depressions and the higher stratigraphic members of unit 1 are exposed (Bloodgood's unit Tra6). Various structural elements and relationships between $F_1$and $F_2$ are illustrated on Photos 6-1 to 6-4.

Locally, north of Spanish Lake, in hinge regions of the $F_1$ folds, the $S_2$ cleavage is rotated away from its typical orientation, into parallelism or near parallelism with the $F_1$ axial surface. This consistent relationship in the area suggests the presence of an $F_1$ antiform overprinted by an $F_2$ antiform. Elsewhere the $S_2$ surface is inclined at a shallow angle to the southwest, subparallel to $S_1$.

## FRACTURES AND QUARTZ VEINS

Fractures, many filled with quartz, are common features at all scales in the Eureka Peak and Spanish Lake areas. Some quartz veins are deformed and others are not, indicating that fracturing occurred throughout the deformational history. It is likely that veins formed as part of a continuum during the evolution in structural development. The quartz veins most commonly vary from 1 to 20 millimetres in width and tens of centimetres in length but can be up to a metre wide and several metres long. Small, early quartz veins outline rootless isoclinal folds, the limbs of which have been removed, probably as a result of pressure solution along the cleavage surfaces. Extensional, quartz-filled fractures and dilations oriented at low angles to bedding and cleavage, as well as sygmoidal fractures perpendicular to fold axes, occur predominantly in the metasedimentary successions.

The quartz in narrow veinlets typically occurs as elongate to fibrous grains, commonly perpendicular to vein walls. The larger veins are characterized by more equant, blockier quartz crystals. Textures characteristic of repeated crack-seal vein growth have been recognized from the study of vein material (Bloodgood, 1987a). Figure 6-3 illustrates the various vein geometries in relation to cleavage and bedding orientations and Photos 6-5 to 6-7 show the various vein styles. Fractures initially formed parallel to the direction of maximum compressive stress, at low angles to bedding, and a high angle to cleavage. During progressive deformation, both bedding and the early formed veins were folded and disrupted.

Undeformed, spaced fractures are developed in all lithologies throughout the region. Spacing of fractures varies from 1 to 100 centimetres and varies in rocks of different competency. Open joints have been recognized throughout the study area. They are oriented perpendicular to the fold axis and axial plane of the mesoscopic folds and dip steeply to the north and south.

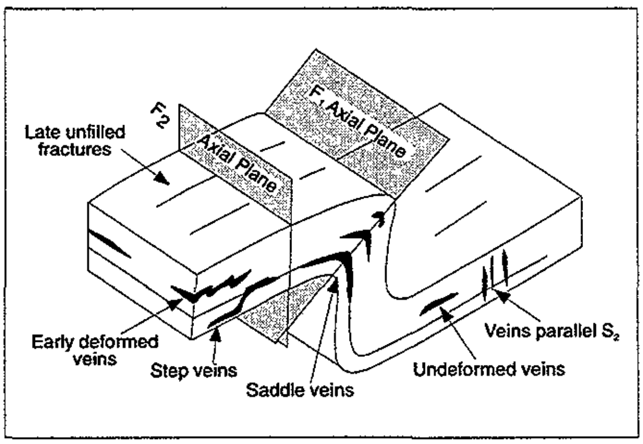



Figure 6-3. Common vein geometries. Earliest veins developed parallel to bedding and perpendicular to the developing cleavage. Pressure solution features associated with $S_1$ and $S_2$ cleavage suggest fluid flow took place throughout deformation and resulted in both deformed and undeformed veins. Gold occurs in the earlier veins particularly near fold hinges and is associated with small amounts of pyrite, chalcopyrite and pyrrhotite.

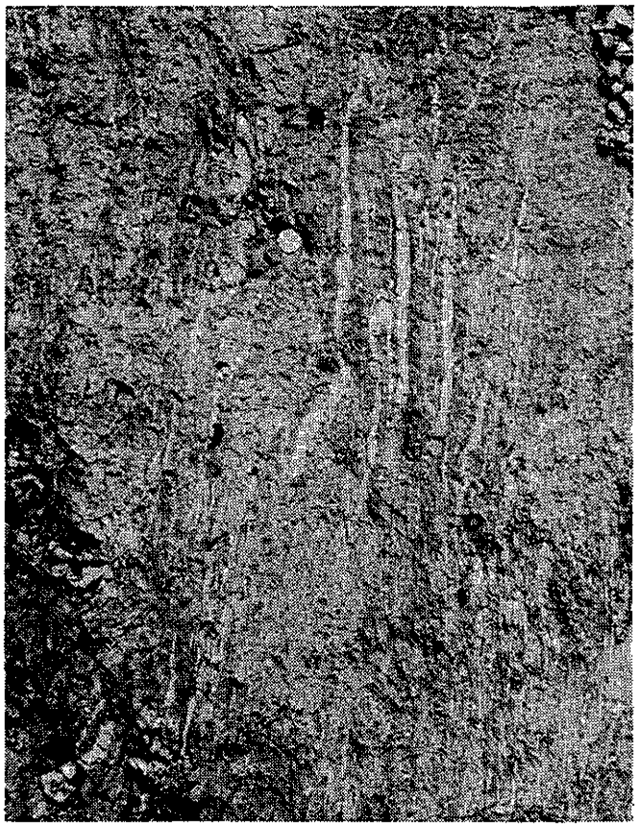


Photo 6-5. Stongly deformed quartz veins within black phyllites. These isoclinally folded veins are plunging at a shallow angle toward the top of the photo, and are overprinted by $F_2$.

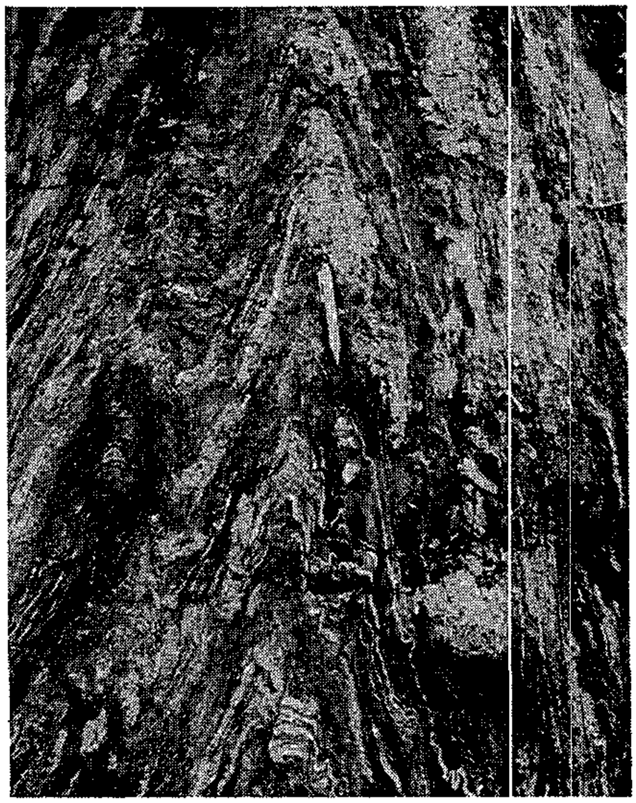


Photo 6-6. Small bedding-parallel quartz veins folded about an upright $F_2$ fold. In some areas remobilization of vein-filling material by pressure solution is suggested by the truncation of some veins against the cleavage surface.

Plate 6-7. Early formed, folded quartz veins truncated by a later, blocky vein.

## EOCENE EXTENSION AND GRABEN DEVELOPMENT

The Tertiary sedimentary and ash-flow deposits in the project area (unit 10) are largely confined to a belt 3 to 6 kilometres wide by 40 kilometres-long in the south-central part of the area studied (Figure 3-8). The poorly exposed Eocene rocks are preserved in a narrow, fault-bounded depression, possibly a graben, that is now occupied over much of its length by the Horsefly River. The belt of Eocene sedimentary and ash-flow deposits is centred on Horsefly from where if can be followed northwesterly to Hazeltine and Edney creeks near Quesnel Lake and east-southeasterly into the headwaters of the Horsefly River. The Eocene ash-flows are part of a once extensive Tertiary cover that unconformably overlies Quesnel belt volcanic rocks and parts of the quartz diorite pluton south of Horsefly, the Takomkane batholith. To the north of the Quesnel River, about 25 kilometres southeast of Quesnel, there are two outliers of these Tertiary rocks overlying sedimentary rocks of unit 1. South of Horsefly around the Takomkane batholith, and even further south in the Bonaparte Lake area (NTS 92P), the Eocene rocks are fairly abundant as relatively thin Tertiary units under a more widespread cover of Miocene basalt flows. Locally thick units of Eocene rocks are present in faulted depressions. There the rocks are referred to as the Kamloops Group but the Tertiary assemblages also include Eocene and younger, units termed the Skull Hill and Deadman River Formations (Campbell and Tipper, 1971).

The Eocene volcanic sequence in the Quesnel belt, consisting of oldest biotite-bearing trachybasalt flows, the thickest part of the sedimentary succession and the younger, overlying ash flows, is preserved in its entirety only in the postulated graben structure. The original structural depression is now largely exhumed and has been infilled by glaciogenic and fluvial deposits and is covered by thick alluvium. Along, or near, the structural margins of the graben there are locally vuggy, quartz-calcite veins that suggest there has been Tertiary hydrothermal activity. The veins contain elements such as arsenic, mercury, barium and silver (Appendix M) and have the appearance of low-temperature open-space filling, typical of epithermal mineralization.

# CHAPTER 7 METAMORPHISM

Metamorphic grade of the rocks of the central Quesnel belt is, for the most part, subgreenschist facies. Read *et al.*, (1991) assigns the rocks of the study area to mainly the prehnite-pumpellyite zone. Prehnite has been infrequently noted (Schink, 1974; Morton, 1986) but the volcanic rocks are characterized by the widespread occurrence of zeolite mineral assemblages, typical of burial metamorphic conditions. Sedimentary rocks of unit 1, however, are metamorphosed to greenschist facies in the easternmost part of the map area. The higher grade in the eastern part of the belt is attributed to crustal thickening caused by thrusting of Quesnellia over the Omineca Belt and to subsequent deformation at the Barkerville-Quesnellia contact. Regional metamorphism of amphibolite facies in the rocks of Barkerville Terrane indicates the sharp transition in metamorphic grade across the terrane boundary.

*Studies of regional metamorphism in the* Quesnel Lake region have been conducted by many workers (*see* 'Previous Work', Chapter 1). Their conclusions have been synthesized by Greenwood *et al.* (1991) and summarized by Campbell (1978) and Read, *et al.* (1991) on maps showing metamorphic isograds in a basic Barrovian sequence (Figure 7-1). A syntectonic to post-tectonic, early-Middle to Late Jurassic regional metamorphic event is a generalization suggested by most investigators. McMullin (1990) concludes that the metamorphic history can be subdivided into three sequential events, all related to specific periods of deformation. He summarizes (McMullin, 1990, page 198) that:

- Metamorphic mica growth was confined to the first phase of deformation ($D_1$) but garnet may have grown late in $D_1$;
- The major mineral growth occurred during $D_2$ deformation (our $F_1$). The $D_2$ foliation wraps around the garnet porphyroblasts but later kyanite and staurolite porphyroblasts overgrow it,

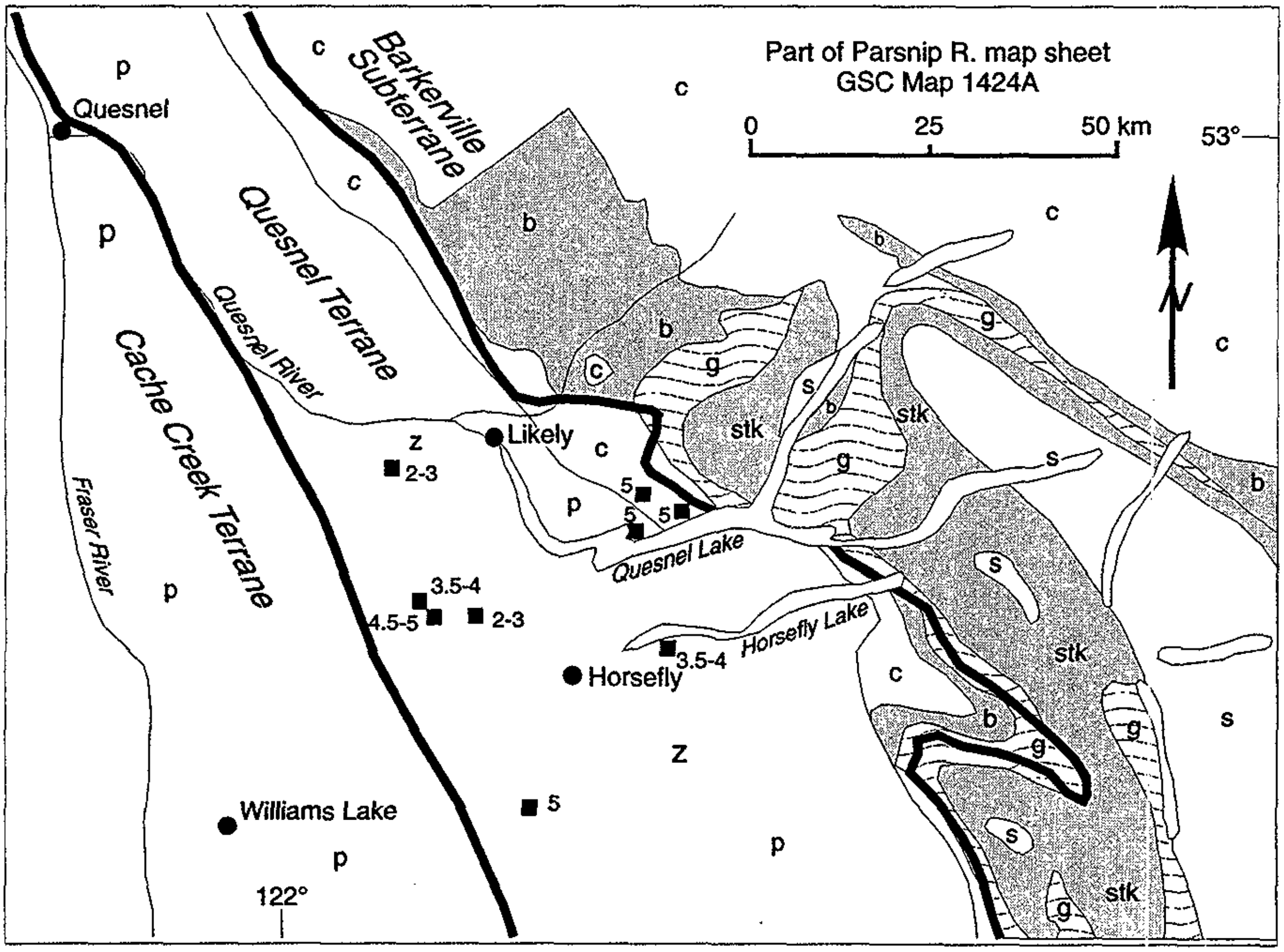



Figure 7-1. Metamorphic facies and zones, central Quesnel Trough (Quesnel Terrane) and adjoining Cache Creek Terrane and Barkerville Subterrane, modified from Read *et al.* (1991) and Greenwood *et al.* (1991). Heavy lines represent terrane boundaries. Symbols used: subgreenschist: **z** - zeolite, **p** - prehnite-pumpellyite; greenschist: **c** - chlorite, **b** - biotite, **g** - almandine garnet; amphibolite: **stk** - kyanite ± staurolite, **s** - sillimanite. Small square with number refers to conodont colour alteration index (CAI).

- Metamorphism waned during late deformation ($D_3$), our $F_2$, and metamorphic recrystallization ceased except in high-grade cores of anticlines; locally there is metamorphic retrogression.

## METAMORPHISM OF THE CENTRAL QUESNEL BELT

Studies of metamorphic rocks at the eastern boundary of Quesnellia, along its tectonic contact with rocks of Barkerville Terrane, were conducted by Bloodgood (1987a,b,c, 1990) in the Eureka Peak area. Her observations (Bloodgood, 1987b) are the basis of much of the following discussion.

Metamorphic grades cut across the tectonic boundary at a low angle and conform to the regional structures related to the emplacement and deformation of the Quesnel Terrane. Metamorphic mineral assemblages are characteristic of the greenschist facies, and vary from chlorite to garnet grade. Metamorphic effects are most evident adjacent to the tectonic boundary, and particularly within the basal part of the metasedimentary succession where rocks of garnet grade are exposed. Metamorphic grade decreases rapidly away from the boundary, both stratigraphically and structurally upsection. Volcanic rocks of chlorite grade are prevalent in the core region of the Eureka Peak syncline.

## METAMORPHIC ASSEMBLAGES - FACIES AND ZONES

### *CROOKED AMPHIBOLITE*

Crooked ampbibolite occurs as fine-grained chlorite-feldspar-amphibolite schist and a coarse-grained actinolite schist. Metamorphic mineral assemblages contain hornblende, actinolite, chlorite, biotite, talc, quartz and calcite. In the chlorite-feldspar-amphibole rock, a strongly developed schistose foliation ($S_1$), defined by planar alignment of chlorite and lesser biotite flakes, is parallel to the compositional layering. Chlorite oriented parallel to the schistose foliation also occurs as intergrowths with fine-grained quartz. Growth of chlorite and biotite was synchronous with first phase deformation but there is evidence for some continued mineral growth during later deformation.

Porphyroblasts of green, pleochroic hornblende are aligned parallel to the schistosity. They contain inclusion trains of ilmenite, quartz and plagioclase and partially to entirely enclose biotite flakes parallel to the $S_1$ foliation. Embayed, inclusion-riddled porphyroblasts of epidote occur randomly throughout the rocks. They vary in size from small to moderately sized grains and are occasionally enveloped by actinolite porphyroblasts. Ilmenite forms blebs, small blades and scaly masses parallel to the foliation and as inclusion trains within porphyroblasts. Rare helicitic textures in hornblende indicate that some rotation of porphyroblasts within the plane of foliation must have occurred during growth. Magnetite occurs both as corroded, anhedral porphyroblasts and as fine stringers parallel to $S_1$. Larger magnetite porphyroblasts appear to truncate $S_1$ schistosity, but smaller grains are commonly oriented parallel to the main foliation.

Microtextures suggest that metamorphism was synchronous with deformation resulting in the development of the primary schistosity. The poikilitic hornblende and epidote enclose a metamorphic foliation and are, therefore, syntectonic to post-tectonic. Growth of biotite during a later phase of deformation is indicated by the growth of biotite across the foliation and parallel to the axial plane of microscopic kinks. Chlorite is pervasive and defines the schistose foliation.

### *PHYLLITES*

Phyllites with a characteristic penetrative foliation ($S_1$), defined by the planar alignment of muscovite, paragonite and minor chlorite, also contain porphyroblasts of garnet, albite, chloritoid and ilmenite. All porphyroblasts are poikilitic, containing inclusions of quartz and opaque minerals. Pressure shadows of quartz and chlorite occur in association with all porphyroblast phases. Compositional layering is defined by quartz-rich versus chlorite-rich bands. Quartz-filled fractures (veins) occur commonly throughout the rocks, mainly oriented parallel or subparallel to bedding. The veins are variably deformed and the quartz is highly strained. The quartz-filled veins and fractures probably formed by pressure-solution processes as fluids generated during dehydration reactions passed through the rocks. There is a marked increase in the intensity of hydraulic fracturing at higher structural and stratigraphic levels, indicated by the increased development of pressure-solution cleavage and the absence of ilmenite porphyroblasts.

Porphyroblast phases include garnet varying from small corroded grains to large, euhedral crystals that range in size from 0.5 to 4 millimetres. Although there is considerable variation in composition and zoning within individual grains, compositions approximate those of almandine. The garnet porphyroblasts generally contain quartz or ilmenite inclusions, but sometimes are completely free of them. McMullin (1990) notes that the weakly poikilitic to inclusion-free nature of the garnets from Quesnellia rocks can be used to distinguish them from the inclusion-rich garnets from rocks of higher metamorphic grade. Albite grains vary in size from 0.5 to 2.5 millimetres although some as large as 7.5 millimetres have been noted. Inclusion trains of quartz in the porphyroblasts sometimes comprise up to 50 per cent of the grain. Albite commonly shows an angular discordance of up to 20° between the external foliation and the foliation within the porphyroblasts, but curved inclusion trains (helicitic textures) are not recorded. Ilmenite forms small porphyroblasts that are oriented parallel to the main foliation and often contains quartz inclusions. Quartz and chlorite strain shadows oriented at low angles to the cleavage plane are associated with the ilmenite.

Chloritoid porphyroblasts, as tabular grains commonly 1 to 3 millimetres in length, grow in a variety of orientations.

The grains occur within pressure shadows of albite porphyroblasts, parallel or at high angles to the main schistosity, parallel to $S_2$ crenulations or at random orientation unrelated to any of the prominent foliations. Chloritoid varies in shape from idiomorphic to strongly poikilitic porphyroblasts containing the $S_1$ foliation. Inclusion trains within the porphyroblasts show no evidence of rotation during growth. On the north limb of the Eureka Peak syncline, the chloritoid occurs as coarse tabular porphyroblasts, showing no preferred orientation, and as intergrown, radiating masses.

Metamorphic grade appears to decrease stratigraphically upsection within the phyllites, and away from the tectonic boundary. Similarly, the size of porphyroblast phases within the phyllites also decreases progressively. Garnet, for example, forms very small grains riddled with quartz before it disappears. At higher elevations, generally above 1900 metres, porphyroblasts are altogether absent in the rocks although they retain a strongly developed foliation outlined by muscovite and paragonite.

### *NICOLA GROUP METAVOLCANICS*

Metavolcanic rocks in the Eureka Peak area equivalent to the Nicola Group, part of our unit 1a, lie within the albite-actinolite-chlorite zone as defined by Winkler (1979). The characteristic metamorphic minerals are actinolite, chlorite, biotite and epidote. Timing of growth of metamorphic minerals within the volcanics is difficult to constrain due to the general lack of deformation features, but is believed to be synchronous with that of the underlying metasediments. The biotite isograd seems to traverse the contact between the two units. Where the rocks are foliated, it is generally a tectonic foliation defined by growth of chlorite. Actinolite needles within the groundmass show a preferred alignment parallel to $S_1$. In a few samples, the tectonic foliation is parallel to a weakly developed primary trachytic flow foliation. Biotite is a minor replacement of mafic minerals but is not sufficiently abundant to define a foliation.

Actinolite occurs as rhombic porphyroblasts and as fine acicular needles in the groundmass and fractures within phenocrysts. It replaces pyroxene and hornblende phenocrysts along cleavage planes, as overgrowths on rims of grains and as fibrous tails parallel to cleavage traces. Albite, commonly together with calcite, is present in fractures and as fibrous growths with radial symmetry in vesicles. Biotite, usually in association with actinolite or chlorite, replaces the mafic minerals. It occurs as stubby, tabular crystals and shows no preferred orientation. Chlorite is usually associated with actinolite and epidote and is predominant where biotite is absent. It occurs most commonly as fine fibres along cleavage traces with actinolite or biotite in hornblende and with calcite in pyroxene. The chlorite also forms as dull green-pleochroic fibres in the groundmass, outlining metamorphic foliation. Both kinking of chlorite and growth of some chlorite synchronous to kinking is evident. Epidote and clinozoisite occur throughout the metavolcanic sequence as 0.1 to 0.5-millimetre grains in fractures and vesicles. Euhedral crystals of zoisite between 0.01 and 0.05 millimetre in size occur in the groundmass and very fine grained epidote is an alteration of plagioclase in association with calcite and sericite (saussurite).

In the main volcanic arc assemblages of units 2, 3 and 4 the rocks are of subgreenschist facies and, in places, virtually unaltered in appearance. The dark green to dark grey pyroxene basalts contain hard, glassy mafic crystals with only slightly chloritized rims, although the plagioclase is universally turbid and saussuritized. Zeolite minerals are widespread. The most abundant zeolite, laumontite, is generally found in veinlets and as coatings on fractures. It also occurs together with calcite as a matrix constituent of sheared and brecciated rocks and volcanic breccias. Amygdules in vesicular flows contain thomsonite and rare analcite together with calcite and lesser quartz. Fibrous scolecite was noted in a few vesicles in the subaerial basalts of unit 4. The presence of heulandite and chabazite in addition to analcite was noted by Bailey (1978). Locally zones of more intense replacement of the greenschist assemblage are interpreted to be products of propylitic alteration related to nearby intrusive activity. Overall the appearance of the main volcanic arc rocks is consistent with conditions of regional burial metamorphism and very localized hydrothermal activity.

Prehnite is rarely observed in the rocks; pumpellyite has not been documented. Schink (1974) recognized prehnite in association with actinolite as an alteration of pyroxene and in stringers cutting microperthite veinlets in monzonite and syenite at the Shiko Lake intrusion. Morton (1976) describes prehnite together with an assemblage of epidote, chlorite, albite, magnetite and hematite as the matrix of lapilli breccias in the Lemon Lake area. He also notes that prehnite is found with carbonate and chlorite in fault zones in volcaniclastic rocks near Quesnel Lake.

## CONDITIONS OF METAMORPHISM

Mineral assemblages in the basal metasedimentary part of Quesnellia are characteristic of greenschist facies. The metamorphic isograd representing the first appearance of garnet closely follows the terrane boundary, and locally lies within Quesnellia, in the southeastern part of the map area. Rocks of higher metamorphic grade, including staurolite, kyanite and sillimanite-bearing rocks, occur immediately to the east in the Barkerville Terrane. The main volcanic arc assemblages of the central Quesnel belt are zeolite-bearing, locally propylitic rocks of subgreenschist facies.

The Crooked amphibolite contains metamorphic hornblende, evidence that it experienced higher temperature conditions within the overall low-grade metamorphic zone in which it occurs. Hornblende porphyroblasts contain optically continuous inclusions of epidote, biotite and chlorite, indicating that the hornblende developed slightly later. The change from actinolite to hornblende is postulated to take place in the Eureka Peak area under pressure-temperature conditions similar to those in the adjoining phyllites, based on the appearance of almandine garnet, which occurs at about 500° C in metapelitic rocks (Winkler, 1979).

The metapelitic black phyllite sequence is characterized by porphyroblasts of almandine garnet, chlorite, albite, chloritoid, muscovite and quartz. The bulk composition of the rocks significantly affects the mineral paragenesis. The presence of chloritoid especially requires a special bulk composition characterized by a high iron/magnesium ratio, a relatively high aluminum content, and low potassium, sodium and calcium (Zen and Thompson, 1974). The presence of almandine-rich garnet indicates the higher temperature zone of greenschist facies metamorphism. The proximity of these assemblages to the upper boundary of the greenschist facies and limited stability of chloritoid together with albite in a limited temperature range of 510 to 575°C according to Hoschek (1969), accounts for the relative rarity of the observed assemblage. A minimum temperature in the order of 345°C can be inferred for chloritoid and chlorite-bearing rocks based on studies of similar rocks in the Blackwater Range of the Rocky Mountains by Ghent *et al.*, (1989). The colour alteration index (CAI) of conodonts ranges from CAI 5 in the phyllites to 2 or 3 in the overlying volcanic rocks. This indicates chlorite zone metamorphic facies in the phyllites and prehnite-pumpellyite to zeolite metamorphic facies in the overlying Nicola volcanic assembalges. These conditions correspond to subgreenschist metamorphic conditions with maximum temperatures slightly in excess of 400° C (Greenwood *et al.*, 1991).

Metamorphic assemblages in Nicola volcanics within or near the top of the basal sedimentary unit, mainly unit 1a, contain actinolite, epidote, chlorite, albite, biotite, quartz and calcite. The metamorphic minerals commonly occur as overgrowths and replacements along cleavage planes in the primary igneous minerals. Chlorite outlines the planar foliation fabric. Saussuritization of plagioclase varies from slight to complete replacement by fine-grained epidote, calcite and sericite.

The growth of metamorphic minerals as porphyroblasts occurred during and outlasted the phase one deformation ($F_1$) that is associated with Early Jurassic convergence and terrane accretion. The first phase foliation is defined in Crooked amphibolite by growth of metamorphic biotite and chlorite; in the metasedimentary phyllitic rocks by muscovite and phengite or paragonite; and in the older Nicola volcanics by chlorite. Most porphyroblasts contain inclusions following the $S_1$ foliation which traverse the porphyroblasts as straight lines, and rarely show any curvature within the porphyroblast. From this widespread textural relationship it is inferred that the porphyroblasts developed at the same time or after $D_1$ deformation.

The prominence of fractures on all scales filled with crystalline quartz throughout the metamorphosed rocks is indicative of the presence of high-pressure fluid or fluids (Cox *et al.*, 1987). Mobile pore fluids were probably generated by dewatering reactions accompanying prograde metamorphism. Pore-fluid pressures during regional metamorphism tend to lower the effective stresses and, together with dissolution processes of pressure solution, increase porosity and permeability (Etheridge *et al.*, 1983, 1984; Cox *et al.*, 1991). The large-scale circulation of fluids probably dissipated heat from the underlying rocks. This may account for the rapid decrease, without a break, in metamorphic grade observed across the tectonic terrane boundary and the abundance of veins and fractures in the overlying rocks of Quesnellia.

# CHAPTER 8 ECONOMIC GEOLOGY

The Quesnel Trough is a well-mineralized region typical of other Late Triassic - Early Jurassic volcano-plutonic island arcs in the Cordillera. It hosts a wide variety of mineral deposits. The area mapped contains 82 mineral occurrences recorded up to 1989 in the MINFILE property file system; a few additional deposits of significance have been added in this report (Table 8-1). Fifty-six of the occurrences are bedrock-hosted base and precious metal deposits; twenty-one are placer gold deposits. The remaining five occurrences are sites with various other commodities, including industrial minerals, or unclassified deposit types. The major deposit types and individual occurrences of most importance are summarized and discussed below. Most of the mineral deposits in the map area not described in this report are summarized in the MINFILE records. Regional geochemical survey results are summarized and lithogeochemical samples (assays) from altered zones and other geochemical indications of mineral occurrences are reported in Table 8-4 and Appendix M, respectively, and results are discussed near the end of this chapter.

The principal recent exploration and economic development targets in the central Quesnel belt are alkalic intrusion-related porphyry copper-gold deposits and gold-bearing propylitic alteration zones formed in volcanic rocks peripheral to some of the intrusions. Other important targets are auriferous quartz veins in the black phyllite metasedimentary succession. These rocks host auriferous quartz veins of two similar-looking but possibly genetically and temporally distinct types. The veins in some black phyllite members have potential to be mined as large tonnage, low-grade deposits. Tertiary rocks are mineralized with copper and gold in association with tourmaline-sericite-pyrite and propylitic alteration. Antimony-arsenic and mercury mineralization in some apparently low-temperature quartz-calcite veins indicates the potential for discovery of epithermal deposits. Placer mining for gold, said to locally occur together with platinum, has been of major historical and economic importance to the region. It continues to have importance because of a small amount of continuing gold production in the district and exploration for buried placer channels, especially those with cemented gravels that are amenable to exploitation by underground mining methods.

## LODE DEPOSITS

### *INTRUSION-RELATED DEPOSITS*

#### PORPHYRY COPPER-GOLD DEPOSITS ASSOCIATED WITH ALKALIC INTRUSIONS

Porphyry copper-gold deposits of the alkalic class (Barr *et al.*, 1976; Mineral Deposit Research Unit (MDRU) current studies, reports in preparation, 1996), and the closely related propylitic gold deposits, are currently the most advanced mine developments and main exploration targets in the region. The largest known deposit in the map area is Mount Polley, previously known as the Cariboo-Bell deposit. Copper showings there were known for decades, probably from the time of the placer gold rush, but the potential for a porphyry deposit was first recognized in 1964 (Hodgson *et al.*, 1976). The style of mineralization and geological setting of Mount Polley are similar to other alkalic porphyry deposits in Quesnellia, notably Mount Milligan (Sketchley *et al.*, 1995). Similar deposits also occur to the north in the Hogem batholith and are found to the south at Afton mine and its nearby deposits in the Iron Mask batholith and at Similco mine (Copper Mountain, Ingerbelle, and others) in the Copper Mountain intrusions. All these alkalic porphyry copper-gold deposits are described in Canadian Institute of Mining Metallurgy and Petroleum - Special Volumes, (Sutherland Brown, 1976); and Special Volume 46 'Porphyry Deposits of the Northern Cordillera', (T.G. Schroeter, Editor, 1995).

The regional distribution of intrusion-related deposits in the Quesnel Trough follows, in large part, the central axis of the volcanic belt. Plutons intrude along the axis of the volcanic arc; less commonly they are emplaced in rocks of the basal metasedimentary unit. From the north, near Quesnel, to the southeast, near Horsefly, at intervals of approximately 8 to 11 kilometres, the main prospects include: Mouse Mountain, Cantin Creek, Gerimi Creek, Maud Lake, QR, Bullion Lode, Mount Polley, Shiko Lake, Kwun Lake and Lemon Lake (Figure 8-1). The 'best looking' plutons for mineralization, that is, those with evidence of hydrothermal alteration, appear, on the basis of their geological settings, to be the highest level, subvolcanic plutons. These were inevitably emplaced in the upper units of the volcanic arc. They are commonly recognized as differentiated diorite-monzonite-syenite zoned or multiple intrusions or as cupolas with irregularly shaped apophyses, dikes and sills. Breccia bodies are common, as both intrusion and hydrothermal breccias. Elsewhere, and most commonly, many of the mapped dioritic plutons and small plugs in the Quesnel belt display only narrow zones of hornfels. These intrusions represent either relatively dry magmas or were emplaced at greater depth, generally in the basal sedimentary portion of the arc assemblage. The ages of the deposits (Table 4-1) and the relationships between the alkalic intrusions and their (in part) cogenetic volcanic hostrocks are discussed in Chapter 4.

##### *Mount Polley (Cariboo-Bell) Deposit; MINFILE 093A/008*

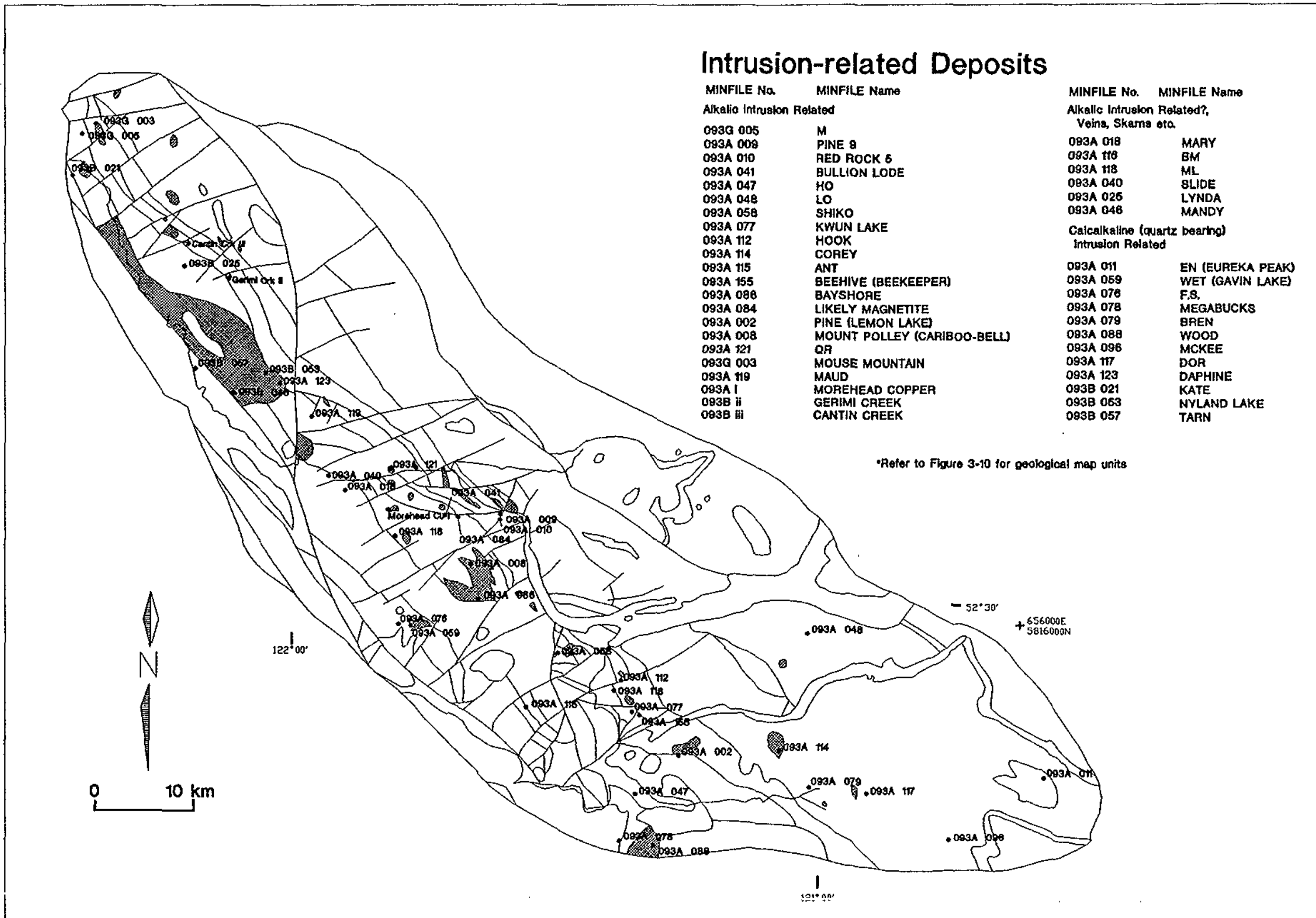
Mount Polley (formerly Cariboo-Bell) is located 56 kilometres northeast of Williams Lake and 8 kilometres southwest of Likely. It lies between Polley Lake and

## TABLE 8-1
## PRINCIPAL MINERAL OCCURRENCES IN THE QUESNEL MAP AREA, CLASSIFIED IN MINFILE ACCORDING TO MAJOR GENETIC TYPES

| MINFILE Number | MINFILE Name | NTS Map | UTM Zone 10 Northing | UTM Zone 10 Easting | Commodities | Deposit Character |
|---|---|---|---|---|---|---|
| **INTRUSION RELATED DEPOSITS:** | | | | | | |
| **Alkalic porphyry Cu-Au and affiliated vein, stockwork, breccia, igneous contact, calcsilicate (skarn) and magnetite deposits** | | | | | | |
| 093G 005 | M | 093G01W | 5876579 | 543919 | Cu, Au | disseminated |
| 093A 009 | PINE 9 | 093A12E | 5830445 | 595836 | Cu | disseminated |
| 093A 010 | RED ROCK 5 | 093A12E | 5829858 | 595848 | Cu | disseminated |
| 093A 041 | BULLION LODE | 093A12E | 5830250 | 589150 | Au,Cu,Ag | disseminated |
| 093A 047 | HO | 093A06W | 5796399 | 612607 | Cu | stockwork |
| 093A 048 | LO | 093A06E | 5816085 | 633409 | Au,Cu | disseminated |
| 093A 058 | SHIKO | 093A06W | 5813499 | 603078 | Cu,Au | disseminated |
| 093A 077 | KWUN LAKE | 093A06W | 5806372 | 612114 | Au,Cu | disseminated, stockwork, breccia |
| 093A 112 | HOOK | 093A06W | 5810205 | 610780 | Cu | stockwork, disseminated |
| 093A 114 | COREY | 093A06E | 5801837 | 630086 | Cu | stockwork, disseminated |
| 093A 115 | ANT | 093A05E | 5806867 | 599210 | Cu | disseminated |
| 093A 155 | BEEHIVE (BEEKEEPER) | 093A06W | 5805990 | 613049 | Cu,Au,Hg | stockwork |
| 093A 086 | BAYSHORE | 093A12E | 5820103 | 593287 | Cu | disseminated |
| 093A 084 | LIKELY MAGNETITE | 093A12E | 5830075 | 590800 | Ma,Au | massive |
| 093A 002 | PINE (LEMON LAKE) | 093A06W | 5801129 | 617931 | Cu,Au | disseminated |
| 093A 008 | MOUNT POLLEY (CARIBOO-BELL) | 093A12E | 5824352 | 592415 | Cu,Au | stockwork |
| 093A 121 | QR | 093A12W | 5835913 | 582162 | Au,Ag,Cu | stockwork |
| 093G 003 | MOUSE MOUNTAIN | 093G01W | 5877831 | 545602 | Cu,Ag,Au | stockwork, breccia |
| 093A 119 | MAUD | 093A12W | 5842249 | 572448 | Cu,Au | breccia, disseminated |
| 093B iii | CANTIN CREEK | 093B16E | 5862750 | 555660 | Cu, Au | disseminated |
| 093B ii | GERIMI CREEK | 093B16E | 5858820 | 560885 | Cu, Au | disseminated |
| 093A i | MOREHEAD COPPER | 093A12W | 5830780 | 581575 | Cu | disseminated, stockwork |
| **Limestone-hosted veins, minor replacement and skarn zones - probably associated with alkalic intrusions** | | | | | | |
| 093A 018 | MARY | 093A12W | 5833166 | 576682 | Cu | vein replacement |
| 093A 116 | BM | 093A06W | 5808950 | 609939 | Cu | vein replacement |
| 093A 118 | ML | 093A12W | 5827702 | 582752 | Cu | vein, disseminated |
| 093A 040 | SLIDE | 093A12W | 5835018 | 574585 | Cu | vein |
| 093B 025 | LYNDA | 093B16E | 5860519 | 556699 | Cu,Ag | stratiform |
| 093B 046 | MANDY | 093B16E | 5845080 | 562749 | Ag,Cu,Au,Sb,Zn | vein |
| **Calcalkaline porphyry Cu-Mo and related vein, stockwork, skarn deposits** | | | | | | |
| 093A 011 | EN (EUREKA PEAK) | 093A07E | 5798525 | 662289 | Cu,Au | vein |
| 093A 059 | WET (GAVIN LAKE) | 093A05W | 5816765 | 584767 | Cu,Mo,Pb,Au,Ag | stockworks, vein, disseminated |
| 093A 076 | F.S. | 093A05W | 5816986 | 583254 | Cu, Mo | vein |
| 093A 078 | MEGABUCKS | 093A06W | 5790666 | 610594 | Au,Cu | stockwork, vein, disseminated |
| 093A 079 | BREN | 093A06E | 5797361 | 633823 | Au | disseminated |
| 093A 088 | WOOD | 093A06W | 5790023 | 614915 | Cu | stockwork |
| 093A 096 | MCKEE | 093A07W | 5790984 | 650713 | Au,Cu | vein, shear, replacement |
| 093A 117 | DOR | 093A07W | 5796626 | 640722 | Cu,Au | vein, shear, disseminated |
| 093A 123 | DAPHNE | 093A13W | 5846269 | 568395 | Mo | stockwork |
| 093B 021 | KATE | 093B16W | 5871564 | 542864 | Cu,Mo | stockwork |
| 093B 053 | NYLAND LAKE | 093B16E | 5847575 | 566728 | Mo | stockwork, vein |
| 093B 057 | TARN | 093B16E | 5847989 | 558102 | Cu,Ag,Au,Mo | disseminated, replacement, skarn |
| **STRUCTURALLY CONTROLLED (MESOTHERMAL) DEPOSITS:** | | | | | | |
| **Veins, stockworks and gash fillings, minor breccia and shear replacements** | | | | | | |
| 093A 149 | JAMBOREE | 093A07W | 5796008 | 641820 | Au,Cu | replacement |
| 093B 027 | AB | 093B16E | 5865196 | 554889 | Pb,Ag | disseminated, vein |
| 093A 003 | PROVIDENCE | 093A11W | 5833518 | 606906 | Ag,Pb,Zn,Au | vein |
| 093A 012 | ZED | 093A07W | 5813967 | 643797 | Cu | vein |
| 093A 043 | CPW | 093A11W | 5827413 | 604762 | Au,Ag,Pb,Cu,Zn | vein |
| 093A 072 | JOY | 093A12E | 5826029 | 600649 | Cu,Pb,Au,Ag | vein |
| 093A 092 | FORKS | 093A07W | 5810260 | 650120 | Au | vein |
| 093A 127 | MOOSE | 093A12E | 5830949 | 599400 | Au,Ag,Cu,Zn,Pb | stockwork |
| 093A 132 | NOV | 093A11W | 5834199 | 602605 | Au,Ag,Pb | vein |
| 093A 133 | PEACOCK | 093A11W | 5844165 | 604703 | Ag,Au,Pb,Zn | vein |
| 093A 136 | SHAW | 093A12E | 5836217 | 590631 | Pb,Zn | vein |
| 093A 147 | TAM | 093A11W | 5831981 | 601523 | Ag,Pb | vein |
| 093A 150 | FRASERGOLD | 093A07E | 5797570 | 665183 | Au | vein |
| 093A 151 | BIG | 093A11W | 5832131 | 608498 | Ag,Au,Pb | vein |
| 093A 154 | TRUMP | 093A11W | 5833847 | 604981 | Ag,Pb | vein |
| 093B 029 | COUSIN JACK | 093B16W | 5860547 | 544551 | Pb,Ag,Au | vein |
| **VOLCANIC-HOSTED COPPER DEPOSITS:** | | | | | | |
| **Native copper, minor chalcocite** | | | | | | |
| 093A 066 | B | 093A12E | 5822230 | 586255 | Cu* | disseminated |
| 093A 064 | RED | 093A06W | 5794946 | 605590 | Cu* | disseminated |
| 093A 075 | MOFFAT | 093A06W | 5794231 | 606856 | Cu* | disseminated |
| **PLACER DEPOSITS:** | | | | | | |
| 093A 014 | MIOCENE, SHAFT | 093A06W | 5799050 | 607950 | Au | unconsolidated |
| 093A 015 | WARD'S HORSEFLY | 093A06W | 5799700 | 608850 | Au | unconsolidated |
| 093A 016 | BLACK CREEK | 093A06E | 5797240 | 630200 | Au | unconsolidated |
| 093A 017 | ANTOINE CREEK | 093A05E | 5807900 | 597300 | Au | unconsolidated |
| 093A 025 | BULLION PIT | 093A12E | 5831450 | 592200 | Au | unconsolidated |
| 093A 042 | HOBSON'S HORSEFLY | 093A06W | 5794392 | 605715 | Au | unconsolidated |
| 093A 067 | SPANISH CREEK | 093A11W | 5834214 | 603319 | Au | unconsolidated |
| 093A 069 | MOREHEAD CREEK | 093A12W | 5832323 | 581866 | Au | unconsolidated |
| 093A 080 | MURDER GULCH | 093A12E | 5830500 | 570810 | Au | unconsolidated |
| 093A 085 | MAUD CREEK | 093A12E | 5830600 | 578550 | Au,Ag,Pt | unconsolidated |
| 093A 137 | BUXTON CREEK | 093A12W | 5835025 | 570865 | Au | unconsolidated |
| 093A 141 | CEDAR CREEK | 093A12E | 5825119 | 601478 | Au | unconsolidated |
| 093B 018 | QUESNEL CANYON | 093B16W | 5871538 | 543424 | Au | unconsolidated |
| 093B 022 | AINSWORTH, SARDINE FLATS | 093B16E | 5854109 | 552770 | Au | unconsolidated |
| 093G 009 | HANNANDOR, LIGHTNING CREEK | 093G01E | 5874786 | 565551 | Au | unconsolidated |
| 093G 022 | MACMILLIAN (COTTONWOOD R.) | 093G01E | 5881987 | 553023 | Au, Pt | unconsolidated |
| 093G 025 | COTTONWOOD | 093G01E | 5882148 | 550789 | Au,Pt | unconsolidated |
| 093G 059 | GAGEN CREEK | 093G01E | 5873328 | 562812 | Au | unconsolidated |
| 093G 060 | MOSTIQUE CREEK | 093G01E | 5874791 | 565906 | Au | unconsolidated |
| 093H 012 | WINGDAM | 093H04W | 5877556 | 569146 | Au | unconsolidated |
| 093H 086 | WINGDAM CREEK | 093H04W | 5876467 | 568621 | Au | unconsolidated |
| **OTHER DEPOSITS:** | | | | | | |
| 093A 013 | SOVEREIGN CREEK | 093A13W | 5871700 | 574396 | Talc,Ni,Ag, Zn,Au | massive |
| 093A 046 | EAGLET | 093A10W | 5825919 | 636852 | F,Ag,Zn,Pb,Mo,Sr | vein |
| 093A 061 | KUSK | 093A07E | 5793993 | 667333 | Au,Ag,Zn,Pb,Cu | stratabound |
| 093A 139 | FONTAINE CREEK | 093A13W | 5866429 | 580975 | Asbestos | stockwork |
| 093A 134 | HORSEFLY | 093A06W | 5794398 | 614301 | Silica | stratiform |

*Database from MINFILE*

*MINFILE abbreviations: Cu = copper (Cu* = native copper), Au = gold, Ag = silver, Pb = lead, Zn = zinc, Ni = nickel, F = fluorite, Mo = molybdenum, Sr = strontium, Hg = mercury, Sb = antimony, Pt = platinum*




## Intrusion-related Deposits

**Alkalic Intrusion Related**

| MINFILE No. | MINFILE Name |
|---|---|
| 093G 005 | M |
| 093A 009 | PINE 9 |
| 093A 010 | RED ROCK 5 |
| 093A 041 | BULLION LODE |
| 093A 047 | HO |
| 093A 048 | LO |
| 093A 058 | SHIKO |
| 093A 077 | KWUN LAKE |
| 093A 112 | HOOK |
| 093A 114 | COREY |
| 093A 115 | ANT |
| 093A 155 | BEEHIVE (BEEKEEPER) |
| 093A 086 | BAYSHORE |
| 093A 084 | LIKELY MAGNETITE |
| 093A 002 | PINE (LEMON LAKE) |
| 093A 008 | MOUNT POLLEY (CARIBOO-BELL) |
| 093A 121 | QR |
| 093G 003 | MOUSE MOUNTAIN |
| 093A 119 | MAUD |
| 093A I | MOREHEAD COPPER |
| 093B ii | GERIMI CREEK |
| 093B iii | CANTIN CREEK |

**Alkalic Intrusion Related?, Veins, Skarns etc.**

| MINFILE No. | MINFILE Name |
|---|---|
| 093A 018 | MARY |
| 093A 116 | BM |
| 093A 118 | ML |
| 093A 040 | SLIDE |
| 093A 025 | LYNDA |
| 093A 046 | MANDY |

**Calcalkaline (quartz bearing) Intrusion Related**

| MINFILE No. | MINFILE Name |
|---|---|
| 093A 011 | EN (EUREKA PEAK) |
| 093A 059 | WET (GAVIN LAKE) |
| 093A 076 | F.S. |
| 093A 078 | MEGABUCKS |
| 093A 079 | BREN |
| 093A 088 | WOOD |
| 093A 096 | MCKEE |
| 093A 117 | DOR |
| 093A 123 | DAPHINE |
| 093B 021 | KATE |
| 093B 053 | NYLAND LAKE |
| 093B 057 | TARN |

*Refer to Figure 3-10 for geological map units

Figure 8-1. Generalized geological map of project area - locations of intrusion-related deposits showing major alkalic porphyry copper-gold prospects.

Bootjack Lake at an elevation of about 1250 metres on the western slopes of Mount Polley. The property is accessible from Highway 97 at 150 Mile House by way of 76 kilometres of paved road and a 14 kilometres forestry access road.

The deposit was discovered in 1964 after examination of trenches with showings of copper oxide minerals within a large magnetic anomaly indicated by a federal-provincial airborne magnetic survey of the Quesnel mineral belt (Hodgson *et al.*, 1976). The initial pit reserves are stated to be 48.8 million tonnes of material with an average grade of 0.38% copper and 0.56 gram per tonne gold (Nikic *et al.*, 1995). Revised ore reserves (1995) reported by the company are: 81.5 million tonnes with 0.30% copper and 0.414 grams per tonne gold. The mining reserves are contained in the West and Central zones (Figure 8-2), within the larger Cariboo-Bell zone, a geological resource containing around 230 million tonnes with an average grade of 0.25% copper and 0.34 gram per tonne gold (MINFILE). Feasibility studies completed in 1990 outline plans for open-pit mining from the coalescing Central and West zones in a 5 million tonne-per-year milling operation. Approval in Principle was granted by the provinical government in June 1991 but development of the property was suspended a short time later when the price of copper dropped. The deposit is being prepared for production in 1996.

**Geology:** The deposit is contained largely within the Polley stock. This intrusion is approximately 2 kilometres by 5 kilometres in size, and elongated in a northwesterly direction. The Polley stock consists of mainly diorite, lesser plagioclase porphyry, intrusion breccia, hydrothermal breccia and minor pyroxenite and gabbro. Late intrusions, mainly post-mineral dikes, include augite porphyry, feldspar porphyry, monzonite porphyry, sanidine monzonite porphyry and biotite lamprophyre. To the southwest, the Bootjack stock is exposed at Bootjack Lake. It comprises pseudoleucite and orbicular syenite porphyry and granophyric nepheline syenite, lithologies similar to those at Mouse Mountain, 70 kilometres to the northwest. Together, all these rocks form the largest, and probably the highest level, alkalic intrusive complex in the Quesnel belt. Hostrocks for the intrusions are felsic-clast bearing pyroclastic rocks of unit 3.

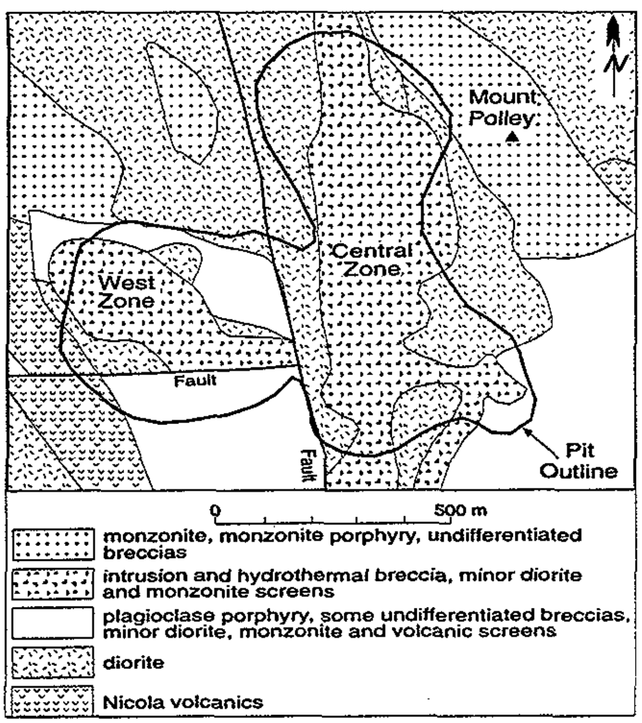



Figure 8-2. Mount. Polley (Cariboo-Bell) simplified geology and proposed pit S-19 outline after Fraser (1994) and Nikic *et al.* (1995). Post mineral dikes have been removed.

The petrochemistry of the alkalic complex is considered by Lang *et al.* (1993) to be part of an unusual silica-undersaturated subtype of the alkalic suite that includes the Galore Creek and Copper Canyon intrusions in Stikinia and the Rayfield River intrusions near Bonaparte Lake. The more common alkalic porphyry deposits in the Cordillera are associated with quartz-saturated or near-saturated alkalic intrusions, referred to by Lang *et al.* as the silica-undersaturated subtype.

**Mineralization and Alteration:** Mineralization is associated mainly with hydrothermal and intrusion breccias in the Polley stock. Intrusion breccia is matrix supported with plagioclase porphyry containing commonly around 35% subangular to rounded clasts of diorite, plagioclase porphyry and lapilli tuff. Hydrothermal breccia is polylithc and contains clasts of intrusive breccia in addition to diorite and plagioclase porphyry. These breccias commonly occur at contacts between the various rocks types. The hydrothermal breccia is vuggy and contains abundant secondary biotite, albite, potassium-feldspar, actinolite, magnetite and diopside. The breccia has extensive stockworks containing chalcopyrite, magnetite, diopside and amphibole.

Fraser (1994, 1995) recognized three stages of breccia emplacement on the basis of crosscutting relationships. The oldest is dominated by diorite and minor volcaniclastic clasts in a matrix of plagioclase porphyry. It is cut by polylithic breccia that contains cavities containing chalcopyrite, pyrite, albite, biotite, magnetitie and diopside. These are hydrothermal breccias that contain the best copper and related gold grades. The latest breccia is an intrusion breccia with distinctive pyroxenite and diorite clasts in a monzonitic matrix; it is post-mineralization in age. Late calcite and zeolite in vugs and dilational veins overprint the older alteration products.

Ore minerals are chalcopyrite, lesser bornite and rare native gold, associated with magnetite and minor pyrite. The minerals occur as disseminated grains and fracture and cavity fillings. Copper mineralization is associated with potassium feldspar, biotite and diopside alteration in both the intrusive rocks, breccias and, to a lesser extent, the host volcanic rocks. Peripheral mineralization with outward-decreasing chalcopyrite to pyrite ratio is associated with epidote-garnet and epidote-chlorite alteration. A weakly developed pyritic halo in propylitic volcanic rocks surrounds the mineralized intrusions and breccias. Supergene copper minerals are present in parts of the deposit but little copper enrichment has occurred due to the widespread presence of calcite, albitic plagioclase, prehnite, zeolite minerals and the overall low sulphide content. Supergene minerals include malachite, chrysocolla, native copper, cuprite, digenite, covellite (Nikic *et al.*, 1995), and probably some brochantite.

**Alteration:** Studies by Fraser (1994, 1995) have identified two distinct alteration assemblages that refine the older descriptions. The alteration is now classified as a copper-gold mineralized calc-potassic type with a (central) potassic and intermediate calc-potassic zone and a peripheral propylitic type outside the economic mineralization. The calc-potassic alteration is characterized by potassium-feldspar, biotite, diopside, albite, magnetite, lesser actinolite and minor garnet. Garnet alteration occurs mainly in two zones at the periphery of the proposed pit. The andradite garnet in the West zone is associated with intense albite and potassium-feldspar alteration in a hydrothermal breccia. In the Central zone, massive garent is overprinted by magentite, diopside and epidote (Fraser, 1994). The peripheral propylitic alteration is characterized by pyrite, epidote and albite. Pyrite is rare overall; its concentration rarely exceeds 1% except in a pyritic halo along the northeast and southwest margins of the calc-potassic zone where up to 6% pyrite has been noted.

**Summary:** Mount Polley is typical of many porphyry deposits with a central potassically-altered core with chalcopyrite, magnetite, lesser bornite and minor pyrite mineralization. The surrounding rocks show widespread propylitic alteration characterized by an epidote-pyrite-albite assemblage. A locally developed, intermediate zone contains garnet. It formed together with albite, younger potassium feldspar and albite and is overprinted by magnetite, diopside, epidote, calcite, chlorite, pyrite, chalcopyrite and zeolites. The Polley stock is part of an intrusive alkalic complex comprising various medium-grained to porphyritic intrusions and breccias that are emplaced into volcanics of common petrogenetic lineage. Fraser (1994) states that the middle of three breccias is associated with the main zone of mineralization. The emplacement of breccias and the intrusions was structurally controlled. North to north-northwest-trending faults separate the complex into two mineralized zones. Each zone has distinctive alteration and mineralization assemblages; together they consitute the orebody at the proposed pit site.

## PORPHYRY COPPER-GOLD PROSPECTS ASSOCIATED WITH ALKALIC STOCKS

### *Lemon Lake (Pine, Fly, Lem); MINFILE 093A/002*

The Lemon Lake prospect, 10 kilometres east-northeast of Horsefly and a few kilometres south of Horsefly Lake is the most southerly of the known alkalic copper-gold prospects in the Quesnel belt. It is associated with a poorly exposed diorite to monzonite stock in which multiple intrusive phases have been recognized from mapping and examination of diamond-drill cores by Morton (1976). The stock intrudes a sequence of Upper Triassic pyroxene basalts of unit 2 but is surrounded by breccias with felsic clasts. These proximal breccias appear to be locally preserved, coeval rocks of unit 3 that form an apron around the stock.

The volcanic hostrocks surrounding the intrusion and part of the stock itself, have undergone propylitic alteration characterized by widespread development of epidote, chlorite and calcite. Zeolite may also be a related, more distal and later-forming hydrothermal alteration mineral. Locally, mainly within the intrusion, secondary biotite and potassium-feldspar alteration is associated with copper mineralization. The mineralization also occurs sparingly in the volcanic hostrocks as chalcopyrite, magnetite, pyrite and pyrrhotite. The best samples from surface trenches reported in 1984 returned assays of 0.25% copper over 21.3 metres.

### *Kwun Lake; MINFILE 093A/077 and Beehive (Beekeeper); MINFILE 093A/155*

The Kwun Lake showing, and Beehive mercury occurrence, about 1.5 kilometres to the southeast, occur about 7.5 kilometres north of Horsefly. They are associated with the Kwun Lake stock, a small, zoned diorite to syenodiorite intrusion typical of Quesnel belt alkalic plutons. The stock is in contact with breccias of unit 3 on three sides. On the western side, the stock and the felsic breccias are separated from older pyroxene basalts by faults. Along this faulted margin of the stock the rocks are locally hydrothermally altered by secondary potassium-feldspar and biotite, gypsum and more widespread propylitic assemblages characterized by epidote, chlorite and calcite. Mineralization consisits of small amounts of chalcopyrite, pyrite and rare bornite in brecciated zones. The propylitically altered rocks are more sparsely mineralized, but they typically contain abundant hydrothermal magnetite. A small zone 3 to 6 metres wide in a monzonitic hostrock, tested by diamond drilling, contains from 0.4 to 1 gram per tonne gold.

The Beekeeper zone near the eastern margin of the Kwun Lake stock has mineralization typical of elsewhere in the stock, comprising chalcopyrite, pyrite and pyrrhotite, with anomalous gold values. The sulphide minerals occur as disseminations and fracture fillings associated with pink potassium-feldspar and calcite-epidote-chlorite alteration. A second period of mineralization superimposed on the first, is characterized by cinnabar, ankerite, fluorite and quartz. The younger episode formed veins and fracture fillings spatially associated with syenitic hornblende porphyry dikes, part of the Kwun Lake intrusive suite. Up to several percent mercury has been reported from some samples (see also Appendix M, 1986-AX8).

Copper mineralization in basaltic rocks similar to the Kwun Lake prospect, and associated with other alkalic intrusions, is also present 3 to 5 kilometres to the north. At the HOOK (MINFILE 093A/112) and BM (MINFILE 093A/116) properties pyrite and chalcopyrite in propylitically-altered basalts appear to be related to small intrusions or a number of dikes of monzonite or syenite.

### *Shiko Lake (Redgold); MINFILE 093A/058*

A zoned, medium-grained diorite to monzonite stock, locally with coarse-grained syenite dikes and granophyric-textured to pegmatitic zones, hosts chalcopyrite-pyrite-bornite mineralization. The stock is about 2.3 kilometres long in a northeast direction. It intrudes the youngest basaltic rocks of unit 2 in the east but to the west is emplaced in, or in fault contact with, breccias and sedimentary rocks of unit 3. An embayment along the southern part of the stock contains breccias with volcanic clasts and grades into an intrusion breccia with diorite matrix closer to the stock. This breccia appears to mark the intrusive centre of an intrusive-extrusive magmatic vent.

### *Bullion Lode; MINFILE 093A/041*

An equigranular to porphyritic, medium-grained pink monzonite intrudes fine-grained diorite in the area of the Bullion placer mine where a number of the dikes and the contact of the pink monzonite are exposed in the western part of the pit. The main monzonitic body is emplaced to the west and north of the Bullion pit in pyroxene basalt hostrocks of unit 2. Widespread pyrite with rare chalcopyrite is present; locally there are concentrations of magnetite. The eastern part of the Bullion stock contains the Likely Magnetite iron-gold-copper showings (MINFILE 093A/084). Rare bornite was noted in basaltic hostrocks on the south bank of the Quesnel River.

### *Others*

A number of other alkalic stocks in the Quesnel belt have been examined for their porphyry copper-gold potential (Figure 8-1). The deposits include: Maud Lake (MINFILE 93A/119), Mouse Mountain (MINFILE 93G/005) and the Cantin Creek and Gerimi Creek prospects in NTS 93B that are not coded in MINFILE. A few, such as Cantin Creek and Mouse Mountain are associated with mafic rocks of the alkalic intrusive suite such as gabbro and pyroxenite, in addition to diorite and monzonite. Some of the mafic rocks are reportedly serpentinized, suggesting that some of the intrusion may be emplaced along large, possibly regional-scale, structural breaks. The prospects have been covered by assessment reports filed with the Ministry of Energy, Mines and Petroleum Resources, but little or no other information has been issued.

## PROPYLITE GOLD DEPOSITS

The type deposit from which a model for 'Propylite gold' deposits has been created is the QR (Quesnel River) prospect. It has alternatively been described as an alkaline copper-gold porphyry-related replacement deposit by Fox *et al.* (1987), Fox (1991), Melling and Watkinson (1988), Melling *et al.* (1990), and a skarn (Fox and Cameron, 1995). Alternate terms proposed for this deposit type are skarnoid, manto and epidote skarn.

### *QR (Quesnel River) Deposit; MINFILE 093A/121*

The QR deposit is near the north bank of the Quesnel River 58 kilometres southeast of Quesnel and 10 kilometres west of Quesnel Forks. It was located in 1975 by Fox Geological Consultants Limited by tracing gold, arsenic and other metal geochemical dispersion anomalies in glacial till. Percussion drilling in 1977 outlined the Main zone; the West zone was discovered in 1983 and the Midwest zone in 1986. Mineable reserves in three zones are 1.3 million tonnes with 4.7 grams per tonne gold (Fox and Cameron, 1995). This deposit represents a new type of bulk-mineable gold occurrence in the Canadian Cordillera - a porphyry-related propylite skarn gold deposit.

The mine was officially opened in September 1995. A five-year mine life with production of 1000 tonnes per day is planned, starting with open-pit mining of the Main and part of the West zone followed by underground mining in the West zone. Conventional milling with gravity separation to recover much of the gold, and carbon-in-pulp cyanide leaching with electrowinning and on-site refining of 'dore' bars, are being used to extract the gold and minor associated silver. Additional reserves are confirmed at depth to the east of the Main zone.

**Geology:** Three main rock-types, part of unit 2a and 2a/2d, underlie the property: basalt, calcareous tuff and mudstone. Strata strike east and dip moderately to the south The lower unit is comprised of at least 850 metres of alkalic basalt, mainly monolithological breccias, pillow basalt, massive flows and volcanic sandstone. The overlying, middle unit is made up of basaltic-source tuffs or epiclastic rock from 5 to 80 metres in thickness. These rocks have a calcite-rich matrix and contain from 5 to 20% pyrite which has framboidal, colloform and banded textures. The uppermost unit is a 200-metres thick sequence of thin bedded mudstone and silstones. It contains up to 10% fine-grained disseminated pyrite and is altered to rusty weathering hornfels near the QR stock. The stock measures 1 by 1.5 kilometres. The intrusion is similar to the other Early Jurassic, compositionally zoned, alkalic diorite stocks in the Quesnel belt. It consists of a 100 metres wide medium grained, equigranular diorite margin, that surrounds a core of monzonite and rare syenite. Hornblende porphyry dikes and sills are common, notably surrounding the QR stock.

**Alteration and Mineralization:** The QR stock is surrounded by a zone of hornfels and propylitized rock that extends up to 300 metres into the surrounding tuff beds. The mineralization occurs in propylitized, carbonate-altered fragmental basalt along the contact with the overlying siltstones near the northern contact of the stock. The basalts are extensively altered by chlorite, epidote and carbonate minerals and contain 1 to 15% pyrite. Fox and Cameron (1995) describe the basaltic tuff as being variably propylitized and "skarn-altered". Other sulphide minerals, mainly chalcopyrite, can form up to 5% of the rock but the sulphide content is generally much less than 1%. Gold is present as small particles along pyrite and chalcopyrite grain boundaries. Best grades are found within 50 metres of the altered basalt-siltstone contact in altered tuffs that Fox and Cameron term epidote-rich skarn and sulphide-rich mantos. A map and cross-sections showing the three ore zones is shown on Figures 8-3 and 8-4.

### *The Propylite Model*

**Rock Types:** Epidote and pyrite-rich auriferous propylitic alteration (epidote-chlorite-tremolite-calcite and rare garnet), with minor other sulphide minerals, occurs as lithologically controlled, conformable replacement zones within a thermal aureole adjacent to an intrusive body. Hostrocks are hornfels and epidote-rich propylite derived from mafic volcanics, commonly with alkalic (shoshonitic) compositions, mafic tuffs and volcanic sandstones and calcareous mudstone. Intrusions are generally small, zoned stocks with diorite to syenite compositions. Their age is similar to, or slightlty younger than, their hostrock alkalic volcanics. Feldspathic hornblende porphyry dikes and sills are common. The stocks exhibit little alteration but have a weakly developed porphyry copper-style mineralization. Related dikes and sills in the mineralized zones external to the stock may be more extensively hydrothermally altered than the main intrusion.

**Mineralization and Alteration:** Propylitic zones with aurifeous pyrite occur within the propylitic alteration aureole. The better grades are generally at the outer periphery of the propylitic alteration zone, commonly at lithologic unit or bedding contacts. Tabular, conformable mantos may form in permeable beds and units, commonly along the contact between hornfels or other less permeable rocks and the propylitic fragmental volcanic rocks. Faults or other, older structural features may be mineralized and form ore zones that are transgressive to strata.

Pervasive propylitic alteration of the matrix and clast rims of fragmental volcanic rocks is characterized by disseminated grains or intergrowths of epidote with chlorite, calcite, tremolite, quartz, albitic plagioclase, clinozoisite and rare andradite garnet. Calcite is abundant peripheral to the propylitic alteration zone and in the mudstone beds.

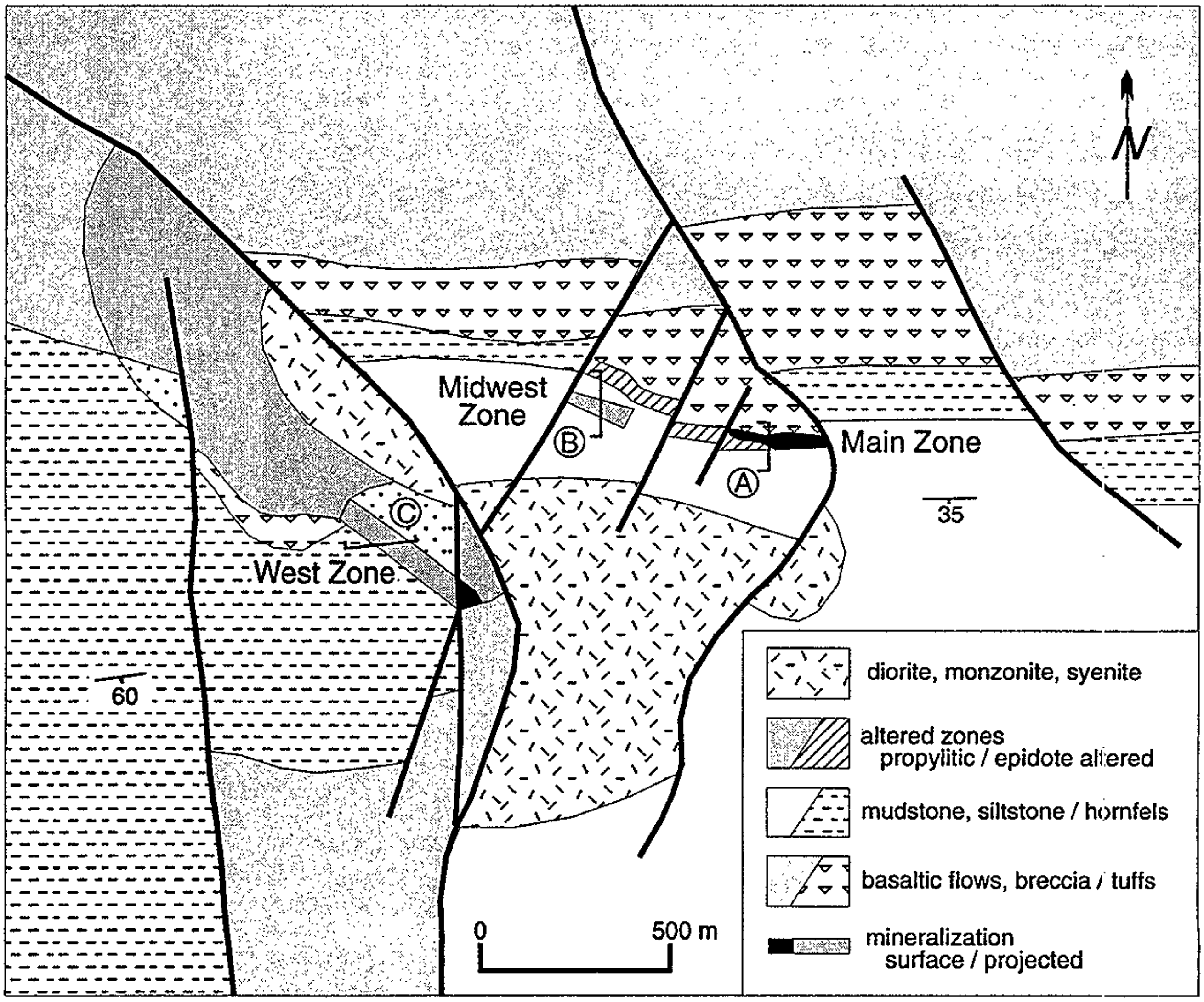



Figure 8-3. Geology of the QR gold deposit after Fox and Cameron (1995). Cross-sections of the three ore zones are shown on Figure 8-4.

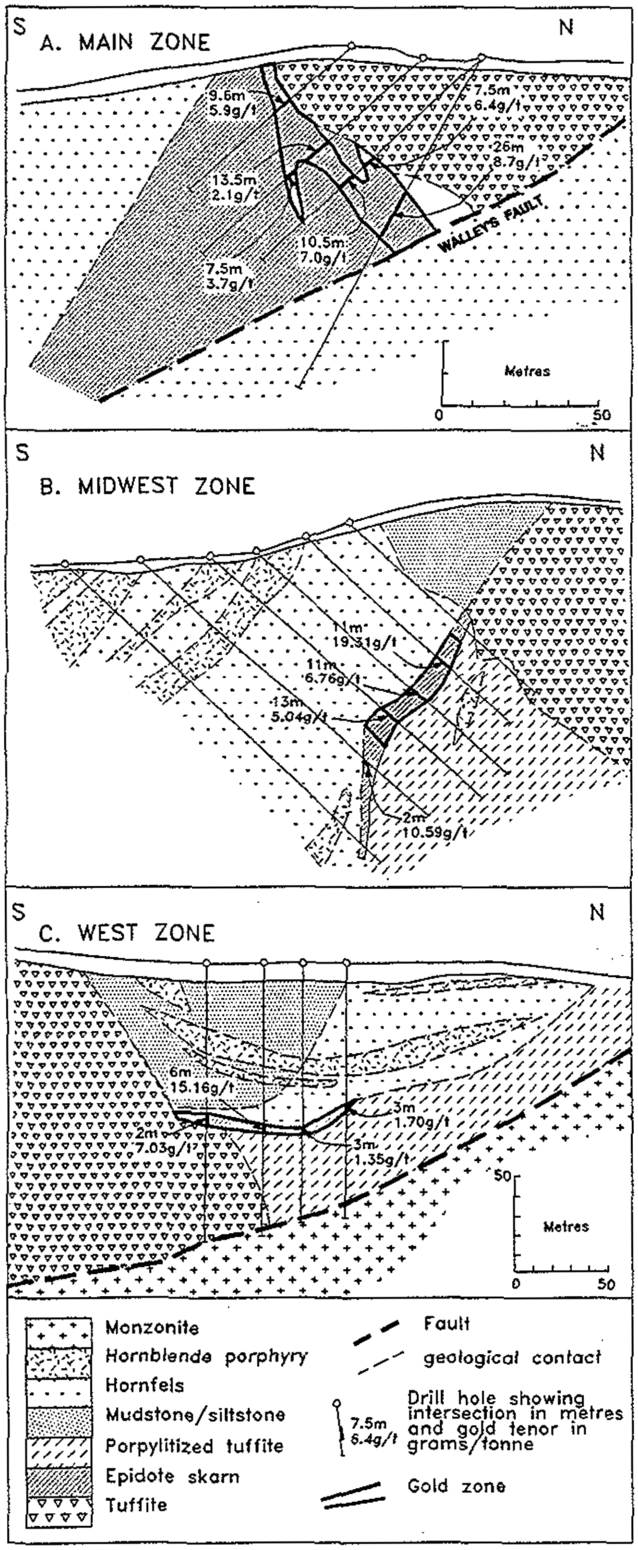



Figure 8-4. Cross-sections of the QR gold deposit Main, Midwest and West ore zones after Fox and Cameron (1995); locations are shown on Figure 8-3.

Fracture controlled quartz-sericite-pyrite zones may occur in subordinate amounts.

Granular pyrite-epidote-calcite aggregates replace the matrix of the volcaniclastic rocks and clast rims. Locally pods and lenses contain up to 80% pyrite and other rare sulphide grains. Pyrite also occurs as fracture coatings, seams and veinlets with calcite and epidote. It is the predominant sulphide mineral; the ore mineral is gold. Subordinate minerals are chalcopyrite, pyrrhotite, sphalerite and marcasite with minor galena, and arsenopyrite. Magnetite may be present as a constituent in some sulphide-rich bands. Gangue minerals in addition to the abundant epidote, chlorite and calcite are tremolite, quartz, clinozoisite and rare andradite garnet. Permeability in the volcaniclastic rocks is a fundamental ore control; secondary controls are tectonic breccias, faults and fracture zones that provide additional fluid flow paths. Chemically reactive hostrocks containing calcite, sulphide minerals or devitrified glass may cause ore deposition by chemically buffering the hydrothermal solutions.

**Origin:** The QR deposit is related to a small, relatively "dry-looking", zoned alkalic stock. Fox (1989, 1991) has described the deposit as a "failed" porphyry system. He suggests that gold is transported by a magmatic-source low density, low-salinity fluid rich in $CO_2$. The writers consider the deposit to be a product of a small geothermal cell with an evolving hydrothermal fluid. A magmatically derived fluid interacted with meteoric water and the mixture evolved, probably through fluid-wallrock interaction with the chemically reactive calcareous siltstones. Melling *et al.* (1990) provide isotopic data that are consistent with other porphyry copper magmatic systems but some modification in carbon by wallrock interaction is indicated. The early alteration is associated with calcite (note the zeolite mineral wairakite should form in this environment but has not been recognized), then the $CO_2$-depleted fluid reacts with the basalts to form propylite - mainly epidote, pyrite, chlorite and (?) tremolite with rare andradite garnet. This is not a retrogressively altered skarn because maximum temperatures of mineralization appear to be in the order of 200 to 300°C. This low temperature produces prograde propylite mineral assemblages without any substantial amount of calc-silicate and silicate minerals typical of gold skarns such as garnet, pyroxene, wollastonite, vesuvianite, axinite, potassium-feldspar and biotite.

**Exploration Guides**: A distinctly anomalous geochemical signature of gold, arsenic, silver and copper are typically associated with ore. Pathfinder elements in the hydrothermally altered rocks include zinc, molybdenum, vanadium, antimony and possibly lead, cadmium, bismuth, cobalt, magnesium and iron (Fox *et al.*, 1987). Glacial till, soil and vegetation exploration geochemistry have been used effectively in this region of extensive glacial dispersion. Magetic surveys have been effective exploration tools. Aeromagnetic highs can be used to detect the presence of intrusions, mainly the magnetite-rich dioritic stocks with which the propylitic alteration is associated. Some of the porphyry copper mineralization contains abundant hydrothermally derived magnetite.

Genetically affiliated mineralization may be manifest as intrusion-related auriferous vein, replacement and pyrite-sericite stockworks, manto and skarn deposits and porphyry copper-gold or porphyry gold deposits, all in propylitic settings. Other deposits with similarities to the QR deposit are the 66 zone at the Milligan porphyry copper-gold deposit in British Columbia, and elswhere the mantos such as Candelaria and Punta del Cobre, Chile.

**Discussion:** The QR deposit and propylite gold deposits in general) appear to be related to mineralization by a (relatively) small volume of 'ponded hydrothermal fluid' related to emplacement of a small alkalic stock. There has been considerable interaction with ('buffering' by) the basaltic country rock to form abundant epidote and pyrite but no substantial amount of skarn. The hydrothermal system exemplifies a lithologically and structurally controlled mineralizing process in which adjacent permeable and impermeable lithologies form a fluid trap against a small, mineralizing intrusion. The West zone, on the other hand, is largely a structural trap and forms a discrete, copper-rich zone.

This type of propylitic alteration can be considered to be a subtype of skarn mineralization - a prograde, low-temperature, auriferous epidote skarn. Unusual aspects that set the propylite model apart from other auriferous skarns are (G.E. Ray, personal communication, 1994): the association with alkalic rocks; the large amount of epidote with lack of pyroxene and only traces of garnet; mineralization with pyrite, lesser magnetite and rare pyrrhotite suggesting an oxidized ore fluid; the high gold to silver ratio and overall low copper content.

This style of mineralization deserves to be identified as a deposit type that is distinct from the gold skarn model largely because it represents a new exploration opportunity. The mineralization has an unspectacular appearance in outcrop and generally has not been highly regarded as an exploration prospect. Many pyritic propylite occurrences, especially those in porphyry copper districts, might have been excluded from further investigation of their gold content.

## PORPHYRY MOLYBDENUM, AND COPPER DEPOSITS AND RELATED VEINS ASSOCIATED WITH CALCALKALINE STOCKS

Quartz-bearing, calcalkaline intrusions occur in the map area as both large plutons and small stocks. They form two distinctive suites of rocks in terms of composition and age, as discussed in Chapter 3. Early Jurassic rocks are represented by the Takomkane batholith, a medium to coarse-grained granodiorite with syenodiorite and porphyritic biotite-bearing phases. Molybdenum mineralization in the stock at the past-producing Boss Mountain mine (MINFILE 093A 001), 43 kilometres to the southeast of Horsefly, is related to a small, late Early Cretaceous intrusion, the Boss mountain stock. This and the other Cretaceous stocks are composed of quartz-phyric granodiorite to quartz monzonite with large quartz grains in fine to medium-grained, leucocratic alaskite to aplite groundmass. This younger intrusive suite commonly carries some porphyry-style molybdenite mineralization. Other Cretaceous intrusions with related molybdenum or molybdenum-copper mineralization are the Gavin Lake stock and related deposits, the copper-molybdenum prospects in the large Nyland Lake stock near the Quesnel River in the northern part of the map area, and EN (Eureka Peak), F.S., Wood, Dor, Daphne, Kate and Tam prospects. Other probably intrusion-related deposits are the Bren and Mckee prospects and some replacements and veins such as the Jamboree (Table 8-1; Figure 8-1).

## *AURIFEROUS QUARTZ VEINS IN METASEDIMENTARY BLACK PHYLLITE UNITS*

The Triassic black phyllites of unit 1 host auriferous quartz veins of two main types (Figure 8-5). The first type, characterized by the Frasergold deposit, comprises the partially concordant, deformed, early forming veins that are localized in a distinctive stratigraphic interval. The second type is represented by fracture-controlled vein mineralization that is associated with quartz-carbonate alteration, such as that in the Spanish Mountain area. The two styles of mineralization are thought to be similar in age and related to deformation during regional metamorphism but the fracture-controlled type may be younger.

### *Frasergold Property; MINFILE 093A/150*

The Frasergold property is located on north-facing slopes in the upper reaches of the McKay River valley (Figure 8-6), approximately 57 and 100 kilometres east of Horsefly and Williams Lake, respectively. Gold on this property occurs in quartz veins and as a geochemical enrichment in a specific lithological unit within the Nicola Group basal sedimentary succession, unit 1 (Figure 8-5). The veins are localized in distinctive porphyroblastic phyllites with underlying graphitic banded phyllites in the basal 100 metres of a 300-metre succession of lustrous porphyroblastic phyllite. The siderite, ankerite and chloritoid-bearing hostrocks, commonly referred to as 'knotted phyllite', are part of Bloodgood's (1987a) unit Tra4. The veins are localized in this unit over a distance of at least 1.5 kilometres along the moderately southwest dipping northern limb of the Eureka Peak syncline. Equivalent rocks can be traced to the southern limb of the syncline where they contain garnet, albite and chloritoid.

Bedding attitudes trend northwest with 40 to 50° dips to the southwest. Beds are defined by thin quartz-sandstone layers, 0.5 to 10 centimetres thick. A penetrative phyllitic foliation is developed axial planar to tight isoclinal folds. The porphyroblasts, which range in size from 1 to 20 millimetres, are commonly flattened within the plane of foliation. The $S_1$ schistosity strikes 130° and dips 55 to 60° to the southwest. In many places bedding has been transposed into

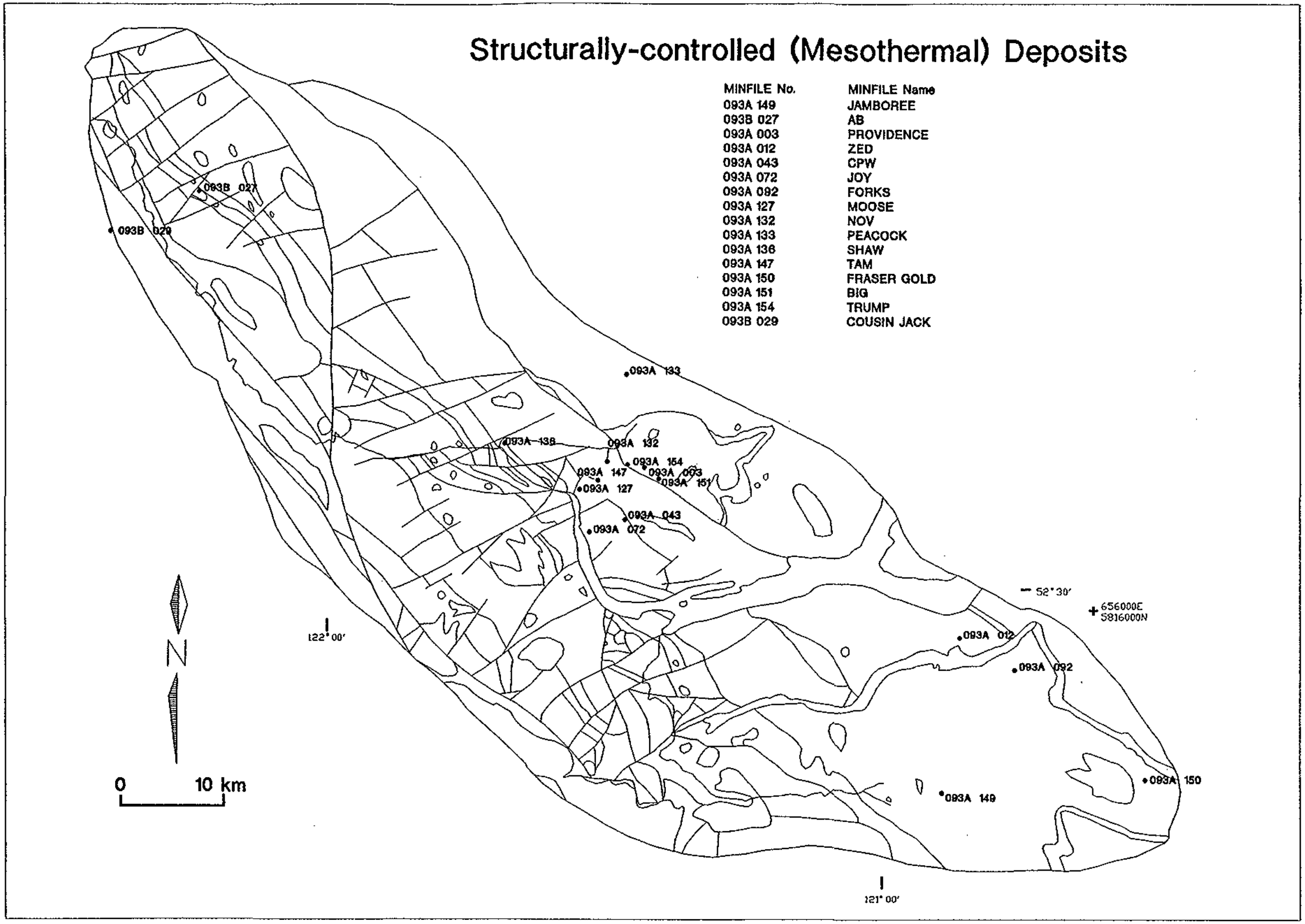



Figure 8-5. Generalized geological map of project area showing locations of structurally controlled, mainly (mesothermal) vein deposits.

and obliterated by the $S_1$ foliation. An $S_2$ crenulation cleavage is subparallel to $S_1$. It trends 115 to 120° and dips southwesterly at 70 to 85°.

Auriferous quartz veins with some carbonate range from 2 to 20 centimetres in thickness and usually extend from 1 to 10 metres along strike. They are generally parallel, or nearly so, to $S_0$ and $S_1$ structures and form lenses, rolls and saddle reefs (*see* Figure 6-3). A few large rods or quartz knots up to a metre across are also present (Photo 8-1). The quartz is generally milky white in colour and forms massive to coarse granular intergrowths commonly containing dolomite and siderite. The veins also contain a small amount of pyrite, less common pyrrhotite and traces of other sulphide minerals. Gold is associated with the sulphide minerals or occurs in quartz near the margins of veins, stringers and boudins as fine, anhedral grains. Gold smears on fold hinges in phyllite suggest that some remobilization took place during folding.

The formation of the quartz veins was synchronous with regional metamorphism and deformation. A sample of hydrothermal sericite from a quartz vein in the Main zone yielded a K-Ar date of 151±5 Ma (*see* Table 4-2 for analytical data). Deformed and undeformed veins occur on all scales, along the limbs and within the hinge regions of folds. Some of the vein fillings are probably products of fluids that were generated during dewatering reactions during the Late Jurassic metamorphic event. The fluids migrated along cleavage surfaces and deposited the vein constituents in dilational zones.

The lithological control, possibly through fluid-rock interactions in the graphitic sedimentary rocks, has produced a zone of geochemical gold enrichment that is defined

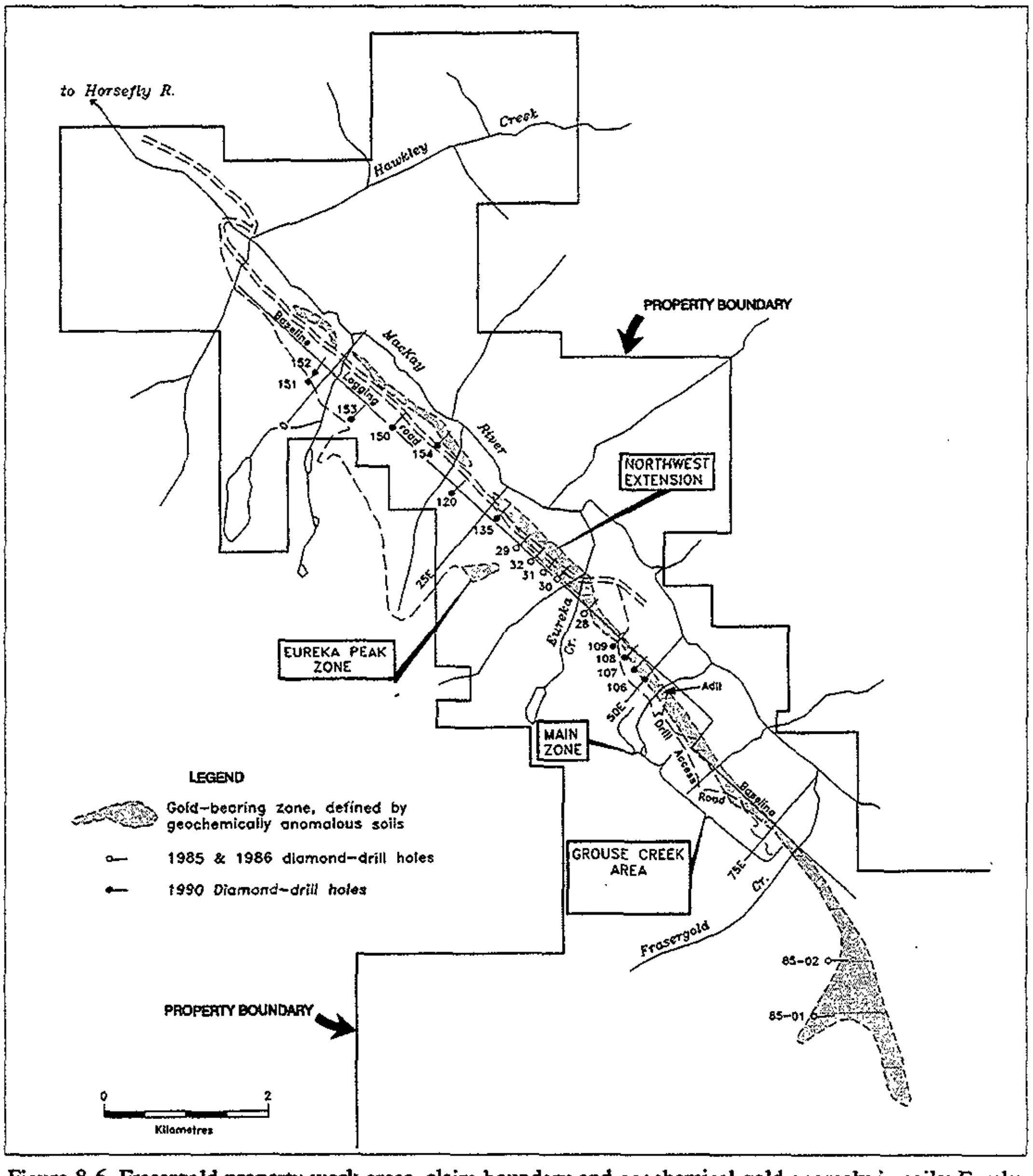



Figure 8-6. Frasergold property work areas, claim boundary and geochemical gold anomaly in soils; Eureka Resources Inc. company report, 1992.

by a soil and rock geochemical anomaly 10 kilometres long (Figure 8-5). Company reports (Eureka Resources Inc., J. Kerr, written communication, 1992) that summarize the economic potential state that drilling at 25-metre intervals and to a depth of 100 metres over an 800-metre zone has established reserves in the order of 3.2 million tonnes containing 1.71 grams per tonne gold. Drilling at wider intervals, over a 3-kilometre strike length, indicates mineral reserves with similar gold content in a larger zone are possibly amenable to open-pit mining. Exploration potential at depth and over an additional 7-kilometre strike of the anomalous zone remains to be tested.

#### *Spanish Mountain Deposits - CPW (Mariner) and Peso Claims; MINFILE 093A/043*

Quartz veins containing gold and minor base metals occur to the southwest of Spanish Lake, about 7 kilometres southeast of Likely. The main lithologies in the area are phyllitic to massive siltstones and interbedded tuffs. Much of the area is affected by pervasive carbonate-silica replacements and listwanite (green mica - quartz - carbonate) alteration associated with quartz veins or fractures. In the more intensely altered zones there are quartz stockworks and larger veins, a number of which define a consistent northeast to east trend. Gold occurs in the quartz veins which range in thickness from 0.01 to 4 metres, dip steeply and trend to the northeast. The veins are typically crystalline to vuggy quartz with lesser carbonate intergrowths and associated minor galena, chalcopyrite, pyrite and sphalerite. Gold is frequently visible as fine particles rimming cavities or as wires where sulphide minerals are oxidized. Two mineralized zones identified by Pundata Gold Corporation are estimated to collectively contain 838 000 tonnes of material with an average grade of 1.95 grams per tonne gold; more recent work has not substantiated this estimate.

The fracture-controlled style of the mineralization suggests that the veins and stockwork postdate metamorphism and deformation. The properties are located on the northeast limb of a northwest-trending anticline that is cut by numerous northwesterly trending, syndeformational thrust faults. The lithologic units and northwest-trending structures are crosscut by a series of prominent northeast to east-trending normal faults. These crosscutting structures and faults control the mineralization.

### *TERTIARY BEDROCK DEPOSITS*

#### *Megabucks Property; MINFILE 093A/078*

The Megabucks copper-gold prospect is underlain predominantly by Eocene volcaniclastic rocks, feldspar-phyric ash flows and possibly some coeval hornblende porphyry dikes. Some of the property covers granodiorite of the Early Jurassic Takomkane batholith. A large part of the area is covered by a mantle of glacial till, fluvioglacial deposits and small outliers of Miocene basalt; older bedrock is rarely exposed.

The Discovery zone is in silicified and propylitized Eocene hornblende feldspar porphyry flows and breccia.

Photo 8-1. Typical auriferous quartz veins at the Frasergold property exposed by stripping of thin overburden to facilitate mapping and sampling of quartz and the surrounding phyllitic hostrocks. The veins are discontinuous along strike; commonly the larger masses of quartz occur as boudins.

Also present are purple and tan-coloured lapilli tuffs and buff to grey tuffaceous sediments. The silicifed rocks contain epidote as blebs and stockwork fillings with magnetite and chalcopyrite. Pyrite is rare to absent in this association. Gold appears to be intimately associated with chalcopyrite. Drilling during 1983 and 1984 has outlined about 750 000 tonnes containing 0.15% copper and 1.37 grams gold per tonne. Some recent drilling records itercepts of 30 metres with 1.2 grams per tonne and 48 metres with 0.64 gram gold per tonne (Campbell, 1984), believed to be typical of the mineralization.

The mineralized rocks are found in faulted and sheared zones in which beds have steeper dips than the regional norm. This suggests that they occur at, or near the margin of a graben or other structurally controlled depression. The rocks are the most strongly altered with pervasive bleaching due to mainly carbonate-sericite-clay alteration. Pyite with lesser chalcopyrite is disseminated and occurs in veinlets. In the central mineralized zone gold is associated with the chalcopyrite. To the southwest there is a pyrite halo partially delineated by drilling that appears to surround the copper-gold zone.

In the southern part of the property, a medium to coarse-grained granodiorite that seemingly is part of the Early Jurassic Takomkane batholith, and the overlapping Eocene tuffaceous rocks, are altered by an assemblage of tourmaline, sericite and abundant fine-grained pyrite. This alteration commonly consists of vuggy, fine to medium-grained masses of radiating black tourmaline needles. Similarly in the northen part of the property and 3.5 kilometres southeast of Starlike Lake, the Eocene tuffaceous rocks have sericite-pyrite assemblages in zones of bleached, siliceous pyritized rocks containing tourmaline-bearing fractures and veins. Peripheral to the tourmalinized rocks, mainly in the older granodiorite and possibly hornfelsic Triassic volcanic rocks, propylitized rocks contain pyritic quartz-sericite stockworks and extensive zones with pervasive replacement of mafic minerals by chlorite, epidote and disseminated grains of pyrite.

#### *Possible Epithermal Targets*

Vuggy, chalcedonic quartz-carbonate veins with elevated values of arsenic, barium and antimony (*see* Figure 8-7; Appendix M) outcrop on the Horsefly River near Hobson's pit at the downstream end of 'The Steps' area in Nicola basalts. Similar veinlets and quartz stockworks, with rare amethystine quartz, were also noted along Hazeltine Creek in the Eocene rocks. A fault zone north of Robert Lake in the Beaver Creek valley contains altered rocks with vuggy texture and open-space filling carbonate and chalcedonic quartz; representative samples returned silver values to 70 ppm silver with anomalous lead, arsenic, mercury and barium. The vuggy textures, banded chalcedony, crustified calcite, as well as the association of metals noted above, is characteristic of epithermal mineralization.

### *OTHER DEPOSITS*

Other mineral deposits in the study area are listed and shown on Figure 8-7. They include three occurrences of native copper in Nicola volcanics and related chalcocite in nearby calcareous and fine-grained clastic sedimentary units. There are two occurrences in ultramafic rocks, one an asbestos showing, the other contains talc, nickel and other metals in shear zones. The Eaglet fluorite and silver prospect consists of a series of steeply-dipping mineralized zone within a 1500 by 900-metre area in gneissic and pegmatitic rocks of the Snowshoe Group. The Kusk property is a gold-silver prospect described as a stratabound zone of quartz and carbonate-altered and quartz-veined phyllites. The Horsefly silica deposit consists of a large zone within the Eocene volcanic succession of poorly indurated siliceous volcanic ash.

## PLACER GOLD DEPOSITS OF HORSEFLY AND QUESNEL RIVER DISTRICT

Records of gold mining in the Quesnel River area date back to the earliest history of placer mining in British Columbia. There is mention as early as 1852 of natives trading gold nuggets from unknown sources at the Hudson's Bay Company trading post at Kamloops. The mining of substantial amounts of placer gold began in 1857 in a tributary of the Thompson River and led to an influx of several thousand miners into the Fraser River valley and areas in the south of the province. A number of the more adventurous prospectors worked up the Fraser River in search of new placers and possibly the lode gold sources. Their continued prospecting efforts took them up the Quesnel River to what is now Quesnel Forks. Rich river-bar placer gold was found there in 1859. During that time, five men led by two natives, proceeded up through Quesnel Lake to the Horsefly River and its confluence with Little Horsefly River. There they reportedly took out 101 ounces of gold in one week before the onset of the winter (Carmichael, 1931).

The news of the rich placers in the Cariboo travelled quickly and the great Cariboo gold rush began. In 1860, prospectors worked from Quesnel Forks up the north fork of the Quesnel River (now the Cariboo River) as far as Cariboo Lake. Rich placer was found on Keithley and Antler creeks. The next season saw further prospecting up the creeks and over the divide into Williams Creek. The phenomenal richness of the gravels in this creek surpassed all the previous diggings to date. Nearly a thousand miners flooded the area and greatly expanded the workings. For four years the surface gravels produced unheard of amounts of gold, approximately $2,000,000 worth (117 647 ounces at $17.00 per fine ounce). Active placer mining continued through to the late 1930s, evolving through many mining methods. By 1945, a recorded 827 741 ounces of gold recovered from the Cariboo goldfields (Holland, 1950). These production figures represent only recorded produc-

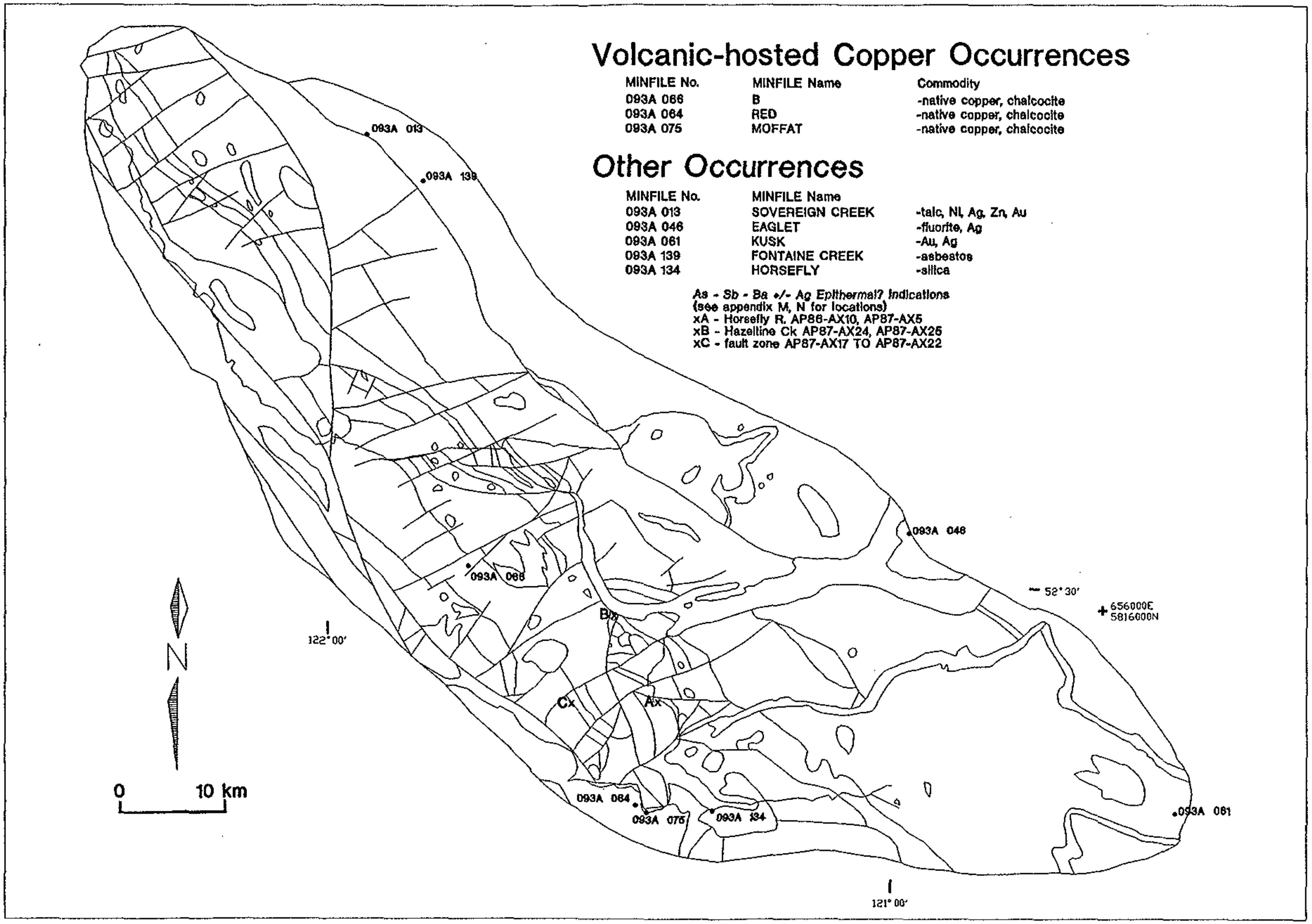



Figure 8-7. Generalized geological map of project area showing locations of volcanic-hosted native copper occurrences and other mineral deposits.

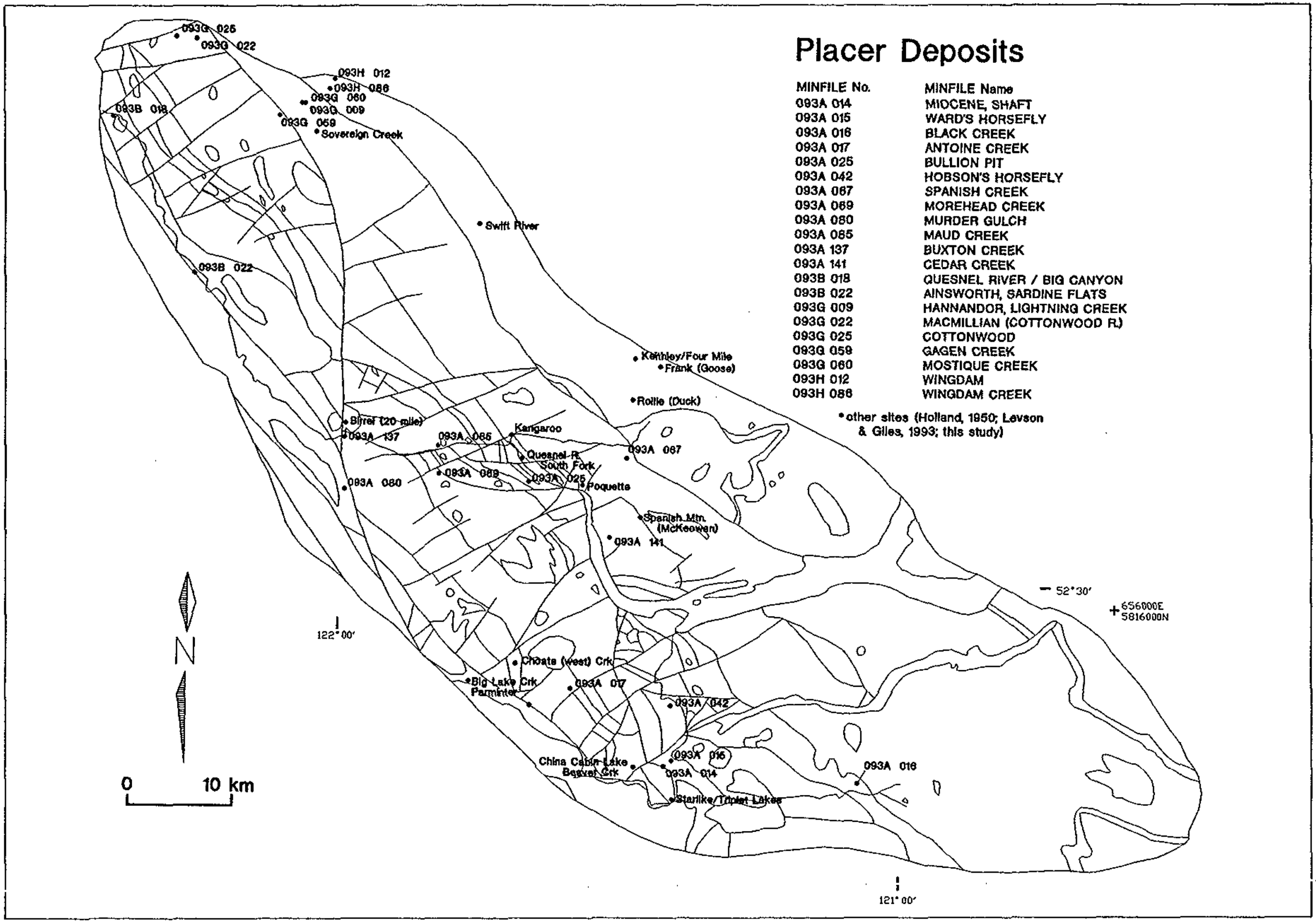



Figure 8-8. Generalized geological map of project area showing locations of placer gold deposits.

tion. It is estimated that total production between 2.5 and 3 million ounces of gold has been achieved in the Cariboo district, more than any other placer area in the province (B.C. Department of Mines Bulletin 21, 1946; Levson and Giles, 1993). The main activity took place in the Wells-Barkerville, Lightning Creek, Keithley Creek, Quesnel Forks - Likely and Horsefly River regions. These areas are still being worked for placer gold, though at a much reduced scale. The surficial geology of the Cariboo district and the origins of the placer deposits have been recently described by Levson and Giles (1993) and Eyles and Kocsis (1988a,b; 1989).

Locations of placer deposits in the study area, as noted by Holland (1950), Levson and Giles (1993) and the authors, this study, are shown on Figure 8-8. Most are described in MINFILE. Fifteen additional sites are listed by name on the figure, including at least five sites on benches above the upper Quesnel River collectively referred to as the Quesnel River South Fork deposits. Sixty-one of the deposits in the Cariboo-Quesnel-Horsefly area have recently been studied by Levson and Giles (1993). They describe the paleogeomorphic settings and depositional environments including: buried paleochannels; buried, braided streams and wandering, gravel-bed river deposits; and surficial deposits. Levson and Giles also assess the placer potential and classify individual deposits in terms of: buried Tertiary placers; paleogulch placers in high-relief areas; pre-Late Wisconsinan, large paleochannel deposits; Late Wisconsinan glacial and glaciofluvial placers; late glacial and postglacial, high to intermediate-level terrace placers; Holocene, low-level terrace placers; and postglacial colluvial and alluvial fan deposits.

## GEOLOGY OF THE HORSEFLY RIVER PLACER FIELDS

The placer gold that occurs in the Horsefly and parts of the Quesnel River watershed differs from most of the other placer deposits in the Quesnel River workings and the more extensive Cariboo goldfields to the north. Many of the Horsefly deposits are buried Tertiary placers, probably Miocene in age, and predate the Cariboo placers by about 14 million years. The Cariboo placers represent mainly a postglacial reworking of older placers or erosion of original lode gold deposits (Johnston and Uglow, 1926, 1933; Levson and Giles, 1993). The Horsefly placers are contained in fluvial gravels under Miocene basalt flows and have an undetermined source to the east. The Quesnel River and tributary creek placer deposits are classified by Levson and Giles (1993) as varieties of paleogulch placers, pre-Late Wisconsinan, large paeochannel deposits or late glacial to postglacial deposits that occur as high to intermediate-level bench deposits or terrace gravels. There are also postglacial colluvium and alluvial fan deposits, Holocene low-level terrace placers and reworked, generally small, creek-bottom deposits in which the gold has been concentrated or reconcentrated in the modern fluvial systems during postglacial stream erosion.

The Miocene deposits overlie either Eocene volcanic or sedimentary rocks or, less commonly, the Triassic-Jurassic Nicola rocks. The sedimentary rocks form a succession of thinly bedded to laminated and frequently varved Eocene lacustrine sediments at least 150 metres-thick. Abundant fossils found in the sediments include fish and leaves as well as pollens, seeds and spores. Fossil fish (Amyzon aggregatum, Eohiodon rosei) have been dated at 50 to 45 Ma (Wilson, 1977). Palynology (Appendix D) corroborates the Middle Eocene age of the sediments. The lacustrine sediments now in large part occupy the Horsefly River valley indicating that this has been a long-lived topographic low. This feature is probably caused by north to northwesterly trending Eocene structures that formed a system of grabens along or oblique to the trend of the Triassic-Jurassic volcanic arc. Above and adjacent to the lacustrine sediments are small outliers of biotite-bearing trachybasalt flows and andesitic to trachyandesitic crystal ash tuffs dated at 52.2±1.8 Ma (Table 4-1). Abundant detrital biotite in the basal part of the lacustrine sequence, and thin ash layers in the unit, indicate contemporaneous deposition during the Middle Eocene.

Capping the Eocene sedimentary sequence is a 100-metre section of Miocene flood basalts. The basalts have been dated at Gravel Creek to be 14.6±0.5 Ma (this study) but, in the region, range from 16 to 9 Ma and younger (Mathews, 1989). They extend from Beaver Creek to the west and south beyond the area mapped and form a continuous plateau covering with its base at approximately 850 metres elevation. Locally the basalts form small hilltop-cappings that are outliers from the main body. This indicates the basalts were originally more extensive but their margin has been eroded along the Horsefly - Quesnel River drainage system.

Sandwiched locally between the Eocene sediments and the Miocene flood basalts are Miocene fluvial deposits. They form the "Miocene channel" referred to by the early miners, that hosts the Horsefly placer gold. Two distinct channels have been identified by mapping in the area (Lay, 1931), based largely on the excavations and workings of the pioneer placer miners. The fluvial channels are filled with a distinctive white quartz pebble to cobble conglomerate. The quartz appears to be derived in large part, if not entirely, from quartrz veins. In places the basal 1 to 3 metres of the gravels has been cemented and indurated by calcite to form a natural concrete. The rocks were sufficiently strong to support fairly extensive underground openings in some workings.

The main Miocene channel follows the Horsefly River valley down from Black Creek through Horsefly village. It has been found to be up to 150 metres deep and up to 610 metres across (Lay, 1931, p. A97). The channel sweeps to the west from the Horsefly River in the vicinity of Hobson's placer workings and runs through Antoine Lake and then into the Beaver Creek valley (Figure 8-9). The second channel, smaller than the first, is to the south and west of the main channel. The Tertiary gravels are exposed on Moffat Creek below Big Moffat Falls as typical quartz-clast fluvial channel gravels capped by Miocene flood basalts. Some

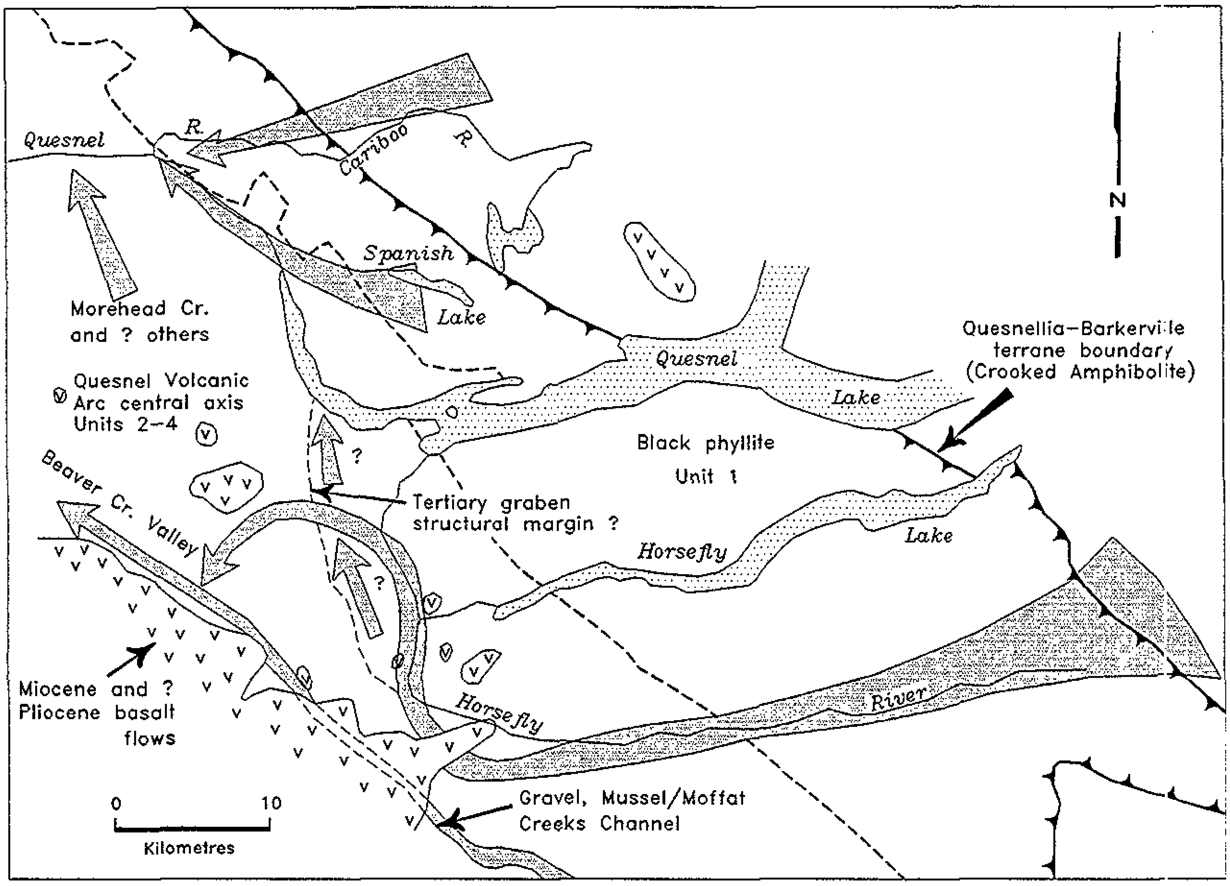



Figure 8-9. Placer channels in the Quesnel Lake - Horsefly River district. The oldest placer deposits are the Tertiary paleochannels of the Miocene Horsefly River and subsidiary Gravel-Moffat-Mussel creeks fluvial systems that have a postulated gold source-area near the Quesnellia-Barkerville terrane boundary near the area of high-grade metamorphic rocks. The Quesnel and Cariboo River placer-bearing gravels were deposited in pre-Late Wisconsinan paleochannels and late glacial to postglacial fluvial systems as high to intermediate-level terrace placers (Levson and Giles, 1993). Their possible lode gold sources are vein deposits in the Quesnel Lake, Spanish Mountain and Cariboo River areas. A number of other placer deposits are formed by, or have been reconcentrated in, postglacial streams as Holocene, low-level terrace placers and colluvial and alluvial fan deposits.

prospecting was done, but no gold recovery is recorded. Tertiary gravels from the same channel also crop out at Gravel Creek where it is crossed by the 150 Mile House - Horsefly road. Here the gravels lie between Miocene basalt and a thin layer of Eocene lacustrine sediments that rest on Triassic basement in Gravel Creek. The sedimentary section is not fully exposed but is no more than 30 metres thick. Also, some Tertiary gravels are poorly exposed to the west of China Cabin Creek. The greater extent of the gravels is indicated by the widespread distribution of white quartz cobbles in gravels and overburden throughout that area. The thickness of the gravels in the southern channel appears to increase toward the north. This suggests that a small river or large stream flowed north down Beaver Creek, and possibly joined the larger Miocene channel.

Pleistocene glaciation has since cut through to the Mesozoic bedrock and extensively scoured the Tertiary section. Variable thickness of till and glaciofluvial deposits have left behind a cover that ranges from a thin veneer a metre or less in thickness, to sections up to 100 metres thick. The glacial deposits have roughly the same stratigraphy as that described in the Cariboo placer district to the north (Levson and Giles, 1993). Glacial and postglacial reconcentration of the Miocene placer gold is generally not significant in the Horsefly area. Exceptions are some of the gold-bearing tributaries of Beaver Creek along Beaver Creek valley where postglacial reworking is evident.

## HORSEFLY AREA PLACER DEPOSITS (MIOCENE CHANNELS)

The village of Horsefly (or Horse-fly) was the centre of a small placer mining community through the height of the Cariboo gold rush into the early 1900s. It was known as Harpers Camp from 1859 through to 1921 when the name was offically changed to Horsefly. The discovery of gold on the Horsefly River in the spring of 1859 is credited to Peter Dunlevey. He and a gang of men were led up the river and shown where there was gold by two natives. The site of the initial placer mining is immediately outside town, to the east, and was known as the Ward's Horsefly mine. In recent years, Horsefly has supported a small community based on forestry, ranching and recreation. The Horsefly River is an important salmon stream and placer staking is no longer permitted. However the surrounding regions near Antoine

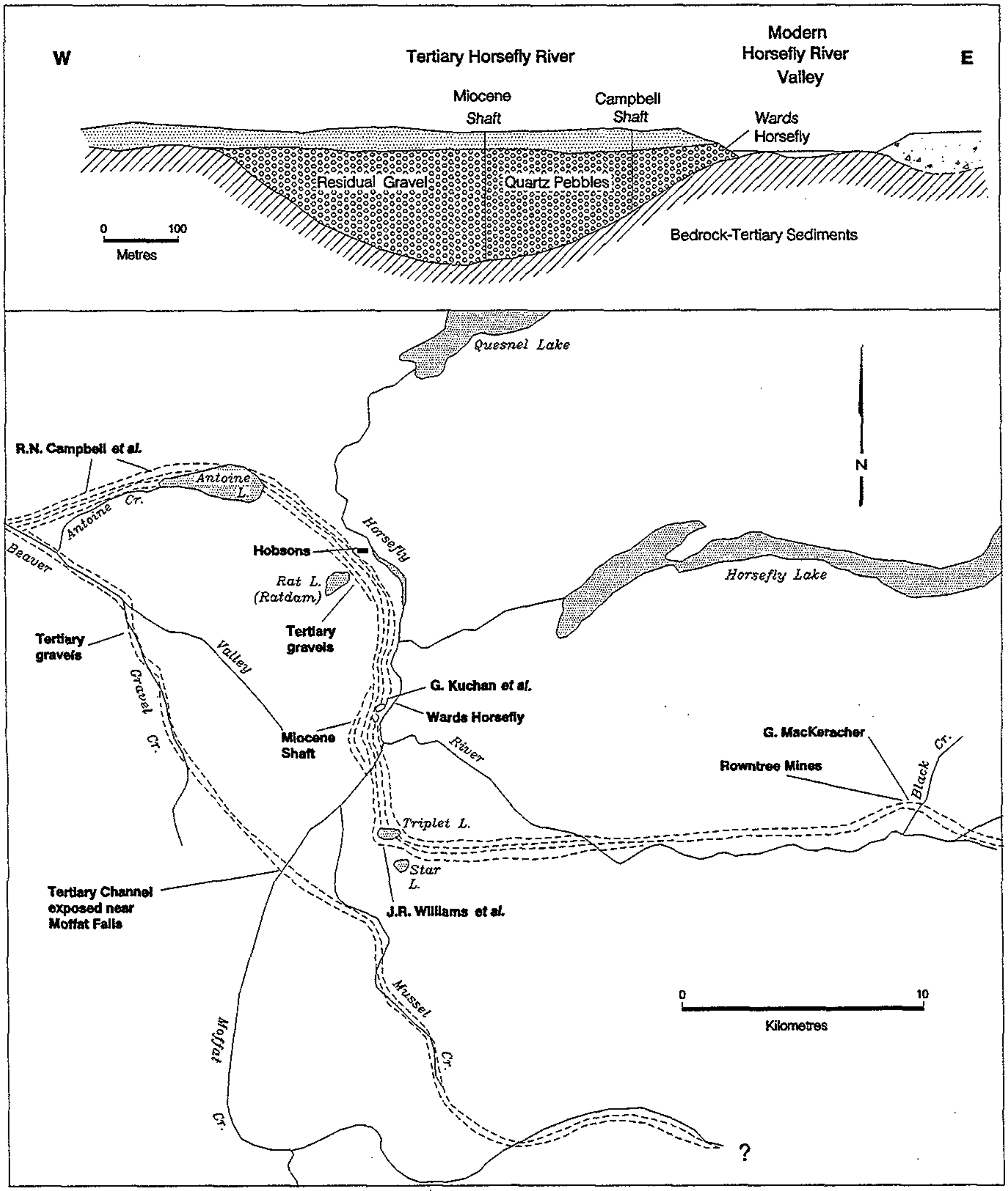



Figure 8-10. Sketch map from Lay (1932) of probable courses of Tertiary channels in the Horsefly area and diagrammatic cross-sections through the Tertiary and modern channels at Ward's Horsefly workings.

Lake, Beaver Valley and Black Creek remain in the placer reserve.

*Ward's Horsefly (Harpers Camp), MINFILE 093A/015*

Initial work at the site by J.T. Ward, as well as the Horsefly Gold Mining Company and International Dredging Company, was in Holocene reconcentrated placer at the margin of the Miocene channel. This ground is said to have been very rich. Later workers have reported that it was the quartz gravels that held the rich pay streaks. Holland (1950) reports that a total of 15 216 ounces of gold were recovered. However, earlier authors estimated production worth $500 000 to $1 250 000 during the life of the mine (Galloway, 1919; p. K137), resulting in a calculated production of 29,000 to 59,000 ounces of gold, assuming an average price for gold of $17.00 per ounce. The quantity is likely to have been greater as much of the gold was sold after 1901 when the price of gold had increased to $20.67.

Reports by the Resident Mining Engineer (Lay 1932, 1939) state that the Ward's Horsefly operation worked the east edge of the Miocene channel. At this point the channel is 150 metres deep and approximately 600 metres wide. The stratigraphy consists of a thin cover of Quaternary sediment over 7 to 24 metres of white quartz pebble conglomerate (Figure 8-10). The bottom 2 to 7 metres of this was the 'Blue Gravel' pay horizon. The "blue gravels" unconformably overlie shaly Eocene lacustrine sediments of unknown thickness, dipping west at 30° to 35°. The dip of the Eocene rocks suggests that they have been tilted after deposition, another indication of Late Eocene, or younger, tectonic activity possibly related to the development of a graben. The Eocene graben is now marked in part by the course of the Miocene and present day Horsefly River fluvial deposits.

The placer gold was initially recovered by surface placer mining methods. However, as mining progressed deeper, the workings were below the grade of the Horsefly River and made normal mining methods difficult. By the late 1880s drift mining was in progress at the site. Ward took over the operation in 1891 and attempted some hydraulic work for a season. No significant work was done for the next five years, but in 1896 Ward undertook an ambitious development. He had two hydraulic elevators installed and a major hydraulic operation began. Water was diverted from both Mussel and Moffat creeks to supply the monitors and elevators. A large pit, 100 metres or more across and up to 18 metres deep was excavated. Gold recoveries were considered good and the operation continued through to 1904. At that time corporate problems resulted in closure of the mine. In 1915, a dredging venture was planned to rework the hydraulic tailings. However, poor Keystone-drilling results from work done by the British Columbia Department of Mines in 1919 killed the venture. No significant work has been done at the site since then.

Due to the overlap of the modern and ancient channels, there has been some recent reconcentration of placer gold. However, the presence of gold is attributed strictly to the Miocene channel as there is no gold in the Quaternary gravels immediately adjacent to the mine.

*Miocene Shaft; MINFILE 093A/014*

Immediately adjacent to Ward's hydraulic operation, R.N. Campbell staked at least twelve placer claims in 1894-97, extending southwest through Harper's Lake, and established the Miocene Gravel Mining Company. In 1898-99, Campbell sank a shaft, collared 300 metres southwest of Ward's pit. This shaft cut 84 metres of quartz gravels and then bottomed in 15 metres of shale (no doubt the Eocene lacustrine sediments). From the bottom of the shaft, a 45-metre drift was driven westward into the gravels. Also a 76-metre decline was driven to the west from the shaft bottom, dropping 38 metres along its length at -39°, similar to the slope of the bedrock surface. Initially, Campbell thought the Miocene channel flowed westward through Harper's Lake into the head of Beaver Valley, but this was not found to be the case. In 1900, he sank a second shaft 600 metres southwest of Ward's pit. This is the locally well known 'Miocene shaft', and is located under the present day B.C. Telephone building at the junction of Walter's Road and the main road in Horsefly village. This was a large three-compartment shaft that was sunk 167 metres, bottoming in the Eocene shales. A 152-metre drift was driven "in the direction of the channel" and raises were cut at 122 to 152 metres to test the gravels. A run of slum from the 152-metre raise flooded the workings and they were abandoned. Testing of the gravels was not extensive but it showed gold in less than "paying quantities" (Galloway, 1919). After the flooding of the shaft, no further work has been done on the Miocene Gravel Mining Company ground.

*Hobson's Horsefly; MINFILE 093A/015*

The earliest record of activity at the site of Hobson pit is from 1887. By that time work had already been done on reworked placer in the Horsefly River and mining was progressing up the bank. Drift mining was undertaken in the cemented gravels and the scope of operations expanded in 1890 to include hydraulic mining. At that time the site was known as the McCallum claims or the Discovery Company ground.

In 1892, J.B. Hobson, of the Cariboo Hydraulic Mining Company and Bullion pit fame, took over the ground and began extensive development of water supply, drift and hydraulic mining. A large-scale operation flourished through to 1899. Over 2000 metres of drifts and crosscuts webbed the cemented gravels at the close of operations in 1899. The mined material was evidently processed in a small stamp mill. As well, several hectares of ground had been sluiced off to the level of the cemented gravels. Some additional hydraulic mining was carried out from 1908-12 by E.J. West. In 1930, George Kuchan took over the ground. He initially reworked the hydraulic tailings but made no advancements in the old pit itself. Later, he worked ground near Ratdam (Rat) Lake for several years.

Production reported in Minister of Mines' Annual Reports for the Hobson pit is 7637 ounces of gold for the years 1894 to 1898 and 1912. As the mine operated for a greater length of time this represents possibly only half, and probably much less, of the total gold recovered. Grades in the drift mining were reported to be around $1.63 per tonne in the cemented gravels. Highest values were found at the base of the cemented gravels. The unconsolidated Miocene (pay) gravels returned $0.33 per metre$^3$ and the overlying 30 to 50 metre section of unconsolidated glaciofluvial gravels carried minor gold, on average about $0.03 per metre$^3$.

The gravel deposits at the Hobson pit overlie from 15 to 23 metres of Eocene lacustrine sedimentary "bedrock" that rests unconformably on Triassic-Jurassic volcanic rocks. In the pit the Miocene channel is about 3 metres thick at the eastern edge but increases to over 9 metres along the western face where it is now covered by talus. The bottom 1.3 to 3 metres is cemented by calcite to form natural concrete. The rock is strong enough to support untimbered workings. At the base of the cemented gravels there is a layer, a few centimetres thick, of partially cemented Eocene sediments. Rip-up clasts of the Eocene sediments are found in the bottom 30 centimetres of the cemented gravels. The gravels at the Hobson pit are identical to those of Ward's pit. They are white quartz pebble and cobble-rich fluvial deposits. Heavy mineral concentrates contain abundant garnet, some kyanite and only a little black sand, mainly pyroxene, magnetite and hornblende.

Since G. Kuchan worked on the ground in the early 1930s no further work was done in the pit until 1987. In the summer of that year a consortium of companies including Laredo Mines Inc. attempted some underground drift mining in the cemented gravels, using an adapted continuous mining machine. A decline was started in the west-pit face and driven for approximately 30 metres before the mining machine failed. The enterprise was considered to be development work and no attempt was made to recover gold from the mined material.

### *Black Creek; MINFILE 093A/016*

Earliest reports of activity on Black Creek indicate prospecting in the late 1890s by a Mr. Campbell (possibly R.N. Campbell of the later Miocene shaft). Later Phil Fraser worked on Black Creek and joined with the Western Mines Exploration Syndicate in 1918 to do some Keystone drilling on a bench about 3.2 kilometres up Black Creek from Horsefly River. The object was to test the bench for gold and determine if it was part of the Miocene channel. Little gold was recovered from the drilling and testing for the Miocene channel was inconclusive. It appears that no mining was done until 1930 when leases held by G. MacKeracher were optioned by Rountree Mines Ltd. and managed by James Armes for further development. A large ground sluice was set up with the dump at the falls, approximately 3000 metres upstream from the mouth of Black Creek, and extended 300 metres upstream. A small hydraulic operation worked the 'lower pit' and washed gravels through the sluice. Another 300 metres upstream, a smaller pit was developed and some adits were driven to test the gravels. The hydraulic operation worked through to about 1935. Holland (1950) records a total of 62 ounces of gold produced from this creek. Since the close of the hydraulic operaton, the Armes family worked the ground intermittently through 1985. No production has been recorded for that time. In 1986, the property was purchased by Lyle Shunter who worked the ground known as the 'lower pit'.

The deposit is located within a narrow steep-sided cleft in Triassic volcanic rocks. The gorge is about 30 metres wide at the falls and widens to about 300 metres at the lower pit and then narrows again to 30 metres at the top of the pit. The lowest sediments exposed are thinly layered muds, clays and fine sands of unknown thickness. A drill hole 23.4 metres deep, collared in the middle of the pit floor, failed to reach bedrock. Unconformably above the fine sediments are cross channeled, normally graded fluvial gravels, 12 to 20 metres thick. Individual channels are up to 2.5 metres thick and 7 metres wide. The placer gold occurs as runs in the coarse channel-lag gravels. A thin veneer of colluvium caps the section.

The gravels were interpreted to be part of the Miocene channel by the early placer miners but Lay (1931) stated that the evidence for the gravels being part of the Miocene channel was inconclusive. Levson and Giles (1993) consider the deposit to be a paleogulch placer. Certainly the abundance of white quartz pebbles and cobbles in the fluvial gravels is not as great as that in the Hobson pit but, overall, quartz pebbles and cobbles are abundant. In addition, the tailings contain fragments of metamorphic rock with kyanite, and heavy mineral concentrates from the washplant show abundant garnet, black sand and kyanite grains. The bench at the Black Creek placer mine is interpreted here to be a higher bench of an upstream Miocene channel that has been reworked by the Recent Black Creek. The character of this small bench is markedly different from the large lower bench that surrounds Patenaude Lake about 100 metres below the elevation of the Black Creek workings. There the gravels are mainly morainal deposits containing abundant metamorphic detritus and quartz cobbles.

The placer operation during 1987 recovered 'good' quantities of gold from the fluvial gravels. Gold size ranged from flour to nuggets 10 millimetres across. The gold is flattened, beaten and frequently coated in iron oxide, indicating extensive transport.

### *Antoine Creek; MINFILE 093A/017*

Placer work on Antoine Creek began in 1928. R.N. Campbell worked the ground from Antoine Lake to the top of the gorge, approximately 1000 metres from the mouth of the creek at Robert Lake. Initial work consisted of test pitting and shaft sinking along the north bank of the valley, followed by a small amount of hydraulicking from 1929 to 1933. The section worked rested on a false bedrock of red clay/soil of undetermined depth. Above that were 'blue gravels' of variable thickness, similar in character to those of the Miocene channel at Horsefly. Glacial drift of variable thickness caps the pay gravels. The gravels were not rich; the bottom metre of the 'blue gravels' reportedly carried coarse flake gold with values up to $0.65 per metre (Lay, 1931, 1933). Holland (1950) reports that a total of 189 ounces of gold were recovered.

Lay (1932) shows the gravels at Antoine Creek to be the downstream extension of the Miocene channel seen in Horsefly. The projected Miocene channel swings west from Hobson's pit, through Ratdam Lake and then Antoine Lake to discharge in Beaver Valley and flow northwest from there (Figure 8-10).

### *Other Placer Workings*

**China Cabin Creek:** This small creek flows northward out of China Cabin Lake into the head of Beaver Valley. The creek has been tested and there is evidence that a small ground sluicing operaton was undertaken immediately downstream from China Cabin Lake. The lake served as one of the sources of water for sluicing operations elsewhere (Hobson's pit?), as there is a large ditch leading away from it. Gravels to the west of the lake contain abundant white quartz clasts, suggesting that the Miocene channel, or its erosion products, are present in the area (authors, field mapping).

**Choate Creek (West Branch):** This creek, also known by the oldtimers as Teasdale Creek, produced a small amount of gold. Here, coarse-boulder fluvioglacial outwash carries fine flakes and small nuggets, but no large-scale mining was done. A Mr. Teasdale lived off the land and augmented his supplies through purchases made with gold that he had mined (Milt Lonneberg, personal communication, 1987).

**Big Lake Creek:** The creek was prospected in the early 1930s but did not yield any appreciable amount of gold. However, as reported Lay (1933), the fineness of the gold (980 fine) was the highest for any placer gold in the province to that date. The gold was recovered about 800 metres upstream from Beaver Creek.

**Starlike and Triplet Lakes:** These lakes were the site of some prospecting in the late 1920s by J. Williams and associates. Quartz gravels were identified but could not be specifically related to either the Moffat Creek drainage or the main Miocene channel (Lay, 1932). The amount of gold recovered, if any, has not been recorded.

Other placer deposits of the Horsefly River system or Miocene channel noted by Holland (1950) include Moffat (Sucker), Mussel, Tisdale or Teasdale (currently locally called West Choate Creek), Frasergold (Fraser) and Eureka creeks. Other creeks said to have produced gold are 'Captain Charlie' (possibly part of Antoine) and Parminter creeks.

## *QUESNEL RIVER DEPOSITS*

### ***Bullion Pit, Including Dancing Bill Gulch (187?-1884) and China Pit (1884-1894); MINFILE 093A/025***

The Bullion pit (Photo 8-2) is on the south side of the Quesnel River, about 8 kilometres downstream from Likely. It was the largest hydraulic mine in the Cariboo region and one of the largest in the world. The pit measures 1600 metres long, 120 metres deep, 75 metres across the bottom and 300 metres across the top. Work began in the early 1870s, continued through to the 1940s, and has since been intermittent. The mine was operated by Cariboo Hydraulic Mining Company, J.B. Hobson (1894-1905), Guggenheim family interests (1906-1919), small operators (1920 to 1930 and 1943 to present), Quatsino Copper-Gold Mining Company cf. p.89, B.C. Hydraulics Limited (1930-1931) and Bullion Placers Limited (1932-1942). The greatest amount of production was through the periods 1894 to 1905 and 1934 to 1941.

Production of gold has been substantial but the quantity is uncertain as much early production was not recorded and the accuracy of later production records is suspect. Holland (1950) quotes a total of 120 187 ounces (3740 kg) reported from the whole of the south fork of the Quesnel River during the period 1874 to 1945. Levson and Giles (1993) state that 150 500 ounces, were produced up to the end of the 1930s. Production from all the Bullion pit operations estimated by the authors, based a variety of sources and reported quatities using average prices for that time, suggest that approximately 171 000 ounces (5320 kg) of gold were recovered up to 1942 (Table 8-2).

Initial work at the site which became the Bullion pit was done by Chinese miners who followed up rich point-bar deposits at the base of Dancing Bill Gulch. They worked a small operation on the Quesnel River at the bottom of the gulch that was expanded into a small hydraulic mine by 1884. In 1894, a syndicate of Canadian Pacific Railway directors bought the Chinese operation and contracted J.B. Hobson to work the "China pit" as it had come to be known. The resulting Consolidated Cariboo Hydraulic Mining Company greatly expanded the water supply network, increased the number of men working and brought in better hydraulic equipment. Huge volumes of gravel were washed in the extensive sluice complex. In 1904, due to a low bedrock grade of 1 to 2%, a sluice tunnel was cut from the Quesnel River up to the middle of the pit. The 3 by 3 metre tunnel was 500 metres long with a grade of 4.5% and a 30-metre raise to the pit bottom (Sharpe, 1939; maps and plans, BCMEMPR Property File). Work continued through 1906 when the mine was bought by the Guggenheim family. Production continued but mining, financial and legal difficulties were encountered and the mine closed at the end of 1907.

At the close of operations a well-organized town existed at Bullion which included segregated quarters for management, Caucasian, Chinese and Japanese miners; a

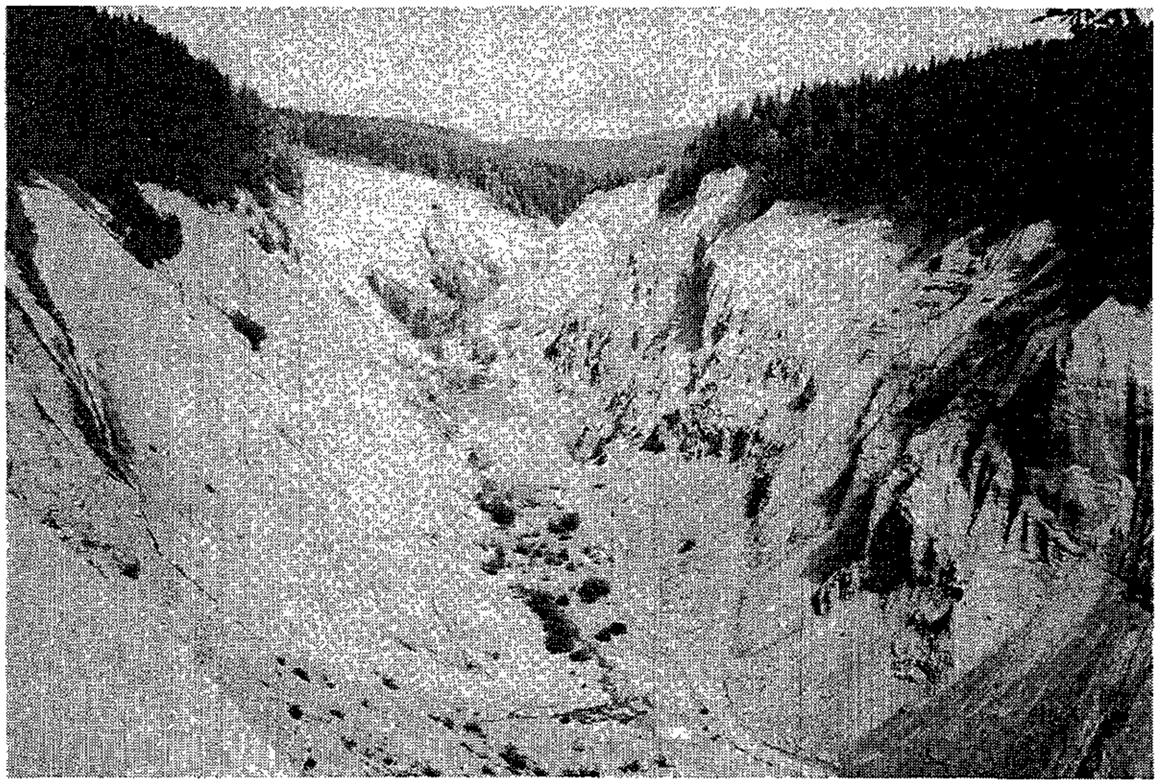


Photo 8-2. View of the Bullion pit, looking northwest. The photograph is taken from the south wall; the large excavation continues to the east into the area of the China pit and Dancing Bill Gulch (right of photograph).

fully equipped smithy; telephone/telegraph to the water supply points and the telegraph along the Fraser River; as well as a complex water supply network capable of supplying large volumes of water (maps and plans, BCMEMPR Property File). For the next 22 years, small operators intermittently attempted to work the mine, mainly at the site of the old China pit.

In 1930 and 1931, the Quatsino Copper-Gold Mining Company, through an affiliate, B.C. Hydraulics Limited, and in 1932 Hireen Placers Limited worked the China pit by hydraulic methods and had modest recoveries of gold. A disasterous failure of the working face destroyed the hydraulic operation, swept away more than a hundred metres of sluice and plugged the top 40 metres of the sluice tunnel (Sharpe, 1939).

In 1933, Bullion Placers Limited, under the direction of president R.F. Sharpe, took over the mine, refurbished the town and pit, renovating and expanding the water supply system over the next four years. A second pit was developed in Drop Creek (called the South Fork pit) so that 24-hour mining could be done. This highly mechanized and well organized operation worked continuously through to 1941 and produced the present outline of the Bullion pit. Sharpe died in 1942 and all work by Bullion Placers ceased. The town of Bullion was abandoned, the water supply system fell into disrepair and subsequently no further hydraulic mining was done. Since the closure, only small operators have worked in the pit and no great recoveries of gold have been made. Interest in the mine is still evident and some limited mining activity still takes place in the pit sporadically.

The gravels at the Bullion pit have the same preglacial origin as those in the Cariboo deposits. The gold recovered from the gravels was generally 'coarse' with many small nuggets worth $0.50 to $4.00 (roughly 1 to 7.5 grams in weight). Most of the gold was well worn and frequently coated with oxidized material. This gold is far travelled and is believed to be derived from distant sources in the Barkerville Terrane. Some of the gold appears to be less worn and possibly originates from nearby quartz veins such as those in the basal Nicola phyllite unit in the Spanish Mountain area. In pan concentrates this gold is accompanied by abundant large, euhedral pyrite crystals and arsenopyrite grains. Some very large nuggets were evidently present as well. In 1988 snipers salvaging old flume boards and sluicebox spillage from the tunnel spillway to the Quesnel River recovered a flattened 300-gram (10 ounce) nugget that had become wedged between some boards.

The lowest gravels in the section are fluvial and may represent a pre-Wisconsin fluvial environment. Above these are glaciofluvial and glacial gravels of the Early Wisconsin stade. This section is 30 to 90 metres thick and contained the richest gravels in the section. Unconformably above these deposits is a layer of consolidated lodgement till,

## TABLE 8-2
## PLACER GOLD PRODUCTION SINCE 1864 FROM BULLION MINE, ESTIMATED FROM REPORTED PRODUCTION RECORDS

| YEAR | YARDS REPORTED | DOLLARS QUOTED | ESTIMATED OUNCES | ESTIMATED GRADE cents/ yard | GRADE QUOTED cents/yard | ESTIMATED OUNCES |
|---|---|---|---|---|---|---|
| *1864 - 1893 | | 900 000 | *52 941* | *5.9* | | |
| 1894 | | 8 239 | *484* | *5.9* | | |
| 1895 | 210 000 | 60 306 | *3 547* | *28.7* | | |
| 1896 | 1 055 350 | 127 445 | *7 497* | *12.1* | | |
| 1897 | 840 130 | 138 559 | *8 150* | *16.5* | | |
| 1898 | | 105 141 | *6 185* | | 12.8 | |
| 1899 | | 92 679 | *5451* | | 4.1 | |
| 1900 | | 350 086 | *20 593* | | 19 | |
| 1901 | | 142 274 | *6 883* | | 5.8 | |
| 1902 | | 61 395 | *2 970* | | | |
| 1903 | | 44 917 | *2 173* | | | |
| 1904 | | 85 896 | *4 156* | | | |
| *1905 | | 17 053 | *825* | | | |
| 1927 | | 6 000 | *290* | | | |
| *1933 | 190 000 | | | | | 1 505 |
| *1934 | 400 000 | | | | | 3 169 |
| *1935 | 696 974 | | | | | 5 522 |
| *1936 | 960 000 | | | | | 7 607 |
| *1937 | 1 323 000 | | | | | 10 482 |
| *1938 | 861 300 | | | | | 6 824 |
| 1939 | 1 135 000 | | | | | 8 993 |
| 1940 | -- | | | | | -- |
| 1941 | 637 000 | | | | | 5 047 |
| TOTALS: | | $2 140 000 | 122 148 | | | 49 149 |

*GRAND TOTAL (estimated): 171 297 ounces gold production from Bullion pit. Unknown Chinese production 1859 - 1863. Values calculated from reported quantities are shown IN ITALICS as ESTIMATED ounces of gold. Calculations use average prices in dollars per ounce fine gold for 1864 to 1900 - $17.00, and for 1901-1941 - $20.67.*

*KEY REFERENCES: Lay (1939), Sharpe (1939, years marked * ), B.C. Minister of Mines Annual Reports, 1894-1897, 1902-1904, 1926, 1938-1941.*

called the boulder clay by the placer miners. The unconformity represents the Olympia glacial interstade of the Middle Wisconsin. The lodgement till represents the base of the Upper Wisconsin Fraser glacial stade. The thickness of the lodgement till is not specified but typically it is rarely more than 10 metres. Well stratified gravels form the upper 30 to 50 metres of the section. The Pleistocene section is capped by a veneer of Holocene debris (Sharpe, 1939, Fulton, 1984; Clague, 1987; Levson and Giles, 1991). The valley fill in the Bullion pit represents an ancient river channel older than 100 000 years BP (Clague, 1987) and is probably a precursor to the present Quesnel River. It appears that the Miocene and Pleistocene channels followed older water courses. This theory has been presented before by other workers in the area and might be useful as a prospecting guide to find other buried channels. Clague (1987) has recently recognized and described a buried channel of this type on the Cariboo River.

**Cedar Creek - MINFILE 093A/141:** This is a notable placer creek as it is one of the rare new major discoveries that was made since the 1860s. The discovery in 1921 of pay gravels at elevations around 300 metres above the present main valley bottoms resulted in recorded production of 37 784 ounces (*1175 kg*) of gold (Holland, 1950). The deposits contained rich gravels. Over 16 000 ounces (500 kg) was recovered during 1921 to 1923 by using simple sluicing and rocking methods; in 1922 recoveries of 7 ounces gold per yard (166g/m$^3$) of gravel over thicknesses of 2 metres are reported by Johnston (1923). The workings were confined largely to the creek bed or, in a few cases, were on benches up to 30 metres above. According to Johnston, the gravels were probably postglacial but some of the benches might include glacial and interglacial accumulations.

**Morehead (Seven Mile) Creek: MINFILE 093A/069:** Levson and Giles (1993) consider the Morehead Creek placers *to be preglacial, large paleochannel deposits.* The setting is similar to the Bullion mine in that deeply buried channel deposits that predate glaciation are overlain by a thick succession of fluvial, lacustrine, glaciofluvial and glacial deposits. Some of the gold recovered in the modern-day drainage channels may be derived from erosion of the older channels.

**Spanish Mountain Area:** Workings along Spanish Creek, MINFILE 093A/067, including Black Bear Creek and the active McKeown mine, are also regarded as preglacial, large paleochannel deposits (Levson and Giles, 1993). The gold-bearing gravels occupy the upper part of a steep sided, elevated paleochannel eroded in bedrock. Gold close to bedrock in the lower gravels, approximately 60 to 80 metres below surface, can be coarse. Nuggets up to 185 grams (6 ounces) have been taken. The large nuggets commonly contain quartz inclusions, are chunky and have rough surfaces; flattened or flaky gold is rare.

**Other Workings:** Quesnel River (South Fork) has numerous workings on benches and terraces below Likely including Lawless (Half Mile), Carberry Creek, Rose Gulch and in the vicinity of The Forks. Two kilometres east of Likely there was placer production at Poquette Creek. Cariboo River ('North Fork' of the Quesnel River) up to Cariboo had workings, as did the tributaries at Kangaroo Creek, Keithley/Four Mile, Rollie (Duck) and Frank (Goose) placers. Placers along the Quesnel River to the west and northwest of Quesnel Forks include the workings at Maud and Birrell (Twenty Mile) creeks. In the lower Quesnel River region, near Quesnel, there was placer mining at Sardine Flats, below the mouth of Deacon Creek and in the Quesnel River Big Canyon area.

Other placer workings noted by Holland (1950) or Levson and Giles (1993) in the northern part of map area include those on the Cottonwood River and on Sovereign, Swift, Wingdam and Lightning creeks as well as Baker Creek, a tributary of the Fraser River, near Quesnel.

## *PLACER GOLD COMPOSITION AND LODE SOURCES*

The placer gold in the Horsefly River area contained in Miocene white quartz bearing channels does not appear to be locally derived from the volcanic arc basaltic deposits. This is in contrast to some of the deposits in the Quesnel River drainange system which appear, in part at least, to be locally derived. The distinctive white quartz clasts are contained in an argillaceous to micaceous matrix composed of an abundance of clay-sized phyllosilicate minerals, mainly muscovite. Typical mineralogy of the heavy mineral fraction

**TABLE 8-3**
**COMPOSITIONS OF GOLD GRAINS RECOVERED FROM PLACER CREEKS AND LODE GOLD SOURCES**

| SAMPLE | GRAIN CORES | RANGE | DISCRETE RIMS AND EDGES | VEINS/ FRACTURES |
|---|---|---|---|---|
| Bullion Pit placer | 766 | | 998 | 994 |
| Choate (West) Ck. placer | 812 | | 996 | - |
| Black Creek placer | 818 | | 998 | 999 |
| Range in placer grains | 775 | | | |
| Average grain core | | 611 - 909 | | |
| Spanish Mtn. vein | 767 | 760-803 | - | - |
| Spanish Mtn. vein | 754 | 680-812 | - | - |
| Spanish Mtn. vein | 781 | 742-822 | - | - |
| Eureka Peak. drill core | 760 | 759-760 | - | - |
| Eureka Peak. drill core | 739 | 736-741 | - | - |

*Microprobe analyses by John Knight, the University of British Columbia, 1989; analysis in weight per cent.*
*Sample sources: placer locations - Bullion pit - 9, West Choate (Teasdale) - 1 nugget, Black Creek - 4; lode gold sources (Bloodgood, 1990) include Spanish Mountain (CPW) quartz veins 8, 27 and 18 particles; Eureka Peak (Frasergold) diamond-drill core, 1 particle in each.*

in pan concentrates includes abundant almandine and some spessartine garnet, kyanite, and only minor black sand (magnetite, amphibole, pyroxene, epidote and olivine). The gold itself is coarse to fine in size, well beaten, flattened and partially coated with iron oxide. All these points indicate that the gold has travelled a long distance. The abundance of white quartz pebbles in the Miocene gravels, the relative sparseness of heavy minerals, black sand and notably pyroxene, all indicate that the local basaltic volcanic terrain and mafic alkalic intrusions are not the source of the placer gold. Instead, the association of placer grains with garnet, kyanite, rare brookite grains and other metamorphic minerals indicates a source area in, or near, the high-grade metamorphic rocks of the Barkerville Terrane. A likely source for the gold is the Middle Jurassic quartz veins in black phyllite units near the Quesnellia-Barkerville terrane boundary. Quartz veins are abundant there in the strongly deformed basal phyllites and a number of veins such as those at the Frasergold deposit, are known to carry gold. A source in the Triassic black phyllites is further supported by historical evidence that some of the recovered gold was still attached to rock grains made up of quartz and black 'slate'. Discussions of lode gold deposits and their sources for placers that are associated with ultramafic (ophiolitic) rocks emplaced along tectonic boundaries are presented by Ash *et al.*, (1996). The compositions of some placer and lode gold from the region are discussed below.

Microprobe analyses of gold grains from a number of placer and lode deposits are shown in Table 8-3. Compositions of gold grains from 44 placer and 16 lode sites in the Cariboo and Quesnel River region are reported by McTaggart and Knight (1993). They document a dominant range of fineness, or parts per thousand gold, from 750 to 810 for samples from the Quesnel River and to the south. Gold from lode sources in the Spanish Lake area is similar in composition or is slightly less fine, commonly from 750 to 790. Compositions of placer gold in the map area reported by Holland (1950) range from 762 to 980 fine. Compositions vary, the average fineness of more than 25 000 ounces of gold recovered from the Bullion pit is 801, according to Holland, but the fineness of individual samples varies from 762.5 to 822.5. The 980 value from Big Lake Creek represents the highest gold content of any placer gold in the province (Holland, 1950).

The probe work on individual grains shows distinct rimming and fracture-filling of placer grains by gold of very high fineness, for example, cores are around 775 fine but rims and healed fractures or veinlets are more than 990 fine. Historic reported fineness represents an average sample composition. Individual deposits will vary in fineness depending on the ratio of core to rim in the grains from various parts of the deposit. Whether the rims with high gold content represent high-purity gold that has grown on the grains or is a product of leaching during transportation and maturation in the sites of deposition is a long-standing argument. The main element contained in the samples in addition to gold is silver; other metals are present in very minor amounts. Copper is generally present in amounts less than 200 ppm. Mercury ranges from a grain average of 100 to 900 ppm in the samples. Anomalous mercury content of up to 1.3% is noted in some probe analyses of the placer grains from Black Creek. McTaggart and Knight (1993) also documented only small concentrations of mercury, generally less than 0.5%, in the Cariboo and Quesnel River areas. A few anomalous placer creeks to the north of Wells and Barkerville contain mercury in excess of 1%, similar to the Black Creek placer.

## SILT AND LITHOGEOCHEMICAL STUDIES

### *REGIONAL GEOCHEMICAL SURVEYS*

Stream sediment and water geochemical surveys in the central Quesnel belt were conducted by the provincial Ministry of Energy, Mines and Petroleum Resources in cooperation with the federal government as part of the province-wide Regional Geochemical Survey (RGS) studies. These surveys in NTS map areas 93A, 93B, 93G and 93H cover the Quesnel-Horsefly project and surrounding areas. Analytical results for 522 sample sites in the map area and immediately adjoining regions, were extracted from the following RGS surveys: RGS 5, 1981, NTS 93A; RGS 6, 1981, NTS 93B; RGS 13, 1986, NTS 93G; and RGS 14, 1986, NTS 93H. These correspond to Geological Survey of Canada publications Open File 776, Open File 777, Open File 1214 and Open File 1215.

The 522 sample sites in the project area, and some from the immediately adjacent region, are represented on Figures 8-11 to 8-14. Stream sediment and water analytical data are summarized in Table 8-4. Symbols plotted on the figures

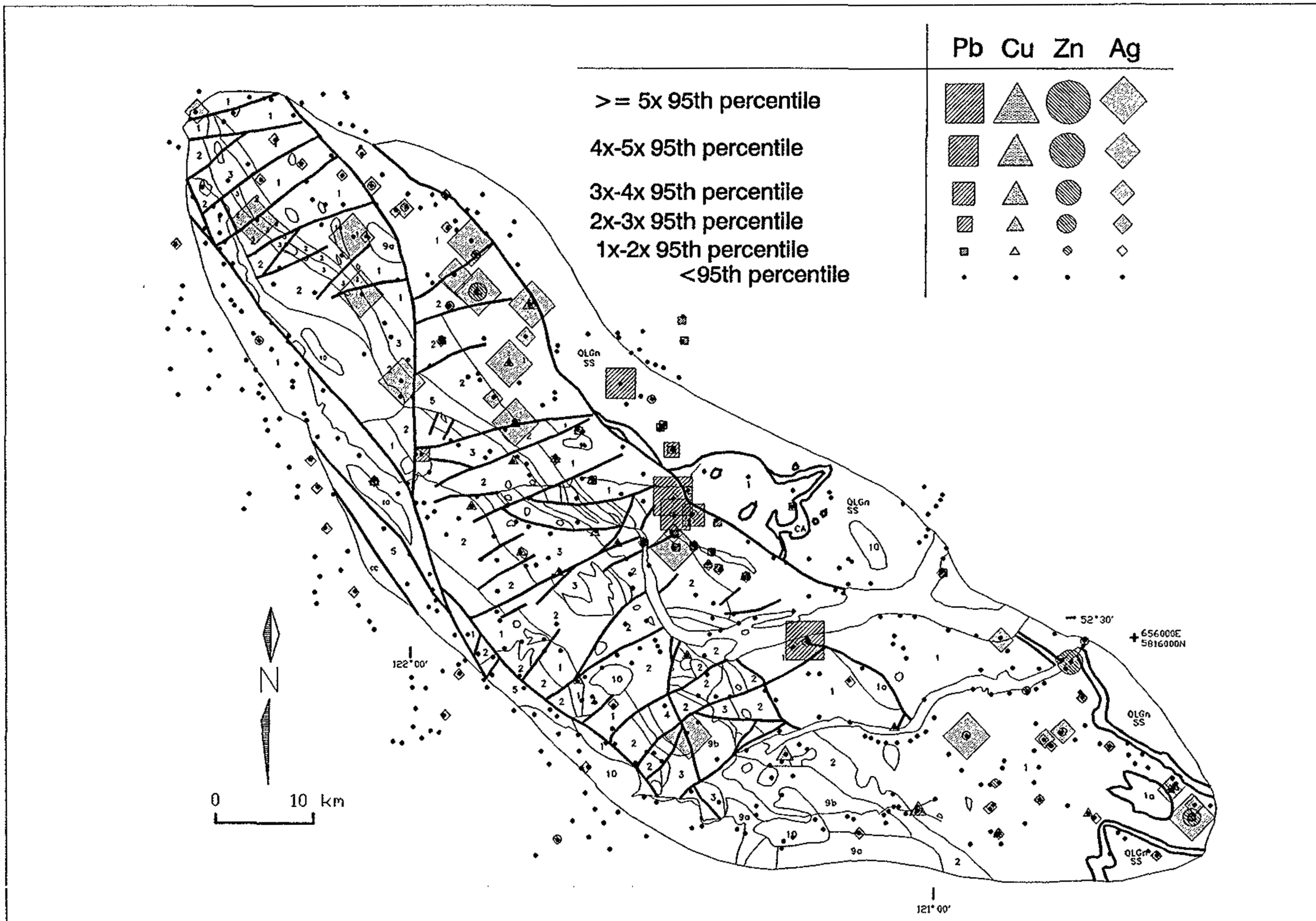



Figure 8-11. RGS stream sediments survey for Pb, Cu, Zn and Ag. Sample sites and symbols for >95 percentile values.

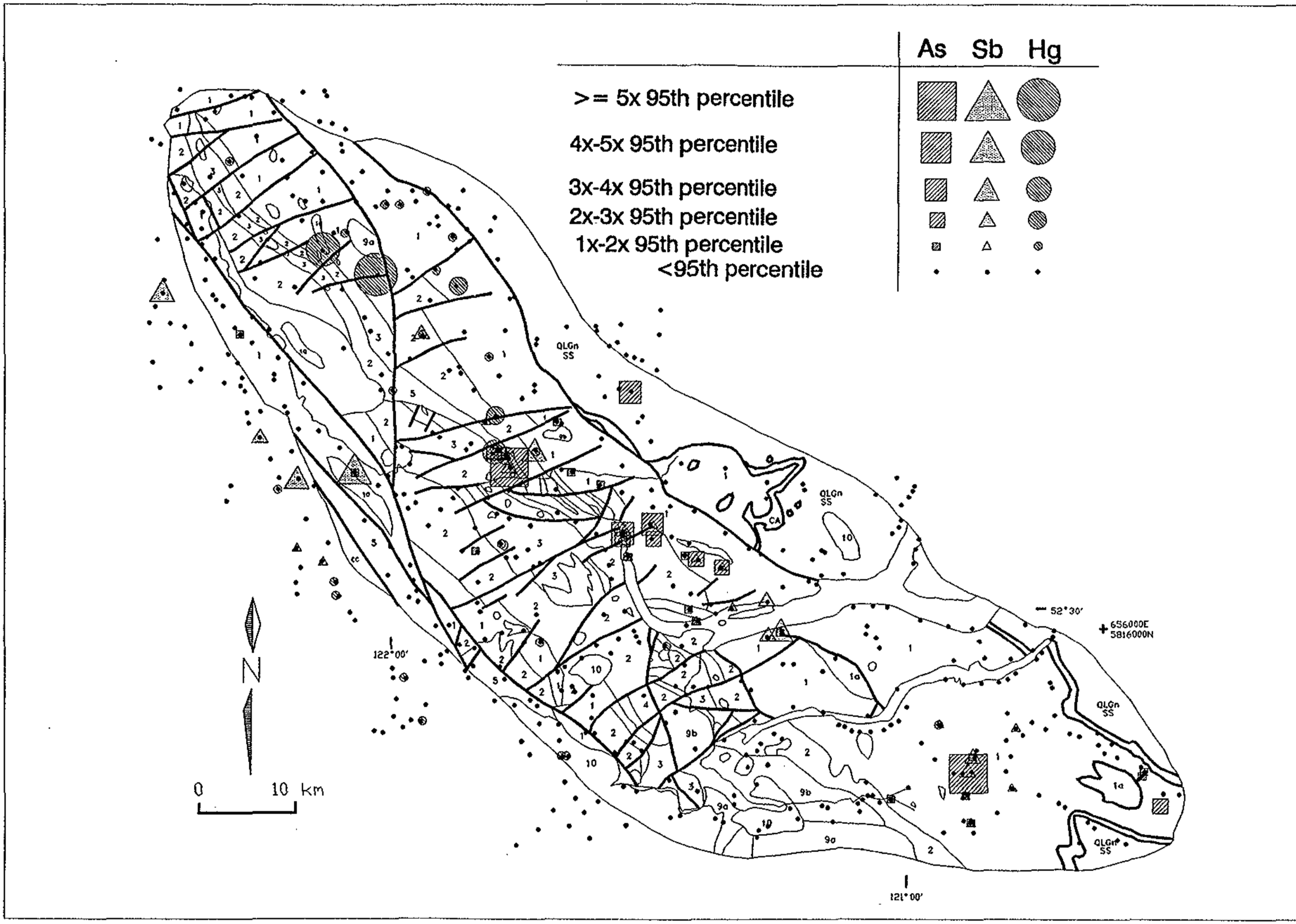



Figure 8-12. RGS stream sediment survey for As, Sb and Hg.

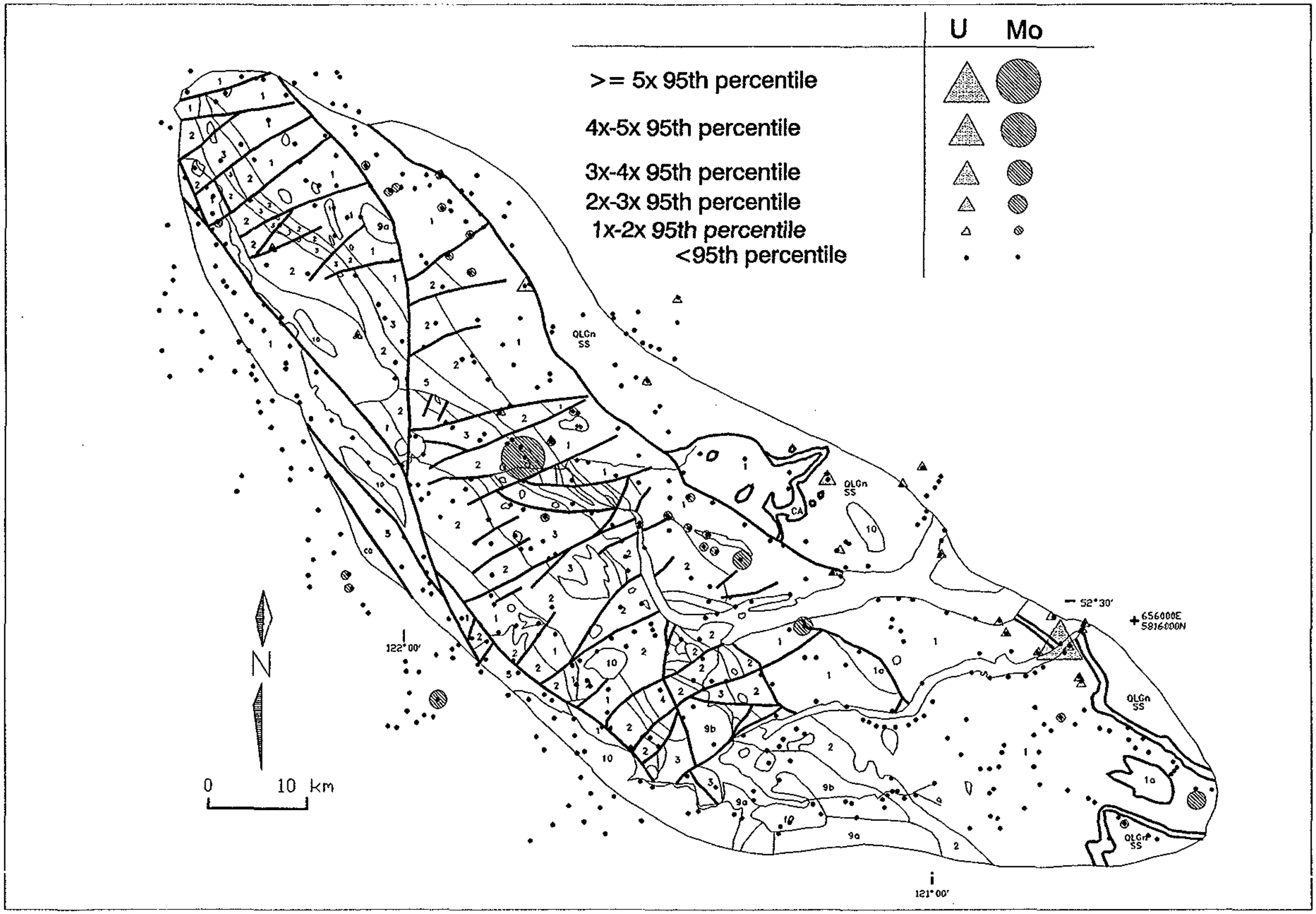



Figure 8-13. RGS stream sediment survey for U and Mo.

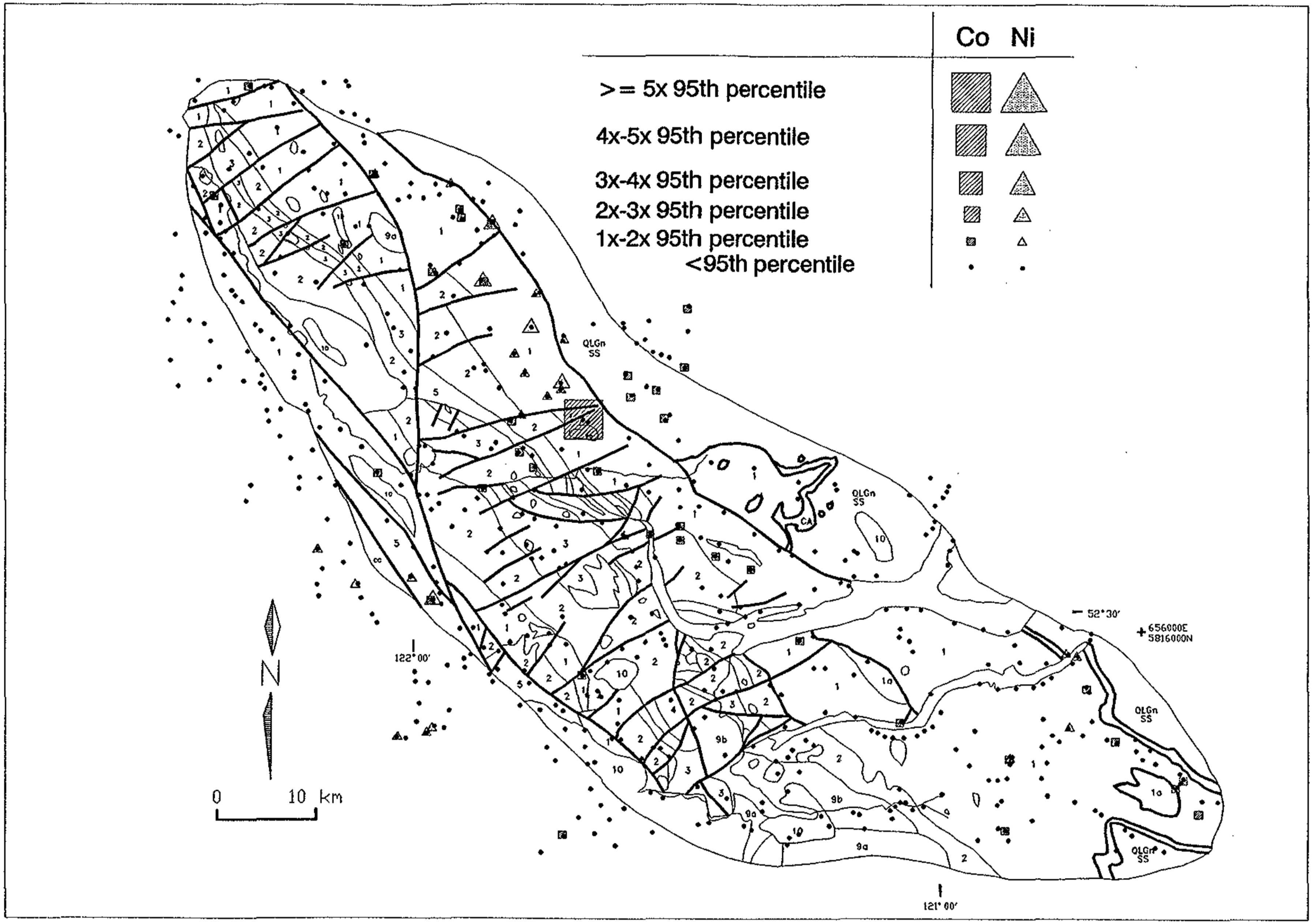



Figure 8-14. RGS stream sediment survey for Co and Ni.

represent analytical results that are equal to or greater than the 95 percentile values of the dataset. In this approach the 95 percentile values are plotted and larger values are shown as symbols of increasing size. This method clearly identifies the largest values and emphasizes the highest 5% analytical values as 'anomalous', in this case about 30 sample sites.

Copper and zinc concentrations are, perhaps surprisingly, subdued with amounts rarely higher than those of the 95 percentile value. Individual elements appear to have the following attributes and distributions of anomalously high values:

- Lead is strongly anomalous in a number of sites from Spanish Lake northwest towards the Cariboo River and further into the high-grade metamorphic rocks.
- Anomalous copper without other associated anomalous elements occurs in sites along the central axis of the volcanic belt and at least partially defines intrusive centres. Copper in association with other elements defines multi-element anomalies in the metasedimentary rocks of unit 1.
- Zinc is present in black phyllites of unit 1 and seemingly is most abundant near the basal contact.
- Silver is strongly anomalous throughout the map area. It might be the most effective element in identifying mineralized regions as the anomaly threshold represents the analytical detection limit (0.2 ppm). Every sample in which silver can be detected can be considered to be anomalous. Silver is most abundant in the metasedimentary rocks of unit 1 and, to a lesser extent, the Cache Creek rocks. Silver is also concentrated in the northern part of the volcanic arc. Perhaps significantly, it is strongly anomalous in one sample

**TABLE 8-4**
**SUMMARY OF STREAM SEDIMENT DATA FOR TOTAL SAMPLE SET, IN PROJECT AREA AND PROXIMITY; N=522**

| Variable | $U_w$ | $F_w$ | pH | Zn | Cu | Pb | Ni | Co | Ag | Mn | As | Mo | Fe | Hg | U | Sb | W |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Units | ppb | ppb | | ppm | ppm | ppm | ppm | ppm | ppm | ppm | ppm | ppm | pct | ppb | ppm | ppm | ppm |
| Detection Limit | 0.05 | 20 | 0.1 | 2 | 2 | 2 | 2 | 2 | 0.2 | 5 | 1 | 1 | 0.02 | 10 | 0.5 | 0.2 | 1 |
| Analytical Method | LIF | ION | GCE | AAS | AAS | AAS | AAS | AAS | AAS | AAS | AAS-H | AAS | AAS | AAS-F | NADNC | AAS | COLOR |
| N | 517 | 517 | 517 | 517 | 517 | 517 | 517 | 517 | 517 | 517 | 517 | 517 | 517 | 517 | 517 | 512 | 517 |
| N > Detection Limit | 340 | 484 | 517 | 517 | 517 | 215 | 514 | 513 | 21 | 517 | 494 | 83 | 517 | 516 | 510 | 350 | 40 |
| Missing | 5 | 5 | 5 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 8 | 3 |
| Mean | 0.19 | 63.9 | 7.68 | 68.5 | 34.4 | 4.1 | 35.7 | 11.4 | 0.14 | 910.5 | 8.1 | 1.7 | 2.23 | 73.4 | 2.8 | 0.71 | 1.4 |
| Median | 0.1 | 54 | 7.8 | 56 | 29 | 2 | 28 | 10 | 0.1 | 555 | 5 | 1 | 2.2 | 59 | 2.5 | 0.4 | 1 |
| Mode | 0.02 | 50 | 8.1 | 56 | 22 | 1 | 28 | 10 | 0.1 | 290 | 3 | 1 | 2.2 | 50 | 2 | 0.2 | 1 |
| Range | 5.88 | 1090 | 3.5 | 456 | 172 | 81 | 234 | 107 | 2.1 | 20410 | 195 | 149 | 5.7 | 3390 | 45.3 | 7.7 | 44 |
| Standard Dev. | 0.38 | 67.43 | 0.61 | 46.22 | 22.59 | 7.05 | 28.54 | 6.54 | 0.16 | 1669.13 | 14.04 | 6.68 | 0.76 | 154.71 | 2.55 | 0.89 | 2.35 |
| Coefficient Var. | 2.004 | 1.056 | 0.079 | 0.675 | 0.656 | 1.71 | 0.799 | 0.573 | 1.181 | 1.833 | 1.73 | 3.87 | 0.339 | 2.106 | 0.912 | 1.245 | 1.699 |
| Log Mean | -0.999 | 1.717 | 0.884 | 1.771 | 1.464 | 0.39 | 1.461 | 1.012 | -0.939 | 2.783 | 0.707 | 0.08 | 0.322 | 1.759 | 0.374 | -0.336 | 0.05 |
| Geo Mean | 0.1 | 52.1 | 7.65 | 59 | 29.1 | 2.5 | 28.9 | 10.3 | 0.12 | 607.2 | 5.1 | 1.2 | 2.1 | 57.5 | 2.37 | 0.46 | 1.1 |
| Log Standard Dev. | 0.477 | 0.267 | 0.036 | 0.227 | 0.251 | 0.394 | 0.278 | 0.197 | 0.186 | 0.326 | 0.363 | 0.23 | 0.157 | 0.247 | 0.238 | 0.391 | 0.191 |
| Log Coefficient Var. | -0.477 | 0.155 | 0.04 | 0.128 | 0.171 | 1.01 | 0.19 | 0.195 | -0.199 | 0.117 | 0.515 | 2.73 | 0.486 | 0.141 | 0.635 | -1.167 | 3.889 |
| Percentiles | | | | | | | | | | | | | | | | | |
| Minimum | <0.02 | <10 | 5.4 | 4 | 6 | <1 | <1 | <1 | <0.1 | 90 | 1 | 1 | 0.2 | 10 | <.2 | <.1 | 1 |
| 10th | <0.02 | 24 | 6.8 | 34 | 14 | <1 | 15 | 6 | <0.1 | 280 | 2 | 1 | 1.4 | 30 | 1.3 | 0.2 | 1 |
| 20th | <0.02 | 34 | 7.2 | 38 | 18 | <1 | 18 | 7 | <0.1 | 340 | 3 | 1 | 1.6 | 40 | 1.5 | 0.2 | 1 |
| 30th | 0.05 | 40 | 7.4 | 46 | 22 | <1 | 21 | 8 | <0.1 | 405 | 3 | 1 | 1.8 | 40 | 2 | 0.2 | 1 |
| 40th | 0.1 | 48 | 7.6 | 52 | 25 | 2 | 24 | 10 | <0.1 | 490 | 4 | 1 | 1.95 | 50 | 2 | 0.4 | 1 |
| 50th | 0.1 | 54 | 7.8 | 56 | 29 | 2 | 28 | 10 | <0.1 | 555 | 5 | 1 | 2.2 | 59 | 2.5 | 0.4 | 1 |
| 60th | 0.14 | 62 | 7.9 | 62 | 32 | 4 | 31 | 11 | <0.1 | 650 | 5 | 1 | 2.35 | 60 | 2.5 | 0.6 | 1 |
| 70th | 0.18 | 70 | 8.1 | 72 | 40 | 4 | 37 | 13 | <0.1 | 760 | 6 | 1 | 2.55 | 70 | 3 | 0.8 | 1 |
| 80th | 0.26 | 80 | 8.2 | 86 | 46 | 6 | 44 | 15 | <0.1 | 980 | 8 | 1 | 2.8 | 90 | 3.5 | 1 | 1 |
| 85th | 0.3 | 92 | 8.2 | 100 | 52 | 6 | 53 | 16 | 0.1 | 1200 | 10 | 2 | 2.95 | 100 | 4 | 1.2 | 1 |
| 90th | 0.38 | 110 | 8.3 | 112 | 59 | 8 | 65 | 18 | 0.2 | 1550 | 15 | 2 | 3.2 | 110 | 4.4 | 1.4 | 1 |
| 95th | 0.52 | 125 | 8.5 | 142 | 74 | 12 | 86 | 20 | 0.2 | 2400 | 25 | 5 | 3.6 | 140 | 5.5 | 1.8 | 3 |
| 98th | 0.72 | 160 | 8.7 | 220 | 96 | 22 | 128 | 24 | 0.6 | 4100 | 50 | 7 | 4 | 190 | 6.7 | 4.2 | 7 |
| 99th | 1.5 | 170 | 8.8 | 260 | 126 | 30 | 158 | 28 | 1 | 6500 | 63 | 9 | 4.25 | 290 | 9.5 | 5.2 | 10 |
| Maximum | 5.9 | 1100 | 8.9 | 460 | 178 | 82 | 235 | 108 | 2.2 | 20500 | 196 | 150 | 5.9 | 3400 | 45.5 | 7.8 | 45 |

*Data source: Regional Geochemical Surveys (RGS) 5,6,13,14 - Open File Reports 776, 777, 1214, 1215*

*$U_w$, $F_w$ = uranium in water; < denotes less than detection limit shown (not detected)*

5 kilometres to the northwest of Horsefly village near the postulated site of the western structural wall of the Eocene graben.

Other elements with expected geochemical associations are arsenic-antimony-mercury, molybdenum-uranium and cobalt-nickel.

- Arsenic occurs in a number of anomalous sites, mainly in unit 1, and clearly in association with auriferous quartz vein systems. It is also strongly anomalous in the vicinity of the QR deposit.
- Antimony is commonly associated with arsenic in rocks of unit 1. It also occurs by itself or with silver and copper in unit 1 metasedimentary rocks but is also present in Cache Creek rocks and in the vicinity of the QR deposit.
- Mercury, with a few notable exceptions, is found mainly to the north of the Quesnel River. It occurs in a variety of rock types and is probably associated with faults. Mercury is present in the QR deposit area and appears to be associated with silver-rich samples farther to the north.
- Molybdenum is concentrated in drainages emanating from the metasedimentary rocks of unit 1 and the Cache Creek assemblage. Locally it occurs together with arsenic and antimony, such as in the QR deposit area.
- Uranium is largely confined to the high-grade metamorphic rocks of the Barkerville Terrane and, to a lesser degree, faults or lithologic contacts in unit 1.
- Cobalt, at first glance, appears to be concentrated throughout the rocks of unit 1, but closer examination shows that it is associated with zones containing anomalous arsenic, silver or other elements, commonly in areas with mineralized quartz veins.
- Nickel is concentrated along both the east and western map boundaries, coincident with the major terrane-boundary fault zones and their contained serpentinized ultramafic rocks.

The associations of elements shown on Table 8-4 (Figures 8-11 to 8-14), as indicated by statistical correlation analysis, show strong correlations between many pairs and groups of elements, notably high values of As-Sb and As-Mo-Ag-Co. Perhaps more significantly, a number of lithologic associations and map patterns are evident when the distribution of anomalous values is displayed on maps. The metasedimentary rocks of unit 1 generate the largest number and greatest concentrations of anomalous samples. Lithology clearly controls the distribution of uranium; structural control of mercury is evident. Possibly both lithology and structure influence the distribution of nickel. Most other anomalous concentrations can be related to discovered or implicit mineralized environments. Copper anomalies in streams emanating from areas underlain by volcanic rocks are a relatively subtle indication of porphyry copper mineralization. Multi-element anomalies effectively outline areas in phyllitic rocks with known mesothermal gold veins. Notable geochemical 'hotspots' identified are: the QR deposit - an arsenic, antimony, mercury, cobalt anomaly; the trend of auriferous veins from Spanish Lake to Likely, marked by arsenic, silver and other element anomalies; the trend of silver-bearing base metal veins to the north-northwest of Spanish Lake, defined by high lead values; and the Eureka Peak area in which the presence of auriferous veins is indicated by multi-element anomalies. Anomalies that require additional investigation in order to relate them to sources are the sites with high silver values, some with mercury, in the northwest part of the map area. Also the sampling in Cache Creek rocks suggests a higher potential for mineralization than might have been expected, particularly along the terrane-boundary fault zone with rocks of Quesnellia. More detailed examination of the data may undoubtedly reveal other significant geochemical and statistical relationships and possibly outline areas of exploration interest.

Conclusions are that multi-element anomalies can be related to known mineralized showings in most cases. Some elements have a clear lithologic association, for example nickel with Crooked amphibolite. Some element distributions are a result of structural effects that juxtapose certain lithologies and mineralization/alteration assemblages, for example, molybdenum with granites; uranium with metamorphic rocks, and so forth. Part of the reason that there is a better apparent geochemical endowment in the sedimentary rocks of unit 1 compared to the volcanic rocks is simply that there is better dispersion in that region, both mechanical and chemical. This is due to greater erosion and more efficient elemental transport in the better established drainage systems in the region of topographically greater relief. This goes counter to any *a priori* reasoning that suggests the areas underlain by volcanic and plutonic rocks are the more intensely mineralized and should have the larger and more evident geochemical anomalies. It is also perhaps significant that because of generally high values of pH in the volcanic belt, generally higher alkalinity than in the region underlain by metasedimentary rocks, some elements will be less mobile in the drainage systems and will be peferentially concentrated in oxidized rocks and overlying soils. Thus even low-level copper anomalies in sediments are very significant in the volcanic belt. For example, the 70 percentile value for copper (40 ppm) clearly marks the regions of the volcanic belt in which most of the known copper occurrences are located.

## LITHOGEOCHEMICAL SAMPLING

Samples of mineralized, strongly altered or otherwise economically interesting rocks were submitted as grab or chip samples for analysis. The samples were analyzed for gold, silver, copper, lead, zinc, cobalt, nickel, molybdenum, mercury, arsenic, antimony and barium. Results for the 125 samples analyzed, sample locations, descriptions and other sampling data are presented in Appendices M and N. Most anomalous values can be attributed to obvious mineralization - usually veins or sulphide minerals contained in the rock. Mercury, arsenic and antimony are effective 'pathfinder' elements that can be used to identify hydrothermally altered rocks. Antimony, even at low levels, is perhaps the most sensitive indicator of mineralization.

In addition, 49 samples representative of the various rock types in the map area were analyzed for platinum and palladium (and gold) as an orientation study to determine regional lithologic background values for those elements (*see* Appendix O). The sample containing 65 ppb platinum is from an unusual 'appenite' pyroxenite exposed in a cirque on Eureka Peak.

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# APPENDICES

# APPENDIX A
# COMPOSITION OF PYROXENE FROM UNIT 2

Analysis of zoning in individual pyroxene grains (this study, M. Mihalynuk, analyst) and map-unit average values from Bailey, (1978).
All values in weight percent.

**87AP 31/6-96; map-unit 2b - alkali basalt:**
**Determinations = 8**

| | $SiO_2$ | $TiO_2$ | $Al_2O_3$ | FeO | MnO | MgO | CaO | $Na_2O$ | $K_2O$ | $Cr_2O_3$ |
|---|---|---|---|---|---|---|---|---|---|---|
| pyroxene graincore | 50.0 | 0.51 | 3.61 | 7.91 | 0.27 | 14.40 | 22.2 | 0.33 | 0.00 | 0.02 |
| centre | 50.5 | 0.56 | 4.03 | 8.09 | 0.29 | 14.30 | 22.0 | 0.38 | 0.00 | 0.03 |
| rim | 50.4 | 0.61 | 4.34 | 8.16 | 0.26 | 14.10 | 22.2 | 0.35 | 0.00 | 0.04 |
| average | 50.6 | 0.56 | 3.99 | 8.05 | 0.27 | 14.30 | 22.1 | 0.35 | 0.00 | 0.03 |

**86AP 4/6-18, analcite pyroxene basalt - map-unit 2e:**
**Determinations = 5.**

| | $SiO_2$ | $TiO_2$ | $Al_2O_3$ | FeO | MnO | MgO | CaO | $Na_2O$ | $K_2O$ | $Cr_2O_3$ |
|---|---|---|---|---|---|---|---|---|---|---|
| pyroxene graincore | 51.2 | 0.41 | 3.61 | 6.94 | 0.20 | 15.00 | 22.8 | 0.30 | 0.00 | 0.12 |
| centre | 50.4 | 0.46 | 4.20 | 7.27 | 0.19 | 14.50 | 22.7 | 0.30 | 0.00 | 0.15 |
| rim | 40.0 | 0.58 | 5.24 | 8.38 | 0.26 | 13.50 | 22.3 | 0.36 | 0.00 | 0.02 |
| average | 50.2 | 0.48 | 4.35 | 7.43 | 0.22 | 14.30 | 22.6 | 0.32 | 0.00 | 0.06 |

**87AP 5/8-14, map-unit 4 - analcite olivine basalt:**
**Determinations = 9**

| | $SiO_2$ | $TiO_2$ | $Al_2O_3$ | FeO | MnO | MgO | CaO | $Na_2O$ | $K_2O$ | $Cr_2O_3$ |
|---|---|---|---|---|---|---|---|---|---|---|
| pyroxene graincore | 49.8 | 0.66 | 5.34 | 7.39 | 0.19 | 14.40 | 22.1 | 0.46 | 0.00 | 0.08 |
| centre | 49.7 | 0.61 | 5.45 | 7.52 | 0.20 | 14.30 | 22.2 | 0.49 | 0.00 | 0.07 |
| rim | 50.0 | 0.68 | 5.02 | 7.51 | 0.22 | 14.48 | 22.2 | 0.41 | 0.00 | 0.03 |
| average | 49.8 | 0.65 | 5.27 | 7.47 | 0.20 | 14.40 | 22.1 | 0.45 | 0.00 | 0.06 |

**Map-unit average values (Bailey, 1978)**

| | $SiO_2$ | $TiO_2$ | $Al_2O_3$ | FeO | MnO | MgO | CaO | $Na_2O$ | $K_2O$ | $Cr_2O_3$ |
|---|---|---|---|---|---|---|---|---|---|---|
| Alkali Olivine bslt, unit 2a, N=19 | 50.3 | 0.71 | 4.39 | 7.73 | 0.11 | 13.90 | 21.9 | 0.53 | 0.02 | 0.14 |
| Alkali bslt unit 2b, N=2 | 51.6 | 0.44 | 4.49 | 6.86 | 0.15 | 13.50 | 22.9 | 0.13 | 0.08 | 0.28 |
| Analcite alkali bslt unit 2e, N=2 | 52.7 | 0.68 | 5.44 | 6.77 | 0.24 | 13.00 | 22.5 | 0.35 | 0.07 | 0.33 |

# APPENDIX B
# MICROFOSSIL (CONODONT) DATA FOR THE QUESNEL MAP AREA

| Field No.<br>GSC No. | Map Unit | Latitude<br>Longitude | NTS Map | Location | Identification | Age | CAI* |
|---|---|---|---|---|---|---|---|
| 86AP-25/3-76-C1<br>C-117601 | 1 | 52°-29'-22"<br>121°-25'-34" | 93A/6 | western tip of Horsefly Penninsula. | worm tubes | Phanerozoic (indeterminate) | |
| 86AP-26/6-80-C2<br>C-117602 | 1 | 52°-27'-54"<br>121°-22'-25" | 93A/6 | 2.5 km S of eastern tip of Horsefly Penninsula, on S shore of Quesnel L. | ichthyoliths<br>shell material | late Paleozoic-Mesozoic | |
| 86AP-25/4-87-C3 | 1 | 52°-28'-33"<br>121°-20'-49" | 93A/6 | on S shore Quesnel L, 1.7km SE of eastern tip Horsefly Penninsula | barren | | |
| 86AP-25/5-88-C4 | 1 | 52°-28'-42"<br>121°-20'-4" | 93A/6 | on S shore Quesnel L, 2.5km SE of eastern tip Horsefly Penninsula | barren | | |
| 86AP-27/4-90-C5 | 2f | 52°-29'-44"<br>121°-21'-9" | 93A/6 | E end of Caribou Island | barren | | |
| 86AP-28/6-93-C6 | 2a | 52°-29'-56"<br>121°-27'-45" | 93A/6 | N. shore Quesnel L, at Mitchell Bay | barren | | |
| 86AP-29/1-102-C7 | 2a | 52°-30'-31"<br>121°-30'-43" | 93A/12 | W shore Quesnel L, 2 km N Hazeltine Pt | barren | | |
| L-87-C4-8<br>C-117642 | 2f | 52°-53'-39"<br>122°-9'-28" | 93B/16 | Cantin Creek area | foraminiferid: (Ammonodiscus?) | Silurian to recent probably Upper Triassic | |
| DB87-004<br>C-117643 | | 52°-40'-06"<br>122°-00'-30" | 93B/9 | S. shore Quesnel R | ichthyoliths | Phanerozoic probably Upper Triassic | |
| 87AP-12/3-31<br>C-117644 | 1 | 52°-24'-47"<br>121°-34'-49" | 93A/5 | Antoine Ck., 1.6 km downstream from Antoine L. | ichthyoliths<br>conodont taxa: *Epigondolella* cf., *E. abneptis* Huckriede<br>ramiform elements, *Neogondolella* sp. | Upper Triassic, probably lower Norian | 2.5-3.5 |
| 88AP-08/05-C1<br>C-154104 | 1 | 52°-25'-18"<br>121°-43'-50" | 93A/5 | Beaver Valley: 8 km NE of George Lk (cliff at Gillespie Ranch) Ollistrome in cliff carbonate | Conodonts, ichthyoliths:<br>Conodont taxa: Neogondolella ? sp. | Mid.-U. Triassic Anisian-Carnian | 4.5 |
| 88AP-10/3-C2<br>C-154105 | 1 | 52°-22'-40"<br>121°-12'-49" | 93A/6 | 5.5 km NE Lemon L approx. 1 km N of 8500 road | Conodonts:<br>Metapolygnathus sp.<br>*ex gr. nodusus (Hayashi)* | U. Triassic Late Carnian | 3.5-4 |
| 88AP-11/4-C3<br>C-154106 | 1 | 52°-26'-36"<br>121°-47'-46" | 93A/5 | 1 km SSE Dorsey L on waterline road | [Halobia site]<br>ichthyoliths | probably Triassic | |
| 88AP-11/4-C4<br>C-154107 | 1 | 52°-26'-36"<br>121°-47'-46" | 93A/5 | 1 km SSE Dorsey L on waterline road | ichthyoliths | Phanerozoic | |
| 88AP-11/4-C5<br>C-154108 | 1 | 52°-26'-36"<br>121°-47'-46" | 93A/5 | 1 km SSE Dorsey L on waterline road | barren | | |
| 88AP-12/6-C6<br>C-154109 | 1 | 52°-26'-43"<br>121°-48'-4" | 93A/5 | 1 km SSE Dorsey L on waterline road | Conodonts, ichthyoliths<br>Conodont taxa: Metapolygnathus | U. Triassic; Late Carnian | 4.5 |
| 85AP-126 | 2a | 52°-28'-29"<br>121°-25'-00" | 93A/06 | Horsefly river road, 0.9km SE of Mitchell Bay | barren | | |
| 85AP-126a | 2a | 52°-28'-29"<br>121°-25'-00" | 93A/06 | Horsefly river road, 0.9km SE of Mitchell Bay | barren | | |
| 85AP-126b | 2a | 52°-28'-29"<br>121°-25'-00" | 93A/06 | Horsefly river road, 0.9km SE of Mitchell Bay | barren | | |

*Collector code in field number: A. Panteleyev - AP; D.G. Bailey - DB; J. Lu -L*
*All identifications by M.J. Orchard, Geological Survey of Canada (Report No. MJO-1995-9)*

# APPENDIX C
# EUREKA PEAK - QUESNEL LAKE MICROFOSSIL (CONODONT) DATA

| Field No.<br>GSC No. | Map Unit | Latitude<br>Longitude | NTS Map | Location | Identification | Age | CAI* |
|---|---|---|---|---|---|---|---|
| 86MB-15-02<br>C-117629 | 1 | 52°-27'-41"<br>120°-45'-46" | 93A/7 | Eureka Peak area | barren | | |
| 86MB-16-08<br>C-117630 | 1 | 52°-26'-33"<br>120°-48'-8" | 93A/7 | Eureka Peak area | barren | | |
| 86MB-17-01<br>C-117631 | 1 | 52°-21'-14"<br>120°-50'-22" | 93A/7 | Eureka Peak area | barren | | |
| 86MB-17-02<br>C-117632 | 1 | 52°-21'-19"<br>120°-50'-11" | 93A/7 | Eureka Peak area | barren | | |
| 86MB-26-09<br>C-117633 | 1 | 52°-16'-2"<br>120°-39'-53" | 93A/7 | Eureka Peak area | barren | | |
| 86MB-27-01<br>C-117634 | 1 | 52°-20'-55"<br>120°-39'-4" | 93A/7 | Eureka Peak area | barren | | |
| 86MB-28-02<br>C-117635 | 1 | 52°-20'-49"<br>120°-44'-42" | 93A/7 | Eureka Peak area | barren | | |
| 86MB-33-13<br>C-117636 | 1 | 52°-19'-56"<br>120°-42'-1" | 93A/7 | Eureka Peak area | barren | | |
| 87MB-01-02<br>C-117645 | 1 | 52°-33'-17"<br>121°-16'-12" | 93A/11 | Abbot Ck rec. road, east of Benny Lake | Conodonts:<br>Neogondolella ex gr. constricta (Mosher & Clark)<br>Neogondolella sp. cf. N. alpina (Kozur & Mostler 1982)<br>ramiform elements | M. Triassic<br>Late Anisian<br>early Ladinian | 5 |
| 87MB-02-04 | 1 | 52°-33'-54"<br>121°-20-51" | 93A/11 | Spanish Lk area | barren | | |
| 87MB-04-05<br>C-117647 | 1 | 52°-40'-9"<br>120°-3'-30" | 93A/9 | Hobson Lk area | barren | | |
| 87MB-07-06<br>C-117648 | 1 | 52°-40'-6"<br>121°-20'-35" | 93A/11 | Spanish Lk area | barren | | |
| 87MB-16-02<br>C-117649 | 1 | 52°-32'-50"<br>121°-21'-1" | 93A/11 | Spanish Mtn., E. | Conodonts:<br>Chiosella timorensis (Nogami 1968)<br>ramiform elements | Middle Triassic<br>Early Anisian | 5-5.5 |
| 87MB-19-02<br>C-117650 | 1 | 52°-35'-32"<br>121°-26'-12" | 93A/11 | Spanish Lk area | barren | | |
| 87MB-19-06<br>C-154101 | 1 | 52°-34'-43"<br>121°-21'-15" | 93A/11 | Spanish Lk area | barren | | |
| 87MB-27-01<br>contaminated | 1 | 52°-34'-42"<br>121°-19'-57" | 93A/11 | Spanish Lk area | barren | | |
| 87MB-FR<br>C-154102 | 1 | 52°-16'-32"<br>120°-33'-19" | 93A/7 | Eureka Peak area | barren | | |

**CAI refers to colour alteration index (Epstein, et al., 1977)*
*All identifications by M.J. Orchard, Geological Survey of Canada (Report No. MJO-1959-9)*

# APPENDIX D
# MICROFOSSILS (PALYNOMORPHS) FROM THE QUESNEL MAP AREA

| Field No. | GSC No. | Map Unit | Latitude Longitude | NTS Map | Location | Lithology | Age |
|---|---|---|---|---|---|---|---|
| 86AP-42/1-166 | UBC analysis** 1986 | 10 | 52°-23'-29" 121°-24'-18" | 93A/6 | on Horsefly R, 6 km N of Horsefly, at "The Steps" | thin-bedded, lacustrine siltstone | Middle Eocene (48-52 Ma) |

**Identifications:**
**Palynomorphs:**

| angiosperm pollen: | conifer pollen: | fungal spores: |
|---|---|---|
| Fraxinoipollenites variabilis | Pinus haploxylon type | *Granatisporites cotalus |
| Juglans nigripites | P. diploxylon type | *Pluricellaesporites psilatus |
| Casuarinidites granilabratus | Picea grandivescipites | *Diporisporites sp. |
| *Sabal granopollenites | Tsuga heterophyllites | |
| Quercus granulata | Keteleeria sp. | **fern:** |
| Carya veripites | | *glochidia of the water fern Azolla |
| C. viridifluminipites | | |
| Araliaceoipollenites granulatus | | |
| A. megaporifer | | |
| Ulmus undulosus | | |
| Pterocarya stellata | | |
| Liquidambar sp. | | |
| Myricipites "novus" | | |
| Milfordia minima | | |
| *Pistillipollenites mcgregorii | | |

| Field No. | GSC No. | Map Unit | Latitude Longitude | NTS Map | Location | Lithology | Age |
|---|---|---|---|---|---|---|---|
| 86AP-42/2-167 | UBC analysis** 1986 | 10 | 52°-23'-29" 121°-24'-18" | 93A/6 | on Horsefly R, 6 km N of Horsefly, at "The Steps" | thin-bedded, lacustrine siltstone | Middle Eocene (48-52 Ma) |

**Identifications:**
**Palynomorphs:**

| angiosperm pollen: | conifer pollen: | fungal spores: |
|---|---|---|
| Myricipites "novus" | Pinus haploxylon type | *Granatisporites cotalus |
| Ulmus undulosus | P. diploxylon type | *Multicellaesporites-6 |
| Quercus granulata | Picea grandivescipites | *Tetracellaesporites sp. |
| *Pistillipollenites mcgregorii | Tsuga heterophyllites | |
| *Casuarinidites granilabratus* | *Sciadopitys verticilata* | |
| Pterocarya stellata | Metasequoia papillapollenites | |
| Carya viridifluminipites | Keteleeria sp. | |
| *Ailanthipites berryi | | |
| Juglans nigipites | | |
| J. infrabaculatus | | |

| Field No. | GSC No. | Map Unit | Latitude Longitude | NTS Map | Location | Lithology | Age |
|---|---|---|---|---|---|---|---|
| 87AP-32/4-99 | UBC analysis** 1988 | 10 | 52°-29'-30" 121°-29'-41" | 93A/12 | Hazeltine Ck, 1 km W of Quesnel L | thin-bedded siltstone, 2 m below Unit 10A source conglomerate | Middle Eocene (48-52 Ma) |

**Identifications:**
***Palynomorphs:***

| angiosperm pollen: | conifer pollen: | fungal spores: |
|---|---|---|
| *Rhoipites retipillatus | Pinus haploxylon type | *Granatisporites cotalus |
| *Pistillipollenites mcgregorii | P. diploxylon type | *Rhizophagites cerasiformis |
| Carpinipites ancipites | Picea grandivescipites | fungal hypha - type C of Norris |
| Quercus shiabensis | Tsuga heterophyllites | |
| *Araliaceoipollenites granulatus | Keteleeria sp. | **algal cyst:** |
| | | Lejeunia hyalina |

**diagnostic identification*
***Analyst: Glenn E. Rouse, The University of British Columbia; samples collected by A. Panteleyev*

# APPENDIX E
# MICROFOSSIL DATA FROM THE QUESNEL MAP AREA

**QUESNEL PROJECT COLLECTIONS**

| Field Number GSC Location Number | Map Unit | Latitude Longitude °-'-" | NTS Map | Location | Identification | Age |
|---|---|---|---|---|---|---|
| 85AP-82 C-118687 | 3 | 52-27-43 121-27-26 | 93A/6 | 4.5 km SE Hazeltine Pt | *Lima* sp. | probably Sinemurian |
| 85AP-96B C-118685 | 3 | 52-28-37 121-29-19 | 93A/6 | 2.25 km S Hazeltine Pt | poorly preserved ammonites, generally small, a fairly small evolute form with constrictions - possibly an *Eolytoceras*; possibly arietitids but no keels noted; strong, simple ribs, fairly numerous - see C-117285 bivalves; inoceramitid?, *Weyla*? fragments; other gastropods, corals | early Lower Jurassic Lower Sinemurian or possibly Hettangian |
| 85AP-96C C-118686 | 3 | 52-28-25 121-29-19 | 93A/6 | 2.5 km S Hazeltine Pt | ammonite, Early Jurassic aspect, simple ribs with ventral nodes, crinoidal fragments; terebratulid brachiopod; *Weyla*? fragments, pectinid bivalves; gastropods, 2 or more species; corals, several species | Lower Jurassic, lower Sinemurian lower Pliensbachian |
| 86AP-20/3-61 C-117626 | 2e,2f? | 52-26-20 121-28-40 | 93A/6E | 0.4 km SE of Shiko L | corals; fragments of bivalves; crinoid columnals?; much organic debris | Nothing definitive,but similar fossiliferous limestone has been found in Upper Triassic rocks in the Quesnel Trough. |
| 86AP-30/5-114 C-117627 | 2f | 52-25-46 121-27-23 | 93A/6E | 2.5 km SE Shiko L | benthonic bivalve assemblage resembling faunas from Tyaughton Ck B.C.; forms cannot be identified with certainty but strong similarities to *Myophoria columbiana* sp. McLearn, *Pecten tyaughtonae* McLearn, other Pecten and possibly *Cassionella* sp. | Probably upper Norian (Amoenum Zone ?). Almost certainly Upper Triassic |
| DB87-43 C-117609 | 2f | 52-38-41 121-47-52 | 93A/12 | 5 km NNE Morehead L on Morehead Ck 28 m above base of section | *Minetrigonia* sp. | Norian, probably upper Norian |
| DB87-44 C-117610 | 2f | 52-38-41 121-47-52 | 93A/12 | 5 km NNE Morehead L on Morehead Ck 1 m above DB 87-43 | *Erugonia* sp. | Norian, probably upper Norian |
| DB87-45 C-117621 | 2f | 52-38-41 121-47-52 | 93A/12 | 5 km NNE Morehead L on Morehead Ck same as DB 87-44 | *Palaeocardita* sp., *Minetrigonia* sp | Norian, probably upper Norian |
| DB87-46 C-117637 | 2f | 52-38-41 121-47-52 | 93A/12 | 5 km NNE Morehead L on Morehead Ck 12 m above base, 16 m below DB 87-43 | bivalve fragments, indeterminate | Age not determined |
| DB87-48 C-117638 | 2f | 52-38-41 121-47-52 | 93A/12 | 5 km NNE Morehead L on Morehead Ck 2 m above DB87-46 | bivalve fragments, indeterminate | Age not determined |
| 87AP-17/3-38 C-117640 | 2f | 52-25-52 121-27-24 | 93A/6 | 2 km ESE Shiko L | benthonic bivalve assemblage, same unit (?) as C-117627 | Upper Triassic |

*(APPENDIX E Continued)*

| | | | | | | |
|---|---|---|---|---|---|---|
| 87AP-17/5-39<br>C-117639 | 2f | 52-25-47<br>121-27-24 | 93A/6 | 2.3 km SE Shiko L | benthonic bivalve assemblage, same unit (?) as C-117627 | Upper Triassic |
| 87AP-25/2-76<br>C-117641 | 1 | 52-23-31<br>121-33-42 | 93A/5 | 2.3 km E Robert L | flattened ammonite ? | |
| 88AP-11/4-35-F1<br>C-154111 | 1A | 52-26-37<br>121-47-46 | 93A/5 | 0.5 km E Beaver L, 1.2 km S. of Dorsey L on waterline road | *Halobia* sp., possibly a flattened ammonite, a bivalve and a brachiopod. | Probably lower Norian or upper Carnian |
| 88AP-12/10-F2<br>C-154110 | 1A | 52-27-24<br>121-48-33 | 93A/5 | 1.0 km W Dorsey L (N of Beaver L) | contains *Halobia* sp. | Probably lower Norian or upper Carnian |
| 88AP-18/3-0-F3<br>C-154112 | 2A | 52-20-30<br>121-12-26 | 93A/6 | 5 km E Lemon L in creek bed | contains *Halobia* sp. | Probably lower Norian or upper Carnian |
| 88AP-22/7-71-F4<br>C-154113 | 1A | 52-19-28<br>121-09-56 | 93A/6 | 1.2 km NE Patenaude L | a bivalve (*Halobia*?) | Probably lower Norian or upper Carnian |
| DB88-001<br>C-154114 | 2A/2D | 52-40-42<br>121-48-44 | 93A/12 | 4.5 km ENE Slide Mtn | bivalves and brachiopods | Upper Triassic |
| DB88-002<br>C-154115 | 2A/2D | 52-40-42<br>121-48-44 | 93A/12 | 4.5 km ENE Slide Mtn | bivalves and brachiopods | Upper Triassic |
| 88AP-11/4-C3<br>C-154106 | 1A | 52-26-36<br>121-47-46 | 93H/05 | 1 km SSE Dorsey L on wterline rd.; sampled for conodonts 1988 sites C3-C6 | *Halobia* sp. | Triassic, Carnian |

Data Sources: Geological Survey of Canada fossil identification reports
C-118685, 118686, 118687 - J15-1986-HWT, J3-1992-HWT, J1-1993-HWT, **H.W. Tipper**; C-11867 - J9-1986-TPP, **T.P. Poulton**; C-117626, 117627 - J11-1987-ETT, **E.T. Tozer**
C-117609, 117610, 117621 - TR4-1987-ETT, **E.T. Tozer**; C-11637, 11638 - TR4-1987-ETT, **E.T. Tozer**; C-154110, 154111, 154112, 154113, 154114, 154115, **H.W. Tipper**;
- written communications, H.W. Tipper, 1986, 1987, 1988, 1992, 1993
Field Number collector sample code: DB - D.G. Bailey; AP - A. Panteleyev sample

**GEOLOGICAL SURVEY of CANADA REPORTS on FOSSILS COLLECTED in the QUESNEL LAKE AREA by VARIOUS GEOLOGISTS**

| Map Unit | GSC Number | Location | Identifications | Age | Collector / Report |
|---|---|---|---|---|---|
| 1 | - | limestone near Prouton L (Beaver Ck area) | *Discotropites* sp., *Juvavites* sp. | Upper Carnian | RBC; DGB (1978) |
| 2 | 91862 | grey basalt 0.5 km N of the E end of Gavin L | *Monotis* sp. | Norian | CJH (1974)<br>Tr-18-1974-ETT |
| 2 | 93215(a) | Morehead Ck 3.2 km N of Morehead L | *Protocardia* (?) sp., Castatoria sp. aff. C. suttonensis (Clapp & Shimer)<br>*Liotrigonia* (?) sp., aff. *L. ovata* Goldfuss, Costatoria (?) or *Myophorigonia* (?) sp.<br>*Septocardia* (?) sp., undetermined brachiopods | U. Triassic, prob. Norian | DGB; J4-1976-TPP |
| 2 | 91858 (?)<br>91859 (?) | Morehead Ck 2.4 km from Quesnel L | *Monotis* sp.;<br>*Palaeocardita* sp., *Plicatula* sp. | Norian<br>Upper Triassic | CJH (1974), HWT - Tr18-1974-ETT |

## *(APPENDIX E Continued)*

| | | | | | |
|---|---|---|---|---|---|
| 2 | 40027<br>42432 | red sandstone, top of unit 2 | Spiriferid indet. (Spondylospira.?), Rhynconellid indet. (*Halorella* ?), *Oxytoma* sp. group of *O. inequivalvis* (Sowerby), Plicatula cf. *perimbricata* Gabb, crinoid columnals | U. Triassic, probably Norian | RBC(1961); DGB; Tr 11-60/61-ETT |
| 3 | 93215(b)<br>93960<br>93961 | Likely Rd 0.8 km east of Morehead L Resort | *Badouxia columbiae* (Frebold), *Weyla acutiplicata*, *Weyla* sp. indet., *Chlamys* (?) sp., *Entolium* (?) sp., *Pholadomya* sp., *Cardinia* (?) sp., Rhynchonellid brachiopod, solitary corals wood fragments, gastropods(?), serpulid worm tubes, other indeterminate bivalve fragments | Lower Sinemurian Canadensis Zone | DGB; J4, J13-1976-TPP<br>J3-1992-HWT |
| 3 | 93214 | Morehead Ck 4.8 km E of road from Morehead L Resort (? placer mine pit area) | *Badouxia canadense* (Frebold) ?, *Badouxia columbiae* (Frebold), *Weyla* sp. of the *W. besa/unca* group, *Weyla* sp. of the *W. alata* group, *Nuculana* (?) sp., *Lima* (?) sp., *Astarte* (?) sp., other indeterminate bivalves, gastropods and brachiopods | Lower Sinemurian Canadensis Zone | DGB; J4-1976-TPP<br>J2-1976-HF<br>J3-1992-HWT |
| 3 | 93216 | Likely road, 2.4 km south of Morehead L Resort in limestone | *Lima* (?) sp., *Septocardia* (?) or *Weyla* (?) sp. | Sinemurian ? | DGB; J4-1976-TPP |
| 3 | 93217 | drill core between Bootjack and Polley lakes | *Weyla* sp., cf. *W. alata* (von Buch) | Lower Jurassic | DGB |
| 3 or 2f | 19578,<br>19580,<br>40019<br>19579, | Morehead Ck placer mine pit 1.6 km upstream from Quesnel R | *Badouxia canadensis* (Frebold) ?, *Badouxia columbiae* (Frebold), *Paracaloceras* sp. *Weyla* sp., *Pecten* sp., *Metophioceras rursicostatum* (Frebold) *Schlotheimia* sp., possibly *Angulaticeras* sp., *Eolytoceras* sp. aff. *E. tasekoi* (Frebold), *Atractites* (?) sp. (a coleoid), various pectinid and other bivalves | Lower Sinemurian, (probably earliest Sinemurian) Canadensis Zone | RBC (1959); WEC; DGB;<br>J3-1992-HWT<br>J1-1993-HWT |
| 3 | 40018 | Morehead Ck, placer mine pit 3.6 km upstream from Quesnel R not in place | *Caenisites turneri* (J. de C. Sowerby) | Latest lower Sinemurian | RBC(1959); DGB;<br>J3-1992-HWT |
| 3 | C-117287 | N shore Morehead L | *Weyla acutiplicata* , *Camptonectes* sp., *Weyla* sp., possibly *W. alata*, brachiopod ?, pectinid bivalves, other bivalves, solitary corals | Lower Jurassic, latest Hettangian to Toarcian | HWT (1986)<br>J1-1993-HWT |
| 3 | C-118685<br>C-117286 | S of Hazeltine Point, Quesnel L lat 52°29'32", long 121°30'42" | *Badouxia columbiae* ? | Lower Sinemurian | HWT(1986)<br>J3-1992-HWT |
| 3 | C-117285<br>C-118685 | S of Hazeltine Point, Quesnel L lat 52°29'24", long 121°30'47" | *Badouxia columbiae* (Frebold) ?, Coleoids - *Atractites* ?, *Eolytoceras* ? sp. Phylloceratids, possibly some small arietitids | Lower Sinemurian | HWT(1986); J3-1992-HWT<br>J1-1993-HWT |
| 5 | 42434<br>93752 | road cut, N bank Quesnel R 4.35 km downstream from Likely | probably *Dubariceras* sp., *Arieticeras* sp.; *Tropidoceras actaeon*, *Tropidoceras* sp., other fragments ammonites, indeterminate - overlying beds with *Weyla* | Lower Pliensbachian; Freboldi Zone | RBC; DGB; J18-1976-HF<br>J4-1969-HF; HWT(1986)<br>J3-1992-HWT; J1-1993-HWT |
| 5 | 90769 | Likely - Tyee (McLeese L) road junction, 90 m to the north | *Amaltheus* sp. ?, *Arieticeras* aff. *A. algovianum* (Oppel), *Protogrammoceras* sp., ? *Fuciniceras* sp. indet., ? *Leptaleoceras* sp. indet. | Upper Pliensbachian, Kunae Zone | RBC; J1-1974-HF<br>J3-1992-HWT |
| 6 | 40030 | 120 m NW of outlet of Beaveridge L | *Erycitoides* sp. | Aalenian | RBC; Poulton and Tipper (1991); J1-1974-HF<br>J3-1992-HWT |
| 6 | 91755<br>C-149638 | Opheim L, road cut at SE end | *Timretoceras* (?) sp., *Erycitoides* (?) sp. | Aalenian | Poulton and Tipper (1991) |

*Data compilation and identifications (except where noted) by H.W. Tipper, written communications, 1986, 1987, 1988, 1992, 1993, 1995.*
*Fossil collections submitted by: J.B. Hobson 1895; R.B. Campbell 1959 (RBC); D.G. Bailey 1975, 1976 (DGB) see Bailey (1978); W.E. Cockfield 1930, 1931 (WEC); C.J. Hodgson 1974 (CJH); H.W. Tipper 1959, 1973, 1986 (HWT)*
*Fossil identifications and report identification: HF - H. Frebold, TPP - T.P. Poulton, HWT - H.W. Tipper, and ETT - E.T. Tozer - Geological Survey of Canada*
*The data revise earlier reports but are subject to further revision.*

# APPENDIX F
# PETROCHEMISTRY SAMPLE DATA FOR THE QUESNEL MAP AREA

| LAB NUMBER | FIELD NUMBER | LATITUDE ° ' " | LONGITUDE ° ' " | NTS MAP | UNIT NUMBER | LOCATION/AREA | ROCK DESCRIPTION |
|---|---|---|---|---|---|---|---|
| 38434 | AP88-24/02-71 | 52-25-38 | 121- 7-27 | 93A/ 6 | 1A | Viewland Mtn area | px bs |
| 35339 | C11-9 | 52-57-56 | 122-16-21 | 93B/16 | 2A | Deacon Ck | px bs purple/green |
| 35340 | C11-11 | 52-58- 2 | 122-16-19 | 93B/16 | 2A | Deacon Ck | px bs maroon |
| 32641 | AP86-21/04-66 | 52-22-38 | 121-18-26 | 93A/ 6 | 2A | Romspert-Horsefly L | alkaline olivine bs |
| 32642 | AP86-28/04-92 | 52-29-46 | 121-26-50 | 93A/ 6 | 2A | Quesnel L (N shore) | alkaline olivine bs |
| 32643 | AP86-28/07-98 | 52-29-57 | 121-27-43 | 93A/ 6 | 2A | Quesnel L (N shore) | alkaline olivine bs |
| 31607 | AP85-09/01-72 | 52-28-23 | 121-24-21 | 93A/ 6 | 2A | Horsefly Peninsula | px bs |
| 31609 | AP85-20/2-115 | 52-29-23 | 121-23-30 | 93A/ 6 | 2A | Horsefly Peninsula | bs bx clast |
| 37026 | AP88-06/05-19 | 52-26- 3 | 121-42-15 | 93A/ 5 | 2A | Prouton L ( E ) | bs flow |
| 38435 | AP88-22/03-70 | 52-19-50 | 121-10-26 | 93A/ 6 | 2A | Patenaude L | px bs flow |
| 35553 | DB87-01 | 52-28-55 | 121-39-53 | 93A/ 5 | 2A | Gavin L (4 km ESE) | px bs (analcite) |
| 35568 | DB87-20 | 52-29-59 | 121-27-58 | 93A/ 6 | 2A | Quesnel L (N shore) | olivine px bs |
| 35569 | DB87-21 | 52-29-22 | 121-41-29 | 93A/ 5 | 2A | Gavin L (1 km NE) | px bs (olivine) |
| 35573 | DB87-25 | 52-32-15 | 121-45-41 | 93A/12 | 2A | Jacobie L | bs purple vesicular |
| 35574 | DB87-26 | 52-37-49 | 121-37-37 | 93A/12 | 2A | Quesnel R (E of Bullion pit) | px bs green |
| 35575 | DB87-27 | 52-37-49 | 121-37-37 | 93A/12 | 2A | Quesnel R (E of Bullion pit) | px hornblende bs 2A/2D? |
| 35580 | DB87-33 | 52-43- 4 | 121-56-14 | 93A/12 | 2A/2D | Maude L (2 km W) | px (hornblende?) bs green/grey |
| 35582 | DB87-35 | 52-40-31 | 121-46-41 | 93A/12 | 2A/2D | QR (2 km NE) | px hornblende bs bx |
| 35586 | DB87-40 | 52-41-41 | 121-53-37 | 93A/12 | 2A/2D | Maude L (3 km SSE) | px hornblende bs green/grey |
| 35325 | C4-10 | 52-53-17 | 122- 8-37 | 93B/16 | 2B | Cantin Ck, Gerimi Ck | bs green/purple/grey |
| 35326 | C4-12B | 52-53-12 | 122- 8-31 | 93B/16 | 2B | Cantin Ck, Gerimi Ck | bs green/purple |
| 35330 | C7-3 | 52-53-33 | 122-10- 5 | 93B/16 | 2B | Cantin Ck, Gerimi Ck (1 km N) | bs maroon |
| 32052 | AP86-06/10-29 | 52-25-54 | 121-21-44 | 93A/ 6 | 2B | Hooker L (3 km NE) | px plagioclase bs |
| 32053 | AP86-10/08-44 | 52-25-37 | 121-22-59 | 93A/ 6 | 2B | Hooker L (1 km N) | px bs |
| 32054 | AP86-13/03-51 | 52-25-25 | 121-20-14 | 93A/ 6 | 2B | Ussa L (1 km W) | px bs |
| 31597 | AP85-1/1-35A | 52-26-47 | 121-28-40 | 93A/ 6 | 2B | Shiko L | px bs agglomerate clast |
| 31611 | AP85-22/3-123 | 52-28-39 | 121-22-31 | 93A/ 6 | 2B | Horsefly Peninsula | bs polylithic bx |
| 35577 | DB87-29 | 52-29-50 | 121-35-48 | 93A/ 5 | 2B | Edney L (4 km N) | px bs |
| 35578 | DB87-30 | 52-29-54 | 121-38-55 | 93A/ 5 | 2B | Edney L (4.5 km NW) | px feldspar bs vesicular |
| DB1 | DB7515-12 | 52-31-42 | 121-43-00 | 93A/12 | 2B | Jacobie L (3 km SE) | px bs maroon |
| DB2 | DB757-1 | 52-32-19 | 121-42-28 | 93A/12 | 2B | Jacobie L (2 km E) | px bs maroon |
| DB3 | DB757-2 | 52-32-13 | 121-42-28 | 93A/12 | 2B | Jacobie L (2 km E) | px bs maroon |
| DB4 | DB751-2 | 52-34- 6 | 121-47- 3 | 93A/12 | 2B | Morehead L (2.5 km SW) | px bs |
| DB5 | DB757-3 | 52-32-10 | 121-42-21 | 93A/12 | 2B | Jacobie L (2.25 km E) | px bs |
| DB6 | DB7532-2 | 52-31- 6 | 121-30-30 | 93A/12 | 2B | Quesnel L, W (4 km SE Polley L) | px bs |
| 35095 | AP87-20/07-49 | 52-22-40 | 121-31-51 | 93A/ 5 | 2C | Beaver Ck (2 km N) | flow in lahar |
| 35563 | DB87-15 | 52-31-17 | 121-43- 9 | 93A/12 | 2C | Trio L (2 km W) | latite tuff |
| DB7 | DB7515-9 | 52-31- 4 | 121-43-26 | 93A/12 | 2C | Jacobie L (1.75 km SE) | px bs bx grey |
| DB8 | DB7515-2 | 52-31-16 | 121-42-54 | 93A/12 | 2C | Jacobie L (2 km SE) | px bs bx maroon |
| RM11 | RM73-34 | 52-25-14 | 121-31- 6 | 93A/ 5 | 2C | Antoine L (N side) | px bs bx |
| 31608 | AP85-12/4-84 | 52-27-43 | 121-27-44 | 93A/ 6 | 2D | Shiko L | px bs |
| 35570 | DB87-22 | 52-30-54 | 121-40-13 | 93A/12 | 2D | W of Bootjack stock | bs purple |
| DB9 | DB7515-5 | 52-31-30 | 121-41-22 | 93A/12 | 2D | Trio L (0.25 km W) | px hornblende bs |
| DB10 | DB7512-1 | 52-37-51 | 121-51-43 | 93A/12 | 2D | Jack Pine L (1 km N) | px hornblende bs |
| 35097 | AP87-26/05-80 | 52-23-52 | 121-33-17 | 93A/ 5 | 2E | Antoine L (SW) | analcite px bs |
| 32050 | AP86-04/06-18 | 52-26- 3 | 121-23-40 | 93A/ 6 | 2E | Hooker L (2 km N) | type analcite px bs |
| 37024 | AP86-30/3-113A | 52-25- 9 | 121-26-15 | 93A/ 6 | 2E | Horsefly R | 'picrite' |
| RM2 | RM73-29 | 52-23-46 | 121-33-13 | 93A/ 5 | 2E | Antoine L (2 km S) | analcite bs |
| 31600 | AP85-5/9-57 | 52-27-21 | 121-28- 4 | 93A/ 6 | 2G | Shiko L | felsic bx |
| 31603 | AP85-08/06-67 | 52-27-30 | 121-28- 5 | 93A/ 6 | 2G | Shiko L | felsic bx |
| 31604 | AP85-08/06-68 | 52-27-30 | 121-28-01 | 93A/ 6 | 2G | Shiko L | px plagioclase bs porphyry |
| 35093 | AP87-09/05-27 | 52-24-10 | 121-31-59 | 93A/ 5 | 3 | Antoine L (S) | pink felsic clast |
| 35094 | AP87-18/05-41 | 52-19-01 | 121-29-19 | 93A/ 6 | 3 | Horsefly (2 km W) | pink felsic clast |
| 36265 | AP87-07/04-20 | 52-19-00 | 121-30-20 | 93A/ 5 | 3 | Horsefly Rd | pink felsic clast |
| 35092 | AP87-06/03-16 | 52-20-00 | 121-27-00 | 93A/ 6 | 3A | Horsefly (2 km W) | hornblende porphyry K/Ar |
| DB11 | DB753-1 | 52-35-27 | 121-36-38 | 93A/12 | 3A | Polley L (1.75 km NNE) | polylithic bx |
| DB12 | DB756-6 | 52-34-32 | 121-45-12 | 93A/12 | 3A | Morehead L (1 km SE) | polylithic bx |
| DB13 | DB757-12 | 52-33-24 | 121-43-28 | 93A/12 | 3A | Morehead L (2 km S) | polylithic bx |
| DB14 | DB757-14 | 52-33-29 | 121-43-35 | 93A/12 | 3A | Morehead L (2 km S) | polylithic bx |
| DB15 | DB756-9 | 52-34-58 | 121-45-11 | 93A/12 | 3A | Morehead L (0.25 km SW) | polylithic bx |
| DB16 | DB756-10 | 52-35- 2 | 121-45- 6 | 93A/12 | 3A | Morehead L (0.20 km SW) | polylithic bx |
| DB17 | DB7512-2 | 52-38- 4 | 121-51-33 | 93A/12 | 3A | Jack Pine L (1.5 km N) | polylithic bx |
| DB18 | DB756-12 | 52-35-32 | 121-46-30 | 93A/12 | 3A | Morehead L (NW end) | polylithic bx |
| DB19 | DB7522-5 | 52-34-24 | 121-40-53 | 93A/12 | 3B | Morehead L (2.4 km ESE) | felsic bx |
| DB20 | DB7522-3 | 52-33-26 | 121-40-11 | 93A/12 | 3B | Bootjack L (0.75 km NW) | felsic bx |
| 35556 | DB87-05 | 52-37- 4 | 121-41-15 | 93A/12 | 4 | Little L (2 km E) | alkaline olivine bs purple |
| DB21 | DB7533-1 | 52-37-28 | 121-43-34 | 93A/12 | 4 | Little L (0.75 km N) | alkaline olivine bs vesicular, maroon |
| DB22 | DB7518-2 | 52-38-00 | 121-47-39 | 93A/12 | 4 | Jack Pine L (3.75 km ENE) | alkaline olivine bs vesicular, maroon |
| 31599 | AP85-5/8-56A | 52-27-16 | 121-27-57 | 93A/ 6 | 7 | Shiko L | syenite lamprophyre |
| 31618 | AP85-7/2-63 | 52-27-26 | 121-28-18 | 93A/ 6 | 7 | Shiko L | hornblende porphyry |
| 31602 | AP85-8/1-64 | 52-27-32 | 121-28-31 | 93A/ 6 | 7 | Shiko L | monzonite-pink |
| 31605 | AP85-08/02-69 | 52-27-53 | 121-28-21 | 93A/ 6 | 7 | Shiko L | diorite |

*(APPENDIX F continued)*

| LAB NUMBER | FIELD NUMBER | LATITUDE ° ' " | LONGITUDE ° ' " | NTS MAP | UNIT NUMBER | LOCATION/AREA | ROCK DESCRIPTION |
|---|---|---|---|---|---|---|---|
| 31606 | AP85-08/09-71 | 52-37-38 | 121-38- 7 | 93A/12 | 7 | Bullion pit | diorite |
| 31610 | AP85-21/2-120 | 52-39-30 | 121-47-58 | 93A/12 | 7 | QR | diorite |
| *37025* | *AP88-04/08-12* | *52-21-26* | *121- 6-21* | *93A/ 6* | *7* | *Horsefly Mtn* | *diorite* |
| 37030 | AP88-16/08-55 | 52-21-30 | 121-14-38 | 93A/ 6 | 7 | Lemon L (3 km NE) | alkaline gabbro |
| 38436 | AP88-25/01-76 | 52-25-49 | 121- 9-54 | 93A/ 6 | 7 | Viewland Pk | subvolcanic alkaline bx |
| RM3 | RM73-7 | 52-26-13 | 121-22-59 | 93A/ 6 | 7 | Hooker L (0.5 km SW) | teschenite dyke |
| 37027 | AP88-08/05-28 | 52-25-13 | 121-43-53 | 93A/ 5 | 8? | George L | diorite/plagioclase porphyry |
| 37028 | AP88-11/03-34 | 52-26-48 | 121-46-30 | 93A/ 5 | 8? | Beaver L-Choate L | qtz diorite/plagioclase porphyry |
| 35091 | AP87-03/01-04 | 52-23-52 | 121-28-30 | 93A/ 6 | 10 | Antoine L (S) | biotite latite K/Ar site |
| 35096 | AP87-24/9-68 | 52-20-20 | 121-27- 6 | 93A/ 6 | 10 | Horsefly | plagioclase crystal ash tuff |
| 37029 | AP88-11/05-36 | 52-26-41 | 121-47-51 | 93A/ 5 | 10 | Beaver L-waterline road | lamprophyre - Eocene |
| 35098 | AP87-18/08-44 | 52-19- 6 | 121-30-33 | 93A/ 5 | 11 | Horsefly road | basalt - 14.6 Ma |

*Abbreviations: bs - basalt, bx - breccia, px - pyroxene. Collector code: A. Panteleyev - AP; D.G.Bailey - DB; J. Lu - C; R.L. Morton - RM*

# APPENDIX G
# MAJOR OXIDE CHEMISTRY OF MAP UNITS

| LAB NO | FIELD NO | MAP UNIT | $SiO_2$ | $TiO_2$ | $Al_2O_3$ | FeO_T | MnO | MgO | CaO | $Na_2O$ | $K_2O$ | $P_2O_5$ | FeO | $Fe_2O_3$ | LOI | $CO_2$ | TOTAL* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 38434 | AP88-24/02-71 | 1A | 46.92 | 0.75 | 16.64 | 8.39 | 0.18 | 5.68 | 13.06 | 1.76 | 1.32 | 0.22 | 5.52 | 2.25 | 5.28 | 1.81 | 100.20 |
| 35339 | C11-9 | 2A | 46.52 | 0.64 | 13.36 | 10.72 | 0.17 | 7.24 | 10.73 | 0.99 | 4.28 | 0.44 | 7.72 | 2.14 | 3.37 | 0.14 | 98.46 |
| 35340 | C11-11 | 2A | 46.49 | 0.76 | 11.59 | 12.59 | 0.21 | 8.35 | 10.69 | 1.51 | 3.59 | 0.26 | 9.29 | 2.26 | 3.36 | 0.07 | 99.40 |
| 32641 | AP86-21/04-66 | 2A | 49.09 | 0.67 | 14.62 | 10.27 | 0.16 | 6.25 | 8.50 | 4.46 | 1.74 | 0.40 | 7.29 | 2.17 | 4.26 | 0.56 | 100.42 |
| 32642 | AP86-28/04-92 | 2A | 49.75 | 0.56 | 16.93 | 8.90 | 0.20 | 3.97 | 5.94 | 3.20 | 5.13 | 0.62 | 6.15 | 2.06 | 3.21 | 0.84 | 98.41 |
| 32643 | AP86-28/07-98 | 2A | 46.33 | 0.60 | 10.33 | 11.18 | 0.19 | 11.47 | 13.60 | 1.03 | 2.58 | 0.39 | 8.17 | 2.10 | 2.24 | 0.42 | 99.94 |
| 31607 | AP85-09/01-72 | 2A | 46.80 | 0.55 | 9.23 | 10.11 | 0.18 | 10.96 | 15.18 | 1.57 | 0.93 | 0.27 | 7.25 | 2.05 | 2.48 | 0.38 | 98.26 |
| 31609 | AP85-20/2-115 | 2A | 49.28 | 0.97 | 11.41 | 8.22 | 0.15 | 7.59 | 13.13 | 4.29 | 0.04 | 0.22 | 5.17 | 2.47 | 5.10 | 3.27 | 100.40 |
| 37026 | AP88-06/05-19 | 2A | 49.33 | 0.72 | 14.26 | 11.41 | 0.21 | 4.71 | 10.33 | 4.98 | 0.07 | 0.30 | 8.27 | 2.22 | 3.26 | 0.62 | 99.58 |
| 38435 | AP88-22/03-70 | 2A | 47.04 | 0.55 | 15.17 | 9.38 | 0.16 | 7.40 | 13.15 | 2.25 | 0.38 | 0.14 | 6.60 | 2.05 | 4.42 | 1.07 | 100.04 |
| 35553 | DB87-01 | 2A | 48.48 | 0.65 | 13.40 | 11.38 | 0.22 | 8.00 | 9.87 | 2.56 | 2.19 | 0.27 | 8.31 | 2.15 | 2.76 | 0.21 | 99.78 |
| 35568 | DB87-20 | 2A | 47.81 | 0.58 | 9.88 | 10.86 | 0.20 | 10.52 | 13.38 | 1.67 | 1.55 | 0.47 | 7.90 | 2.08 | 2.81 | 0.34 | 99.73 |
| 35569 | DB87-21 | 2A | 47.15 | 0.69 | 13.22 | 11.68 | 0.21 | 9.16 | 11.42 | 1.76 | 1.89 | 0.33 | 8.54 | 2.19 | 2.28 | 0.07 | 99.79 |
| 35573 | DB87-25 | 2A | 46.09 | 0.63 | 17.80 | 9.41 | 0.19 | 4.52 | 10.07 | 2.79 | 2.77 | 0.37 | 6.55 | 2.13 | 5.02 | 0.28 | 99.66 |
| 35574 | DB87-26 | 2A/2D | 50.70 | 0.81 | 14.79 | 10.25 | 0.19 | 6.96 | 9.32 | 2.18 | 1.70 | 0.25 | 7.14 | 2.31 | 2.57 | 0.07 | 99.72 |
| 35575 | DB87-27 | 2A/2D | 51.69 | 0.73 | 15.02 | 9.44 | 0.25 | 5.43 | 7.16 | 2.77 | 2.42 | 0.31 | 6.49 | 2.23 | 3.85 | 0.28 | 99.07 |
| 35580 | DB87-33 | 2A/2D | 50.81 | 0.59 | 17.06 | 8.73 | 0.13 | 4.71 | 8.08 | 3.63 | 2.58 | 0.31 | 5.97 | 2.09 | 2.92 | 0.28 | 99.55 |
| 35582 | DB87-35 | 2A/2D | 48.44 | 0.69 | 16.50 | 11.17 | 0.13 | 5.49 | 8.50 | 3.80 | 1.48 | 0.38 | 8.08 | 2.19 | 2.83 | 0.56 | 99.41 |
| 35586 | DB87-40 | 2A/2D | 50.01 | 0.83 | 16.57 | 9.82 | 0.16 | 5.51 | 7.20 | 4.25 | 2.16 | 0.31 | 6.74 | 2.33 | 2.82 | 0.42 | 99.64 |
| 35325 | C4-10 | 2B | 46.64 | 0.68 | 11.59 | 10.64 | 0.18 | 8.59 | 9.16 | 2.07 | 3.83 | 0.76 | 7.61 | 2.18 | 4.92 | 0.41 | 99.06 |
| 35326 | C4-12B | 2B | 47.14 | 0.78 | 13.72 | 11.36 | 0.20 | 6.23 | 9.25 | 4.65 | 1.29 | 0.70 | 8.17 | 2.28 | 3.34 | 0.21 | 98.66 |
| 35330 | C7-3 | 2B | 47.36 | 0.62 | 13.45 | 10.56 | 0.21 | 5.71 | 10.05 | 2.41 | 3.96 | 0.53 | 7.59 | 2.12 | 3.73 | 0.64 | 98.59 |
| 32052 | AP86-06/10-29 | 2B | 49.23 | 0.60 | 15.07 | 9.20 | 0.16 | 7.01 | 7.14 | 2.92 | 3.37 | 0.53 | 6.39 | 2.10 | 3.03 | 0.14 | 98.26 |
| 32053 | AP86-10/08-44 | 2B | 47.13 | 0.68 | 13.64 | 11.87 | 0.26 | 6.26 | 9.94 | 3.27 | 2.72 | 0.41 | 8.72 | 2.18 | 3.10 | 0.88 | 99.28 |
| 32054 | AP86-13/03-51 | 2B | 46.79 | 0.69 | 12.86 | 11.70 | 0.18 | 8.29 | 11.03 | 1.75 | 2.50 | 0.17 | 8.56 | 2.19 | 2.62 | 0.95 | 98.58 |
| 31597 | AP85-1/1-35A | 2B | 49.19 | 0.57 | 11.15 | 10.18 | 0.16 | 9.21 | 12.96 | 3.51 | 0.65 | 0.41 | 7.30 | 2.07 | 2.37 | 0.70 | 100.36 |
| 31611 | AP85-22/3-123 | 2B | 48.51 | 0.69 | 16.63 | 8.64 | 0.21 | 4.07 | 6.80 | 4.68 | 2.96 | 0.50 | 5.80 | 2.19 | 4.66 | 0.73 | 98.35 |
| 35577 | DB87-29 | 2B | 45.96 | 0.71 | 12.42 | 11.48 | 0.24 | 6.56 | 13.67 | 1.68 | 3.36 | 0.72 | 8.34 | 2.21 | 2.38 | 0.07 | 99.18 |
| 35578 | DB87-30 | 2B | 47.99 | 0.62 | 9.65 | 10.93 | 0.19 | 10.35 | 11.92 | 2.14 | 2.04 | 0.52 | 7.93 | 2.12 | 3.08 | 0.14 | 99.43 |
| DB1 | DB7515-12 | 2B | 47.90 | 0.85 | 15.75 | 12.60 | 0.24 | 5.85 | 8.98 | 4.15 | 1.78 | 0.58 | 8.99 | 2.35 | 2.64 | 0.00 | 101.32 |
| DB2 | DB757-1 | 2B | 48.30 | 0.69 | 13.10 | 11.99 | 0.23 | 7.10 | 8.32 | 0.95 | 6.88 | 0.71 | 8.60 | 2.19 | 2.86 | 0.00 | 101.13 |
| DB3 | DB757-2 | 2B | 48.70 | 0.69 | 12.90 | 11.07 | 0.19 | 9.50 | 10.25 | 2.55 | 2.12 | 0.72 | 7.77 | 2.19 | 2.49 | 0.00 | 101.18 |
| DB4 | DB751-2 | 2B | 45.70 | 0.77 | 11.70 | 13.40 | 0.18 | 7.90 | 12.65 | 2.52 | 1.63 | 0.67 | 9.79 | 2.27 | 3.14 | 0.00 | 100.26 |
| DB5 | DB757-3 | 2B | 47.40 | 0.72 | 11.90 | 11.61 | 0.18 | 10.20 | 11.35 | 3.95 | 0.95 | 0.74 | 8.23 | 2.22 | 2.81 | 0.00 | 101.81 |
| DB6 | DB7532-2 | 2B | 46.20 | 0.82 | 13.10 | 13.04 | 0.19 | 6.70 | 11.20 | 4.30 | 1.79 | 0.52 | 9.41 | 2.32 | 4.70 | 0.00 | 102.56 |
| 35095 | AP87-20/07-49 | 2C | 50.77 | 1.00 | 18.50 | 8.62 | 0.23 | 3.19 | 6.81 | 5.40 | 1.82 | 0.50 | 5.51 | 2.50 | 2.79 | 0.61 | 99.63 |
| 35563 | DB87-15 | 2C | 46.36 | 0.72 | 17.12 | 10.22 | 0.20 | 5.35 | 8.25 | 3.83 | 2.38 | 0.44 | 7.20 | 2.22 | 4.58 | 0.48 | 99.45 |
| DB7 | DB7515-9 | 2C | 48.20 | 0.62 | 13.75 | 11.06 | 0.23 | 7.85 | 12.65 | 2.00 | 3.12 | 0.56 | 7.83 | 2.12 | 2.22 | 0.00 | 102.26 |
| DB8 | DB7515-2 | 2C | 48.40 | 0.81 | 17.80 | 11.30 | 0.24 | 4.85 | 8.65 | 5.00 | 0.64 | 0.47 | 7.86 | 2.31 | 3.04 | 0.00 | 101.20 |
| RM1 | RM73-34 | 2C | 51.43 | 0.75 | 15.76 | 9.41 | 0.17 | 3.86 | 6.65 | 3.87 | 4.80 | 0.38 | 6.22 | 2.25 | 2.12 | 0.00 | 99.20 |
| 31608 | AP85-12/4-84 | 2D | 50.32 | 0.51 | 10.64 | 9.39 | 0.19 | 12.54 | 9.51 | 1.50 | 1.88 | 0.23 | 6.64 | 2.01 | 2.82 | 0.01 | 99.53 |
| 35570 | DB87-22 | 2D | 47.60 | 0.68 | 10.31 | 12.11 | 0.20 | 9.59 | 14.14 | 2.09 | 1.51 | 0.42 | 8.94 | 2.18 | 0.86 | 0.07 | 99.51 |
| DB9 | DB7515-5 | 2D | 46.50 | 0.81 | 12.00 | 13.35 | 0.24 | 9.75 | 11.00 | 3.90 | 0.82 | 0.54 | 9.70 | 2.31 | 3.87 | 0.00 | 102.78 |
| DB10 | DB7512-1 | 2D | 47.80 | 0.93 | 17.10 | 12.45 | 0.23 | 5.10 | 7.00 | 3.62 | 3.20 | 0.35 | 8.77 | 2.43 | 3.79 | 0.00 | 101.57 |
| 35097 | AP87-26/05-80 | 2E | 48.61 | 0.84 | 17.70 | 8.56 | 0.20 | 2.91 | 5.56 | 5.33 | 3.45 | 0.51 | 5.60 | 2.34 | 5.79 | 0.34 | 99.46 |
| 32050 | AP86-04/06-18 | 2E | 48.13 | 0.64 | 13.74 | 11.56 | 0.21 | 6.20 | 9.31 | 3.21 | 2.78 | 0.45 | 8.48 | 2.14 | 2.83 | 0.27 | 99.06 |
| 37024 | AP86-30/3-113A | 2E | 45.20 | 0.74 | 13.72 | 11.81 | 0.24 | 5.84 | 10.31 | 3.28 | 1.87 | 0.68 | 8.61 | 2.24 | 5.64 | 0.35 | 99.33 |
| RM2 | RM73-29 | 2E | 51.48 | 0.74 | 17.69 | 7.79 | 0.20 | 4.12 | 4.14 | 4.55 | 5.51 | 0.48 | 4.77 | 2.24 | 4.39 | 0.00 | 101.09 |
| 31600 | AP85-5/9-57 | 2G | 55.18 | 0.64 | 17.31 | 9.03 | 0.24 | 4.05 | 5.21 | 5.11 | 1.30 | 0.23 | 6.20 | 2.14 | 2.48 | 0.01 | 100.78 |
| 31603 | AP85-08/06-67 | 2G | 54.40 | 0.55 | 16.75 | 6.79 | 0.14 | 4.42 | 5.88 | 3.13 | 4.38 | 0.25 | 4.27 | 2.05 | 2.21 | 0.11 | 93.90 |
| 31604 | AP85-08/06-68 | 2G | 48.07 | 0.76 | 16.23 | 9.28 | 0.19 | 5.56 | 11.18 | 2.91 | 1.13 | 0.57 | 6.32 | 2.26 | 2.67 | 0.01 | 93.55 |
| 35093 | AP87-09/05-27 | 3 | 48.96 | 0.80 | 16.36 | 9.19 | 0.24 | 3.71 | 8.20 | 2.88 | 4.44 | 0.39 | 6.20 | 2.30 | 4.18 | 0.62 | 99.35 |
| 35094 | AP87-18/05-41 | 3 | 57.94 | 0.46 | 17.19 | 6.48 | 0.15 | 1.59 | 3.51 | 6.98 | 2.08 | 0.39 | 4.07 | 1.96 | 2.96 | 1.51 | 99.73 |
| 36265 | AP87-07/04-20 | 3 | 54.87 | 0.70 | 18.61 | 5.92 | 0.18 | 1.49 | 5.56 | 5.42 | 3.81 | 0.23 | 3.35 | 2.20 | 2.82 | 0.84 | 99.61 |
| 35092 | AP87-06/03-16 | 3A | 56.17 | 0.77 | 17.58 | 7.79 | 0.17 | 2.96 | 5.78 | 4.72 | 1.76 | 0.25 | 4.97 | 2.27 | 1.93 | 0.62 | 99.88 |
| DB11 | DB753-1 | 3A | 47.70 | 0.76 | 17.40 | 9.35 | 0.22 | 4.40 | 7.82 | 4.30 | 3.60 | 0.60 | 6.15 | 2.26 | 4.99 | 0.00 | 101.14 |
| DB12 | DB756-6 | 3A | 46.00 | 0.99 | 15.60 | 13.05 | 0.26 | 6.20 | 9.93 | 3.05 | 3.63 | 0.56 | 9.25 | 2.49 | 2.10 | 0.00 | 101.37 |
| DB13 | DB757-12 | 3A | 51.90 | 0.75 | 19.40 | 8.83 | 0.22 | 2.63 | 6.87 | 5.30 | 2.62 | 0.33 | 5.70 | 2.25 | 2.87 | 0.00 | 101.72 |
| DB14 | DB757-14 | 3A | 53.50 | 0.74 | 19.90 | 8.82 | 0.21 | 3.03 | 6.85 | 5.00 | 2.70 | 0.41 | 5.70 | 2.24 | 2.04 | 0.00 | 103.20 |
| DB15 | DB756-9 | 3A | 49.80 | 1.07 | 18.00 | 9.77 | 0.22 | 3.00 | 8.18 | 4.90 | 1.68 | 0.42 | 6.22 | 2.57 | 3.26 | 0.00 | 100.30 |
| DB16 | DB756-10 | 3A | 48.60 | 0.84 | 17.50 | 10.32 | 0.21 | 3.65 | 8.32 | 3.95 | 2.90 | 0.40 | 6.95 | 2.34 | 4.26 | 0.00 | 100.95 |
| DB17 | DB7512-2 | 3A | 50.00 | 0.83 | 17.80 | 10.21 | 0.24 | 4.45 | 5.10 | 5.30 | 3.32 | 0.38 | 6.86 | 2.33 | 3.86 | 0.00 | 101.49 |
| DB18 | DB756-12 | 3A | 53.70 | 0.64 | 13.10 | 7.73 | 0.21 | 3.95 | 4.60 | 5.30 | 4.52 | 0.28 | 4.82 | 2.14 | 2.03 | 0.00 | 96.06 |
| DB19 | DB7522-5 | 3B | 47.10 | 0.82 | 18.40 | 11.79 | 0.25 | 5.05 | 8.72 | 1.98 | 3.93 | 0.29 | 8.29 | 2.32 | 2.87 | 0.00 | 101.20 |
| DB20 | DB7522-3 | 3B | 50.50 | 0.88 | 18.50 | 9.38 | 0.12 | 3.52 | 6.62 | 4.30 | 3.28 | 0.31 | 6.06 | 2.38 | 3.86 | 0.00 | 101.27 |
| 35556 | DB87-05 | 4 | 48.50 | 0.80 | 16.67 | 10.48 | 0.22 | 4.40 | 7.88 | 4.17 | 2.38 | 0.52 | 7.36 | 2.30 | 3.65 | 0.49 | 99.67 |
| DB21 | DB7533-1 | 4 | 47.90 | 0.95 | 16.90 | 11.96 | 0.21 | 4.15 | 7.95 | 4.18 | 3.22 | 0.53 | 8.31 | 2.45 | 3.92 | 0.00 | 101.87 |
| DB22 | DB7518-2 | 4 | 50.40 | 0.73 | 14.20 | 12.48 | 0.17 | 5.80 | 8.40 | 4.90 | 0.91 | 0.38 | 9.00 | 2.23 | 2.96 | 0.00 | 101.33 |
| 31599 | AP85-5/8-56A | 7 | 48.13 | 0.61 | 9.94 | 11.19 | 0.20 | 10.63 | 13.33 | 1.56 | 2.18 | 0.30 | 8.17 | 2.11 | 2.11 | 0.11 | 100.18 |
| 31618 | AP85-7/2-63 | 7 | 52.20 | 1.04 | 14.98 | 10.22 | 0.22 | 6.16 | 9.25 | 2.97 | 1.82 | 0.30 | 6.91 | 2.54 | 1.32 | 0.01 | 100.48 |
| 31602 | AP85-8/1-64 | 7 | 54.35 | 0.59 | 17.71 | 7.75 | 0.15 | 3.31 | 6.69 | 3.90 | 3.65 | 0.45 | 5.10 | 2.08 | 1.10 | 0.06 | 99.65 |
| 31605 | AP85-08/02-69 | 7 | 50.35 | 0.68 | 15.61 | 10.90 | 0.21 | 4.95 | 9.31 | 2.48 | 3.65 | 0.45 | 7.85 | 2.18 | 0.47 | 0.34 | 99.06 |
| 31606 | AP85-08/09-71 | 7 | 48.20 | 0.99 | 17.80 | 10.38 | 0.11 | 4.13 | 9.65 | 3.02 | 2.50 | 0.37 | 7.10 | 2.49 | 2.46 | 0.34 | 99.61 |
| 31610 | AP85-21/2-120 | 7 | 53.55 | 0.77 | 17.93 | 8.36 | 0.19 | 3.01 | 7.41 | 3.71 | 2.55 | 0.40 | 5.48 | 2.27 | 1.47 | 0.01 | 99.35 |
| 37025 | AP88-04/08-12 | 7 | 54.89 | 0.61 | 18.34 | 6.95 | 0.19 | 3.19 | 7.84 | 3.48 | 2.52 | 0.30 | 4.36 | 2.11 | 1.86 | 0.15 | 100.17 |
| 37030 | AP88-16/08-55 | 7 | 47.51 | 0.76 | 17.37 | 11.07 | 0.22 | 4.98 | 9.03 | 3.13 | 2.72 | 0.49 | 7.93 | 2.26 | 2.42 | 0.15 | 99.70 |
| 38436 | AP88-25/01-76 | 7 | 52.26 | 0.72 | 16.75 | 7.61 | 0.13 | 5.01 | 10.05 | 2.22 | 2.28 | 0.25 | 4.85 | 2.22 | 2.81 | 1.14 | 100.09 |
| RM3 | RM73-7 | 7 | 48.53 | 1.11 | 14.10 | 11.20 | 0.15 | 7.04 | 10.01 | 3.61 | 2.08 | 0.40 | 7.47 | 2.61 | 1.79 | 0.00 | 100.02 |

## (APPENDIX G continued)

| LAB NO | FIELD NO | MAP UNIT | $SiO_2$ | $TiO_2$ | $Al_2O_3$ | FeO_T | MnO | MgO | CaO | $Na_2O$ | $K_2O$ | $P_2O_5$ | FeO | $Fe_2O_3$ | LOI | $CO_2$ | TOTAL* |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 37027 | AP88-08/05-28 | 8 | 54.29 | 1.04 | 16.75 | 9.67 | 0.14 | 3.84 | 5.90 | 4.76 | 0.38 | 0.13 | 6.42 | 2.54 | 3.02 | 0.17 | 99.92 |
| 37028 | AP88-11/03-34 | 8 | 59.73 | 0.63 | 13.92 | 5.88 | 0.12 | 4.83 | 5.05 | 4.05 | 2.20 | 0.22 | 3.37 | 2.13 | 2.94 | 1.14 | 99.57 |
| 35091 | AP87-03/01-04 | 10a | 51.23 | 1.01 | 11.87 | 5.83 | 0.11 | 5.43 | 6.97 | 2.85 | 4.31 | 0.78 | 2.99 | 2.51 | 8.74 | 7.53 | 99.13 |
| 35096 | AP87-24/9-68 | 10b | 58.59 | 0.41 | 17.54 | 5.31 | 0.19 | 1.15 | 5.66 | 4.00 | 2.30 | 0.18 | 3.06 | 1.91 | 4.24 | 1.77 | 99.57 |
| 37029 | AP88-11/05-36 | 10c | 45.54 | 1.11 | 11.43 | 9.11 | 0.16 | 8.86 | 8.77 | 2.63 | 0.96 | 0.89 | 5.85 | 2.61 | 8.94 | 5.60 | 98.40 |
| 35098 | AP87-18/08-44 | 11 | 48.55 | 2.04 | 13.06 | 12.71 | 0.17 | 8.43 | 8.92 | 2.91 | 0.77 | 0.33 | 8.25 | 3.54 | 1.88 | 1.71 | 99.77 |

**Totals calculated using FeO_T as $Fe_2O_3$ total*

*Iron is recalculated as: $Fe_2O_3 = TiO_2 + 1.5$ (Irvine & Baragar, 1971) and FeO_T (of FeO*) = $FeO + Fe_2O_3 * 0.8998$; $Fe_2O_3* = Fe_2O_3 + FeO * 1.11135$*

*Analytical method, detection limit in brackets in ppm; values quoted by analytical laboratory 1989.*

*XRF - Ba(10), Sr(5), Rb(10), Cr(10), Zr(20), Y(10), Nb(5), V(5), Ti(10),*

*INA - Ce(0.5), Cs(0.5), Eu(0.2), Hf(1), La(2), Lu(0.05), Sm(0.1), Sc(0.2), TA(0.5), Tb(0.5), Th(0.2), U(0.2), YB(2), ND(5)*

*AA - Co(3), Ni(5)*

*XRF and AA analyses: Geological Survey Branch, Analytical Science Laboratory*

*INAA analyses: Bondar-Clegg & Company Ltd., Vancouver, 1988, and/or X-Ray Assay Laboratories Ltd., Don Mills, Ontario, 1986*

*Data Sources: AP - Panteleyev; DB - D. Bailey; C - J. Lu - this study; lab no. with DB from Bailey (1978), Rm from Morton (1976).*

*Analyses by B.C. Geological Survey Branch, Analytical Sciences Laboratory*

## APPENDIX H
## REPLICATE AND DUPLICATE ANALYSES (PRECISION AND VARIABILITY)

| Lab No. | $SiO_2$ | $TiO_2$ | $Al_2O_3$ | FeO_T | MnO | MgO | CaO | $Na_2O$ | $K_2O$ | $P_2O_5$ | LOI |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 31602 | 54.34 | 0.55 | 18.07 | 7.65 | 0.15 | 3.33 | 6.76 | 4 | 3.56 | ---- | 1.09 |
| Duplicate | 53.2 | 0.63 | 17.8 | 7.98 | 0.17 | 3.25 | 6.65 | 3.79 | 3.81 | 0.45 | 1.1 |
| Repeat | 52.36 | 0.62 | 17.34 | 7.85 | 0.16 | 3.28 | 6.62 | 3.79 | 3.74 | 0.45 | ---- |
| | | | | | | | | | | | |
| 37027 | 49.49 | 0.72 | 14.25 | 11.37 | 0.21 | 4.68 | 10.25 | 5.05 | 0.06 | 0.3 | 3.27 |
| Duplicate | 49.17 | 0.73 | 14.27 | 11.45 | 0.22 | 4.74 | 10.41 | 4.91 | 0.08 | 0.3 | 3.3 |

*Analytical precision for x-ray fluorescence method quoted by Geological Survey Branch, Analytical Sciences*

*Laboratory, 1992 - percent at midrange value: 1% - $SiO_2$, $Al_2O_3$, MgO, CaO, $Na_2O$, MnO, $P_2O_5$; 5% - $Fe_2O_3$; 2% - $K_2O$, $TiO_2$; 5% - LOI.*
*LOI by combustion method (1050°C) ± 0.01%*

## APPENDIX I
## MINOR ELEMENT CHEMISTRY OF MAP UNITS

| LAB NO | FIELD NO | MAP UNIT | Ba | Ce | Cs | Cr | V | Co | Eu | Hf | La | Lu | Ni | Rb | Sm | Sc | Ta | Tb | Th | U | Yb | Sr | Y | Ti | Nd | Nb | Zr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 38434 | AP88-24/02-71 | 1A | 373 | --- | --- | 94 | 270 | --- | --- | --- | --- | --- | 35 | 24 | --- | --- | --- | --- | --- | --- | --- | 593 | 23.0 | 4496 | --- | 5.0 | 57 |
| 35339 | C11-9 | 2A | 2343 | --- | --- | 207 | 276 | --- | --- | --- | --- | --- | 64 | 74 | --- | --- | --- | --- | --- | --- | --- | 483 | 16.0 | 4182 | --- | 3.0 | 56 |
| 35340 | C11-11 | 2A | 1665 | 7 | 5.2 | 353 | 276 | 52 | 0.1 | 1.0 | 6 | 0.20 | 79 | 76 | 2.7 | 39.8 | --- | 0.6 | 0.9 | 0.4 | 0.2 | 336 | 13.0 | 4182 | --- | 0.1 | 38 |
| 32641 | AP86-21/04-66 | 2A | 950 | 22 | 148.0 | 5 | 321 | 47 | 0.2 | 0.2 | 12 | 0.05 | 24 | 57 | 3.1 | 33.0 | 0.1 | 1.0 | 1.7 | 1.0 | 0.5 | 530 | 7.0 | 4016 | --- | 16.0 | 71 |
| 32642 | AP86-28/04-92 | 2A | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 3357 | --- | --- | --- |
| 32643 | AP86-28/07-98 | 2A | 740 | 29 | 0.1 | 470 | 268 | 69 | 0.2 | 0.2 | 14 | 0.05 | 69 | 26 | 3.1 | 42.0 | 0.1 | 0.1 | 1.7 | 1.0 | 0.5 | 825 | 2.0 | 3596 | --- | 20.0 | 57 |
| 31607 | AP85-09/01-72 | 2A | 770 | 14 | 2.1 | 273 | 253 | 55 | 0.9 | 0.1 | 9 | 0.22 | 38 | 13 | 2.6 | 76.0 | 0.1 | --- | 1.1 | 0.1 | 1.3 | 533 | 5.0 | 3600 | 11.0 | 12.0 | 63 |
| 31609 | AP85-20/2-115 | 2A | 30 | 19 | 0.1 | 1020 | 242 | 64 | 0.7 | 2.0 | 6 | 0.33 | 377 | 5 | 3.1 | 45.9 | 0.1 | --- | 0.3 | 0.1 | 2.3 | 323 | 15.0 | 5100 | 9.0 | 6.0 | 100 |
| 37026 | AP88-06/05-19 | 2A | 48 | --- | --- | 22 | 302 | --- | --- | --- | --- | --- | 10 | 6 | --- | --- | --- | --- | --- | --- | --- | 328 | 17.0 | 4316 | --- | 18.0 | 57 |
| 38435 | AP88-22/03-70 | 2A | 126 | --- | --- | 156 | 245 | --- | --- | --- | --- | --- | 60 | 11 | --- | --- | --- | --- | --- | --- | --- | 448 | 16.0 | 3297 | --- | 5.0 | 37 |
| 35553 | DB87-01 | 2A | 1000 | --- | --- | 170 | 247 | --- | --- | --- | --- | --- | 23 | 41 | --- | --- | --- | --- | --- | --- | --- | 580 | 9.0 | 3893 | --- | 15.0 | 55 |
| 35568 | DB87-20 | 2A | 1300 | --- | --- | 470 | 263 | --- | --- | --- | --- | --- | 56 | 32 | --- | --- | --- | --- | --- | --- | --- | 500 | 23.0 | 3474 | --- | 8.0 | 76 |
| 35569 | DB87-21 | 2A | 1100 | --- | --- | 400 | 289 | --- | --- | --- | --- | --- | 98 | 51 | --- | --- | --- | --- | --- | --- | --- | 1200 | 24.0 | 4133 | --- | 11.0 | 41 |
| 35573 | DB87-25 | 2A | 460 | --- | --- | 5 | 250 | --- | --- | --- | --- | --- | 11 | 35 | --- | --- | --- | --- | --- | --- | --- | 420 | 23.0 | 3774 | --- | 1.0 | 75 |
| 35574 | DB87-26 | 2A/2D | 1200 | --- | --- | 150 | 257 | --- | --- | --- | --- | --- | 46 | 32 | --- | --- | --- | --- | --- | --- | --- | 575 | 19.0 | 4852 | --- | 10.0 | 84 |
| 35575 | DB87-27 | 2A/2D | 1900 | --- | --- | 100 | 273 | --- | --- | --- | --- | --- | 26 | 45 | --- | --- | --- | --- | --- | --- | --- | 635 | 7.0 | 4373 | --- | 17.0 | 93 |
| 35580 | DB87-33 | 2A/2D | 720 | --- | --- | 63 | 210 | --- | --- | --- | --- | --- | 22 | 51 | --- | --- | --- | --- | --- | --- | --- | 570 | 9.0 | 3534 | --- | 10.0 | 92 |
| 35582 | DB87-35 | 2A/2D | 460 | --- | --- | 92 | 263 | --- | --- | --- | --- | --- | 29 | 29 | --- | --- | --- | --- | --- | --- | --- | 645 | 15.0 | 4133 | --- | 7.0 | 74 |
| 35586 | DB87-40 | 2A/2D | 760 | --- | --- | 5 | 271 | --- | --- | --- | --- | --- | 22 | 1 | --- | --- | --- | --- | --- | --- | --- | 1000 | 12.0 | 4972 | --- | 1.0 | 59 |
| 35325 | C4-10 | 2B | 939 | 47 | 4.9 | 288 | 288 | 49 | 0.1 | 2.0 | 30 | 0.02 | 43 | 63 | 5.2 | 31.7 | 0.5 | --- | 3.4 | 0.6 | 0.2 | 994 | 15.0 | 4316 | --- | 0.1 | 65 |
| 35326 | C4-12B | 2B | 698 | 27 | 5.2 | 73 | 297 | 55 | 2.0 | 1.0 | 18 | 0.20 | 21 | 31 | 4.2 | 30.5 | --- | 0.6 | 2.3 | 1.0 | 0.2 | 1147 | 15.0 | 4844 | --- | 2.0 | 62 |
| 35330 | C7-3 | 2B | 1095 | 22 | 2.4 | 105 | 247 | 53 | 0.1 | 1.0 | 13 | 0.02 | 27 | 74 | 3.0 | 29.6 | --- | 0.7 | 1.8 | 1.3 | 0.2 | 1482 | 14.0 | 4057 | --- | 1.0 | 57 |
| 32052 | AP86-06/10-29 | 2B | 860 | 36 | 0.1 | 270 | 287 | 54 | 0.2 | 2.0 | 13 | 0.05 | 82 | 66 | 3.1 | 20.0 | 0.1 | 0.1 | 1.7 | 1.1 | 0.5 | 1200 | 2.0 | 3596 | --- | 20.0 | 50 |
| 32053 | AP86-10/08-44 | 2B | 820 | 22 | 0.1 | 59 | 354 | 66 | 2.0 | 0.2 | 8 | 0.05 | 32 | 32 | 3.3 | 29.0 | 0.1 | 1.1 | 1.0 | 0.9 | 0.5 | 890 | 20.0 | 4076 | --- | 12.0 | 61 |
| 32054 | AP86-13/03-51 | 2B | 1700 | 18 | 0.1 | 270 | 330 | 63 | 0.2 | 0.2 | 5 | 0.05 | 63 | 54 | 2.4 | 37.0 | 0.1 | 0.1 | 0.8 | 0.1 | 0.5 | 1000 | 2.0 | 4136 | --- | 17.0 | 26 |
| 31597 | AP85-1/1-35A | 2B | 200 | 21 | 0.1 | 620 | --- | 62 | 0.7 | 0.1 | 10 | 0.20 | --- | 1 | 2.4 | 54.0 | 0.1 | --- | 1.0 | 1.1 | 1.5 | 620 | 12.0 | 3300 | 9.0 | 4.0 | --- |
| 31611 | AP85-22/3-123 | 2B | 1150 | 70 | 2.0 | 15 | 286 | 29 | 1.8 | 2.0 | 42 | 0.34 | 8 | 82 | 5.9 | 30.8 | 0.1 | --- | 8.3 | 3.2 | 2.4 | 703 | 18.0 | 4300 | 31.0 | 14.0 | 98 |
| 35577 | DB87-29 | 2B | 1000 | --- | --- | 85 | 249 | --- | --- | --- | --- | --- | 24 | 74 | --- | --- | --- | --- | --- | --- | --- | 730 | 22.0 | 4253 | --- | 11.0 | 68 |
| 35578 | DB87-30 | 2B | 760 | --- | --- | 350 | 266 | --- | --- | --- | --- | --- | 71 | 27 | --- | --- | --- | --- | --- | --- | --- | 565 | 8.0 | 3714 | --- | 23.0 | 67 |
| DB1 | DB7515-12 | 2B | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 5091 | --- | --- | --- |
| DB2 | DB757-1 | 2B | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 4133 | --- | --- | --- |
| DB3 | DB757-2 | 2B | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 4133 | --- | --- | --- |
| DB4 | DB751-2 | 2B | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 4612 | --- | --- | --- |
| DB5 | DB757-3 | 2B | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 4312 | --- | --- | --- |
| DB6 | DB7532-2 | 2B | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 4911 | --- | --- | --- |
| 35095 | AP87-20/07-49 | 2C | 660 | 60 | 0.1 | 5 | 170 | 33 | 0.2 | 3.0 | 25 | 0.05 | 2 | 1 | 5.2 | 10.0 | 2.3 | 0.1 | 2.1 | 1.5 | 0.5 | 1133 | 30.0 | 5990 | --- | 24.0 | 173 |
| 35563 | DB87-15 | 2C | 740 | --- | --- | 5 | 219 | --- | --- | --- | --- | --- | 15 | 52 | --- | --- | --- | --- | --- | --- | --- | 660 | 11.0 | 4313 | --- | 14.0 | 82 |
| DB7 | DB7515-9 | 2C | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 3713 | --- | --- | --- |
| DB8 | DB7515-2 | 2C | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 4851 | --- | --- | --- |
| RM1 | RM73-34 | 2C | 1196 | --- | --- | 19 | --- | --- | --- | --- | --- | --- | --- | 99 | --- | --- | --- | --- | --- | --- | --- | 1231 | 22.0 | 4492 | --- | 6.0 | 103 |
| 31608 | AP85-12/4-84 | 2D | 500 | 17 | 2.9 | 1000 | --- | 57 | 0.3 | 1.0 | 7 | 0.24 | --- | 50 | 2.0 | 40.3 | 0.1 | --- | 1.1 | 0.8 | 1.9 | 330 | 14.0 | 3100 | 9.0 | 4.0 | --- |
| 35570 | DB87-22 | 2D | 500 | --- | --- | 410 | 285 | --- | --- | --- | --- | --- | 49 | 44 | --- | --- | --- | --- | --- | --- | --- | 775 | 9.0 | 4073 | --- | 5.0 | 77 |
| DB9 | DB7515-5 | 2D | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 4851 | --- | --- | --- |
| DB10 | DB7512-1 | 2D | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 5570 | --- | --- | --- |

*(APPENDIX I Continued)*

| LAB NO | FIELD NO | MAP UNIT | Ba | Ce | Cs | Cr | V | Co | Eu | Hf | La | Lu | Ni | Rb | Sm | Sc | Ta | Tb | Th | U | Yb | Sr | Y | Ti | Nd | Nb | Zr |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 35097 | AP87-26/05-80 | 2E | 1000 | 50 | 1.7 | 5 | 189 | 30 | 0.2 | 2.0 | 18 | 0.05 | 2 | 88 | 4.4 | 9.1 | 1.1 | 0.1 | 2.2 | 2.1 | 0.5 | 1099 | 25.0 | 5032 | --- | 6.0 | 109 |
| 32050 | AP86-04/06-18 | 2E | 1100 | 17 | 0.1 | 90 | 357 | 73 | 0.2 | 2.0 | 10 | 0.05 | 29 | 32 | 3.2 | 30.0 | 0.1 | 0.1 | 1.3 | 0.7 | 0.5 | 1100 | 2.0 | 3836 | --- | 18.0 | 50 |
| 37024 | AP86-30/3-113A | 2E | 1653 | --- | --- | 60 | 360 | --- | --- | --- | --- | --- | 11 | 49 | --- | --- | --- | --- | --- | --- | --- | 783 | 20.0 | 4436 | --- | 6.0 | 62 |
| RM2 | RM73-29 | 2E | 1534 | --- | --- | 15 | --- | --- | --- | --- | --- | --- | --- | 84 | --- | --- | --- | --- | --- | --- | --- | 999 | --- | 4432 | --- | --- | 91 |
| 31600 | AP85-5/9-57 | 2G | 700 | 19 | 0.1 | 30 | --- | 21 | --- | 0.1 | 8 | 0.31 | --- | 40 | 2.7 | 29.2 | 0.1 | --- | 1.1 | 1.1 | 2.4 | 480 | 22.0 | 3900 | 9.0 | 4.0 | --- |
| 31603 | AP85-08/06-67 | 2G | 1500 | 35 | 0.1 | 220 | --- | 19 | 1.1 | 2.0 | 15 | 0.39 | --- | 100 | 3.7 | 26.2 | 0.1 | --- | 2.3 | 1.1 | 2.5 | 510 | 24.0 | 3500 | 13.0 | 4.0 | --- |
| 31604 | AP85-08/06-68 | 2G | 790 | 34 | 9.3 | 413 | 334 | 27 | 1.1 | 2.0 | 19 | 0.38 | 127 | 50 | 4.8 | 28.0 | 0.1 | 0.7 | 2.6 | 4.4 | 2.6 | 868 | 18.0 | 4400 | 17.0 | 7.0 | 80 |
| 35093 | AP87-09/05-27 | 3 | --- | --- | --- | 5 | --- | --- | --- | --- | --- | --- | 9 | 89 | --- | --- | 0.1 | --- | --- | 11.0 | 1.0 | 797 | 25.0 | 4796 | --- | 1.0 | 67 |
| 35094 | AP87-18/05-41 | 3 | --- | --- | --- | 11 | --- | --- | --- | --- | --- | --- | 9 | 21 | --- | --- | 3.0 | --- | --- | 21.0 | 6.0 | 515 | 25.0 | 2758 | --- | 12.0 | 70 |
| 36265 | AP87-07/04-20 | 3 | 1096 | --- | --- | 13 | 148 | --- | --- | --- | --- | --- | 1 | 59 | --- | --- | --- | --- | --- | 0.0 | 0.0 | 1150 | 25.0 | 4197 | --- | 16.0 | 188 |
| 35092 | AP87-06/03-16 | 3A | 1500 | 34 | 1.0 | 5 | 143 | 30 | 0.2 | 0.2 | 8 | 0.05 | 27 | 54 | 3.8 | 9.5 | 0.1 | 0.1 | 1.7 | 1.0 | 0.5 | 542 | 30.0 | 4612 | --- | 10.0 | 132 |
| DB11 | DB753-1 | 3A | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 4552 | --- | --- | --- |
| DB12 | DB756-6 | 3A | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 5930 | --- | --- | --- |
| DB13 | DB757-12 | 3A | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 4492 | --- | --- | --- |
| DB14 | DB757-14 | 3A | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 4432 | --- | --- | --- |
| DB15 | DB756-9 | 3A | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 6409 | --- | --- | --- |
| DB16 | DB756-10 | 3A | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 5031 | --- | --- | --- |
| DB17 | DB7512-2 | 3A | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 4971 | --- | --- | --- |
| DB18 | DB756-12 | 3A | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 3833 | --- | --- | --- |
| DB19 | DB7522-5 | 3B | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 4911 | --- | --- | --- |
| DB20 | DB7522-3 | 3B | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 5271 | --- | --- | --- |
| 35556 | DB87-05 | 4 | 1100 | 43 | 0.1 | 5 | 305 | 46 | 0.2 | 2.0 | 17 | 0.05 | 4 | 44 | 3.8 | 19.0 | 0.1 | 0.1 | 2.4 | 1.5 | 0.5 | 955 | 16.0 | 4792 | --- | 15.0 | 67 |
| DB21 | DB7533-1 | 4 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 5690 | --- | --- | --- |
| DB22 | DB7518-2 | 4 | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | 4372 | --- | --- | --- |
| 37027 | AP88-08/05-28 | 8 | 82 | --- | --- | 24 | 199 | --- | --- | --- | --- | --- | 6 | 4 | --- | --- | --- | --- | --- | --- | --- | 242 | 28.0 | 6235 | --- | 8.0 | 124 |
| 37028 | AP88-11/03-34 | 8 | 1579 | --- | --- | 224 | 128 | --- | --- | --- | --- | --- | 44 | 38 | --- | --- | --- | --- | --- | --- | --- | 612 | 18.0 | 3777 | --- | 17.0 | 116 |
| 31599 | AP85-5/8-56A | 7 | 900 | 14 | 1.9 | 600 | --- | 65 | 0.6 | 0.1 | 7 | 0.22 | --- | 40 | 2.2 | 64.3 | 0.1 | --- | 0.9 | 0.5 | 1.5 | 410 | 12.0 | 3600 | 8.0 | 4.0 | --- |
| 31618 | AP85-7/2-63 | 7 | 1100 | 26 | 2.3 | 170 | --- | 49 | 1.5 | 2.0 | 11 | 0.49 | --- | 50 | 3.9 | 41.3 | 0.1 | --- | 1.4 | 1.2 | 3.3 | 390 | 26.0 | 7100 | 11.0 | 6.0 | --- |
| 31602 | AP85-8/1-64 | 7 | 1500 | 27 | 1.6 | 10 | --- | 40 | 0.9 | 2.0 | 14 | 0.31 | --- | 90 | 3.1 | 21.7 | 0.1 | --- | 2.6 | 1.4 | 2.2 | 770 | 19.0 | 3650 | 14.0 | 5.0 | --- |
| 31605 | AP85-08/02-69 | 7 | 1200 | 28 | 0.1 | 40 | --- | 52 | 0.9 | 0.1 | 13 | 0.23 | --- | 100 | 3.4 | 38.3 | 0.1 | --- | 1.2 | 0.9 | 1.9 | 780 | 16.0 | 4100 | 11.0 | 4.0 | --- |
| 31606 | AP85-08/09-71 | 7 | 1100 | 23 | 0.1 | 7 | 316 | 36 | 0.9 | 1.0 | 12 | 0.34 | 3 | 90 | 3.5 | 30.4 | 0.1 | --- | 1.2 | 1.0 | 2.0 | 675 | 16.0 | 6400 | 13.0 | 11.0 | 71 |
| 31610 | AP85-21/2-120 | 7 | 1500 | 30 | 3.0 | 10 | --- | 35 | 1.4 | 2.0 | 17 | 0.38 | --- | 80 | 4.1 | 23.9 | 1.0 | --- | 3.6 | 2.2 | 2.5 | 560 | 24.0 | 4600 | 21.0 | 6.0 | --- |
| 37025 | AP88-04/08-12 | 7 | 982 | --- | --- | 21 | 211 | --- | --- | --- | --- | --- | 2 | 46 | --- | --- | --- | --- | --- | --- | --- | 1109 | 22.0 | 3657 | --- | 2.0 | 96 |
| 37030 | AP88-16/08-55 | 7 | 874 | --- | --- | 31 | 340 | --- | --- | --- | --- | --- | 7 | --- | --- | --- | --- | --- | --- | --- | --- | 1137 | --- | 4556 | --- | --- | 40 |
| 38436 | AP88-25/01-76 | 7 | 774 | --- | --- | 68 | 282 | --- | --- | --- | --- | --- | 29 | 22 | --- | --- | --- | --- | --- | --- | --- | 600 | 19.0 | 4316 | --- | 2.0 | 52 |
| RM3 | RM73-7 | 7 | 567 | --- | --- | 86 | --- | --- | --- | --- | --- | --- | --- | 54 | --- | --- | --- | --- | --- | --- | --- | 1075 | 21.0 | 6648 | --- | --- | 70 |
| 35091 | AP87-03/01-04 | 10a | 2800 | --- | --- | 327 | 138 | --- | --- | --- | --- | --- | 87 | 102 | --- | --- | 2.0 | --- | --- | 14.0 | 4.0 | 1220 | 23.0 | 6050 | --- | 9.0 | 235 |
| 35096 | AP87-24/9-68 | 10b | --- | --- | --- | 13 | --- | --- | --- | --- | --- | --- | 36 | 44 | --- | --- | 0.1 | --- | --- | 19.0 | 6.0 | 586 | 22.0 | 2458 | --- | 9.0 | 87 |
| 37029 | AP88-11/05-36 | 10c | 5097 | --- | --- | 520 | 221 | --- | --- | --- | --- | --- | 160 | 20 | --- | --- | --- | --- | --- | --- | --- | 1044 | 23.0 | 6655 | --- | 9.0 | 164 |
| 35098 | AP87-18/08-44 | 11 | 190 | --- | --- | 297 | 191 | --- | --- | --- | --- | --- | 147 | 7 | --- | --- | 0.1 | --- | --- | 10.0 | 0.5 | 481 | 22.0 | 12219 | --- | 15.0 | 124 |

*Analytical method, detection limit in brackets in ppm; values quoted by analytical laboratory 1989.*
*XRF - Ba(10), Sr(5), Rb(10), Cr(10), Zr(20), Y(10), Nb(5), V(5), Ti(10),*
*INA - Ce(0.5), Cs(0.5), Eu(0.2), Hf(1), La(2), Lu(0.05), Sm(0.1), Sc(0.2), TA(0.5), Tb(0.5), Th(0.2), U(0.2), YB(2), ND(5;*
*AA - Co(3), Ni(5)*
*XRF and AA analyses: Geological Survey Branch, Analytical Science Laboratory*
*INAA analyses: Bondar-Clegg & Company Ltd., Vancouver, 1988, and/or X-Ray Assay Laboratories Ltd., Don Mills, Ontario, 1986*

# APPENDIX J
# MAJOR OXIDE AND MINOR ELEMENT CHEMISTRY

| SAMPLE NO | $SiO_2$ | $TiO_2$ | $Al_2O_3$ | FeO_T | MnO | MgO | CaO | $Na_2O$ | $K_2O$ | $P_2O_5$ | FeO | $Fe_2O_3$ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 274 | 51.45 | 0.71 | 13.88 | --- | 0.16 | 8.00 | 9.29 | 2.39 | 2.54 | 0.40 | --- | 11.37 |
| 218 | 50.75 | 0.66 | 12.38 | --- | 0.17 | 10.50 | 10.80 | 2.31 | 1.71 | 0.34 | --- | 10.38 |
| 252 | 49.87 | 0.55 | 14.48 | --- | 0.17 | 11.61 | 9.42 | 1.32 | 2.75 | 0.29 | --- | 9.56 |
| 05 | 52.67 | 0.61 | 10.25 | --- | 0.18 | 8.64 | 10.42 | 3.40 | 1.42 | 0.30 | --- | 11.51 |
| 02 | 44.13 | 1.12 | 15.59 | --- | 0.21 | 10.51 | 10.51 | 3.00 | 0.60 | 0.34 | --- | 13.98 |
| 219 | 51.45 | 0.55 | 10.84 | --- | 0.18 | 9.28 | 9.75 | 2.56 | 2.01 | 0.40 | --- | 10.84 |
| 407 | 50.46 | 0.95 | 14.02 | --- | 0.15 | 8.37 | 10.80 | 2.69 | 1.27 | 0.30 | --- | 10.98 |
| 358A | 53.08 | 0.54 | 14.58 | --- | 0.17 | 4.75 | 10.93 | 4.89 | 1.35 | 0.43 | --- | 9.28 |
| WS70 | 53.76 | 0.55 | 15.03 | --- | 0.16 | 5.20 | 8.04 | 4.94 | 1.59 | 0.44 | --- | 10.25 |
| 300 | 50.03 | 0.47 | 13.21 | --- | 0.17 | 13.53 | 8.59 | 0.90 | 2.56 | 0.24 | --- | 10.30 |
| 374 | 52.82 | 0.55 | 11.89 | --- | 0.19 | 9.18 | 11.32 | 2.13 | 1.05 | 0.34 | --- | 10.73 |
| 358B | 48.15 | 0.85 | 14.64 | --- | 0.22 | 7.74 | 10.91 | 2.98 | 1.70 | 0.39 | --- | 12.42 |
| 409 | 52.44 | 0.65 | 12.76 | --- | 0.18 | 8.34 | 10.34 | 1.52 | 1.81 | 0.35 | --- | 11.61 |
| 395 | 51.73 | 0.81 | 14.01 | --- | 0.19 | 8.10 | 9.28 | 3.58 | 1.56 | 0.26 | --- | 10.47 |
| 269 | 45.92 | 0.49 | 10.97 | --- | 0.38 | 17.09 | 7.99 | 0.03 | 1.10 | 0.31 | --- | 15.72 |
| 358C | 46.88 | 0.75 | 14.68 | --- | 0.22 | 7.87 | 9.04 | 0.80 | 3.98 | 0.38 | --- | 15.40 |
| 48 | 49.57 | 0.78 | 14.97 | --- | 0.18 | 11.54 | 9.16 | 0.67 | 1.42 | 0.46 | --- | 11.25 |
| 275 | 48.85 | 0.40 | 9.82 | --- | 0.18 | 17.01 | 10.68 | 0.35 | 1.65 | 0.17 | --- | 10.89 |
| 260 | 50.95 | 0.52 | 15.57 | --- | 0.19 | 9.14 | 7.26 | 1.21 | 3.54 | 0.31 | --- | 11.31 |
| 293 | 51.88 | 0.51 | 13.79 | --- | 0.19 | 9.23 | 8.92 | 1.38 | 2.37 | 0.32 | --- | 11.42 |
| 16 | 50.39 | 0.79 | 13.08 | --- | 0.17 | 8.20 | 10.83 | 3.16 | 2.21 | 0.37 | --- | 10.79 |
| 15 | 53.74 | 0.86 | 15.54 | --- | 0.16 | 6.45 | 7.84 | 2.72 | 3.42 | 0.40 | --- | 8.57 |
| 185 | 48.70 | 0.46 | 11.28 | --- | 0.19 | 13.69 | 11.71 | 0.21 | 2.31 | 0.28 | --- | 11.16 |
| 172 | 54.36 | 0.72 | 13.79 | --- | 0.17 | 6.34 | 9.18 | 3.61 | 2.03 | 0.41 | --- | 9.37 |
| WS86 | 51.85 | 0.79 | 14.55 | --- | 0.20 | 5.46 | 10.40 | 4.78 | 0.58 | 0.37 | --- | 10.91 |
| 01 | 43.53 | 0.74 | 13.30 | --- | 0.24 | 16.30 | 12.55 | 0.61 | 0.60 | 0.23 | --- | 11.89 |
| 332 | 45.96 | 0.88 | 16.08 | --- | 0.13 | 5.48 | 18.25 | 1.69 | 0.30 | 0.56 | --- | 10.68 |
| 25 | 46.16 | 0.79 | 13.95 | --- | 0.21 | 17.59 | 8.89 | 0.00 | 0.33 | 0.23 | --- | 11.85 |
| WS41 | 44.90 | 0.81 | 16.45 | --- | 0.14 | 5.66 | 19.34 | 1.04 | 0.30 | 0.50 | --- | 10.85 |
| AVERAGE | 49.88 | 0.68 | 13.63 | --- | 0.19 | 9.68 | 10.43 | 2.10 | 1.73 | 0.35 | --- | 11.23 |

| SAMPLE NO | Ba (ppm) | Rb (ppm) | Sr (ppm) | Nb (ppm) | Y (ppm) | Zr (ppm) | Cr (ppm) | Ni (ppm) | Co (ppm) | Cu (ppm) | V (ppm) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 274 | 1013.00 | 51.00 | 389.00 | <DET | 18.00 | 48.00 | 114.00 | 83.00 | --- | --- | 265.00 |
| 218 | 607.00 | 33.00 | 1089.00 | <DET | 19.00 | 29.00 | 430.00 | 143.00 | --- | --- | 276.00 |
| 252 | 829.00 | 66.00 | 424.00 | <DET | 21.00 | 53.00 | <DET | 320.00 | --- | --- | 248.00 |
| 5 | 687.00 | 24.00 | 355.00 | <DET | 15.00 | 40.00 | 227.00 | 65.00 | --- | --- | 224.00 |
| 2 | 250.00 | <DET | 1064.00 | 2222* | 17.00 | 35.00 | 137.00 | 77.00 | --- | --- | 384.00 |
| 219 | 624.00 | 44.00 | 442.00 | 2222* | 17.00 | 62.00 | 370.00 | 113.00 | --- | --- | 238.00 |
| 407 | 527.00 | 20.00 | 1947.00 | 8.00 | 14.00 | 23.00 | 111.00 | 56.00 | --- | --- | 321.00 |
| 358A | 469.00 | 25.00 | 1821.00 | <DET | 16.00 | 26.00 | 23.00 | 21.00 | --- | --- | 232.00 |
| WS70 | 571.00 | 29.00 | 1923.00 | <DET | 17.00 | 24.00 | 13.00 | 21.00 | --- | --- | 239.00 |
| 300 | 1241.00 | 72.00 | 228.00 | <DET | 17.00 | 54.00 | 838.00 | 405.00 | --- | --- | 240.00 |
| 374 | 468.00 | 15.00 | 838.00 | 2222* | 15.00 | 47.00 | 344.00 | 102.00 | --- | --- | 229.00 |
| 358B | 702.00 | 27.00 | 943.00 | 2222* | 20.00 | 48.00 | 37.00 | 41.00 | --- | --- | 332.00 |
| 409 | 660.00 | 32.00 | 640.00 | <DET | 18.00 | 55.00 | 270.00 | 80.00 | --- | --- | 273.00 |
| 395 | 769.00 | 24.00 | 603.00 | 5.00 | 13.00 | 47.00 | 10.00 | 30.00 | --- | --- | 282.00 |
| 269 | 430.00 | 26.00 | 77.00 | <DET | 14.00 | 36.00 | 2607.00 | 476.00 | --- | --- | 226.00 |
| 358C | 1365.00 | 78.00 | 993.00 | <DET | 22.00 | 33.00 | 18.00 | 34.00 | --- | --- | 365.00 |
| 48 | 598.00 | 23.00 | 2150.00 | 5.00 | 23.00 | 25.00 | 11.00 | 33.00 | --- | --- | 335.00 |
| 275 | 1190.00 | 20.00 | 131.00 | <DET | 12.00 | 30.00 | 1484.00 | 532.00 | --- | --- | 204.00 |
| 260 | 1706.00 | 88.00 | 375.00 | <DET | 17.00 | 51.00 | 401.00 | 167.00 | --- | --- | 288.00 |
| 293 | 912.00 | 50.00 | 1324.00 | <DET | 18.00 | 40.00 | 409.00 | 148.00 | --- | --- | 253.00 |
| 16 | 1234.00 | 32.00 | 731.00 | 6.00 | 17.00 | 45.00 | 165.00 | 84.00 | --- | --- | 243.00 |
| 15 | 1464.00 | 41.00 | 1348.00 | 8.00 | 18.00 | 55.00 | 56.00 | 43.00 | --- | --- | 285.00 |
| 185 | 1172.00 | 37.00 | 97.00 | 2222* | 12.00 | 33.00 | 831.00 | 214.00 | --- | --- | 230.00 |
| 172 | 819.00 | 28.00 | 887.00 | 5.00 | 20.00 | 52.00 | 85.00 | 36.00 | --- | --- | 238.00 |
| WS86 | 172.00 | 6.00 | 772.00 | 10.00 | 20.00 | 67.00 | 51.00 | 41.00 | --- | --- | 243.00 |
| 1 | 266.00 | 9.00 | 403.00 | <DET | 19.00 | 61.00 | 944.00 | 402.00 | --- | --- | 251.00 |
| 332 | 72.00 | <DET | 1969.00 | 5.00 | 22.00 | 28.00 | 65.00 | 38.00 | --- | --- | 317.00 |
| 25 | 135.00 | <DET | 365.00 | 2222* | 19.00 | 64.00 | 965.00 | 401.00 | --- | --- | 269.00 |
| WS41 | 91.00 | <DET | 1990.00 | 2222* | 21.00 | 25.00 | 73.00 | 41.00 | --- | --- | 345.00 |
| AVERAGE | 726.00 | 36.00 | 908.00 | 7.00 | 18.00 | 43.00 | 396.00 | 146.00 | --- | --- | 272.00 |

**limit of analytical capability*

*from Bloodgood, 1987, included in Unit 1a*

# APPENDIX K
## QUESNEL CIPW NORMS FOR ALL ANALYZED SAMPLES, n = 84

| SAMPLE | 274 | 218 | 252 | 5 | 2 | 219 | 407 | 358A | WS70 | 300 | 374 | 358B | 409 | 395 | 269 | 358C | 48 | 275 | 260 | 293 | 16 | 15 | 185 | 172 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MAP UNIT | 1A | 1A | 1A | 1A | 1A | 1A | 1A | 1A | 1A | 1A | 1A | 1A | 1A | 1A | 1A | 1A | 1A | 1A | 1A | 1A | 1A | 1A | 1A | 1A |
| **OXIDES AS DETERMINED; (nd = not determined)** | | | | | | | | | | | | | | | | | | | | | | | | |
| $SiO_2$ | 51.45 | 50.75 | 49.87 | 52.67 | 44.13 | 51.45 | 50.46 | 53.08 | 53.76 | 50.03 | 52.82 | 48.15 | 52.44 | 51.73 | 45.92 | 46.88 | 49.57 | 48.85 | 50.95 | 51.88 | 50.39 | 53.74 | 48.70 | 54.36 |
| $TiO_2$ | 0.71 | 0.66 | 0.55 | 0.61 | 1.12 | 0.55 | 0.95 | 0.54 | 0.55 | 0.47 | 0.55 | 0.85 | 0.65 | 0.81 | 0.49 | 0.75 | 0.78 | 0.40 | 0.52 | 0.51 | 0.79 | 0.86 | 0.46 | 0.72 |
| $Al_2O_3$ | 13.88 | 12.38 | 14.48 | 10.25 | 15.59 | 10.84 | 14.02 | 14.58 | 15.03 | 13.21 | 11.89 | 14.64 | 12.76 | 14.01 | 10.97 | 14.68 | 14.97 | 9.82 | 15.57 | 13.79 | 13.08 | 15.54 | 11.28 | 13.79 |
| $Fe_2O_3$ | 11.37 | 10.38 | 9.56 | 11.51 | 13.98 | 10.84 | 10.98 | 9.28 | 10.25 | 10.30 | 10.73 | 12.42 | 11.61 | 10.47 | 15.72 | 15.40 | 11.25 | 10.89 | 11.31 | 11.42 | 10.79 | 8.57 | 11.16 | 9.37 |
| MnO | 0.16 | 0.17 | 0.17 | 0.18 | 0.21 | 0.18 | 0.15 | 0.17 | 0.16 | 0.17 | 0.19 | 0.22 | 0.18 | 0.19 | 0.38 | 0.22 | 0.18 | 0.18 | 0.19 | 0.19 | 0.17 | 0.16 | 0.19 | 0.17 |
| MgO | 8.00 | 10.50 | 11.61 | 8.64 | 10.51 | 9.28 | 8.37 | 4.75 | 5.20 | 13.53 | 9.18 | 7.74 | 8.34 | 8.10 | 17.09 | 7.87 | 11.54 | 17.01 | 9.14 | 9.23 | 8.20 | 6.45 | 13.69 | 6.34 |
| CaO | 9.29 | 10.80 | 9.42 | 10.42 | 10.51 | 9.75 | 10.80 | 10.93 | 8.04 | 8.59 | 11.32 | 10.91 | 10.34 | 9.28 | 7.99 | 9.04 | 9.16 | 10.68 | 7.26 | 8.92 | 10.83 | 7.84 | 11.71 | 9.18 |
| $Na_2O$ | 2.39 | 2.31 | 1.32 | 3.40 | 3.00 | 2.56 | 2.69 | 4.89 | 4.94 | 0.90 | 2.13 | 2.98 | 1.52 | 3.58 | 0.03 | 0.80 | 0.67 | 0.35 | 1.21 | 1.38 | 3.16 | 2.72 | 0.21 | 3.61 |
| $K_2O$ | 2.54 | 1.71 | 2.75 | 1.42 | 0.60 | 2.01 | 1.27 | 1.35 | 1.59 | 2.56 | 1.05 | 1.70 | 1.81 | 1.56 | 1.10 | 3.98 | 1.42 | 1.65 | 3.54 | 2.37 | 2.21 | 3.42 | 2.31 | 2.03 |
| $P_2O_5$ | 0.40 | 0.34 | 0.29 | 0.30 | 0.34 | 0.40 | 0.30 | 0.43 | 0.44 | 0.24 | 0.34 | 0.39 | 0.35 | 0.26 | 0.31 | 0.38 | 0.46 | 0.17 | 0.31 | 0.32 | 0.37 | 0.40 | 0.28 | 0.41 |
| $CO_2$ | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| LOI | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd | nd |
| TOTAL | 100.19 | 100.00 | 100.02 | 99.40 | 99.99 | 97.86 | 99.99 | 100.00 | 99.96 | 100.00 | 100.20 | 100.00 | 100.00 | 99.99 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.01 | 99.99 | 99.70 | 99.99 | 99.98 |
| **OXIDES RECALCULATED VOLATILE FREE** | | | | | | | | | | | | | | | | | | | | | | | | |
| $SiO_2$ | 51.35 | 50.75 | 49.86 | 52.99 | 44.13 | 52.58 | 50.47 | 53.08 | 53.78 | 50.03 | 52.71 | 48.15 | 52.44 | 51.74 | 45.92 | 46.88 | 49.57 | 48.85 | 50.95 | 51.87 | 50.40 | 53.90 | 48.70 | 54.37 |
| $TiO_2$ | 0.71 | 0.66 | 0.55 | 0.61 | 1.12 | 0.56 | 0.95 | 0.54 | 0.55 | 0.47 | 0.55 | 0.85 | 0.65 | 0.81 | 0.49 | 0.75 | 0.78 | 0.40 | 0.52 | 0.51 | 0.79 | 0.86 | 0.46 | 0.72 |
| $Al_2O_3$ | 13.85 | 12.38 | 14.48 | 10.31 | 15.59 | 11.08 | 14.02 | 14.58 | 15.04 | 13.21 | 11.87 | 14.64 | 12.76 | 14.01 | 10.97 | 14.68 | 14.97 | 9.82 | 15.57 | 13.79 | 13.08 | 15.59 | 11.28 | 13.79 |
| $Fe_2O_3$ | 11.35 | 10.38 | 9.56 | 11.58 | 13.98 | 11.08 | 10.98 | 9.28 | 10.25 | 10.30 | 10.71 | 12.42 | 11.61 | 10.47 | 15.72 | 15.40 | 11.25 | 10.89 | 11.31 | 11.42 | 10.79 | 8.60 | 11.16 | 9.37 |
| MnO | 0.16 | 0.17 | 0.17 | 0.18 | 0.21 | 0.18 | 0.15 | 0.17 | 0.16 | 0.17 | 0.19 | 0.22 | 0.18 | 0.19 | 0.38 | 0.22 | 0.18 | 0.18 | 0.19 | 0.19 | 0.17 | 0.16 | 0.19 | 0.17 |
| MgO | 7.98 | 10.50 | 11.61 | 8.69 | 10.51 | 9.48 | 8.37 | 4.75 | 5.20 | 13.53 | 9.16 | 7.74 | 8.34 | 8.10 | 17.09 | 7.87 | 11.54 | 17.01 | 9.14 | 9.23 | 8.20 | 6.47 | 13.69 | 6.34 |
| CaO | 9.27 | 10.80 | 9.42 | 10.48 | 10.51 | 9.96 | 10.80 | 10.93 | 8.04 | 8.59 | 11.30 | 10.91 | 10.34 | 9.28 | 7.99 | 9.04 | 9.16 | 10.68 | 7.26 | 8.92 | 10.83 | 7.86 | 11.71 | 9.18 |
| $Na_2O$ | 2.39 | 2.31 | 1.32 | 3.42 | 3.00 | 2.62 | 2.69 | 4.89 | 4.94 | 0.90 | 2.13 | 2.98 | 1.52 | 3.58 | 0.03 | 0.80 | 0.67 | 0.35 | 1.21 | 1.38 | 3.16 | 2.73 | 0.21 | 3.61 |
| $K_2O$ | 2.54 | 1.71 | 2.75 | 1.43 | 0.60 | 2.05 | 1.27 | 1.35 | 1.59 | 2.56 | 1.05 | 1.70 | 1.81 | 1.56 | 1.10 | 3.98 | 1.42 | 1.65 | 3.54 | 2.37 | 2.21 | 3.43 | 2.31 | 2.03 |
| $P_2O_5$ | 0.40 | 0.34 | 0.29 | 0.30 | 0.34 | 0.41 | 0.30 | 0.43 | 0.44 | 0.24 | 0.34 | 0.39 | 0.35 | 0.26 | 0.31 | 0.38 | 0.46 | 0.17 | 0.31 | 0.32 | 0.37 | 0.40 | 0.28 | 0.41 |
| TOTAL | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| **CIPW NORM VOLATILE FREE** | | | | | | | | | | | | | | | | | | | | | | | | |
| Q | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.32 | 0.00 | 2.82 | 0.00 | 0.00 | 0.00 | 1.17 | 0.00 | 0.00 | 0.57 | 0.00 | 0.00 | 0.00 | 0.00 |
| or | 14.98 | 10.10 | 16.25 | 8.44 | 3.55 | 12.14 | 7.51 | 7.98 | 9.40 | 15.13 | 6.19 | 10.05 | 10.70 | 9.22 | 6.50 | 23.52 | 8.39 | 9.75 | 20.92 | 14.00 | 13.06 | 20.27 | 13.65 | 12.00 |
| ab | 20.18 | 19.54 | 11.16 | 28.93 | 12.30 | 22.13 | 22.76 | 31.76 | 39.66 | 7.61 | 17.98 | 17.38 | 12.86 | 30.29 | 0.25 | 6.77 | 5.67 | 2.96 | 10.24 | 11.67 | 19.50 | 23.08 | 1.78 | 30.54 |
| an | 19.62 | 18.37 | 25.47 | 8.57 | 27.32 | 12.43 | 22.44 | 13.86 | 14.16 | 24.45 | 19.75 | 21.56 | 22.66 | 17.56 | 26.55 | 24.72 | 33.65 | 20.36 | 26.61 | 24.44 | 14.99 | 20.16 | 23.02 | 15.44 |
| ne | 0.00 | 0.00 | 0.00 | 0.00 | 7.09 | 0.00 | 0.00 | 5.20 | 1.16 | 0.00 | 0.00 | 4.24 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 3.92 | 0.00 | 0.00 | 0.00 |
| di | 19.37 | 26.59 | 15.53 | 33.76 | 18.38 | 27.84 | 23.65 | 30.87 | 18.83 | 13.31 | 27.64 | 24.56 | 21.48 | 21.71 | 8.95 | 14.59 | 7.08 | 25.21 | 6.00 | 14.41 | 29.48 | 13.10 | 26.74 | 22.30 |
| hy | 10.49 | 6.62 | 12.32 | 3.81 | 0.00 | 11.36 | 7.80 | 0.00 | 0.00 | 22.58 | 21.48 | 0.00 | 23.40 | 0.94 | 32.65 | 1.60 | 37.31 | 20.86 | 24.51 | 29.37 | 0.00 | 16.25 | 16.99 | 11.98 |
| ol | 9.00 | 12.81 | 13.85 | 10.61 | 23.54 | 8.17 | 8.97 | 4.65 | 10.95 | 11.79 | 0.00 | 15.30 | 0.00 | 14.00 | 19.20 | 21.94 | 0.00 | 16.08 | 6.18 | 0.00 | 12.54 | 0.54 | 12.56 | 1.50 |
| mt | 3.20 | 3.13 | 2.97 | 3.08 | 3.80 | 3.04 | 3.55 | 2.96 | 2.97 | 2.86 | 2.97 | 3.41 | 3.12 | 3.35 | 2.89 | 3.26 | 3.31 | 2.75 | 2.93 | 2.91 | 3.32 | 3.43 | 2.84 | 3.22 |
| il | 1.35 | 1.25 | 1.04 | 1.17 | 2.13 | 1.07 | 1.80 | 1.03 | 1.05 | 0.89 | 1.04 | 1.61 | 1.23 | 1.54 | 0.93 | 1.42 | 1.48 | 0.76 | 0.99 | 0.97 | 1.50 | 1.64 | 0.87 | 1.37 |
| ap | 0.93 | 0.79 | 0.68 | 0.70 | 0.79 | 0.95 | 0.70 | 1.00 | 1.03 | 0.56 | 0.79 | 0.91 | 0.82 | 0.61 | 0.72 | 0.89 | 1.07 | 0.40 | 0.72 | 0.75 | 0.86 | 0.94 | 0.65 | 0.96 |
| AN= | 49.29 | 48.46 | 69.52 | 22.86 | 68.95 | 35.96 | 49.65 | 30.38 | 26.31 | 76.26 | 52.34 | 55.37 | 63.80 | 36.71 | 99.05 | 78.51 | 85.59 | 87.30 | 72.22 | 67.68 | 43.46 | 46.63 | 92.84 | 33.58 |

*(APPENDIX K Continued)*

**Quesnel CIPW Norms**

| SAMPLE | WS86 | 1 | 332 | 25 | WS41 | AVE | 38434 | 35339 | 35340 | 32641 | 32642 | 32643 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MAP UNIT | 1A | 1A | 1A | 1A | 1A | 1A | 1A | 2A | 2A | 2A | 2A | 2A |
| **OXIDES AS DETERMINED** | | | | | | 11.2431 | | | | | | |
| $SiO_2$ | 51.85 | 43.53 | 45.96 | 46.16 | 44.90 | 49.88 | 46.92 | 46.52 | 46.49 | 49.09 | 49.75 | 46.33 |
| $TiO_2$ | 0.79 | 0.74 | 0.88 | 0.79 | 0.81 | 0.68 | 0.75 | 0.64 | 0.76 | 0.67 | 0.56 | 0.60 |
| $Al_2O_3$ | 14.55 | 13.30 | 16.08 | 13.95 | 16.45 | 13.63 | 16.64 | 13.36 | 11.59 | 14.62 | 16.93 | 10.33 |
| $Fe_2O_3$ | 10.91 | 11.89 | 10.68 | 11.85 | 10.85 | 11.23 | 2.25 | 2.14 | 2.26 | 2.17 | 2.06 | 2.10 |
| FeO | nd | nd | nd | nd | nd | nd | 5.52 | 7.72 | 9.29 | 7.29 | 6.15 | 8.17 |
| MnO | 0.20 | 0.24 | 0.13 | 0.21 | 0.14 | 0.19 | 0.18 | 0.17 | 0.21 | 0.16 | 0.20 | 0.19 |
| MgO | 5.46 | 16.30 | 5.48 | 17.59 | 5.66 | 9.68 | 5.68 | 7.24 | 8.35 | 6.25 | 3.97 | 11.47 |
| CaO | 10.40 | 12.55 | 18.25 | 8.89 | 19.34 | 10.43 | 13.06 | 10.73 | 10.69 | 8.50 | 5.94 | 13.60 |
| $Na_2O$ | 4.78 | 0.61 | 1.69 | 0.00 | 1.04 | 2.10 | 1.76 | 0.99 | 1.51 | 4.46 | 3.20 | 1.03 |
| $K_2O$ | 0.58 | 0.60 | 0.30 | 0.33 | 0.30 | 1.73 | 1.32 | 4.28 | 3.59 | 1.74 | 5.13 | 2.58 |
| $P_2O_5$ | 0.37 | 0.23 | 0.56 | 0.23 | 0.50 | 0.35 | 0.22 | 0.44 | 0.26 | 0.40 | 0.62 | 0.39 |
| $CO_2$ | nd | nd | nd | nd | nd | nd | 1.81 | 0.14 | 0.07 | 0.56 | 0.84 | 0.42 |
| LOI | nd | nd | nd | nd | nd | nd | 5.28 | 3.37 | 3.36 | 4.26 | 3.21 | 2.24 |
| TOTAL | 99.89 | 99.99 | 100.01 | 100.00 | 99.99 | 99.90 | 99.58 | 97.60 | 98.36 | 99.61 | 97.72 | 99.03 |
| **OXIDES RECALCULATED VOLATILE FREE** | | | | | | | | | | | | |
| $SiO_2$ | 51.91 | 43.53 | 45.96 | 46.16 | 44.90 | 49.93 | 49.76 | 49.37 | 48.94 | 51.48 | 52.64 | 47.87 |
| $TiO_2$ | 0.79 | 0.74 | 0.88 | 0.79 | 0.81 | 0.68 | 0.80 | 0.68 | 0.80 | 0.70 | 0.59 | 0.62 |
| $Al_2O_3$ | 14.57 | 13.30 | 16.08 | 13.95 | 16.45 | 13.64 | 17.65 | 14.18 | 12.20 | 15.33 | 17.91 | 10.67 |
| $Fe_2O_3$ | 10.92 | 11.89 | 10.68 | 11.85 | 10.85 | 11.24 | 2.39 | 2.27 | 2.38 | 2.28 | 2.18 | 2.17 |
| FeO | nd | nd | nd | nd | nd | nd | 5.85 | 8.19 | 9.78 | 7.65 | 6.51 | 8.44 |
| MnO | 0.20 | 0.24 | 0.13 | 0.21 | 0.14 | 0.19 | 0.19 | 0.18 | 0.22 | 0.17 | 0.21 | 0.20 |
| MgO | 5.47 | 16.30 | 5.48 | 17.59 | 5.66 | 9.69 | 6.02 | 7.68 | 8.79 | 6.55 | 4.20 | 11.85 |
| CaO | 10.41 | 12.55 | 18.25 | 8.89 | 19.34 | 10.44 | 13.85 | 11.39 | 11.25 | 8.91 | 6.29 | 14.05 |
| $Na_2O$ | 4.79 | 0.61 | 1.69 | 0.00 | 1.04 | 2.10 | 1.87 | 1.05 | 1.59 | 4.68 | 3.39 | 1.06 |
| $K_2O$ | 0.58 | 0.60 | 0.30 | 0.33 | 0.30 | 1.73 | 1.40 | 4.54 | 3.78 | 1.82 | 5.43 | 2.67 |
| $P_2O_5$ | 0.37 | 0.23 | 0.56 | 0.23 | 0.50 | 0.35 | 0.23 | 0.47 | 0.27 | 0.42 | 0.66 | 0.40 |
| TOTAL | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| **CIPW NORM VOLATILE FREE** | | | | | | | | | | | | |
| Q | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| or | 3.43 | 3.55 | 1.77 | 1.95 | 1.77 | 10.23 | 8.27 | 26.84 | 22.33 | 10.78 | 32.08 | 15.75 |
| ab | 34.95 | 3.88 | 6.77 | 0.00 | 1.60 | 17.78 | 15.79 | 4.13 | 5.03 | 28.12 | 20.51 | 0.68 |
| an | 16.56 | 31.79 | 35.41 | 37.10 | 39.34 | 22.69 | 35.65 | 20.56 | 15.00 | 15.47 | 17.66 | 16.48 |
| ne | 2.99 | 0.70 | 4.08 | 0.00 | 3.90 | 0.00 | 0.00 | 2.58 | 4.56 | 6.20 | 4.41 | 4.51 |
| di | 26.87 | 23.21 | 42.22 | 4.40 | 43.79 | 21.73 | 25.56 | 26.82 | 31.91 | 21.27 | 7.61 | 40.83 |
| hy | 0.00 | 0.00 | 0.00 | 39.05 | 0.00 | 9.35 | 6.13 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| ol | 8.66 | 30.75 | 2.53 | 11.22 | 2.71 | 12.07 | 3.11 | 13.43 | 15.59 | 12.58 | 11.95 | 16.52 |
| mt | 3.32 | 3.25 | 3.45 | 3.32 | 3.35 | 3.16 | 3.46 | 3.29 | 3.45 | 3.30 | 3.16 | 3.15 |
| il | 1.50 | 1.41 | 1.67 | 1.50 | 1.54 | 1.29 | 1.51 | 1.29 | 1.52 | 1.33 | 1.13 | 1.18 |
| ap | 0.86 | 0.54 | 1.31 | 0.54 | 1.17 | 0.82 | 0.54 | 1.09 | 0.64 | 0.98 | 1.53 | 0.94 |
| AN= | 32.15 | 89.13 | 83.95 | 100.00 | 96.10 | 56.06 | 69.31 | 83.27 | 74.89 | 35.48 | 46.27 | 96.02 |

| SAMPLE | 31607 | 31609 | 37026 | 38435 | 35553 | 35568 | 35569 | 35573 | 35574 | 35575 | 35580 | 35582 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MAP UNIT | 2A | 2A | 2A | 2A | 2A | 2A | 2A | 2A | 2A/2D | 2A/2D | 2A/2D | 2A/2D |
| **OXIDES AS DETERMINED** | | | | | | | | | | | | |
| $SiO_2$ | 46.80 | 49.28 | 49.33 | 47.04 | 48.48 | 47.81 | 47.15 | 46.09 | 50.70 | 51.69 | 50.81 | 48.44 |
| $TiO_2$ | 0.55 | 0.97 | 0.72 | 0.55 | 0.65 | 0.58 | 0.69 | 0.63 | 0.81 | 0.73 | 0.59 | 0.69 |
| $Al_2O_3$ | 9.23 | 11.41 | 14.26 | 15.17 | 13.40 | 9.88 | 13.22 | 17.80 | 14.79 | 15.02 | 17.06 | 16.50 |
| $Fe_2O_3$ | 2.05 | 2.47 | 2.22 | 2.05 | 2.15 | 2.08 | 2.19 | 2.13 | 2.31 | 2.23 | 2.09 | 2.19 |
| FeO | 7.25 | 5.17 | 8.27 | 6.60 | 8.31 | 7.90 | 8.54 | 6.55 | 7.14 | 6.49 | 5.97 | 8.08 |
| MnO | 0.18 | 0.15 | 0.21 | 0.16 | 0.22 | 0.20 | 0.21 | 0.19 | 0.19 | 0.25 | 0.13 | 0.13 |
| MgO | 10.96 | 7.59 | 4.71 | 7.40 | 8.00 | 10.52 | 9.16 | 4.52 | 6.96 | 5.43 | 4.71 | 5.49 |
| CaO | 15.18 | 13.13 | 10.33 | 13.15 | 9.87 | 13.38 | 11.42 | 10.07 | 9.32 | 7.16 | 8.08 | 8.50 |
| $Na_2O$ | 1.57 | 4.29 | 4.98 | 2.25 | 2.56 | 1.67 | 1.76 | 2.79 | 2.18 | 2.77 | 3.63 | 3.80 |
| $K_2O$ | 0.93 | 0.04 | 0.07 | 0.38 | 2.19 | 1.55 | 1.89 | 2.77 | 1.70 | 2.42 | 2.58 | 1.48 |
| $P_2O_5$ | 0.27 | 0.22 | 0.30 | 0.14 | 0.27 | 0.47 | 0.33 | 0.37 | 0.25 | 0.31 | 0.31 | 0.38 |
| $CO_2$ | 0.38 | 3.27 | 0.62 | 1.07 | 0.21 | 0.34 | 0.07 | 0.28 | 0.07 | 0.28 | 0.28 | 0.56 |
| LOI | 2.48 | 5.10 | 3.26 | 4.42 | 2.76 | 2.81 | 2.28 | 5.02 | 2.57 | 3.85 | 2.92 | 2.83 |
| TOTAL | 97.45 | 99.82 | 98.66 | 99.31 | 98.86 | 98.85 | 98.84 | 98.93 | 98.92 | 98.35 | 98.88 | 98.51 |
| **OXIDES RECALCULATED VOLATILE FREE** | | | | | | | | | | | | |
| $SiO_2$ | 49.28 | 52.03 | 51.71 | 49.57 | 50.45 | 49.78 | 48.83 | 49.08 | 52.62 | 54.70 | 52.95 | 50.63 |
| $TiO_2$ | 0.58 | 1.02 | 0.75 | 0.58 | 0.68 | 0.60 | 0.71 | 0.67 | 0.84 | 0.77 | 0.61 | 0.72 |
| $Al_2O_3$ | 9.72 | 12.05 | 14.95 | 15.99 | 13.94 | 10.29 | 13.69 | 18.95 | 15.35 | 15.89 | 17.78 | 17.24 |
| $Fe_2O_3$ | 2.16 | 2.61 | 2.33 | 2.16 | 2.24 | 2.17 | 2.27 | 2.27 | 2.40 | 2.36 | 2.18 | 2.29 |
| FeO | 7.63 | 5.46 | 8.67 | 6.96 | 8.65 | 8.23 | 8.84 | 6.97 | 7.41 | 6.87 | 6.22 | 8.44 |
| MnO | 0.19 | 0.16 | 0.22 | 0.17 | 0.23 | 0.21 | 0.22 | 0.20 | 0.20 | 0.26 | 0.14 | 0.14 |
| MgO | 11.54 | 8.01 | 4.94 | 7.80 | 8.32 | 10.95 | 9.49 | 4.81 | 7.22 | 5.75 | 4.91 | 5.74 |
| CaO | 15.98 | 13.86 | 10.83 | 13.86 | 10.27 | 13.93 | 11.83 | 10.72 | 9.67 | 7.58 | 8.42 | 8.88 |
| $Na_2O$ | 1.65 | 4.53 | 5.22 | 2.37 | 2.66 | 1.74 | 1.82 | 2.97 | 2.26 | 2.93 | 3.78 | 3.97 |
| $K_2O$ | 0.98 | 0.04 | 0.07 | 0.40 | 2.28 | 1.61 | 1.96 | 2.95 | 1.76 | 2.56 | 2.69 | 1.55 |
| $P_2O_5$ | 0.28 | 0.23 | 0.31 | 0.15 | 0.28 | 0.49 | 0.34 | 0.39 | 0.26 | 0.33 | 0.32 | 0.40 |
| TOTAL | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| **CIPW NORM VOLATILE FREE** | | | | | | | | | | | | |
| Q | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 1.41 | 2.27 | 0.00 | 0.00 |
| or | 5.79 | 0.25 | 0.43 | 2.37 | 13.47 | 9.54 | 11.57 | 17.43 | 10.43 | 15.13 | 15.89 | 9.14 |
| ab | 9.30 | 27.35 | 35.06 | 20.06 | 20.38 | 13.47 | 14.95 | 14.27 | 19.14 | 24.79 | 31.15 | 30.04 |
| an | 16.21 | 12.43 | 17.15 | 31.81 | 19.37 | 15.51 | 23.40 | 29.69 | 26.53 | 22.66 | 23.60 | 24.67 |
| ne | 2.54 | 5.94 | 4.93 | 0.00 | 1.17 | 0.67 | 0.25 | 5.89 | 0.00 | 0.00 | 0.46 | 1.93 |
| di | 49.29 | 43.91 | 28.62 | 29.18 | 24.26 | 40.74 | 26.86 | 17.23 | 16.08 | 10.45 | 13.15 | 13.85 |
| hy | 0.00 | 0.00 | 0.00 | 2.60 | 0.00 | 0.00 | 0.00 | 0.00 | 20.77 | 19.07 | 0.00 | 0.00 |
| ol | 12.00 | 3.89 | 8.29 | 9.44 | 16.20 | 14.68 | 17.55 | 10.05 | 0.00 | 0.00 | 10.70 | 14.79 |
| mt | 3.13 | 3.78 | 3.37 | 3.13 | 3.24 | 3.14 | 3.29 | 3.29 | 3.48 | 3.42 | 3.16 | 3.32 |
| il | 1.10 | 1.94 | 1.43 | 1.10 | 1.28 | 1.15 | 1.36 | 1.27 | 1.60 | 1.47 | 1.17 | 1.37 |
| ap | 0.66 | 0.54 | 0.73 | 0.34 | 0.65 | 1.14 | 0.80 | 0.92 | 0.60 | 0.76 | 0.75 | 0.93 |
| AN= | 63.55 | 31.24 | 32.85 | 61.33 | 48.73 | 53.52 | 61.02 | 67.54 | 58.09 | 47.75 | 43.11 | 45.09 |

## (APPENDIX K Continued)

**Quesnel CIPW Norms**

| SAMPLE | 35586 | 35325 | 35326 | 35330 | 32052 | 32053 | 32054 | 31597 | 31611 | 35577 | 35578 | DB1 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MAP UNIT | 2A/2D | 2B | 2B | 2B | 2B | 2B | 2B | 2B | 2B | 2B | 2B | 2B |
| **OXIDES AS DETERMINED** | | | | | | | | | | | | |
| $SiO_2$ | 50.01 | 46.64 | 47.14 | 47.36 | 49.23 | 47.13 | 46.79 | 49.19 | 48.51 | 45.96 | 47.99 | 47.90 |
| $TiO_2$ | 0.83 | 0.68 | 0.78 | 0.62 | 0.60 | 0.68 | 0.69 | 0.57 | 0.69 | 0.71 | 0.62 | 0.85 |
| $Al_2O_3$ | 16.57 | 11.59 | 13.72 | 13.45 | 15.07 | 13.64 | 12.86 | 11.15 | 16.63 | 12.42 | 9.65 | 15.75 |
| $Fe_2O_3$ | 2.33 | 2.18 | 2.28 | 2.12 | 2.10 | 2.18 | 2.19 | 2.07 | 2.19 | 2.21 | 2.12 | 2.35 |
| FeO | 6.74 | 7.61 | 8.17 | 7.59 | 6.39 | 8.72 | 8.56 | 7.30 | 5.80 | 8.34 | 7.93 | 8.99 |
| MnO | 0.16 | 0.18 | 0.20 | 0.21 | 0.16 | 0.26 | 0.18 | 0.16 | 0.21 | 0.24 | 0.19 | 0.24 |
| MgO | 5.51 | 8.59 | 6.23 | 5.71 | 7.01 | 6.26 | 8.29 | 9.21 | 4.07 | 6.56 | 10.35 | 5.85 |
| CaO | 7.20 | 9.16 | 9.25 | 10.05 | 7.14 | 9.94 | 11.03 | 12.96 | 6.80 | 13.67 | 11.92 | 8.98 |
| $Na_2O$ | 4.25 | 2.07 | 4.65 | 2.41 | 2.92 | 3.27 | 1.75 | 3.51 | 4.68 | 1.68 | 2.14 | 4.15 |
| $K_2O$ | 2.16 | 3.83 | 1.29 | 3.96 | 3.37 | 2.72 | 2.50 | 0.65 | 2.96 | 3.36 | 2.04 | 1.78 |
| $P_2O_5$ | 0.31 | 0.76 | 0.70 | 0.53 | 0.53 | 0.41 | 0.17 | 0.41 | 0.50 | 0.72 | 0.52 | 0.58 |
| $CO_2$ | 0.42 | 0.41 | 0.21 | 0.64 | 0.14 | 0.88 | 0.95 | 0.70 | 0.73 | 0.07 | 0.14 | 0.00 |
| LOI | 2.82 | 4.92 | 3.34 | 3.73 | 3.03 | 3.10 | 2.62 | 2.37 | 4.66 | 2.38 | 3.08 | 2.64 |
| TOTAL | 98.89 | 98.21 | 97.75 | 97.74 | 97.55 | 98.31 | 97.63 | 99.55 | 97.70 | 98.25 | 98.55 | 100.06 |
| **OXIDES RECALCULATED VOLATILE FREE** | | | | | | | | | | | | |
| $SiO_2$ | 52.06 | 49.99 | 49.93 | 50.38 | 52.08 | 49.50 | 49.25 | 50.62 | 52.14 | 47.94 | 50.27 | 49.17 |
| $TiO_2$ | 0.86 | 0.73 | 0.83 | 0.66 | 0.63 | 0.71 | 0.73 | 0.59 | 0.74 | 0.74 | 0.65 | 0.87 |
| $Al_2O_3$ | 17.25 | 12.42 | 14.53 | 14.31 | 15.94 | 14.33 | 13.54 | 11.47 | 17.87 | 12.96 | 10.11 | 16.17 |
| $Fe_2O_3$ | 2.43 | 2.34 | 2.41 | 2.26 | 2.22 | 2.29 | 2.31 | 2.13 | 2.35 | 2.31 | 2.22 | 2.41 |
| FeO | 7.02 | 8.16 | 8.65 | 8.07 | 6.76 | 9.16 | 9.01 | 7.51 | 6.23 | 8.70 | 8.31 | 9.23 |
| MnO | 0.17 | 0.19 | 0.21 | 0.22 | 0.17 | 0.27 | 0.19 | 0.16 | 0.23 | 0.25 | 0.20 | 0.25 |
| MgO | 5.74 | 9.21 | 6.60 | 6.07 | 7.42 | 6.57 | 8.73 | 9.48 | 4.37 | 6.84 | 10.84 | 6.00 |
| CaO | 7.49 | 9.82 | 9.80 | 10.69 | 7.55 | 10.44 | 11.61 | 13.34 | 7.31 | 14.26 | 12.49 | 9.22 |
| $Na_2O$ | 4.42 | 2.22 | 4.93 | 2.56 | 3.09 | 3.43 | 1.84 | 3.61 | 5.03 | 1.75 | 2.24 | 4.26 |
| $K_2O$ | 2.25 | 4.11 | 1.37 | 4.21 | 3.57 | 2.86 | 2.63 | 0.67 | 3.18 | 3.50 | 2.14 | 1.83 |
| $P_2O_5$ | 0.32 | 0.81 | 0.74 | 0.56 | 0.56 | 0.43 | 0.18 | 0.42 | 0.54 | 0.75 | 0.54 | 0.60 |
| TOTAL | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| **CIPW NORM VOLATILE FREE** | | | | | | | | | | | | |
| or | 13.29 | 24.26 | 8.07 | 24.89 | 21.07 | 16.88 | 15.55 | 3.95 | 18.80 | 19.98 | 12.63 | 10.80 |
| ab | 32.33 | 10.98 | 25.48 | 9.53 | 25.50 | 13.69 | 11.89 | 20.66 | 27.43 | 0.00 | 14.55 | 23.16 |
| an | 20.58 | 11.82 | 13.52 | 15.10 | 19.12 | 15.25 | 20.90 | 13.13 | 16.81 | 17.14 | 11.22 | 19.61 |
| ne | 2.76 | 4.22 | 8.76 | 6.59 | 0.34 | 8.32 | 2.00 | 5.36 | 8.19 | 8.03 | 2.39 | 6.98 |
| di | 11.84 | 25.60 | 24.82 | 28.14 | 11.92 | 27.78 | 28.96 | 40.66 | 13.09 | 39.96 | 38.13 | 18.35 |
| lc | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.57 | 0.00 | 0.00 |
| hy | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| ol | 13.32 | 16.48 | 12.57 | 9.94 | 16.35 | 12.43 | 15.58 | 11.08 | 9.64 | 7.85 | 15.40 | 14.60 |
| mt | 3.52 | 3.39 | 3.50 | 3.27 | 3.22 | 3.32 | 3.34 | 3.09 | 3.41 | 3.34 | 3.22 | 3.50 |
| il | 1.64 | 1.38 | 1.57 | 1.25 | 1.21 | 1.36 | 1.38 | 1.11 | 1.41 | 1.41 | 1.23 | 1.66 |
| ap | 0.75 | 1.90 | 1.73 | 1.31 | 1.31 | 1.00 | 0.42 | 0.98 | 1.25 | 1.75 | 1.27 | 1.39 |
| AN= | 38.89 | 51.86 | 34.67 | 61.31 | 42.85 | 52.70 | 63.74 | 38.85 | 38.00 | 100.00 | 43.53 | 45.85 |

| SAMPLE | DB2 | DB3 | DB4 | DB5 | DB6 | 35095 | 35563 | DB7 | DB8 | RM1 | 31608 | 35570 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MAP UNIT | 2B | 2B | 2B | 2B | 2B | 2C | 2C | 2C | 2C | 2C | 2D | 2D |
| **OXIDES AS DETERMINED** | | | | | | | | | | | | |
| $SiO_2$ | 48.30 | 48.70 | 45.70 | 47.40 | 46.20 | 50.77 | 46.36 | 48.20 | 48.40 | 51.43 | 50.32 | 47.60 |
| $TiO_2$ | 0.69 | 0.69 | 0.77 | 0.72 | 0.82 | 1.00 | 0.72 | 0.62 | 0.81 | 0.75 | 0.51 | 0.68 |
| $Al_2O_3$ | 13.10 | 12.90 | 11.70 | 11.90 | 13.10 | 18.50 | 17.12 | 13.75 | 17.80 | 15.76 | 10.64 | 10.31 |
| $Fe_2O_3$ | 2.19 | 2.19 | 2.27 | 2.22 | 2.32 | 2.50 | 2.22 | 2.12 | 2.31 | 2.25 | 2.01 | 2.18 |
| FeO | 8.60 | 7.77 | 9.79 | 8.23 | 9.41 | 5.51 | 7.20 | 7.83 | 7.86 | 6.22 | 6.64 | 8.94 |
| MnO | 0.23 | 0.19 | 0.18 | 0.18 | 0.19 | 0.23 | 0.20 | 0.23 | 0.24 | 0.17 | 0.19 | 0.20 |
| MgO | 7.10 | 9.50 | 7.90 | 10.20 | 6.70 | 3.19 | 5.35 | 7.85 | 4.85 | 3.86 | 12.54 | 9.59 |
| CaO | 8.32 | 10.25 | 12.65 | 11.35 | 11.20 | 6.81 | 8.25 | 12.65 | 8.65 | 6.65 | 9.51 | 14.14 |
| $Na_2O$ | 0.95 | 2.55 | 2.52 | 3.95 | 4.30 | 5.40 | 3.83 | 2.00 | 5.00 | 3.87 | 1.50 | 2.09 |
| $K_2O$ | 6.88 | 2.12 | 1.63 | 0.95 | 1.79 | 1.82 | 2.38 | 3.12 | 0.64 | 4.80 | 1.88 | 1.51 |
| $P_2O_5$ | 0.71 | 0.72 | 0.67 | 0.74 | 0.52 | 0.50 | 0.44 | 0.56 | 0.47 | 0.38 | 0.23 | 0.42 |
| $CO_2$ | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.61 | 0.48 | 0.00 | 0.00 | 0.00 | 0.01 | 0.07 |
| LOI | 2.86 | 2.49 | 3.14 | 2.81 | 4.70 | 2.79 | 4.58 | 2.22 | 3.04 | 2.12 | 2.82 | 0.86 |
| TOTAL | 99.93 | 100.07 | 98.92 | 100.65 | 101.25 | 99.02 | 98.65 | 101.15 | 100.07 | 98.26 | 98.79 | 98.52 |
| **OXIDES RECALCULATED VOLATILE FREE** | | | | | | | | | | | | |
| $SiO_2$ | 49.76 | 49.91 | 47.71 | 48.45 | 47.85 | 52.76 | 49.28 | 48.72 | 49.88 | 53.49 | 52.43 | 48.74 |
| $TiO_2$ | 0.71 | 0.71 | 0.80 | 0.74 | 0.85 | 1.04 | 0.77 | 0.63 | 0.83 | 0.78 | 0.53 | 0.70 |
| $Al_2O_3$ | 13.50 | 13.22 | 12.22 | 12.16 | 13.57 | 19.22 | 18.20 | 13.90 | 18.34 | 16.39 | 11.09 | 10.56 |
| $Fe_2O_3$ | 2.26 | 2.24 | 2.37 | 2.27 | 2.40 | 2.60 | 2.36 | 2.14 | 2.38 | 2.34 | 2.09 | 2.23 |
| FeO | 8.86 | 7.96 | 10.22 | 8.41 | 9.75 | 5.73 | 7.65 | 7.91 | 8.10 | 6.47 | 6.92 | 9.15 |
| MnO | 0.24 | 0.19 | 0.19 | 0.18 | 0.20 | 0.24 | 0.21 | 0.23 | 0.25 | 0.18 | 0.20 | 0.20 |
| MgO | 7.31 | 9.74 | 8.25 | 10.43 | 6.94 | 3.31 | 5.69 | 7.93 | 5.00 | 4.01 | 13.07 | 9.82 |
| CaO | 8.57 | 10.50 | 13.21 | 11.60 | 11.60 | 7.08 | 8.77 | 12.79 | 8.91 | 6.92 | 9.91 | 14.48 |
| $Na_2O$ | 0.98 | 2.61 | 2.63 | 4.04 | 4.45 | 5.61 | 4.07 | 2.02 | 5.15 | 4.03 | 1.56 | 2.14 |
| $K_2O$ | 7.09 | 2.17 | 1.70 | 0.97 | 1.85 | 1.89 | 2.53 | 3.15 | 0.66 | 4.99 | 1.96 | 1.55 |
| $P_2O_5$ | 0.73 | 0.74 | 0.70 | 0.76 | 0.54 | 0.52 | 0.47 | 0.57 | 0.48 | 0.40 | 0.24 | 0.43 |
| TOTAL | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| **CIPW NORM VOLATILE FREE** | | | | | | | | | | | | |
| or | 35.98 | 12.84 | 10.06 | 5.74 | 10.96 | 11.18 | 14.95 | 18.64 | 3.90 | 29.50 | 11.58 | 9.14 |
| ab | 0.00 | 20.32 | 10.57 | 17.25 | 10.55 | 39.20 | 20.17 | 5.69 | 32.59 | 21.82 | 13.22 | 9.18 |
| an | 11.51 | 17.94 | 16.51 | 12.21 | 11.57 | 21.70 | 23.93 | 19.55 | 24.99 | 11.93 | 17.46 | 14.64 |
| ne | 4.48 | 0.96 | 6.33 | 9.16 | 14.70 | 4.48 | 7.73 | 6.18 | 5.96 | 6.62 | 0.00 | 4.84 |
| di | 21.50 | 23.76 | 36.46 | 32.69 | 34.96 | 8.24 | 13.57 | 32.74 | 13.28 | 16.33 | 24.13 | 44.22 |
| lc | 4.63 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| hy | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 22.87 | 0.00 |
| ol | 15.61 | 17.89 | 13.52 | 16.54 | 10.95 | 8.28 | 13.72 | 11.62 | 13.15 | 8.03 | 6.16 | 12.46 |
| mt | 3.27 | 3.25 | 3.44 | 3.29 | 3.48 | 3.77 | 3.42 | 3.11 | 3.45 | 3.39 | 3.04 | 3.24 |
| il | 1.35 | 1.34 | 1.53 | 1.40 | 1.61 | 1.97 | 1.45 | 1.19 | 1.59 | 1.48 | 1.01 | 1.32 |
| ap | 1.70 | 1.72 | 1.63 | 1.76 | 1.26 | 1.21 | 1.09 | 1.32 | 1.13 | 0.92 | 0.56 | 1.00 |
| AN= | 100.00 | 46.88 | 60.97 | 41.45 | 52.31 | 35.63 | 54.26 | 77.44 | 43.41 | 35.34 | 56.91 | 61.47 |

**Quesnel CIPW Norms**

| SAMPLE | DB9 | DB10 | 35097 | 32050 | 37024 | RM2 | 31600 | 31603 | 31604 | 35093 | 35094 | 36265 | 35092 | DB11 | DB12 | DB13 | DB14 | DB15 | DB16 | DB17 | DB18 | DB19 | DB20 | 35556 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MAP UNIT | 2D | 2D | 2E | 2E | 2E | 2E | 2G | 2G | 2G | 3 | 3 | 3 | 3A | 3A | 3A | 3A | 3A | 3A | 3A | 3A | 3A | 3B | 3B | 4 |
| **OXIDES AS DETERMINED** | | | | | | | | | | | | | | | | | | | | | | | | |
| $SiO_2$ | 46.50 | 47.80 | 48.61 | 48.13 | 45.20 | 51.48 | 55.18 | 54.40 | 48.07 | 48.96 | 57.94 | 54.87 | 56.17 | 47.70 | 46.00 | 51.90 | 53.50 | 49.80 | 48.60 | 50.00 | 53.70 | 47.10 | 50.50 | 48.50 |
| $TiO_2$ | 0.81 | 0.93 | 0.84 | 0.64 | 0.74 | 0.74 | 0.64 | 0.55 | 0.76 | 0.80 | 0.46 | 0.70 | 0.77 | 0.76 | 0.99 | 0.75 | 0.74 | 1.07 | 0.84 | 0.83 | 0.64 | 0.82 | 0.88 | 0.80 |
| $Al_2O_3$ | 12.00 | 17.10 | 17.70 | 13.74 | 13.72 | 17.69 | 17.31 | 16.75 | 16.23 | 16.36 | 17.19 | 18.61 | 17.58 | 17.40 | 15.60 | 19.40 | 19.90 | 18.00 | 17.50 | 17.80 | 13.10 | 18.40 | 18.50 | 16.67 |
| $Fe_2O_3$ | 2.31 | 2.43 | 2.34 | 2.14 | 2.24 | 2.24 | 2.14 | 2.05 | 2.26 | 2.30 | 1.96 | 2.20 | 2.27 | 2.26 | 2.49 | 2.25 | 2.24 | 2.57 | 2.34 | 2.33 | 2.14 | 2.32 | 2.38 | 2.30 |
| FeO | 9.70 | 8.77 | 5.60 | 8.48 | 8.61 | 4.77 | 6.20 | 4.27 | 6.32 | 6.20 | 4.07 | 3.35 | 4.97 | 6.15 | 9.25 | 5.70 | 5.70 | 6.22 | 6.95 | 6.86 | 4.82 | 8.29 | 6.06 | 7.36 |
| MnO | 0.24 | 0.23 | 0.20 | 0.21 | 0.24 | 0.20 | 0.24 | 0.14 | 0.19 | 0.24 | 0.15 | 0.18 | 0.17 | 0.22 | 0.26 | 0.22 | 0.21 | 0.22 | 0.21 | 0.24 | 0.21 | 0.25 | 0.12 | 0.22 |
| MgO | 9.75 | 5.10 | 2.91 | 6.20 | 5.84 | 4.12 | 4.05 | 4.42 | 5.56 | 3.71 | 1.59 | 1.49 | 2.96 | 4.40 | 6.20 | 2.63 | 3.03 | 3.00 | 3.65 | 4.45 | 3.95 | 5.05 | 3.52 | 4.40 |
| CaO | 11.00 | 7.00 | 5.56 | 9.31 | 10.31 | 4.14 | 5.21 | 5.88 | 11.18 | 8.20 | 3.51 | 5.56 | 5.78 | 7.82 | 9.93 | 6.87 | 6.85 | 8.18 | 8.32 | 5.10 | 4.60 | 8.72 | 6.62 | 7.88 |
| $Na_2O$ | 3.90 | 3.62 | 5.33 | 3.21 | 3.28 | 4.55 | 5.11 | 3.13 | 2.91 | 2.88 | 6.98 | 5.42 | 4.72 | 4.30 | 3.05 | 5.30 | 5.00 | 4.90 | 3.95 | 5.30 | 5.30 | 1.98 | 4.30 | 4.17 |
| $K_2O$ | 0.82 | 3.20 | 3.45 | 2.78 | 1.87 | 5.51 | 1.30 | 4.38 | 1.13 | 4.44 | 2.08 | 3.81 | 1.76 | 3.60 | 3.63 | 2.62 | 2.70 | 1.68 | 2.90 | 3.32 | 4.52 | 3.93 | 3.28 | 2.38 |
| $P_2O_5$ | 0.54 | 0.35 | 0.51 | 0.45 | 0.68 | 0.48 | 0.23 | 0.25 | 0.57 | 0.39 | 0.39 | 0.23 | 0.25 | 0.60 | 0.56 | 0.33 | 0.41 | 0.42 | 0.40 | 0.38 | 0.28 | 0.29 | 0.31 | 0.52 |
| $CO_2$ | 0.00 | 0.00 | 0.34 | 0.27 | 0.35 | 0.00 | 0.01 | 0.11 | 0.01 | 0.62 | 1.51 | 0.84 | 0.62 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.49 |
| LOI | 3.87 | 3.79 | 5.79 | 2.83 | 5.64 | 4.39 | 2.48 | 2.21 | 2.67 | 4.18 | 2.96 | 2.82 | 1.93 | 4.99 | 2.10 | 2.87 | 2.04 | 3.26 | 4.26 | 3.86 | 2.03 | 2.87 | 3.86 | 3.65 |
| TOTAL | 101.44 | 100.32 | 98.84 | 98.12 | 98.37 | 100.31 | 100.09 | 98.43 | 97.85 | 98.66 | 99.28 | 99.24 | 99.33 | 100.20 | 100.06 | 100.84 | 102.32 | 99.32 | 99.92 | 100.47 | 95.29 | 100.02 | 100.33 | 98.85 |
| **OXIDES RECALCULATED VOLATILE FREE** | | | | | | | | | | | | | | | | | | | | | | | | |
| $SiO_2$ | 47.66 | 49.52 | 52.24 | 50.51 | 48.74 | 53.67 | 56.53 | 56.54 | 50.50 | 51.82 | 60.15 | 56.91 | 57.67 | 50.10 | 46.96 | 52.98 | 53.35 | 51.84 | 50.80 | 51.75 | 57.58 | 48.48 | 52.35 | 50.95 |
| $TiO_2$ | 0.83 | 0.96 | 0.90 | 0.67 | 0.80 | 0.77 | 0.66 | 0.57 | 0.80 | 0.85 | 0.48 | 0.73 | 0.79 | 0.80 | 1.01 | 0.77 | 0.74 | 1.11 | 0.88 | 0.86 | 0.69 | 0.84 | 0.91 | 0.84 |
| $Al_2O_3$ | 12.30 | 17.71 | 19.02 | 14.42 | 14.80 | 18.44 | 17.73 | 17.41 | 17.05 | 17.32 | 17.85 | 19.30 | 18.05 | 18.28 | 15.92 | 19.80 | 19.84 | 18.74 | 18.29 | 18.42 | 14.05 | 18.94 | 19.18 | 17.51 |
| $Fe_2O_3$ | 2.37 | 2.52 | 2.51 | 2.25 | 2.42 | 2.34 | 2.19 | 2.13 | 2.37 | 2.43 | 2.03 | 2.28 | 2.33 | 2.37 | 2.54 | 2.30 | 2.23 | 2.68 | 2.45 | 2.41 | 2.29 | 2.39 | 2.47 | 2.42 |
| FeO | 9.94 | 9.09 | 6.02 | 8.90 | 9.29 | 4.97 | 6.35 | 4.44 | 6.64 | 6.56 | 4.23 | 3.47 | 5.10 | 6.46 | 9.44 | 5.82 | 5.68 | 6.48 | 7.27 | 7.10 | 5.17 | 8.53 | 6.28 | 7.73 |
| MnO | 0.25 | 0.24 | 0.21 | 0.22 | 0.26 | 0.21 | 0.25 | 0.15 | 0.20 | 0.25 | 0.16 | 0.19 | 0.17 | 0.23 | 0.27 | 0.22 | 0.21 | 0.23 | 0.22 | 0.25 | 0.23 | 0.26 | 0.12 | 0.23 |
| MgO | 9.99 | 5.28 | 3.13 | 6.51 | 6.30 | 4.30 | 4.15 | 4.59 | 5.84 | 3.93 | 1.65 | 1.55 | 3.04 | 4.62 | 6.33 | 2.68 | 3.02 | 3.12 | 3.82 | 4.61 | 4.24 | 5.20 | 3.65 | 4.62 |
| CaO | 11.27 | 7.25 | 5.98 | 9.77 | 11.12 | 4.32 | 5.34 | 6.11 | 11.75 | 8.68 | 3.64 | 5.77 | 5.93 | 8.21 | 10.14 | 7.01 | 6.83 | 8.52 | 8.70 | 5.28 | 4.93 | 8.98 | 6.86 | 8.28 |
| $Na_2O$ | 4.00 | 3.75 | 5.73 | 3.37 | 3.54 | 4.74 | 5.24 | 3.25 | 3.06 | 3.05 | 7.25 | 5.62 | 4.85 | 4.52 | 3.11 | 5.41 | 4.99 | 5.10 | 4.13 | 5.49 | 5.68 | 2.04 | 4.46 | 4.38 |
| $K_2O$ | 0.84 | 3.32 | 3.71 | 2.92 | 2.02 | 5.74 | 1.33 | 4.55 | 1.19 | 4.70 | 2.16 | 3.95 | 1.81 | 3.78 | 3.71 | 2.67 | 2.69 | 1.75 | 3.03 | 3.44 | 4.85 | 4.05 | 3.40 | 2.50 |
| $P_2O_5$ | 0.55 | 0.36 | 0.55 | 0.47 | 0.73 | 0.50 | 0.24 | 0.26 | 0.60 | 0.41 | 0.40 | 0.24 | 0.26 | 0.63 | 0.57 | 0.34 | 0.41 | 0.44 | 0.42 | 0.39 | 0.30 | 0.30 | 0.32 | 0.55 |
| TOTAL | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| **CIPW NORM VOLATILE FREE** | | | | | | | | | | | | | | | | | | | | | | | | |
| Q | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.72 | 0.39 | 0.00 | 0.00 | 0.00 | 0.00 | 4.34 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| or | 4.97 | 19.59 | 21.91 | 17.24 | 11.92 | 33.95 | 7.87 | 26.90 | 7.02 | 27.77 | 12.76 | 23.35 | 10.68 | 22.34 | 21.90 | 15.80 | 15.91 | 10.33 | 17.91 | 20.31 | 28.64 | 23.90 | 20.09 | 14.77 |
| ab | 16.14 | 20.40 | 27.83 | 18.46 | 17.33 | 23.33 | 44.28 | 27.52 | 25.86 | 16.90 | 61.30 | 40.29 | 40.99 | 16.46 | 3.84 | 33.93 | 36.44 | 34.53 | 22.96 | 28.23 | 33.23 | 11.32 | 29.18 | 27.32 |
| an | 13.15 | 21.73 | 15.26 | 15.62 | 18.55 | 12.08 | 20.97 | 19.47 | 29.31 | 19.70 | 9.81 | 15.78 | 22.18 | 18.44 | 18.55 | 21.87 | 23.83 | 23.08 | 22.44 | 15.52 | 0.00 | 30.60 | 22.29 | 20.75 |
| ne | 9.57 | 6.13 | 11.17 | 5.44 | 6.82 | 9.10 | 0.00 | 0.00 | 0.00 | 4.81 | 0.00 | 3.93 | 0.00 | 11.78 | 12.19 | 6.41 | 3.11 | 4.67 | 6.49 | 9.85 | 6.53 | 3.21 | 4.62 | 5.27 |
| ac | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 2.46 | 0.00 | 0.00 | 0.00 |
| di | 31.91 | 9.84 | 8.94 | 24.50 | 26.24 | 4.93 | 3.27 | 7.41 | 20.43 | 17.05 | 4.70 | 9.31 | 4.60 | 14.93 | 23.09 | 8.92 | 6.12 | 13.52 | 14.91 | 6.68 | 18.42 | 9.91 | 7.96 | 13.84 |
| hy | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 17.94 | 13.57 | 3.55 | 0.00 | 4.72 | 0.00 | 11.77 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| ol | 17.99 | 16.02 | 8.28 | 13.15 | 12.45 | 10.63 | 0.00 | 0.00 | 7.52 | 7.69 | 1.94 | 2.13 | 0.00 | 9.65 | 13.54 | 7.53 | 9.03 | 6.88 | 9.13 | 13.41 | 6.65 | 15.33 | 9.83 | 11.70 |
| mt | 3.43 | 3.65 | 3.65 | 3.26 | 3.50 | 3.39 | 3.18 | 3.09 | 3.44 | 3.53 | 2.95 | 3.31 | 3.38 | 3.44 | 3.69 | 3.33 | 3.24 | 3.88 | 3.55 | 3.50 | 2.10 | 3.46 | 3.58 | 3.50 |
| il | 1.58 | 1.83 | 1.71 | 1.28 | 1.52 | 1.47 | 1.25 | 1.09 | 1.52 | 1.61 | 0.91 | 1.38 | 1.50 | 1.52 | 1.92 | 1.45 | 1.40 | 2.12 | 1.67 | 1.63 | 1.30 | 1.60 | 1.73 | 1.60 |
| ap | 1.29 | 0.85 | 1.28 | 1.10 | 1.71 | 1.17 | 0.55 | 0.61 | 1.40 | 0.96 | 0.94 | 0.56 | 0.60 | 1.47 | 1.33 | 0.79 | 0.95 | 1.02 | 0.97 | 0.92 | 0.70 | 0.70 | 0.75 | 1.27 |
| AN= | 44.89 | 51.57 | 35.41 | 45.83 | 51.71 | 34.11 | 32.14 | 41.43 | 53.13 | 53.82 | 13.80 | 28.14 | 35.11 | 52.84 | 82.85 | 39.19 | 39.54 | 40.07 | 49.43 | 35.47 | 0.00 | 72.99 | 43.31 | 43.17 |

## *(APPENDIX K Continued)*

**Quesnel CIPW Norms**

| SAMPLE | DB21 | DB22 | 31599 | 31618 | 31602 | 31605 | 31606 | 31610 | 37025 | 37030 | 38436 | RM3 | 37027 | 37028 | 35091 | 35096 | 37029 | 35098 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MAP UNIT | 4 | 4 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 7 | 8 | 8 | 10a | 10b | 10c | 11 |
| **OXIDES AS DETERMINED** | | | | | | | | | | | | | | | | | | |
| $SiO_2$ | 47.90 | 50.40 | 48.13 | 52.20 | 54.35 | 50.35 | 48.20 | 53.55 | 54.89 | 47.51 | 52.26 | 48.53 | 54.29 | 59.73 | 51.23 | 58.59 | 45.54 | 48.55 |
| $TiO_2$ | 0.95 | 0.73 | 0.61 | 1.04 | 0.59 | 0.68 | 0.99 | 0.77 | 0.61 | 0.76 | 0.72 | 1.11 | 1.04 | 0.63 | 1.01 | 0.41 | 1.11 | 2.04 |
| $Al_2O_3$ | 16.90 | 14.20 | 9.94 | 14.98 | 17.71 | 15.61 | 17.80 | 17.93 | 18.34 | 17.37 | 16.75 | 14.10 | 16.75 | 13.92 | 11.87 | 17.54 | 11.43 | 13.06 |
| $Fe_2O_3$ | 2.45 | 2.23 | 2.11 | 2.54 | 2.08 | 2.18 | 2.49 | 2.27 | 2.11 | 2.26 | 2.22 | 2.61 | 2.54 | 2.13 | 2.51 | 1.91 | 2.61 | 3.54 |
| FeO | 8.31 | 9.00 | 8.17 | 6.91 | 5.10 | 7.85 | 7.10 | 5.48 | 4.36 | 7.93 | 4.85 | 7.47 | 6.42 | 3.37 | 2.99 | 3.06 | 5.85 | 8.25 |
| MnO | 0.21 | 0.17 | 0.20 | 0.22 | 0.15 | 0.21 | 0.11 | 0.19 | 0.19 | 0.22 | 0.13 | 0.15 | 0.14 | 0.12 | 0.11 | 0.19 | 0.16 | 0.17 |
| MgO | 4.15 | 5.80 | 10.63 | 6.16 | 3.31 | 4.95 | 4.13 | 3.01 | 3.19 | 4.98 | 5.01 | 7.04 | 3.84 | 4.83 | 5.43 | 1.15 | 8.86 | 8.43 |
| CaO | 7.95 | 8.40 | 13.33 | 9.25 | 6.69 | 9.31 | 9.65 | 7.41 | 7.84 | 9.03 | 10.05 | 10.01 | 5.90 | 5.05 | 6.97 | 5.66 | 8.77 | 8.92 |
| $Na_2O$ | 4.18 | 4.90 | 1.56 | 2.97 | 3.90 | 2.48 | 3.02 | 3.71 | 3.48 | 3.13 | 2.22 | 3.61 | 4.76 | 4.05 | 2.85 | 4.00 | 2.63 | 2.91 |
| $K_2O$ | 3.22 | 0.91 | 2.18 | 1.82 | 3.65 | 3.65 | 2.50 | 2.55 | 2.52 | 2.72 | 2.28 | 2.08 | 0.38 | 2.20 | 4.31 | 2.30 | 0.96 | 0.77 |
| $P_2O_5$ | 0.53 | 0.38 | 0.30 | 0.30 | 0.45 | 0.45 | 0.37 | 0.40 | 0.30 | 0.49 | 0.25 | 0.40 | 0.13 | 0.22 | 0.78 | 0.18 | 0.89 | 0.33 |
| $CO_2$ | 0.00 | 0.00 | 0.11 | 0.01 | 0.06 | 0.34 | 0.34 | 0.01 | 0.15 | 0.15 | 1.14 | 0.00 | 0.17 | 1.14 | 7.53 | 1.77 | 5.60 | 1.71 |
| LOI | 3.92 | 2.96 | 2.11 | 1.32 | 1.10 | 0.47 | 2.46 | 1.47 | 1.86 | 2.42 | 2.81 | 1.79 | 3.02 | 2.94 | 8.74 | 4.24 | 8.94 | 1.88 |
| TOTAL | 100.67 | 100.08 | 99.27 | 99.71 | 99.08 | 98.19 | 98.82 | 98.74 | 99.69 | 98.82 | 99.55 | 98.90 | 99.21 | 99.19 | 98.80 | 99.23 | 97.75 | 98.85 |
| **OXIDES RECALCULATED VOLATILE FREE** | | | | | | | | | | | | | | | | | | |
| $SiO_2$ | 49.51 | 51.89 | 49.54 | 53.05 | 55.47 | 51.52 | 50.02 | 55.05 | 56.11 | 49.28 | 54.02 | 49.97 | 56.44 | 62.06 | 56.88 | 61.68 | 51.28 | 50.07 |
| $TiO_2$ | 0.98 | 0.75 | 0.63 | 1.06 | 0.60 | 0.70 | 1.03 | 0.79 | 0.62 | 0.79 | 0.74 | 1.14 | 1.08 | 0.65 | 1.12 | 0.43 | 1.25 | 2.10 |
| $Al_2O_3$ | 17.47 | 14.62 | 10.23 | 15.23 | 18.08 | 15.97 | 18.47 | 18.43 | 18.75 | 18.02 | 17.31 | 14.52 | 17.41 | 14.46 | 13.18 | 18.47 | 12.87 | 13.47 |
| $Fe_2O_3$ | 2.53 | 2.30 | 2.17 | 2.58 | 2.12 | 2.23 | 2.58 | 2.33 | 2.16 | 2.34 | 2.29 | 2.69 | 2.64 | 2.21 | 2.79 | 2.01 | 2.94 | 3.65 |
| FeO | 8.59 | 9.27 | 8.41 | 7.02 | 5.21 | 8.03 | 7.37 | 5.63 | 4.46 | 8.23 | 5.01 | 7.69 | 6.67 | 3.50 | 3.32 | 3.22 | 6.59 | 8.51 |
| MnO | 0.22 | 0.18 | 0.21 | 0.22 | 0.15 | 0.21 | 0.11 | 0.20 | 0.19 | 0.23 | 0.13 | 0.15 | 0.15 | 0.12 | 0.12 | 0.20 | 0.18 | 0.18 |
| MgO | 4.29 | 5.97 | 10.94 | 6.26 | 3.38 | 5.07 | 4.29 | 3.09 | 3.26 | 5.17 | 5.18 | 7.25 | 3.99 | 5.02 | 6.03 | 1.21 | 9.98 | 8.69 |
| CaO | 8.22 | 8.65 | 13.72 | 9.40 | 6.83 | 9.53 | 10.01 | 7.62 | 8.01 | 9.37 | 10.39 | 10.31 | 6.13 | 5.25 | 7.74 | 5.96 | 9.88 | 9.20 |
| $Na_2O$ | 4.32 | 5.05 | 1.61 | 3.02 | 3.98 | 2.54 | 3.13 | 3.81 | 3.56 | 3.25 | 2.29 | 3.72 | 4.95 | 4.21 | 3.16 | 4.21 | 2.96 | 3.00 |
| $K_2O$ | 3.33 | 0.94 | 2.24 | 1.85 | 3.73 | 3.74 | 2.59 | 2.62 | 2.58 | 2.82 | 2.36 | 2.14 | 0.40 | 2.29 | 4.79 | 2.42 | 1.08 | 0.79 |
| $P_2O_5$ | 0.55 | 0.39 | 0.31 | 0.30 | 0.46 | 0.46 | 0.38 | 0.41 | 0.31 | 0.51 | 0.26 | 0.41 | 0.14 | 0.23 | 0.87 | 0.19 | 1.00 | 0.34 |
| TOTAL | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| **CIPW NORM VOLATILE FREE** | | | | | | | | | | | | | | | | | | |
| Q | 0.00 | 0.00 | 0.00 | 0.31 | 0.00 | 0.00 | 0.00 | 1.77 | 4.01 | 0.00 | 3.84 | 0.00 | 4.73 | 11.39 | 1.50 | 12.99 | 0.00 | 0.00 |
| or | 19.67 | 5.54 | 13.26 | 10.93 | 22.01 | 22.07 | 15.33 | 15.49 | 15.22 | 16.67 | 13.93 | 12.66 | 2.33 | 13.51 | 28.28 | 14.31 | 6.39 | 4.69 |
| ab | 18.21 | 35.41 | 8.36 | 25.53 | 33.67 | 20.00 | 22.27 | 32.26 | 30.09 | 19.09 | 19.41 | 20.41 | 41.86 | 35.59 | 26.77 | 35.62 | 25.05 | 25.38 |
| an | 18.46 | 14.50 | 14.09 | 22.54 | 20.47 | 21.18 | 28.69 | 25.45 | 27.59 | 26.27 | 29.99 | 16.62 | 24.15 | 13.84 | 7.64 | 24.35 | 18.64 | 20.94 |
| ne | 9.93 | 3.93 | 2.83 | 0.00 | 0.00 | 0.79 | 2.29 | 0.00 | 0.00 | 4.54 | 0.00 | 5.98 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| ac | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| di | 15.58 | 21.36 | 42.01 | 18.00 | 8.56 | 19.07 | 15.26 | 7.98 | 8.31 | 13.94 | 16.07 | 25.87 | 4.44 | 8.55 | 19.82 | 3.32 | 19.05 | 18.12 |
| hy | 0.00 | 0.00 | 0.00 | 16.26 | 6.56 | 0.00 | 0.00 | 11.23 | 9.78 | 0.00 | 11.45 | 0.00 | 16.31 | 12.16 | 7.84 | 5.27 | 17.52 | 16.73 |
| ol | 11.37 | 13.62 | 14.42 | 0.00 | 3.47 | 11.29 | 9.59 | 0.00 | 0.00 | 13.43 | 0.00 | 11.47 | 0.00 | 0.00 | 0.00 | 0.00 | 4.41 | 4.07 |
| mt | 3.67 | 3.33 | 3.15 | 3.74 | 3.08 | 3.23 | 3.75 | 3.38 | 3.13 | 3.40 | 3.33 | 3.90 | 3.83 | 3.21 | 4.04 | 2.92 | 4.26 | 5.29 |
| il | 1.86 | 1.43 | 1.19 | 2.01 | 1.14 | 1.32 | 1.95 | 1.50 | 1.18 | 1.50 | 1.41 | 2.17 | 2.05 | 1.24 | 2.13 | 0.82 | 2.37 | 4.00 |
| ap | 1.28 | 0.91 | 0.72 | 0.71 | 1.07 | 1.07 | 0.90 | 0.96 | 0.71 | 1.18 | 0.60 | 0.96 | 0.32 | 0.53 | 2.02 | 0.44 | 2.34 | 0.79 |
| AN= | 50.33 | 29.04 | 62.76 | 46.89 | 37.80 | 51.43 | 56.29 | 44.10 | 47.84 | 57.91 | 60.71 | 44.87 | 36.59 | 27.99 | 22.19 | 40.60 | 42.67 | 45.21 |

*(APPENDIX K Continued)*

| SAMPLE | AVE | AVE | AVE | AVE | AVE | AVE | AVE | AVE | AVE | AVE | AVE | AVE | AVE | AVE | AVE | AVE | AVE | AVE |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MAP UNIT | 1A | 2A | 2A/2D | 2B | 2C | 2D | 2E | 2G | 3 | 3A | 3B | 4 | 7 | 8 | 10a | 10b | 10c | 11 |
| **OXIDES AS DETERMINED** | | | | | | | | | | | | | | | | | | |
| $SiO_2$ | 49.78 | 47.70 | 50.33 | 47.51 | 49.03 | 48.06 | 48.36 | 52.55 | 53.92 | 50.82 | 48.80 | 48.93 | 51.00 | 57.01 | 51.23 | 58.59 | 45.54 | 48.55 |
| $TiO_2$ | 0.69 | 0.66 | 0.73 | 0.70 | 0.78 | 0.73 | 0.74 | 0.65 | 0.65 | 0.82 | 0.85 | 0.83 | 0.79 | 0.84 | 1.01 | 0.41 | 1.11 | 2.04 |
| $Al_2O_3$ | 13.73 | 13.17 | 15.99 | 13.04 | 16.59 | 12.51 | 15.71 | 16.76 | 17.39 | 17.36 | 18.45 | 15.92 | 16.05 | 15.34 | 11.87 | 17.54 | 11.43 | 13.06 |
| $Fe_2O_3$ | 11.23 | 2.16 | 2.23 | 2.20 | 2.28 | 2.23 | 2.24 | 2.15 | 2.15 | 2.32 | 2.35 | 2.33 | 2.29 | 2.34 | 2.51 | 1.91 | 2.61 | 3.54 |
| FeO | ----- | 7.48 | 6.88 | 8.08 | 6.92 | 8.51 | 6.87 | 5.60 | 4.54 | 6.29 | 7.18 | 8.22 | 6.52 | 4.90 | 2.99 | 3.06 | 5.85 | 8.25 |
| MnO | 0.19 | 0.19 | 0.17 | 0.20 | 0.21 | 0.22 | 0.21 | 0.19 | 0.19 | 0.22 | 0.19 | 0.20 | 0.18 | 0.13 | 0.11 | 0.19 | 0.16 | 0.17 |
| MgO | 9.55 | 7.70 | 5.62 | 7.47 | 5.02 | 9.25 | 4.77 | 4.68 | 2.26 | 3.81 | 4.29 | 4.78 | 5.24 | 4.34 | 5.43 | 1.15 | 8.86 | 8.43 |
| CaO | 10.52 | 11.23 | 8.05 | 10.29 | 8.60 | 10.41 | 7.33 | 7.42 | 5.76 | 7.05 | 7.67 | 8.08 | 9.26 | 5.48 | 6.97 | 5.66 | 8.77 | 8.92 |
| $Na_2O$ | 2.09 | 2.54 | 3.33 | 2.97 | 4.02 | 2.78 | 4.09 | 3.72 | 5.09 | 4.65 | 3.14 | 4.42 | 3.01 | 4.41 | 2.85 | 4.00 | 2.63 | 2.91 |
| $K_2O$ | 1.71 | 2.09 | 2.07 | 2.61 | 2.55 | 1.85 | 3.40 | 2.27 | 3.44 | 2.97 | 3.61 | 2.17 | 2.60 | 1.29 | 4.31 | 2.30 | 0.96 | 0.77 |
| $P_2O_5$ | 0.34 | 0.34 | 0.31 | 0.57 | 0.47 | 0.39 | 0.53 | 0.35 | 0.34 | 0.40 | 0.30 | 0.48 | 0.37 | 0.18 | 0.78 | 0.18 | 0.89 | 0.33 |
| $CO_2$ | 1.81 | 0.64 | 0.32 | 0.30 | 0.22 | 0.02 | 0.24 | 0.04 | 0.99 | 0.07 | 0.00 | 0.16 | 0.23 | 0.66 | 7.53 | 1.77 | 5.60 | 1.71 |
| LOI | 5.28 | 3.43 | 3.00 | 3.24 | 2.95 | 2.84 | 4.66 | 2.45 | 3.32 | 3.04 | 3.37 | 3.51 | 1.78 | 2.98 | 8.74 | 4.24 | 8.94 | 1.88 |
| TOTAL | 99.89 | 98.70 | 98.71 | 98.88 | 99.43 | 99.77 | 98.91 | 98.79 | 99.06 | 99.75 | 100.18 | 99.87 | 99.08 | 99.20 | 98.80 | 99.23 | 97.75 | 98.85 |
| **OXIDES RECALCULATED VOLATILE FREE** | | | | | | | | | | | | | | | | | | |
| $SiO_2$ | 49.92 | 50.08 | 52.59 | 49.68 | 50.83 | 49.59 | 51.29 | 54.52 | 56.29 | 52.56 | 50.42 | 50.78 | 52.40 | 59.25 | 56.88 | 61.68 | 51.28 | 50.07 |
| $TiO_2$ | 0.69 | 0.69 | 0.76 | 0.73 | 0.81 | 0.76 | 0.79 | 0.68 | 0.69 | 0.85 | 0.88 | 0.86 | 0.81 | 0.87 | 1.12 | 0.43 | 1.25 | 2.10 |
| $Al_2O_3$ | 13.78 | 13.84 | 16.70 | 13.65 | 17.21 | 12.92 | 16.67 | 17.40 | 18.16 | 17.93 | 19.06 | 16.53 | 16.50 | 15.94 | 13.18 | 18.47 | 12.87 | 13.47 |
| $Fe_2O_3$ | 11.24 | 2.27 | 2.33 | 2.30 | 2.36 | 2.30 | 2.38 | 2.23 | 2.25 | 2.40 | 2.43 | 2.42 | 2.35 | 2.43 | 2.79 | 2.01 | 2.94 | 3.65 |
| FeO | ----- | 7.84 | 7.19 | 8.44 | 7.17 | 8.78 | 7.30 | 5.81 | 4.75 | 6.50 | 7.41 | 8.53 | 6.71 | 5.09 | 3.32 | 3.22 | 6.59 | 8.51 |
| MnO | 0.19 | 0.20 | 0.18 | 0.21 | 0.22 | 0.22 | 0.23 | 0.20 | 0.20 | 0.23 | 0.19 | 0.21 | 0.18 | 0.14 | 0.12 | 0.20 | 0.18 | 0.18 |
| MgO | 9.57 | 8.07 | 5.87 | 7.80 | 5.19 | 9.54 | 5.06 | 4.86 | 2.38 | 3.94 | 4.43 | 4.96 | 5.39 | 4.51 | 6.03 | 1.21 | 9.98 | 8.69 |
| CaO | 10.55 | 11.78 | 8.41 | 10.75 | 8.89 | 10.73 | 7.80 | 7.73 | 6.03 | 7.28 | 7.92 | 8.38 | 9.52 | 5.69 | 7.74 | 5.96 | 9.88 | 9.20 |
| $Na_2O$ | 2.09 | 2.67 | 3.47 | 3.10 | 4.18 | 2.86 | 4.35 | 3.85 | 5.31 | 4.81 | 3.25 | 4.58 | 3.09 | 4.58 | 3.16 | 4.21 | 2.96 | 3.00 |
| $K_2O$ | 1.72 | 2.19 | 2.16 | 2.74 | 2.64 | 1.92 | 3.60 | 2.36 | 3.60 | 3.08 | 3.73 | 2.26 | 2.67 | 1.35 | 4.79 | 2.42 | 1.08 | 0.79 |
| $P_2O_5$ | 0.35 | 0.36 | 0.33 | 0.60 | 0.49 | 0.40 | 0.56 | 0.37 | 0.35 | 0.42 | 0.31 | 0.50 | 0.38 | 0.19 | 0.87 | 0.19 | 1.00 | 0.34 |
| TOTAL | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 | 100.00 |
| **CIPW NORM VOLATILE FREE** | | | | | | | | | | | | | | | | | | |
| Q | 0.19 | 0.00 | 0.74 | 0.00 | 0.00 | 0.00 | 0.00 | 0.37 | 0.00 | 0.48 | 0.00 | 0.00 | 0.99 | 8.06 | 1.50 | 12.99 | 0.00 | 0.00 |
| or | 10.15 | 12.97 | 12.78 | 15.78 | 15.63 | 11.32 | 21.26 | 13.93 | 21.29 | 18.20 | 22.00 | 13.33 | 15.76 | 7.92 | 28.28 | 14.31 | 6.39 | 4.69 |
| ab | 15.73 | 16.41 | 27.49 | 15.10 | 23.89 | 14.74 | 21.74 | 32.55 | 39.50 | 27.85 | 20.25 | 26.98 | 23.11 | 38.73 | 26.77 | 35.62 | 25.05 | 25.38 |
| an | 23.12 | 19.29 | 23.61 | 15.21 | 20.42 | 16.75 | 15.38 | 23.25 | 15.10 | 18.43 | 26.45 | 17.90 | 23.29 | 19.00 | 7.64 | 24.35 | 18.64 | 20.94 |
| ne | 1.07 | 3.36 | 1.03 | 6.05 | 6.19 | 5.14 | 8.13 | 0.00 | 2.91 | 6.78 | 3.92 | 6.38 | 1.64 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| ac | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.27 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| di | 21.91 | 29.89 | 13.07 | 27.92 | 16.83 | 27.53 | 16.15 | 10.37 | 10.35 | 12.35 | 8.94 | 16.93 | 17.51 | 6.50 | 19.82 | 3.32 | 19.05 | 18.12 |
| lc | 0.00 | 0.00 | 0.00 | 0.33 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| hy | 11.83 | 0.20 | 7.97 | 0.00 | 0.00 | 5.72 | 0.00 | 11.69 | 1.57 | 1.31 | 0.00 | 0.00 | 5.53 | 14.24 | 7.84 | 5.27 | 17.52 | 16.73 |
| ol | 9.85 | 12.47 | 7.76 | 13.53 | 10.96 | 13.16 | 11.13 | 2.51 | 3.92 | 8.42 | 12.58 | 12.23 | 6.37 | 0.00 | 0.00 | 0.00 | 4.41 | 4.07 |
| mt | 3.18 | 3.29 | 3.38 | 3.33 | 3.43 | 3.34 | 3.45 | 3.24 | 3.26 | 3.35 | 3.52 | 3.50 | 3.41 | 3.52 | 4.04 | 2.92 | 4.26 | 5.29 |
| il | 1.31 | 1.31 | 1.45 | 1.39 | 1.54 | 1.44 | 1.50 | 1.29 | 1.30 | 1.61 | 1.67 | 1.63 | 1.54 | 1.65 | 2.13 | 0.82 | 2.37 | 4.00 |
| ap | 0.81 | 0.84 | 0.76 | 1.40 | 1.13 | 0.93 | 1.32 | 0.85 | 0.82 | 0.97 | 0.73 | 1.15 | 0.89 | 0.43 | 2.02 | 0.44 | 2.34 | 0.79 |
| AN= | 61.92 | 58.13 | 46.59 | 54.69 | 49.22 | 53.71 | 41.77 | 42.23 | 31.92 | 41.61 | 58.15 | 40.85 | 51.06 | 32.29 | 22.19 | 40.60 | 42.67 | 45.21 |

**CIPW norms calculated by GSB program (Don MacIntyre 1992)*
***Averages calculated for 84 analyses plus 29 analyses of unit 1A from Bloodgood, 1987. AVE = average value for Unit*
****$Fe_2O_3$ values for unit 1A = $Fe_2O_3$ Total; nd = not determined*

## APPENDIX L
## ANALYSIS OF FERRIC AND FERROUS IRON ($Fe^{=3}$ and $Fe^{+2}$), IN PERCENT, FROM QUESNEL VOLCANIC AND INTRUSIVE ROCKS COMPARED TO VALUES CALCULATED FROM TOTAL Fe (FeO*)

| Lab No | Map unit | FeO Analyzed | FeO Calculated | $Fe_2O_3$ Analyzed | $Fe_2O_3$ Calculated |
|---|---|---|---|---|---|
| 31597 | 2b | 4.5 | 7.3 | 5.2 | 2.1 |
| 611 | 2a | 4.9 | 5.8 | 3.2 | 2.2 |
| 607 | 2a | 5.4 | 7.3 | 4.1 | 2.1 |
| 609 | 2a | 6.1 | 5.2 | 1.5 | 2.5 |
| 600 | 2g | 4.2 | 6.2 | 4.3 | 2.1 |
| 603 | 2g | 3.4 | 4.3 | 3 | 2.1 |
| 604 | 2g | 4.1 | 6.3 | 4.7 | 2.3 |
| 608 | 2d | 5.9 | 6.6 | 2.9 | 2 |
| 599 | 7 | 5.4 | 8.2 | 5.2 | 2.1 |
| 602 | 7 | 3.6 | 5.1 | 3.7 | 2.1 |
| 605 | 7 | 5.3 | 7.9 | 5 | 2.2 |
| 606 | 7 | 4.6 | 7.1 | 5.2 | 2.5 |
| 610 | 7 | 4.4 | 5.5 | 3.5 | 2.3 |

*Convention used - Irvine and Baragar (1971): FeO* or FeOT reported as Fe2O3; Fe2O3 = approximately Ti + 1.5 and FeO* = FeO + $Fe_2O_3$ x 0.8998 and Fe2O3* = $Fe_2O_3$ + FeO x 1.11135*

# APPENDIX M
## LITHOGEOCHEMICAL ANALYSES (125 ASSAY SAMPLES), IN ppm

| LAB NO | FIELD NO | Au ppb | Ag | Cu | Pb | Zn | Co | Ni | Mo | Hg ppb | As | Sb | Ba |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 31617 | 85AP-20/12-118-AX9 | < | < | 110 | 10 | 70 | 16 | 21 | 0 | 0 | 0 | < | 0 |
| 32647 | 86AP-14/12-AX3 | *84 | < | 0 | 0 | 0 | 0 | 0 | 0 | 82 | 0 | < | 0 |
| 32649 | 86AP-25/4-77-AX5 | 21 | < | 0 | 0 | 0 | 0 | 0 | 0 | 101 | 0 | < | 0 |
| 32651 | 86AP-26/4-87-AX7 | < | < | 0 | 0 | 0 | 0 | 0 | 0 | 20 | 0 | < | 0 |
| 34904 | 87AP-12/3-AX03 | < | < | 61 | 11 | 88 | 0 | 0 | < | 60 | 51 | .5 | 449 |
| 34907 | 87AP-14/4-AX06 | < | < | 67 | < | 66 | 0 | 0 | < | 250 | 4 | < | 125 |
| 34909 | 87AP-16/5-AX08 | < | < | 50 | 10 | 57 | 0 | 0 | < | 19 | 51 | 10 | 391 |
| 34917 | 87AP-24/1-74-AX16 | < | < | 32 | 11 | 120 | 0 | 0 | < | 15 | *90 | 1 | 828 |
| 37033 | 88AP-01/08-AX02 | 1 | < | 27 | 8 | 62 | 0 | 0 | 0 | 88 | 23 | 3 | 1169 |
| 37385 | 88AP-04/05-AX03 | 3 | < | 32 | 10 | 97 | 0 | 14 | *12 | *328 | 4 | 3 | 349 |
| 37034 | 88AP-04/06-AX04 | 1 | 1 | 111 | 14 | *420 | 0 | 0 | 0 | *370 | 15 | 6 | 437 |
| 37036 | 88AP-05/01-AX06 | 1 | < | 25 | 6 | 93 | 0 | 0 | 0 | 50 | 17 | 10 | 124 |
| 37037 | 88AP-05/03-AX07 | *260 | 2 | 34 | 6 | 68 | 0 | 0 | 0 | 324 | 6 | 2 | 263 |
| 37038 | 88AP-07/10-AX08 | 1 | < | 118 | 6 | 68 | 0 | 0 | 0 | 115 | 11 | 2 | 811 |
| 37043 | 88AP-13/07-AX12 | 1 | < | 128 | 6 | 79 | 0 | 0 | 0 | 116 | 15 | 3 | 860 |
| 37044 | 88AP-15/02-AX13 | 1 | .4 | 101 | 8 | 69 | 0 | 0 | 0 | *330 | 8 | 4 | 269 |
| 38432 | 88AP-26/13-AX19 | *40 | 1 | 55 | *48 | *128 | 0 | 0 | 0 | *683 | 62 | *34 | 1635 |
| 38433 | 88AP-32/07-AX20 | 1 | .8 | 134 | 12 | 96 | 0 | 0 | 0 | 46 | 1 | 3 | 840 |
| 38526 | 88AP-11/06-37-AX21 | 32 | .5 | 26 | 7 | 97 | 0 | 0 | 0 | 38 | 9 | < | 260 |
| 35303 | C10-1B | < | < | 112 | 9 | 124 | 0 | 0 | < | < | 17 | .6 | 0 |
| 35335 | C10-1C | < | < | *246 | 4 | 87 | 0 | 18 | < | < | < | < | 0 |
| 35304 | C10-1D | < | < | 32 | 12 | 90 | 0 | 0 | < | < | 24 | .9 | 0 |
| 35305 | C10-1E | < | < | 75 | 16 | 84 | 0 | 0 | < | 183 | 10 | < | 0 |
| 35306 | C10-1F | 30 | < | 26 | 12 | 79 | 0 | 0 | 10 | 44 | *78 | 1 | 0 |
| 35307 | C10-2D | *50 | < | 125 | 17 | 95 | 0 | 0 | < | 154 | 33 | 1.6 | 0 |
| 35307 | C10-2E | 30 | < | 42 | 17 | 72 | 0 | 0 | < | 26 | 13 | .7 | 0 |
| 35314 | C13-2B | < | < | 8 | 12 | 12 | 0 | 0 | < | 10 | 0 | < | 0 |
| 35315 | C13-4 | < | < | 11 | 13 | 67 | 0 | 0 | < | 13 | 2 | .9 | 0 |
| 35316 | C13-6 | *40 | < | 10 | 17 | 80 | 0 | 0 | < | 18 | 9 | 1.6 | 0 |
| 35343 | C13-7 | < | < | 54 | 6 | *133 | 0 | 12 | < | < | 6 | 2.5 | 0 |
| 35317 | C13-8B | 30 | < | 170 | 10 | 87 | 0 | 0 | < | 35 | 5 | .7 | 0 |
| 34911 | 87AP-18/11-AX10 | < | 5 | *880 | 15 | 122 | 0 | 0 | < | *1554 | *78 | *45 | 74 |
| 37042 | 88AP-13/05-AX11 | 9 | < | 122 | 6 | 104 | 0 | 0 | 0 | 17 | 8 | < | 622 |
| 37045 | 88AP-17/04-AX14 | 1 | 2 | 52 | 6 | 53 | 0 | 0 | 0 | 142 | *112 | .9 | 168 |
| 37046 | 88KH-02/05-1A-AX90 | 1 | 1 | 104 | 8 | 71 | 0 | 0 | 0 | 315 | 56 | 3 | 458 |
| 38428 | 88AP-22/05-AX15 | 1 | 1 | 54 | 11 | 100 | 0 | 0 | 0 | 30 | 2 | 1 | 873 |
| 38429 | 88AP-22/05-AX16 | 1 | 1 | 63 | 13 | 87 | 0 | 0 | 0 | 13 | 2 | 2 | 741 |
| 38430 | 88AP-23/02-AX17 | *55 | 1 | 154 | 12 | 101 | 0 | 0 | 0 | 132 | 32 | 2 | 408 |
| 35336 | C10-3A | *40 | < | 62 | 16 | 24 | 0 | *205 | < | 60 | 13 | 5.3 | 0 |
| 35337 | C10-3B | 20 | < | 15 | 15 | 83 | 0 | < | < | 76 | 8 | 6 | 0 |
| 35338 | C10-3D | 30 | < | 89 | 4 | 60 | 0 | 4 | < | 11 | 3 | 3 | 0 |
| 35318 | C11-4 | 30 | < | 140 | 11 | 98 | 0 | 0 | < | 19 | 10 | 2.8 | 0 |
| 31615 | 85AP-19/1-110-AX7 | < | < | 164 | 22 | 85 | 30 | 25 | 0 | 0 | 26 | < | 0 |
| 31616 | 85AP-19/3-110B-AX8 | < | < | 126 | 21 | 95 | 23 | 22 | 0 | 0 | < | < | 0 |
| 32048 | 86AP-9/4-37-AX1 | < | < | 44 | 5 | 63 | 0 | *480 | < | *380 | 0 | *85 | 0 |
| 32049 | 86AP-12/5-48-AX2 | < | < | 70 | 8 | 58 | 0 | 19 | < | *380 | < | < | 0 |
| 32648 | 86AP-23/4-AX4 | 38 | < | 0 | 0 | 0 | 0 | 0 | 0 | 27 | < | < | 0 |
| 32650 | 86AP-26/2-86-AX6 | < | < | 0 | 0 | 0 | 0 | 0 | 0 | 38 | < | < | 0 |
| 32652 | 86AP-38/1-145-AX8 | 33 | < | 0 | 0 | 0 | 0 | 0 | 0 | *0.93% | < | < | 0 |
| 32653 | 86AP-41/1-161-AX9 | < | < | 0 | 0 | 0 | 0 | 0 | 0 | 281 | 0 | 8 | 0 |
| 32654 | 86AP-42/2-165-AX10 | < | < | 0 | 0 | 0 | 0 | 0 | 0 | 252 | *0.21% | < | 0 |
| 34905 | 87AP-13/2-AX04 | < | < | 42 | 17 | 59 | 0 | 0 | < | 10 | 45 | < | 523 |
| 34906 | 87AP-13/3-AX05 | < | < | 30 | 11 | 64 | 0 | 0 | *56 | 170 | *90 | 5 | *1.24% |
| 34914 | 87AP-22/4-58-AX13 | < | < | 79 | 7 | 127 | 0 | 0 | < | 29 | 18 | < | 851 |
| 34915 | 87AP-22/5-59-AX14 | < | < | 147 | 18 | 60 | 0 | 0 | < | 72 | 13 | < | 832 |

*(APPENDIX M continued)*

| LAB NO | FIELD NO | Au ppb | Ag | Cu | Pb | Zn | Co | Ni | Mo | Hg ppb | As | Sb | Ba |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 34916 | 87AP-24/3-66-AX15 | < | < | *430 | 16 | 95 | 0 | 0 | < | 91 | *78 | 2 | 843 |
| 34918 | 87AP-28/1-87-AX23 | < | < | 21 | 11 | *130 | 0 | 0 | < | 11 | 40 | 2 | 980 |
| 37039 | 88AP-08/03-AX09 | 1 | < | 116 | 8 | 85 | 0 | 0 | 0 | 13 | 8 | 5 | 943 |
| 37040 | 88AP-08/04-AX10 | 1 | < | 80 | 8 | 81 | 0 | 0 | 0 | 15 | 5 | 2 | 210 |
| 35325 | C4-10 | < | < | 8 | 14 | 105 | 0 | 50 | < | 10 | 11 | 1.8 | 0 |
| 35301 | C4-12 | < | < | 9 | *28 | *187 | 0 | 0 | < | < | 19 | 3.4 | 0 |
| 35326 | C4-12B | 30 | < | 13 | 8 | 105 | 0 | 19 | < | < | 14 | .6 | 0 |
| 35328 | C6-2C | 20 | < | 90 | 9 | 89 | 0 | 50 | < | < | 1 | < | 0 |
| 35329 | C6-3A | 20 | < | 19 | 14 | 80 | 0 | 92 | < | < | 12 | .8 | 0 |
| 35330 | C7-3 | < | < | 168 | 10 | 97 | 0 | 23 | < | 48 | *284 | < | 0 |
| 35312 | C11-17 | 20 | < | 12 | 13 | 81 | 0 | 0 | < | 127 | 20 | .7 | 0 |
| 35341 | C11-19 | < | < | 22 | 8 | 77 | 0 | < | < | < | 13 | .9 | 0 |
| 31613 | 85AP-17/2-102-AX5 | < | < | 117 | 11 | 87 | 23 | 13 | 0 | 0 | 0 | < | 0 |
| 31614 | 85AP-17/2-102-AX6 | < | < | 138 | 13 | 87 | 44 | 22 | 0 | 0 | 60 | < | 0 |
| 34908 | 87AP-16/1-AX07 | < | < | 167 | 10 | 100 | 0 | 0 | < | 16 | 5 | < | 640 |
| 34910 | 87AP-4/1-AX09 | < | < | 145 | 22 | 118 | 0 | 0 | < | 18 | 40 | 1 | 699 |
| 34798 | 87AP-25/2-AX17 | < | *25 | 170 | 20 | 0 | 0 | 0 | < | 6 | *106 | 6 | *5970 |
| 34799 | 87AP-25/2-AX18 | < | *70 | 40 | *30 | 30 | 0 | 0 | < | *970 | 55 | 10 | 1031 |
| 34800 | 87AP-26/6-AX19 | < | *44 | 47 | *30 | 100 | 0 | 0 | < | 165 | *74 | 6 | 689 |
| 34801 | 87AP-26/7-AX20 | < | < | 54 | *38 | 50 | 0 | 0 | < | 10 | *194 | 10 | 743 |
| 34802 | 87AP-26/7-AX21 | < | 9 | 66 | *42 | 100 | 0 | 0 | < | *360 | 22 | 10 | 81 |
| 34803 | 87AP-26/7-AX22 | < | 6 | 83 | *39 | 80 | 0 | 0 | < | *340 | 57 | *13 | 110 |
| 30118 | AP85-65-AX3 | < | < | 18 | < | 9 | 0 | 0 | 0 | 0 | 0 | < | 0 |
| 30119 | AP85-66-AX4 | < | < | 36 | < | 8 | 0 | 0 | 0 | 0 | 0 | < | 0 |
| 30116 | AP85-14-AX1 | < | < | 7 | < | 17 | 0 | 0 | 0 | 0 | 30 | < | 0 |
| 37041 | 88AP-12/01-38-AX10A | 1 | < | 10 | 6 | 77 | 0 | 0 | 0 | 220 | 16 | .9 | 118 |
| 34902 | 87AP-8/1-AX01 | < | < | 42 | 22 | *151 | 0 | 0 | < | 78 | *108 | 2 | 692 |
| 34912 | 87AP-21/9-55-AX11 | < | 1 | 27 | 9 | 30 | 0 | 0 | < | 12 | 51 | < | 252 |
| 34913 | 87AP-22/1-57-AX12 | < | 1 | *2100 | 7 | 64 | 0 | 0 | < | 54 | 6 | < | 975 |
| 35321 | C3-3 | 20 | < | 58 | 20 | 90 | 0 | 140 | < | *560 | 2 | 2.8 | 0 |
| 35322 | C3-4 | 20 | < | 85 | 6 | 82 | 0 | 33 | < | 15 | 30 | .6 | 0 |
| 35323 | C3-10 | < | < | 14 | 10 | 78 | 0 | < | < | 78 | 11 | 4.2 | 0 |
| 35324 | C4-2C | < | < | 7 | 6 | 46 | 0 | < | < | < | 30 | .6 | 0 |
| 35309 | C11-8A | 30 | < | 102 | 10 | 74 | 0 | 0 | < | < | 7 | .7 | 0 |
| 35339 | C11-9 | *40 | < | 123 | 9 | 95 | 0 | 70 | < | 12 | 5 | < | 0 |
| 35310 | C11-10 | < | < | 108 | 12 | 85 | 0 | 0 | < | < | 13 | < | 0 |
| 35340 | C11-11 | < | < | *510 | 8 | 75 | 0 | 82 | < | 17 | 12 | < | 0 |
| 35311 | C11-12 | 30 | < | 82 | 8 | 113 | 0 | 0 | < | < | 7 | < | 0 |
| 35313 | C11-13 | 20 | < | *440 | 21 | 107 | 0 | 0 | < | 165 | 20 | .5 | 0 |
| 35348 | G8-1 | 20 | < | *221 | 5 | 76 | 0 | 59 | < | 16 | 14 | < | 0 |
| 35349 | G8-3 | < | < | 15 | 7 | 46 | 0 | 3 | < | 20 | 23 | 1.7 | 0 |
| 35350 | G8-4 | 20 | < | *295 | 8 | 98 | 0 | 52 | < | 2 | 19 | 0.8 | 0 |
| 34903 | 87AP-8/4-AX02 | < | < | 40 | 3 | 59 | 0 | 0 | < | 43 | 45 | < | 956 |
| 34804 | DB87-010 | < | *10 | 40 | *40 | 70 | 0 | 0 | < | 10 | 4 | .7 | 0 |
| 35589 | DB87-011 | 32 | < | 63 | 11 | 75 | 0 | 0 | < | 15 | 3 | 1 | 0 |
| 37032 | 88AP-01/04-AX01 | 1 | < | 35 | 8 | 114 | 0 | 0 | 0 | 24 | 63 | 2 | 471 |
| 35344 | G3-3 | *50 | < | 30 | 15 | 47 | 0 | 23 | < | 82 | 12 | 1.1 | 0 |
| 35345 | G3-4 | 20 | < | 13 | < | 78 | 0 | 89 | < | 38 | < | < | 0 |
| 33265 | 84AP-01 | *52 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | < | < | 0 |
| 33266 | 84AP -01A | *450 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | < | < | 0 |
| 30117 | AP85-33-AX2 | < | < | 12 | < | 11 | 0 | 0 | 0 | 0 | < | < | 0 |
| 37035 | 88AP-04/09-AX05 | 1 | < | 177 | 6 | 76 | 0 | 0 | 0 | *445 | 11 | 2 | 364 |
| 38431 | 88AP-26/04-79-AX18 | 1 | 1 | *269 | 12 | 85 | 0 | 0 | 0 | 12 | < | 1 | 1644 |
| 34805 | DB87-037 | < | 2.4 | 20 | *30 | *130 | 0 | 0 | < | 140 | 4 | .5 | 0 |

*(APPENDIX M continued)*

| LAB NO | FIELD NO | Au ppb | Ag | Cu | Pb | Zn | Co | Ni | Mo | Hg ppb | As | Sb | Ba |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 35346 | G5-2 | 30 | < | 66 | 12 | 23 | 0 | 20 | < | 26 | 21 | 1.9 | 0 |
| 35347 | G7-3 | 30 | < | 11 | < | 55 | 0 | *360 | < | 28 | 2 | < | 0 |
| 35319 | C1-9 | 20 | < | 3 | 15 | 38 | 0 | 3 | < | < | 4 | < | 0 |
| 35298 | C2-1 | < | .6 | 4 | *43 | 3 | 0 | 0 | < | < | 0 | < | 0 |
| 35320 | C2-3 | 30 | < | 69 | 12 | 58 | 0 | 9 | < | 33 | 1 | < | 0 |
| 35299 | C2-4 | < | .5 | 2 | 20 | 4 | 0 | 0 | < | < | 0 | < | 0 |
| 35300 | C2-11 | < | < | 2 | 3 | 3 | 0 | 0 | < | 49 | 0 | < | 0 |
| 35342 | C12-6 | < | < | 38 | *28 | 94 | 0 | 3 | < | 19 | 22 | 1.2 | 0 |
| 35302 | C8-2 | < | < | 4 | *25 | 19 | 0 | 0 | < | < | 3 | .5 | 0 |
| 35331 | C8-3 | < | < | 4 | 16 | 18 | 0 | < | < | < | 13 | < | 0 |
| 35332 | C8-6 | < | < | 2 | *27 | 30 | 0 | 14 | < | < | < | < | 0 |
| 35333 | C8-7C | < | < | 110 | 8 | 93 | 0 | 7 | < | < | < | 3.4 | 0 |
| 35334 | C8-7K | < | < | 11 | 16 | 63 | 0 | 11 | < | 10 | 14 | 1.1 | 0 |
| 34919 | 87AP-32/3-98-AX24 | < | < | *780 | 11 | *128 | 0 | 0 | < | 5 | 51 | .9 | *3188 |
| 34920 | 87AP-32/5-AX25 | < | < | 36 | 9 | *167 | 0 | 0 | < | *785 | *96 | 2 | 813 |
| 35327 | C5-2 | 20 | < | 51 | 5 | *153 | 0 | 147 | < | < | 12 | < | 0 |

## STATISTICS SUMMARY

| | Au | Ag | Cu | Pb | Zn | Co | Ni | Mo | Hg | As | Sb | Ba |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NUMBER of ANALYSES N | 125 | 123 | 115 | 115 | 114 | 5 | 34 | 36 | 113 | 111 | 125 | 47 |
| MEAN | 12 | 1.6 | 86 | 13 | 80 | 27 | 65 | 3 | 113 | 27 | 3.0 | 782 |
| STANDARD DEVIATION | 27 | 7.8 | 108 | 9.5 | 48 | 11 | 102 | 9 | 215 | 40 | 9.2 | 936 |
| ANOMALOUS X+1STD DEV (anomalous values indicated by *) | 39 | 9.4 | 194 | 22.5 | 128 | 38 | 167 | 12 | 328 | 67 | 12.2 | 1718 |
| **MAP-UNIT AVERAGES** | | | | | | | | | | | | |
| UNIT 1 N=31 MEAN | 20 | <1 | 72 | 11.3 | 96 | - | 16 | - | 117 | 22 | 4.9 | 587 |
| UNIT 2 N=50 MEAN | 7 | 3.3 | 100 | 14.1 | 82 | - | 79 | - | 150 | 38 | 4.9 | 598 |
| UNIT 3 N=16 MEAN | 13 | <1 | 142 | 10.5 | 82 | - | 49 | - | 65 | 22 | 0.9 | 640 |
| UNIT 7 N=14 MEAN | 16 | <1 | 51 | 14.2 | 50 | - | - | - | 67 | 6 | 0.6 | - |
| UNIT 8 N=5 MEAN | <1 | <1 | 26 | 18.4 | 45 | - | - | - | 3 | 6 | 1.0 | - |

**NOTE:**

0 - NOT ANALYZED; < NOT DETECTED

**SAMPLE LOCATIONS and DESCRIPTIONS SHOWN IN APPENDIX N**

# APPENDIX N
## ASSAY SAMPLES (APPENDIX M) - LOCATIONS AND DESCRIPTIONS

| LAB NUM | REC NUM | FIELD NUM | LATITUDE ° ' " | LONGITUDE ° ' " | NTS MAP | MAP UNIT | LOCATION/AREA | SAMPLE DESCRIPTION |
|---|---|---|---|---|---|---|---|---|
| 31617 | 1 | 85AP-20/12-118-AX9 | 52-29-12.9 | 121-23-41.7 | 93A/6 | 1 | 1.8 km W of E tip Horsefly Peninsula | pyrite with carbonate veinlets |
| 32647 | 2 | 86AP-14/12-AX3 | 52-24-11.2 | 121-16- 6.7 | 93A/6 | 1 | 1.5 km S of Nikwit L | carbonate alteration + quartz veinlets |
| 32649 | 3 | 86AP-25/4-77-AX5 | 52-29-21.6 | 121-25-12.3 | 93A/6 | 1 | 0.5 km E of W tip Horsefly Peninsula | pyritic bleached rock |
| 32651 | 4 | 86AP-26/4-87-AX7 | 52-28-33.3 | 121-20-49.1 | 93A/6 | 1 | on S shore of Quesnel L | quartz vein |
| 34904 | 5 | 87AP-12/3-AX03 | 52-24-47.7 | 121-34-48.3 | 93A/5 | 1 | 1.7 km W of western tip Antoine L | rusty, carbonate-altered veinlets |
| 34907 | 6 | 87AP-14/4-AX06 | 52-24- .7 | 121-11- .8 | 93A/6 | 1 | N shore Horsefly L, 3.5 km SSW of Viewland Mtn | grab samp over 1 m rusty zone of quartz-ankerite vein-breccia infilling |
| 34909 | 7 | 87AP-16/5-AX08 | 52-24-26.4 | 121-33-17.2 | 93A/5 | 1 | 1 km S western tip Antoine L | pyrite-carbonate altered fault zone |
| 34917 | 8 | 87AP-24/1-74-AX16 | 52-23-56.7 | 121-35-48.0 | 93A/5 | 1 | on Antoine Ck, 0.6 km NE Robert L | pervasive carbonate-altered, fine-grained pyrite or (?) marcasite clots |
| 37033 | 9 | 88AP-01/08-AX02 | 52-24-28.9 | 121-40-49.4 | 93A/5 | 1 | 0.5 km N of McCauley L | orange carbonate veins at basalt - argillite contact along fault |
| 37385 | 10 | 88AP-04/05-AX03 | 52-21-27.1 | 121- 6-53.2 | 93A/6 | 1 | 2 km NW of Horsefly Mtn | calcite veinlets in shear zone with clay gouge |
| 37034 | 11 | 88AP-04/06-AX04 | 52-21-25.1 | 121- 6-52.1 | 93A/6 | 1 | 2 km NW of Horsefly Mtn | carbonate-altered, bleached, above shear zone |
| 37036 | 12 | 88AP-05/01-AX06 | 52-23-32.7 | 121-39-36.4 | 93A/5 | 1 | 1 km SE of McCauley L | orange carbonate-altered, moderately fractured sandstone-conglomerate. Chip sample |
| 37037 | 13 | 88AP-05/03-AX07 | 52-23- 4.5 | 121-40- 5.4 | 93A/5 | 1 | 2 km S of McCauley L | pyrite carbonate veinlets + pervasive alteration |
| 37038 | 14 | 88AP-07/10-AX08 | 52-26- .9 | 121-39- 7.4 | 93A/5 | 1 | 3.5 km SW of Moorhouse L | pervasive orange carbonate-altered sandstone, trace pyrite |
| 37043 | 15 | 88AP-13/07-AX12 | 52-28-21.6 | 121-43-40.5 | 93A/5 | 1 | 1.5 km S of Gavin L | carbonate-altered fault (?) zone |
| 37044 | 16 | 88AP-15/02-AX13 | 52-29-37.3 | 121-47-28.9 | 93A/5 | 1 | 2.2 km W of Gavin L | carbonate-altered pyroxene basalt |
| 38432 | 17 | 88AP-26/13-AX19 | 52-26-34.7 | 121- 7-34.5 | 93A/6 | 1 | 3 km NE of Viewland Mtn | sheared, rusty, fine-grained sediments; large shear |
| 38433 | 18 | 88AP-32/07-AX20 | 52-28-24.8 | 121-16-42.4 | 93A/6 | 1 | 3 km NE of Niquidet L | rusty polylithic conglomerate with calcite veinlets |
| 38526 | 19 | 88AP-11/06-37-AX21 | 52-26-44.0 | 121-48- 5.9 | 93A/5 | 1 | 1 km SSE of Dorsey L on waterline road | sulphides (pyrite and ? others) in feldspathic grit beds |
| 35303 | 20 | C10-1B | 52-58-14.6 | 122-18-51.9 | 93B/16 | 1 | on Quesnel R, 3 km N of Deacon Ck | red tuff |
| 35335 | 21 | C10-1C | 52-58-16.0 | 122-18-53.7 | 93B/16 | 1 | on Quesnel R, 3 km N of Deacon Ck | pyroxene-bearning wacke |
| 35304 | 22 | C10-1D | 52-58-17.2 | 122-18-55.2 | 93B/16 | 1 | on Quesnel R, 3 km N of Deacon Ck | red tuff |
| 35305 | 23 | C10-1E | 52-58-18.6 | 122-18-56.2 | 93B/16 | 1 | on Quesnel R, 3 km N of Deacon Ck | altered zone |
| 35306 | 24 | C10-1F | 52-58-19.8 | 122-18-56.8 | 93B/16 | 1 | on Quesnel R, 3 km N of Deacon Ck | tuff |
| 35307 | 25 | C10-2D | 52-58-25.5 | 122-19- 1.3 | 93B/16 | 1 | on Quesnel R, 3 km N of Deacon Ck | argillite |
| 35308 | 26 | C10-2E | 52-58-26.3 | 122-19- 1.8 | 93B/16 | 1 | on Quesnel R, 3 km N of Deacon Ck | tuffaceous wacke |
| 35314 | 27 | C13-2B | 52-55- 7.3 | 122-17-34.7 | 93B/16 | 1 | on Deacon Ck, 4 km from Quesnel R | altered basalt |
| 35315 | 28 | C13-4 | 52-55- 8.1 | 122-17-34.3 | 93B/16 | 1 | on Quesnel R, between Vase and Cantin Ck | pyritic basalt |
| 35316 | 29 | C13-6 | 52-55- 8.9 | 122-17-33.3 | 93B/16 | 1 | on Quesnel R, between Vase and Cantin Ck | calcite vein in basalt |
| 35343 | 30 | C13-7 | 52-55-29.3 | 122-17-25.9 | 93B/16 | 1 | on Quesnel R, between Vase and Cantin Ck | basalt with local chlorite veining |

(APPENDIX N Continued)

| LAB NUM | REC NUM | FIELD NUM | LATITUDE ° ' " | LONGITUDE ° ' " | NTS MAP | MAP UNIT | LOCATION/AREA | SAMPLE DESCRIPTION |
|---|---|---|---|---|---|---|---|---|
| 35317 | 31 | C13-8B | 52-55-39.3 | 122-17-37.7 | 93B/16 | 1 | on Quesnel R, between Vase and Cantin Ck | chlorite & epidote altered basalt |
| 34911 | 32 | 87AP-18/11-AX10 | 52-19-17.6 | 121-31-27.9 | 93A/ 5 | 2A | on Gravel Ck, 7.5 km WSW of Horsefly | carbonate-altered shear zone, sampled for Cu |
| 37042 | 33 | 88AP-13/05-AX11 | 52-28-13.6 | 121-44-37.2 | 93A/ 5 | 2A | 2 km S of Gavin L | epidote-altered breccia matrix; chip sample |
| 37045 | 34 | 88AP-17/04-AX14 | 52-28-53.6 | 121-46- .5 | 93A/ 5 | 2A | 1.4 km WSW of Gavin L | carbonate-altered breccia, chlorite veining |
| 37046 | 35 | 88KH-02/05-1A-AX90 | 52-28-34.1 | 121-38-38.4 | 93A/ 5 | 2A | 3.3 km W of Edney L | carbonate alteration + quartz veining |
| 38428 | 36 | 88AP-22/05-AX15 | 52-19-48.1 | 121-10-12.3 | 93A/ 6 | 2A | 2 km N of Patenaude L | rusty, limonite-altered with trace pyrite |
| 38429 | 37 | 88AP-22/05-AX16 | 52-19-48.0 | 121-10-12.2 | 93A/ 6 | 2A | 2 km N of Patenaude L | rusty, limonite-altered with trace pyrite |
| 38430 | 38 | 88AP-23/02-AX17 | 52-19- 2.3 | 121-10-28.5 | 93A/ 6 | 2A | 0.5 km N of Patenaude L | epidotized, sheared pyroxene basalt breccia |
| 35336 | 39 | C10-3A | 52-59-19.0 | 122-20-47.2 | 93B/16 | 2A | on Quesnel R, 3 km NNW of Deacon Ck | basalt |
| 35337 | 40 | C10-3B | 52-59-20.8 | 122-20-50.5 | 93B/16 | 2A | on Quesnel R, 3 km NNW of Deacon Ck | basalt, pyritic |
| 35338 | 41 | C10-3D | 52-59-24.1 | 122-20-58.8 | 93B/16 | 2A | on Quesnel R, 3 km NNW of Deacon Ck | volcanic pyroxene-bearing wacke |
| 35318 | 42 | C11-4 | 52-58-14.8 | 122-16-11.0 | 93B/16 | 2A | on Deacon Ck, 4 km from Quesnel R | basalt |
| 31615 | 43 | 85AP-19/1-110-AX7 | 52-29- 8.9 | 121-24-49.1 | 93A/ 6 | 2B | 1 km SE of W tip of Horsefly Peninsula | silicified breccia with pyrite in bleached volcanic |
| 31616 | 44 | 85AP-19/3-110B-AX8 | 52-29-19.3 | 121-24-54.3 | 93A/ 6 | 2B | 1 km E of W tip of Horsefly Peninsula | soil |
| 32048 | 45 | 86AP-9/4-37-AX1 | 52-25-12.4 | 121-21-16.4 | 93A/ 6 | 2B | 2.3 km NW of Kwun L | quartz gashes, chip sample |
| 32049 | 46 | 86AP-12/5-48-AX2 | 52-24-36.0 | 121-21-32.3 | 93A/ 6 | 2B | 2 km W Kwun L | sheared, carbonate altered |
| 32648 | 47 | 86AP-23/4-AX4 | 52-23-58.5 | 121-19- 7.5 | 93A/ 6 | 2B | 0.6 km S of Kwun L | quartz veinlets |
| 32650 | 48 | 86AP-26/2-86-AX6 | 52-27-35.8 | 121-23-34.9 | 93A/ 6 | 2B | Horsefly R, 1 km upstream from Quesnel L outlet | very fine grained pyrite, trace chalcopyrite |
| 32652 | 49 | 86AP-38/1-145-AX8 | 52-23-44.4 | 121-20-23.8 | 93A/ 6 | 2B | 0.8 km SW of Kwun L | cinnabar with pyrite in quartz-carbonate veinlets |
| 32653 | 50 | 86AP-41/1-161-AX9 | 52-25-48.8 | 121-24-23.9 | 93A/ 6 | 2B | 2.2 km SW of Hooker L | carbate-altered fault zone |
| 32654 | 51 | 86AP-42/2-165-AX10 | 52-23-38.6 | 121-24-38.2 | 93A/ 6 | 2B | on Horsefly R, 0.8 km NE of Ratdam L | quartz-calcite drusy vein, (?) marcasite |
| 34905 | 52 | 87AP-13/2-AX04 | 52-23-41.7 | 121-24-47.2 | 93A/ 6 | 2B | on Horsefly R, 0.8 km NE of Ratdam L | pervasive chlorite & carbonate alteration; grab sample |
| 34906 | 53 | 87AP-13/3-AX05 | 52-23-45.0 | 121-24-59.4 | 93A/ 6 | 2B | on Horsefly R, 0.8 km NE of Ratdam L | quartz-calcite vein with rusty margin |
| 34914 | 54 | 87AP-22/4-58-AX13 | 52-23-39.1 | 121-24-33.7 | 93A/ 6 | 2B | on Horsefly R, 0.8 km NE of Ratdam L | vuggy calcite - chalcedony veinlets |
| 34915 | 55 | 87AP-22/5-59-AX14 | 52-24-52.6 | 121-25-42.0 | 93A/ 6 | 2B | on Horsefly R, 3.5 km E of Antoine L | carbonate and zeolite alteration in pyroxene basalt |
| 34916 | 56 | 87AP-24/3-66-AX15 | 52-24-36.4 | 121-25-52.9 | 93A/ 6 | 2B | on Horsefly R, 3.5 km ESE of Antoine L | rusty fracturess with calcite, chlorite & epidote |
| 34918 | 57 | 87AP-28/1-87-AX23 | 52-21-38.4 | 121-21-18.0 | 93A/ 6 | 2B | 2.5 km W of SW end of Horsefly L | pervasive chlorite alteration epidote-calcite clots |
| 37039 | 58 | 88AP-08/03-AX09 | 52-25-22.4 | 121-41-59.8 | 93A/ 5 | 2B | 3 km E of SE end George L | epidotized patches in coarse breccia |
| 37040 | 59 | 88AP-08/04-AX10 | 52-25-33.7 | 121-42-32.4 | 93A/ 5 | 2B | 2.4 km ENE of SE end George L | epidotized breccia |
| 35325 | 60 | C4-10 | 52-53-18.0 | 122- 8-51.1 | 93B/16 | 2B | headwaters of Cantin and Gerimi Cks | basalt with minor pyrite |
| 35301 | 61 | C4-12 | 52-53-14.3 | 122- 8-43.7 | 93B/16 | 2B | headwaters of Cantin and Gerimi Cks | disseminated pyrite in siltstone |
| 35326 | 62 | C4-12B | 52-53-14.2 | 122- 8-44.7 | 93B/16 | 2B | headwaters of Cantin and Gerimi Cks | silicified basalt with Cu staining |
| 35328 | 63 | C6-2C | 52-54- 9.5 | 122-11-52.0 | 93B/16 | 2B | headwaters of Cantin and Gerimi Cks | basalt |
| 35329 | 64 | C6-3A | 52-53-54.7 | 122-11-44.1 | 93B/16 | 2B | headwaters of Cantin and Gerimi Cks | basalt |
| 35330 | 65 | C7-3 | 52-53-37.6 | 122-10-33.0 | 93B/16 | 2B | headwaters of Cantin and Gerimi Cks | basalt |
| 35312 | 66 | C11-17 | 52-57-41.6 | 122-16-28.9 | 93B/16 | 2B | on Deacon Ck, 4 km from Quesnel R | epidotized basaltic breccia |
| 35341 | 67 | C11-19 | 52-57-39.9 | 122-16-30.2 | 93B/16 | 2B | on Deacon Ck, 4 km from Quesnel R | basaltic tuff |

(APPENDIX N Continued)

| LAB NUM | REC NUM | FIELD NUM | LATITUDE ° ' " | LONGITUDE ° ' " | NTS MAP | MAP UNIT | LOCATION/AREA | SAMPLE DESCRIPTION |
|---|---|---|---|---|---|---|---|---|
| 31613 | 68 | 85AP-17/2-102-AX5 | 52-28- 6.2 | 121-27- .5 | 93A/ 6 | 2E | 4.3 km NE of Shiko L | carbonate in limonitic shear |
| 31614 | 69 | 85AP-17/2-102-AX6 | 52-28- 6.3 | 121-27- .5 | 93A/ 6 | 2E | 4.3 km NE of Shiko L | |
| 34908 | 70 | 87AP-16/1-AX07 | 52-23-56.1 | 121-32-31.7 | 93A/ 5 | 2E | 2 km S of Antoine L | epidotized analcite basalt breccia |
| 34910 | 71 | 87AP-4/1-AX09 | 52-21-52.1 | 121-30-51.1 | 93A/ 5 | 2E | 2.5 km E of junction of Gravel Ck road | native Cu in amygdaloidal, analcite pyroxene basalt |
| 34798 | 72 | 87AP-25/2-AX17 | 52-23-31.0 | 121-33-42.5 | 93A/ 5 | 2E | 2 km E of Robert L | silicified, vuggy with pervasive chalcedony and some carbonate alteration |
| 34799 | 73 | 87AP-25/2-AX18 | 52-23-31.0 | 121-33-42.5 | 93A/ 5 | 2E | 2 km E of Robert L | peripheral to AX17: grab over 30 m of carbonate-altered volcanic breccia |
| 34800 | 74 | 87AP-26/6-AX19 | 52-23-31.4 | 121-33-55.4 | 93A/ 5 | 2E | 2 km E of Robert L | pervasive carbonate alteration |
| 34801 | 75 | 87AP-26/7-AX20 | 52-23-28.4 | 121-33-55.1 | 93A/ 5 | 2E | 2 km E of Robert L | random grab over 30 m of vuggy, silicified amygdaloidal pyroxene basalt breccia |
| 34802 | 76 | 87AP-26/7-AX21 | 52-23-28.4 | 121-33-55.1 | 93A/ 5 | 2E | 2 km E of Robert L | grab sample over 20 m of carbonate-silica altered rock |
| 34803 | 77 | 87AP-26/7-AX22 | 52-23-28.4 | 121-33-55.2 | 93A/ 5 | 2E | 2 km E of Robert L | grab over 20 m of carbonate-silica altered rock |
| 30118 | 78 | AP85-65-AX3 | 52-27-22.2 | 121-27-58.1 | 93A/ 6 | 2G | Shiko L | pyrite and epidote in pyroxene-plagioclase basalt |
| 30119 | 79 | AP85-66-AX4 | 52-27-38.0 | 121-27-57.9 | 93A/ 6 | 2G | Shiko L | epidote-altered pyroxene-plagioclase basalt |
| 30116 | 80 | AP85-14-AX1 | 52-54-16.0 | 122-22-30.6 | 93B/16 | 2H | Dragon Mtn | rusty, leached quartz-calcite veinlets |
| 37041 | 81 | 88AP-12/01-38-AX10A | 52-26-21.0 | 121-47-16.1 | 93A/ 5 | 2H | 0.5 km SE of Beaver L | pervasive carbonate alteration, calcite veinlets |
| 34902 | 82 | 87AP-8/1-AX01 | 52-19- 9.9 | 121-26-26.3 | 93A/ 6 | 3 | 1 km ENE of China Cabin L | carbonate veinlets in lahar |
| 34912 | 83 | 87AP-21/9-55-AX11 | 52-23-20.3 | 121-30-54.4 | 93A/ 5 | 3 | 3 km S of Antoine L | rustry fragmented basalt with limestone clasts |
| 34913 | 84 | 87AP-22/1-57-AX12 | 52-20- 5.9 | 121-28- 7.4 | 93A/ 6 | 3 | 4.5 km W of Horsefly village | malachite-staind lahar and sandstone debris |
| 35321 | 85 | C3-3 | 52-55-13.9 | 122-12-51.1 | 93B/16 | 3A | headwaters of Cantin and Gerimi Cks | altered basalt with trace pyrite |
| 35322 | 86 | C3-4 | 52-55- 6.8 | 122-13- .4 | 93B/16 | 3A | headwaters of Cantin and Gerimi Cks | basalt |
| 35323 | 87 | C3-10 | 52-55- 7.5 | 122-12-40.5 | 93B/16 | 3A | headwaters of Cantin and Gerimi Cks | basalt, locallly with pyrite in calcite veins |
| 35324 | 88 | C4-2C | 52-54-14.6 | 122-10- 2.1 | 93B/16 | 3A | headwaters of Cantin and Gerimi Cks | basaltic breccia |
| 35309 | 89 | C11-8A | 52-58- 6.3 | 122-16-12.9 | 93B/16 | 3A | on Deacon Ck, 4 km from Quesnel R | gabbro? dark green, coarse grained |
| 35339 | 90 | C11-9 | 52-58- 1.7 | 122-16-13.2 | 93B/16 | 3A | on Deacon Ck, 4 km from Quesnel R | basalt |
| 35310 | 91 | C11-10 | 52-57-57.2 | 122-16-16.9 | 93B/16 | 3A | on Deacon Ck, 4 km from Quesnel R | epidotized basalt |
| 35340 | 92 | C11-11 | 52-57-55.5 | 122-16-18.9 | 93B/16 | 3A | on Deacon Ck, 4 km from Quesnel R | baslt |
| 35311 | 93 | C11-12 | 52-57-53.6 | 122-16-20.3 | 93B/16 | 3A | on Deacon Ck, 4 km from Quesnel R | altered baslt |
| 35313 | 94 | C11-13 | 52-57-51.0 | 122-16-20.8 | 93B/16 | 3A | on Deacon Ck, 4 km from Quesnel R | epidotized wacke |
| 35344 | 95 | G3-3 | 52-54-33.8 | 122-10-10.9 | 93B/16 | 3A | headwaters of Cantin and Gerimi Cks | syenite |
| 35345 | 96 | G3-4 | 52-54-33.8 | 122-10-10.9 | 93B/16 | 3A | headwaters of Cantin and Gerimi Cks | pyroxenite |
| 35348 | 97 | G8-1 | 52-54-25.6 | 122- 9-59.1 | 93B/16 | 3A | headwaters of Cantin and Gerimi Cks | basalt porphyry |
| 35349 | 98 | G8-3 | 52-54-25.6 | 122- 9-59.1 | 93B/16 | 3A | headwaters of Cantin and Gerimi Cks | basaltic tuff |
| 35350 | 99 | G8-4 | 52-54-25.7 | 122- 9-59.1 | 93B/16 | 3A | headwaters of Cantin and Gerimi Cks | basaltic porphyry |
| 34903 | 100 | 87AP-8/4-AX02 | 52-19-15.8 | 121-27- 7.4 | 93A/ 6 | 4 | 0.5 km N of China Cabin L | carbonate alteration - minor veins, mainly pervasive |
| 34804 | 101 | DB87-010 | 52-36-31.4 | 121-40-41.1 | 93A/12 | 4 | Prior L | epidote-altered matrix of baslt breccia |
| 35589 | 102 | DB87-011 | 52-36-31.4 | 121-40-41.3 | 93A/12 | 4 | Prior L | grey basalt |
| 37032 | 103 | 88AP-01/04-AX01 | 52-24- 1.9 | 121-36-33.1 | 93A/ 5 | 6 | 0.25 km N of Robert L | calcite veins |

*(APPENDIX N Continued)*

| LAB NUM | REC NUM | FIELD NUM | LATITUDE ° ' " | LONGITUDE ° ' " | NTS MAP | MAP UNIT | LOCATION/AREA | SAMPLE DESCRIPTION |
|---|---|---|---|---|---|---|---|---|
| 33265 | 104 | 84AP-01 | 52-39-29.1 | 121-47-58.6 | 93A/12 | 7 | QR deposit trench | propylitic basalt - weakly altered, minor pyrite |
| 33266 | 105 | 84AP-01A | 52-39-29.1 | 121-47-58.6 | 93A/12 | 7 | QR deposit trench | propylitic basalt - intensly altered, abundant pyrite |
| 30117 | 106 | AP85-33-AX2 | 52-37-32.4 | 121-38- 5.0 | 93A/12 | 7 | Bullion Pit | talus chips from dense, slightly rusty rocks |
| 37035 | 107 | 88AP-04/09-AX05 | 52-21-24.3 | 121- 5-52.6 | 93A/ 6 | 7 | 1.2 km NNW of Horsefly Mtn | carbonate-altered chloritized diorite in fault zone |
| 38431 | 108 | 88AP-26/04-79-AX18 | 52-25-36.9 | 121- 4-50.4 | 93A/ 6 | 7 | 4.5 km N of Horn Bluff (Horsefly L) | weak silicification, blebby pyrite in diorite dike |
| 34805 | 109 | DB87-037 | 52-39-41.5 | 121-45-20.9 | 93A/12 | 7 | on Quesnel R, 2.8 km E of QR deposit | calcite vein |
| 35346 | 110 | G5-2 | 52-54-37.4 | 122-10-24.1 | 93B/16 | 7A | headwaters of Cantin and Gerimi Cks | altered basalt |
| 35347 | 111 | G7-3 | 52-54-55.2 | 122-11-12.2 | 93B/16 | 7A | headwaters of Cantin and Gerimi Cks | pyroxenite |
| 35319 | 112 | C1-9 | 52-58- 5.7 | 122-11-41.8 | 93B/16 | 7B | headwaters of Deacon and Cantin Cks | syenite porphyry with sparse pyrite |
| 35298 | 113 | C2-1 | 52-57-34.9 | 122-11-47.3 | 93B/16 | 7B | headwaters of Deacon and Cantin Cks | quartz vein |
| 35320 | 114 | C2-3 | 52-57-37.4 | 122-11-45.7 | 93B/16 | 7B | headwaters of Deacon and Cantin Cks | syenite porphyry cut by K-feldspar veins |
| 35299 | 115 | C2-4 | 52-57-39.4 | 122-11-47.1 | 93B/16 | 7B | headwaters of Deacon and Cantin Cks | quartz vein |
| 35300 | 116 | C2-11 | 52-57-37.3 | 122-10-55.7 | 93B/16 | 7B | headwaters of Deacon and Cantin Cks | quartz vein |
| 35342 | 117 | C12-6 | 52-56-17.3 | 122-12-36.7 | 93B/16 | 7B | headwaters of Cantin and Gerimi Cks | syenite porphyry |
| 35302 | 118 | C8-2 | 52-53-43.3 | 122-16-41.1 | 93B/16 | 8 | on Quesnel R, 2 km S of Cantin Ck | altered granite |
| 35331 | 119 | C8-3 | 52-54-17.9 | 122-16-38.9 | 93B/16 | 8 | on Quesnel R, 2 km S of Cantin Ck | basaltic tuff |
| 35332 | 120 | C8-6 | 52-54-34.8 | 122-17-10.4 | 93B/16 | 8 | on Quesnel R, 2 km S of Cantin Ck | granite |
| 35333 | 121 | C8-7C | 52-54-35.0 | 122-16-54.7 | 93B/16 | 8 | on Quesnel R, 2 km S of Cantin Ck | volcanic-source, pyroxene-bearing wacke |
| 35334 | 122 | C8-7K | 52-54-35.1 | 122-16-54.9 | 93B/16 | 8 | on Quesnel R, 2 km S of Cantin Ck | granite porphyry |
| 34919 | 123 | 87AP-32/3-98-AX24 | 52-29-38.3 | 121-30-51.8 | 93A/ 5 | 9A/B | 1.6 km W of Hazeltine Pt, Quesnel L | rusty fractures, minor chalcedony and calcite in feldspar crystal ash tuff |
| 34920 | 124 | 87AP-32/5-AX25 | 52-29-58.1 | 121-31- 9.9 | 93A/ 5 | 9A/B | 1.6 km W of Hazeltine Pt, Quesnel L | rusty orange carbonate and vuggy chalcedony-quartz veinlets, in Tertiary conglomerate |
| 35327 | 125 | C5-2 | 52-56- 7.0 | 122-14-35.5 | 93B/16 | TILL | headwaters of Cantin and Gerimi Cks | altered basalt |

## APPENDIX O
## PLATINUM, PALLADIUM AND GOLD ANALYSES

| LAB NO | FIELD NO | Pt (ppb) | Pd (ppb) | Au (ppb) |
|---|---|---|---|---|
| 32365 | 84AP-1 | 4.3 | 6.2 | 15.9 |
| 33266 | 84AP-1A | < | 3.8 | 16.9 |
| 31597 | 85AP-1/1-35A | 5.0 | 7.1 | 8.0 |
| 31559 | 85AP-5/8-56A | 9.9 | 13.2 | 11.8 |
| 31601 | 85AP-7/2-63 | 3.0 | 6.7 | 3.2 |
| 31603 | 85AP-8/6-67 | < | < | < |
| 31605 | AP85-8/2-69 | 1.0 | 12.0 | 7.2 |
| 31606 | AP85-8/9-71 | < | < | 3 |
| 31609 | 85AP-20/2-115 | 2.4 | 6.1 | < |
| 31610 | 85AP-21/2-120 | < | < | 2.7 |
| 32050 | 86AP-4/6-18 | < | 24.4 | 2.0 |
| 32051 | 86AP-4/6-26 | 1.8 | 6.6 | 4.8 |
| 32052 | 86AP-6/10-29 | 1.8 | 19.3 | 2.1 |
| 32053 | 86AP-10/8-44 | 3.3 | 21.2 | 2.3 |
| 32054 | 86AP-13/3-51 | 4.9 | 17.8 | 1.9 |
| 32641 | 86AP-21/4-66 | 4.0 | 11.3 | 17.7 |
| 32642 | 86AP-28/4-92 | < | 9.3 | 10.1 |
| 32643 | 86AP-28/7-98 | 6.4 | 10.3 | 3.8 |
| 34799 | 87AP-25/2-AX18 | < | 2.6 | 8.8 |
| 35319 | C1-9 | < | < | < |
| 35320 | C2-3 | < | 1.1 | 8.0 |
| 35328 | C6-2C | 5.8 | 5.1 | 7.6 |
| 35329 | C6-3A | 3.0 | 4.3 | < |
| 35330 | C7-3 | 1.2 | 8.9 | 2.4 |
| 35331 | C8-3 | < | < | < |
| 35332 | C8-6 | < | < | < |
| 35339 | C11-9 | 5.2 | 8.1 | 1.7 |
| 35340 | C11-11 | 7.1 | 3.9 | 1.6 |
| 35343 | C13-7 | < | < | < |
| 35345 | G3-4 | 11.4 | 2.7 | 1.7 |
| 35347 | G7-3 | 26.3 | 2.3 | 2.7 |
| 35348 | G8-1 | 4.8 | 11.0 | 8.6 |
| 35350 | G8-4 | 4.6 | 11.1 | 8.8 |
| 35797 | MB-15 | 5.0 | 5.1 | < |
| 35798 | MB-02 | 13.5 | 11.0 | < |
| 35799 | MB-16 | 3.5 | 5.9 | < |
| 35800 | MB-05 | 1.0 | 9.7 | < |
| 35801 | MB-185 | 14.6 | 10.0 | < |
| 35802 | MB-219 | 5.4 | 9.0 | 1.0 |
| 35803 | MB-269 | 7.1 | 5.6 | 1.2 |
| 35804 | MB-274 | 4.6 | 11.3 | < |
| 35805 | MB-358A | < | 5.3 | < |
| 35806 | MB-172 | 5.7 | 9.1 | < |
| 35807 | MB-395 | 5.7 | 9.1 | < |
| 35808 | MB-374 | 2.4 | 4.9 | < |
| 35809 | MB-409 | 2.3 | 11.7 | 1.7 |
| 35810 | 63310A | 4.0 | 8.8 | 1.0 |
| 35811 | 63310B | < | < | < |
| 35812 | 86MB-20 | 64.9 | < | 1.4 |

*below detection limit indicated by <*

*Collector code: A. Panteleyev - AP;*

*J. Lu - c; M.A. Bloodgood - others*

BRITISH COLUMBIA

Ministry of Employment and Investment
Energy and Minerals Division
Geological Survey Branch

Geological Survey Branch

BULLETIN 97

Map 1

# GEOLOGY OF THE CENTRAL QUESNEL BELT BRITISH COLUMBIA

NTS 93A/5, 6, 7, 11, 12, 13; 93B/9, 16; 93G/1; 93H/4

Geology by D.G. Bailey (1976, 1978, 1988, 1989, 1990); M.A. Bloodgood (1987, 1990); R.B. Campbell (1978); A. Panteleyev and K.D. Hancock (1989); L. C. Struik (1983, 1984)

Scale 1:100 000

0 2 4 6 8 10 KILOMETRES

## LEGEND

### SEDIMENTARY AND VOLCANIC ROCKS

**PLEISTOCENE - RECENT**

- Qal — Unconsolidated glacial, fluvioglacial sediments (gravel, sand, silt and clay)

**TERTIARY**

MIOCENE (may include some younger)

- 11 — Maroon and grey vesicular alkali olivine basalt flows, breccia
- 11a — Conglomerate, sandstone

EOCENE

- 10 — Grey, mauve trachyandesite, trachyte, latite flows, breccia, ash flow tuffs, tuff
- 10a — Grey and cream sandstone, mudstone, siltstone minor conglomerate and tuff

**CRETACEOUS**

- 9 — Grey polymictic cobble conglomerate; dark grey mudstone, sandstone and conglomerate (fining-up sequences); distinctive orange-weathering carbonate matrix

**JURASSIC**

AALENIAN

- 6 — Grey and maroon polylithic cobble and pebble conglomerate; shale, siltstone, sandstone; minor redbeds

PLIENSBACHIAN-TOARCIAN?

- 5 — Grey siltstone and sandstone, massive to well bedded commonly pyritic, calcareous

PLIENSBACHIAN ?

- 4 — Maroon amygdaloidal and vesicular, analcite-bearing olivine pyroxene basalt breccias and flows

SINEMURIAN-PLIENSBACHIAN

- 3c — Feldspathic tuffaceous siltstone, sandstone; minor volcanic breccia
- 3b — Latitic crystal tuff, tuff breccia and tuffaceous sandstone; minor latite flow breccia
- 3a — Maroon and grey polylithic volcanic breccia, characterized by the presence of felsic clasts
- 3 — Polylithic breccias - undifferentiated 3a, 3b, 3c. Coarse to medium-grained plagioclase-pyroxene basaltic to intermediate, feldspathic ('felsic') volcano-clastic rocks, flows, flow-dome complexes. Top of unit has conglomerate, sandstone and limestone beds

**TRIASSIC**

CARNIAN-NORIAN

- 2g — Plagioclase lath and pyroxene-phyric basalt flows, breccia and lithic tuffs. In Beaver Creek Valley mainly polylithic conglomerate with abundant feldspathic clasts and rare granodiorite cobbles - olistostrome? unit
- 2f — Dark brown to grey and grey-green mafic sandstone, siltstone; calcareous siltstone and sandstone, limestone
- 2e — Dark green and maroon analcite-bearing pyroxene basalt flows and breccia; locally crystal and lithic tuffs. 2e1 - aphanitic plug with rare plagioclase laths
- 2d — Greenish-grey to maroon hornblende-bearing pyroxene basalt; locally dark green pyroxene crystal wacke
- 2c — Polylithic maroon and grey basaltic breccia with rare to absent felsic clasts; basaltic lithic tuff, pyroxene grain wacke
- 2b — Maroon and grey pyroxene-phyric and plagioclase microlite alkali basalt flows, breccia, minor maroon and dark green basaltic lithic tuff and sandstone
- 2a — Green and grey pyroxene-phyric alkali olivine and aphanitic alkali basalt flows, breccia, minor pillow basalt; interbedded mudstone, limestone breccia

ANISIAN-CARNIAN

- 1 — Dark grey and brown sandstone (pyroxene grain wacke), siltstone, shale; micaceous, phyllitic rocks in the eastern map area. Minor mafic tuffaceous units
- 1a — Dark green pyroxene-hornblende-plagioclase microlite to phyric basalt flows, breccia, tuffs; breccia and conglomerate volcaniclastic aprons around volcanic centres interfingering with unit 1

**PENNSYLVANIAN - PERMIAN**

- DTS — Serpentinite, amphibolite, sheared ultramafic rocks talc schist

**MISSISSIPPIAN - UPPER TRIASSIC**

- MTC — Ribbon chert, argillite, greenstone, mafic volcanic rocks; lesser limestone, basalt and serpentinite, includes minor serpentinized peridotite and other ultramafic rocks

**PROTEROZOIC - MISSISSIPPIAN**

- DMqQ — Megacrystic granodiorite to granite augen orthogneiss
- PP — Schist, gneiss, schistose quartzite, phyllite, marble, amphibolite; minor quartzite clast conglomerate, siltite

### INTRUSIVE ROCKS

- 8 — Medium to coarse-grained, hornblende granodiorite and quartz monzonite; leucocratic quartz monzonite and alaskite
- 7b — Medium to coarse-grained, hornblende and/or pyroxene-bearing, nepheline syenite, orbicular in part
- 7 — Pink and grey medium to fine-grained diorite, monzonite syenite; minor plagioclase and hornblende-phyric units; rare clinopyroxene gabbro and peridotite. 7a - dikes
- 7A — Grey, medium grained equigranular to porphyritic quartz diorite, granodiorite (Takomkane batholith in part)

## SYMBOLS

- Geological contact
- Fold axis: antiform, synform
- Fold axis - overturned: antiform, synform
- Fault, generally high-angle and inferred
- Fault, lateral movement
- Thrust fault
- bedding (65, 22, 34)
- Foliation: steep, inclined, measured (75)
- Jointing: steep, inclined
- Minor fold axis and direction of plunge
- Lineation: plunge, trend (10, 05)
- Glacial striae
- Radiometric date in Ma (188 A)
- Fossil locality (F)
- Mineral prospects, number in legend tabulation (8)
- Placer workings: abandoned, active
- Pyrite, chalcopyrite, native copper, malachite — py cpy cu mal
- Ore body
- Contour interval 200m (1200)

## SELECTED MINERAL OCCURRENCES

(Refer to text table 5 for full listing)

| MAP No | NAME | MINFILE NUMBER | COMMODITY | TYPE |
|---|---|---|---|---|
| 1 | Mouse Mountain | O93G-003 | Cu Au | Alkalic porphyry copper & related veins skarns |
| 2 | M | O93G-005 | Cu Au | |
| 5 | Cantin Creek | O93B | Cu Au | |
| 6 | Gerimi | O93B | Cu | |
| 17 | Maud Lake | O93A-119 | Cu Au | |
| **16** | **QR** | **O93A-121** | **Au Cu** | |
| 18 | Bullion Lode | O93A-041 | Cu Au | |
| 20 | Likely Magnetite | O93A-084 | Cu | |
| 22 | Morehead | O93A | Cu | |
| **24** | **Cariboo-Bell (Mt. Polley)** | **O93A-008** | **Cu Au** | |
| 27 | Bayshore | O93A-086 | Cu | |
| 33 | Shiko | O93A-058 | Cu Au | |
| 35 | Hook | O93A-112 | Cu | |
| 36 | BM | O93A-116 | Cu | |
| 37 | Kwun | O93A-77 | Cu Au | |
| 38 | Beekeeper | O93A-155 | Cu Ag Au (Hg) | |
| 41 | Pine | O93A-002 | Cu | |
| 10 | Tam | O93B-057 | Cu Au Ag Mo | Veins and porphyry copper in granodiorite (calcalkalic porphyry) |
| 11 | Nyland Lake | O93B-053 | Mo | |
| 26 | Wet | O93A-059 | Cu Mo | |
| 26 | FS | O93A-076 | Cu Mo | |
| 45 | Megabucks | O93A-078 | Cu Au | |
| 46 | DOR | O93A-117 | Cu Au | |
| 7 | Lynda | O93B-025 | Cu Ag | Limestone-hosted veins (may be related to alkalic stocks |
| 12 | Mandy | O93A-046 | Ag Cu Au Zn | |
| 14 | Slide | O93A-040 | Cu | |
| 23 | ML | O93A-118 | Cu | |
| 8 | AB | O93B-027 | Pb Zn | Mesothermal veins |
| 28 | Joy | O93A-072 | Cu Pb Ag Au | |
| 30 | CPW | O93A-043 | Au Pb Zn Ag Cu | |
| 31 | Tam | O93A-147 | Ag Pb | |
| 32 | Nov | O93A-132 | Au Ag Pb | |
| 47 | Frasergold | O93A-150 | Au Ag | |
| 25 | B | O93A-066 | Cu | Volcanic-hosted native copper |
| 42 | Red | O93A-064 | Cu | |
| 44 | Moffat | O93A-075 | Cu | |
| 3 | Cottonwood | O93G-025 | Au | Placer gold |
| 4 | MacMillan | O93G-022 | Au | |
| 9 | Ainsworth | O93B-022 | Au | |
| 13 | Quesnel Canyon | O93B-018 | Au | |
| 15 | Buxton Creek | O93A-137 | Au | |
| 19 | Bullion Pit | O93A-025 | Au | |
| 21 | Morehead Creek | O93A-069 | Au | |
| 29 | Cedar Creek | O93A-141 | Au | |
| 39 | Ward's Horsefly | O93A-015 | Au | |
| 40 | Miocene | O93A-014 | Au | |
| 43 | Hobson's Horsefly | O93A-042 | Au | |
| 48 | Black Creek | O93A-016 | Au | |
| 34 | Antoine Creek | O93A-017 | Au | |

Many other occurrences, marked

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