CACHE CREEK GROUP AND CONTIGUOUS ROCKS, NEAR CACHE CREEK, B.C.

By

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ABSTRACT

The Cache Creek Group in the type area is characterized by oceanic rocks such as radiolarian chert, fusulinid limestone and pillow basalt. Three divisions have been made in the Cache Creek Group in this study: 1) structurally lowest is the mélange unit (which has been identified as a subduction complex); 2) an overlying greenstone unit; and 3) the Marble Canyon Formation. Emplacement of the Marble Canyon Formation and greenstone unit on the underlying mélange unit is believed to have occurred in the Early to Mid-Jurassic along a shallow dipping thrust fault. This emplacement may have caused soft sediment deformation features in the Early to Mid-Jurassic Ashcroft Formation.

Felsic volcanic rocks and associated tuffs and volcaniclastic sediments are found mainly along the east side of the Cache Creek Group. These felsic rocks have been called the Nicola(?) Group and based on lithological correlation are of probable Late Triassic age. The Nicola(?) Group is correlated both with the western belt of the Nicola Group as described by Preto (1977) and the Pavilion beds as described by Trettin (1961). Blocks of Nicola(?) Group tuffs have been found in the Cache Creek Group mélange unit. This indicates that in Late Triassic time the Cache Creek Group and Nicola(?) Group were adjacent to one another.

Paleoenvironmental and geochemical evidence indicate an ocean island or platform depositional environment for the Cache Creek Group. Tropical shallow seas covered most of these islands. Lack of continental sediments indicates that the Cache

Creek Group was distant from any major land masses.

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INTRODUCTION

Considerable interest has been directed towards the Cache Creek Group because of the implied transport of stratigraphic terranes proposed by Danner (1970) and Monger and Ross (1971). Permian fusulinids found in limestones of the Cache Creek Group are Tethyan in origin (Dunbar, 1932) with counterparts in the Permian of the Mediterranean sea area, Japan, Indochina and south China. Fusulinids in the Harper Ranch Assemblage 100 km to the east, in part of similar age, belong to a different and cooler water fauna and may have originally evolved a great distance from the Cache Creek fauna (W.R. Danner, pers comm, 1981). The more recent interpretation of features in the Cache Creek Group thought to be typical of subduction complexes such as subduction mélanges and associated island arcs has been made by W. Travers (1978). Subduction of oceanic plates would provide a mechanism for the juxtaposition of the Cache Creek Group Tethyan fusulinids and the Harper Ranch Assemblage subtropical fusulinids. Preliminary discoveries of subduction complex features by W. Travers (1978) indicated the need for regional mapping of the Cache Creek Group and surrounding rocks at the type locality at Cache Creek, B.C. This thesis mapping is a continuation of regional mapping done earlier to the south by Grette (1978) and Ladd (1979). To the east of the Cache Creek Group is a package of felsic volcanic rocks and immature clastic rocks with some silicified sediments and minor limestone. These felsic volcaniclastic rocks have been dated as Late Triassic by Grette (1978) and Travers (1978) who correlated them with the Nicola Group to the east. The present study suggests on the basis of similar age and lithology that these felsic volcaniclastic rocks may be correlative with the Pavilion beds of Trettin (1961). Until the detailed stratigraphy of the Nicola Group is known, the felsic volcaniclastic rocks will be referred to as the Nicola(?) Group.

Controversy has been generated over the origin of the Cache Creek Group and its mechanism of emplacement in models put forward by Monger (1977) and Travers (1978). Work to the south of this present study was undertaken by Grette (1978) and Ladd (1979) in an effort to solve some of these problems. Such problems include: 1) what was the environment of deposition of the Cache Creek Group; 2) regional structure and stratigraphy of the Cache Creek Group; 3) the nature of the relationship between the Cache Creek Group and the Nicola(?) Group; and 4) the time of juxtaposition of the Cache Creek Group and Nicola(?) Group. The purpose of this thesis was to try to provide answers to the above problems.

A regional mapping project (1:50,000) was undertaken during the summer of 1980, near Cache Creek, B.C. and forms the basis of this thesis. This project was part of regional remapping of the Ashcroft map area by the Geological Survey of Canada. Extensive sampling of limestones and cherts of the Cache Creek Group was undertaken in the hopes of providing more fossil dates concerning the age of this group.

LOCATION AND ACCESS

The area mapped is about 600 km^2, extending from Ashcroft Manor on the south to 20 Mile House on the north and Hat Creek Valley on the west to Bonaparte Valley on the east (Fig. 2). The area lies on the western margin of the Intermontane Belt which consists mainly of unmetamorphosed to low-grade metamorphic sediments and volcanic rocks ranging in age from Mississippian to Recent (Monger, 1981). To the west across the Fraser River Fault system lies the Coast Plutonic Complex and to the east is the high-grade metamorphic to igneous Omineca Crystalline Belt (Fig. 1).

Access to the area is good via Highways 1, 97 and 12, as well as by numerous logging and ranching roads. Some of the latter are only accessible by 4-wheel drive. New logging roads were being constructed in the area during this study and furnished new and important outcrops. Much of the map area is covered by overburden and the best exposures occur along road cuts and stream valleys. Outcrops are more easily seen at lower altitudes because of the sparse plant cover of grass, sagebrush and cactus. Higher altitude outcrops are obscured by forests of Ponderosa pine and Douglas fir.

PREVIOUS WORK

A. Selwyn (1872) was the first to describe the geology of the study area and named the Cache Creek Group after the small village near the type locality. G. Dawson (1895a) made the first geological map of the area and divided the Cache Creek

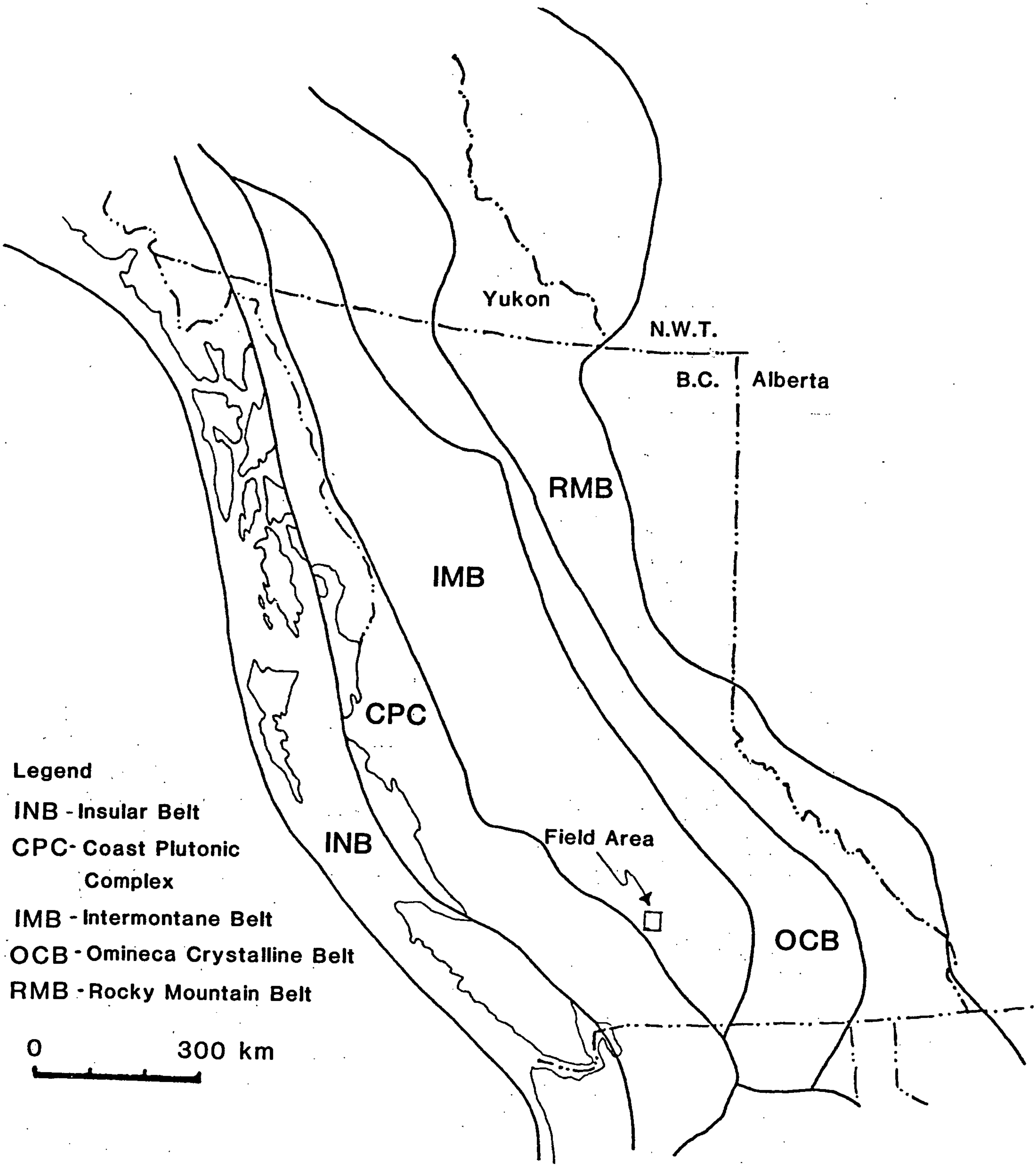

Figure 1. Map showing tectonostratigraphic belts of B.C.

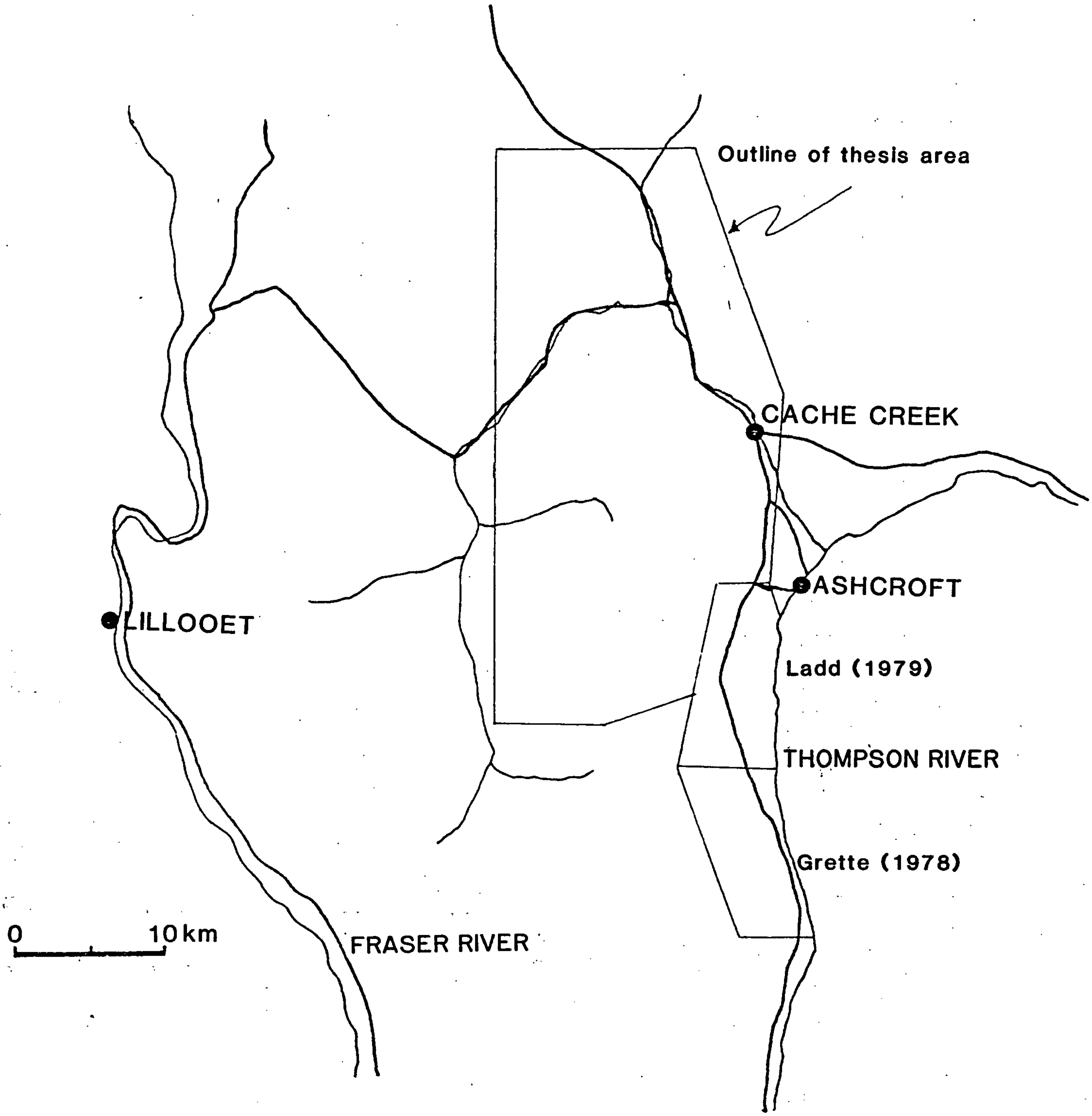

Figure 2. Map showing location of field area

Group into a lower unit of sedimentary rocks and greenstone and an upper unit predominantly of limestone, which he called the Marble Canyon Formation. G. Dawson's reconnaissance mapping was updated by Duffell and McTaggart (1952) who divided the Cache Creek Group into an eastern, central and western belt.

Most of the felsic volcanic rocks and limestones along Highway 1 between Martel and Cache Creek were included with the Cache Creek Group by both Dawson (1895) and Duffell and McTaggart (1952). These felsic volcanic rocks were reassigned from the Cache Creek Group to the Nicola Group by Grette (1978), Travers (1978), and Ladd (1979). From field evidence Grette (1978) and Travers (1978) defined the Cache Creek-Nicola contact as a steeply west dipping NW-SE trending fault. This relationship was in agreement with work done by Ladd (1979) who also suggested the contact may be in part a thrust fault with older Cache Creek rocks being emplaced on top of Nicola rocks.

Paleontological and paleo-environmental studies of Cache Creek Group carbonate rocks in the type area have been carried out by Danner (1966, 1968, 1976). W.R. Danner (pers comm, 1981) suggests that the Marble Canyon Formation is composed of carbonate banks formed on a volcanic to sedimentary substrate in warm shallow tropical waters. Ages of fusulinids found in the Cache Creek Group in southern British Columbia range from Middle Pennsylvanian to Late Permian.

A preliminary report on the regional geology has been published by Monger (1981) and early results of this thesis project have been published by Shannon (1981).

CACHE CREEK GROUP

Work completed during the summer of 1980 showed that the eastern and central belts of the Cache Creek Group in the type area, can be divided into three main divisions; a mélange unit, a greenstone unit and the Marble Canyon Formation. The greenstone unit and Marble Canyon Formation appear to overlie the mélange unit possibly along a thrust contact. Serpentinite is included as a fourth unit in the Cache Creek Group and is described separately although it crops out in all divisions. Geology of the field area is summarized in Fig. 3 and a stratigraphic column indicating the relationships of the main lithological units is shown in Fig. 4. Below, each of the four divisions of the Cache Creek Group is described separately starting with the lowest structural unit.

I) MELANGE UNIT

Tectonic mélanges are bodies of deformed rocks characterized by the inclusion of tectonically mixed fragments or blocks, which may range up to several kilometres in size, in a pervasively sheared matrix (Hsu, 1968). Sedimentary mélanges are sheared olistostromes or debris flows which include blocks fragmented and mixed by sedimentary processes that are now embedded in a pervasively sheared matrix (Hsu, 1974). The Cache Creek mélange unit contains a variety of blocks in a pervasively sheared matrix. Except for the serpentinite bodies which are fault controlled, most of the blocks could have been emplaced by either tectonic or sedimentary processes. Evidence presented

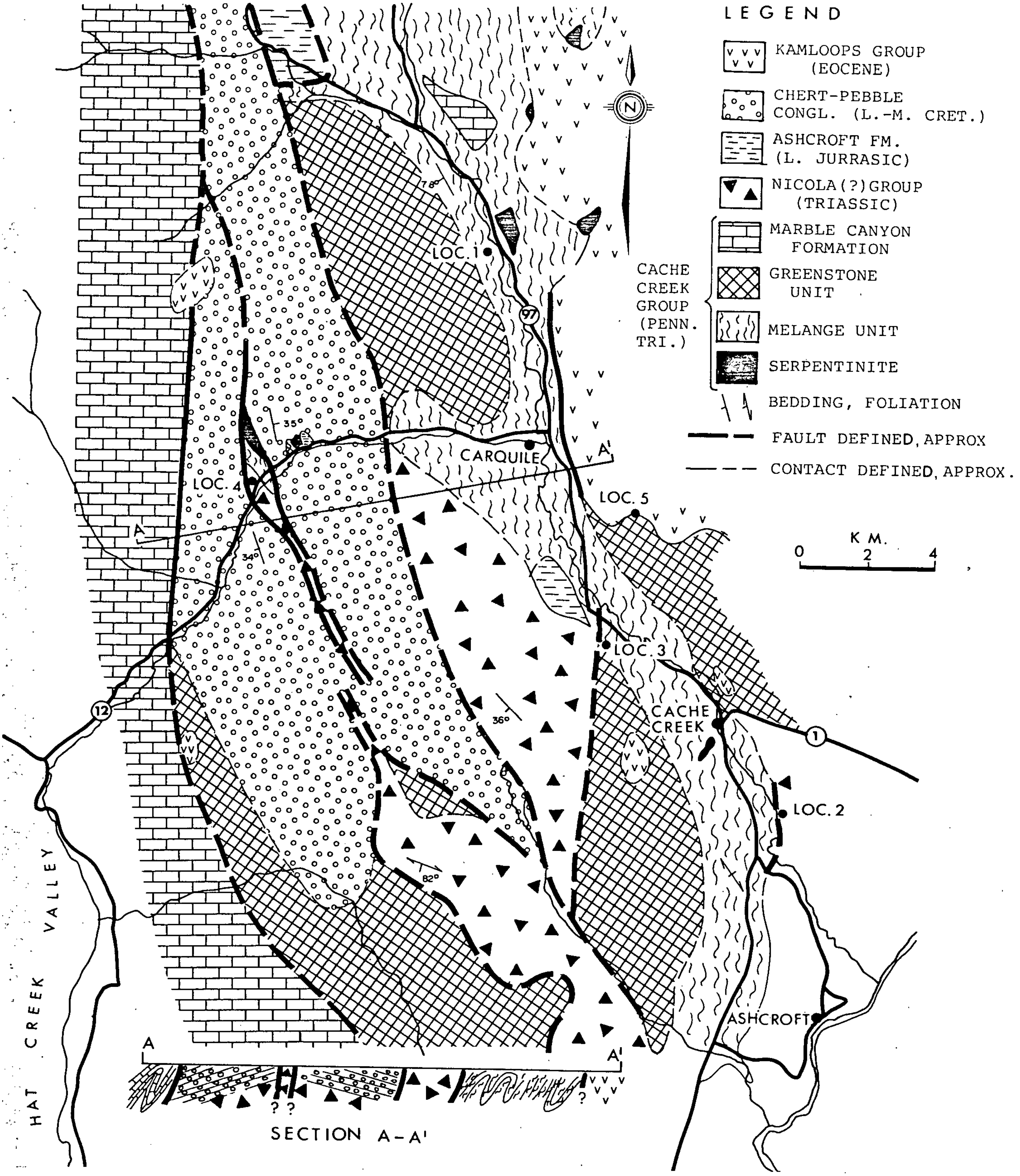

Figure 3. General geology of field area, from Shannon, 1981

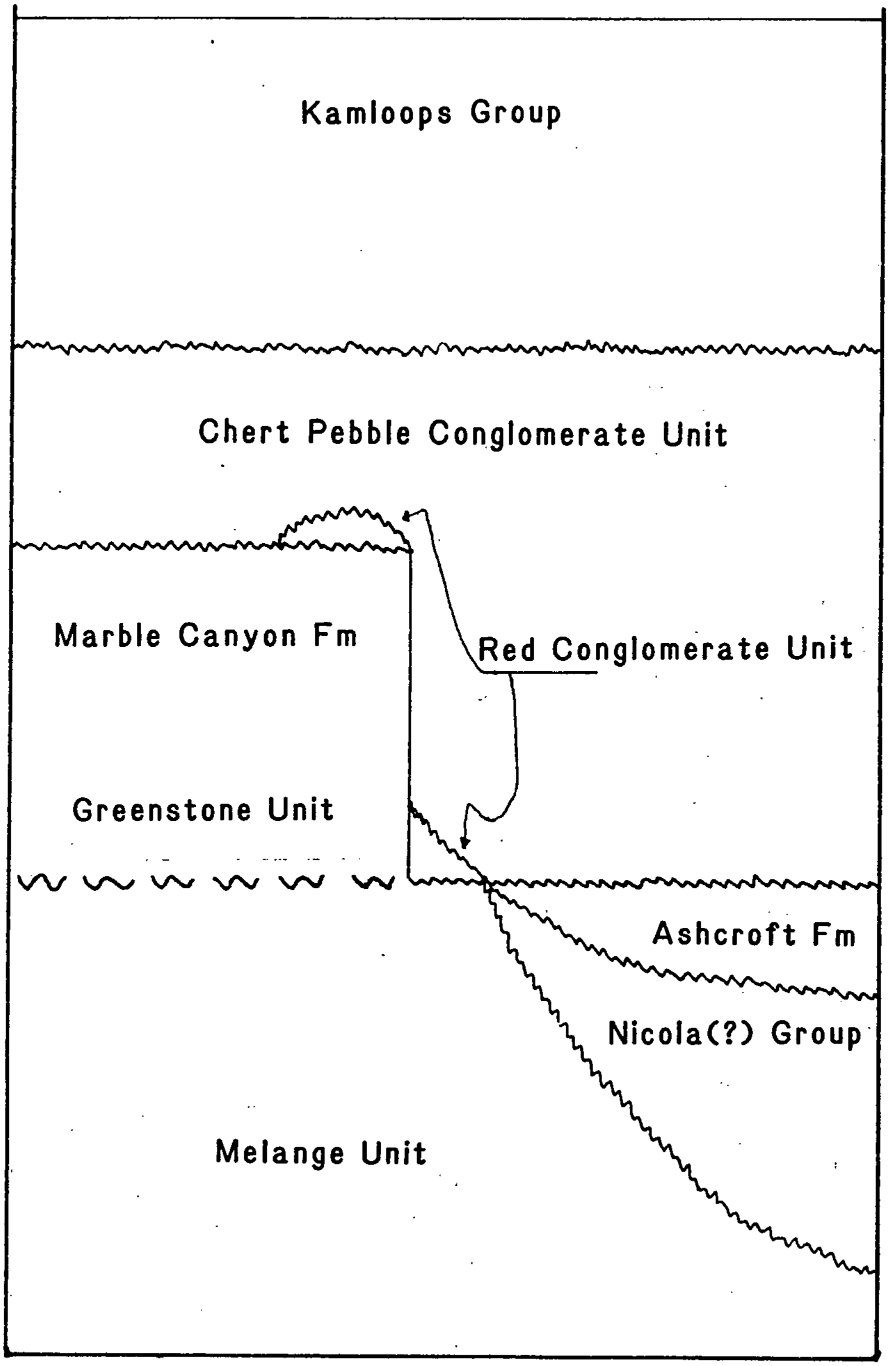

Figure 4. Summary stratigraphic column showing units in field area

during description of the geology of the mélange blocks indicates that both tectonic and sedimentary processes have been involved in the genesis of the mélange unit.

Best exposures of the mélange unit are in the town of Cache Creek, on the west side of the Bonaparte River. Additional outcrops are found along the Bonaparte Valley extending from Ashcroft Manor to 20 Mile House; other exposures are in stream valleys such as along lower Hat Creek. Within the thesis area the mélange unit is exposed only in these topographically low regions. Natural outcrops of the mélange unit may show only blocks as the recessive matrix usually is not exposed.

The mélange unit comprises blocks of limestone, greenstone, radiolarian chert, greywacke, gabbro, serpentinite and felsic tuff breccia in a variably sheared matrix of carbonaceous argillite and phyllite. The blocks range in size from centimetres to hundreds of metres. Changes in the relative percentage of blocks versus matrix greatly affect the physical characteristics of the mélange. Where the mélange is predominantly argillite or phyllite with few blocks present, it is highly sheared and bedding cannot normally be followed for more that a few metres. This is a reflection of the extreme incompetency of these rocks. As the proportion of chert or limestone blocks increases, the competency of the mélange also increases and degree of shearing decreases. Large outcrops of ribbon chert or limestone are usually not extensively broken, although they may be deformed.

Lithologies of blocks in the mélange are rocks types common in the Cache Creek Group but include some that are typical of the Nicola(?) Group as well. Most of the blocks in the mélange unit are radiolarian chert (>50%), with some limestone (5-20%) and minor greenstone, serpentinite and Nicola(?) Group blocks (5-15%). Numerous blocks of felsic volcanic material are present in the vicinity of Cache Creek but only appear occasionally elsewhere in the mélange. Radiolarian chert normally occurs scattered randomly in the mélange with a few blocks in excess of 100 metres across. When mapping in the mélange, geological contacts could not be followed in a normal fashion because each block was not in stratigraphic contact with other blocks. It is difficult to determine if a small outcrop is in fact an outcrop or a recent slide block because there is no geological continuity between blocks, and units show up as scattered knobs topographically.

The matrix of the mélange unit is formed of interbedded ribbon chert and argillite in varying proportions. Areas with mixed ribbon chert and argillite or argillite alone are quite incompetent and when deformed, become highly sheared. Areas with thick sequences of ribbon chert acted independently from the matrix because of their competence and formed blocks. Ribbon chert is the most frequent type of block in the mélange and often forms the bulk of the outcrop.

Ia) Bedded Radiolarian Chert Blocks

Colours of the ribbon cherts are variable although grey and black varieties probably form over 90% of the cherts. Red, green, white and brown varieties are present, probably reflecting impurities such as iron and manganese. Ribbon chert commonly forms layers 1-5 cm thick separated by thin argillaceous partings. On some of the larger relatively undeformed blocks an effort was made to trace the extent of single beds laterally. After a few metres at best the chert bed would pinch out, as is common for radiolarian chert (Danner, 1970a).

Locally, the cherts contain abundant well preserved radiolaria, usually seen as clear glassy spheres less than 0.5 mm in diameter. In most modern interpretations of the origin of ribbon chert, radiolaria are thought to be the source of silica for the ribbon chert sequences (McBride and Folk,1979). Previously, subaqueous volcanic emanations were thought to provide the source of silica for the ribbon chert sequences (Davis, 1918). There is still controversy as to the method of formation of the rhythmic layering in ribbon cherts. Current theories rely on an alternating combination of turbidite and pelagic deposition (McBride and Folk, 1979). Previous theories focused around diagenetic alteration of the ribbon chert into bands (Davis, 1918).

A chert breccia crops out two kilometres north of Cache Creek, above and to the west of Highway 97. The outcrop is composed of sub-rounded to sub-angular chert clasts, usually less than 2 cm in size in a matrix of chert (Fig. 5). Colours of the clasts range from black to gray. This unit is interbedded with radiolarian ribbon chert. The variety of chert

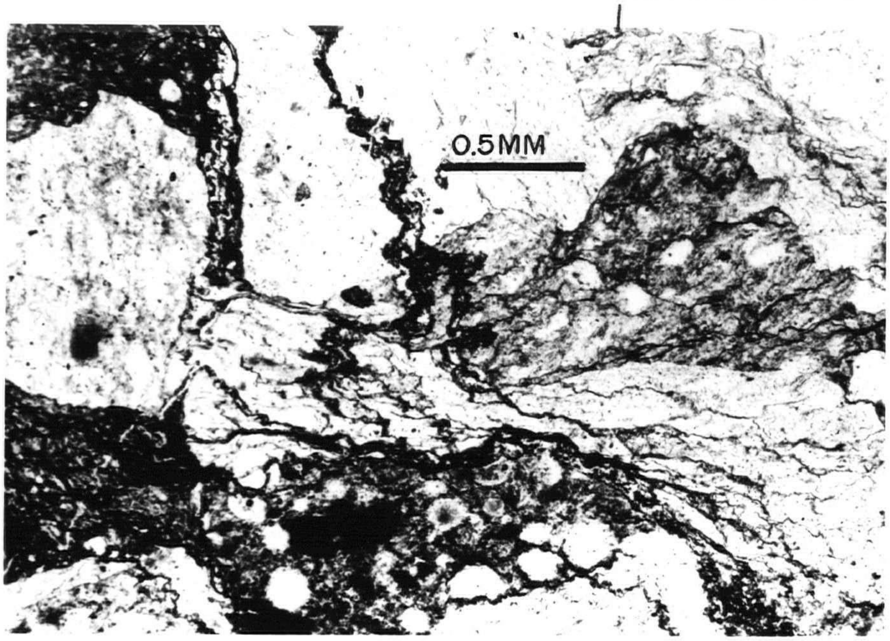

Figure 5. Photomicrograph of radiolarian chert breccia, two km north of Cache Creek, B.C.

Figure 6. Rotated limestone block in mélange unit, on west side of Bonaparte River, Cache Creek, B.C.

clasts in the breccia and the occurrence of other lithologies such as limestone cobbles indicates that this breccia unit might be a slide breccia. The breccia unit is only found in one other location in the study area and is probably best explained by localized submarine sliding.

Limestone beds occasionally interbedded with the ribbon cherts and argillite are usually less than 1 metre thick. These limestone beds sometimes contain shallow water fossils such as fusulinids, which indicate that either the radiolarian chert formed in shallow water, or the limestone beds were emplaced in the chert stratigraphy as turbidite units. Some of the limestones appear to be composed of sorted clastic fossil debris which would support a turbidite origin. Examples of these turbidite limestones are found along the east side of the Bonaparte River 2 km northeast of 20 Mile House (station #4, Fig. 30) and south of Cache Creek just to the west of Boston Flats (station #355, Fig. 30).

Ib) Limestone Blocks

Limestone blocks commonly are in tectonic contact with the mélange (Fig. 6). However some blocks grade into the matrix of the mélange over a distance of usually <1 metre. The gradational contact appears to be developed as a progressive decrease in the amount of fine-grained carbonate away from the edge of the block into the matrix. A suggested interpretation of these gradational contacts is that the limestone blocks are large slide blocks which broke off in shallow water and slid to the site of deposition as coarse sediments with a fine grained carbonate cloud around them. In most cases this gradational contact is not present because of later tectonism of the mélange. Another interpretation proposed by W.R. Danner (pers comm, 1981) is that at least some of the limestone blocks are large in situ carbonate accumulations such as algal mounds. The contacts of these mounds have been modified by later tectonism. Some of the limestones in the mélange unit south of Cache Creek have finely laminated structures which have been interpreted as algal laminations (Danner, 1976).

Intensive recrystallization has obliterated original textures in many limestone blocks, leaving a grey and white, mottled, coarsely crystalline rock with rare fusulinids and crinoid columnals. Limestone is very resistant to weathering in the arid climate of interior B.C., and on highly eroded hillsides it may form the only outcrop (Fig. 7). Dolomite comprises up to 10% of some samples. A fetid, bituminous odor was noticed when the limestones were freshly broken. Some of the limestones in the mélange south of Cache Creek exibit a strange columnar radial jointing that morphologically looks similar to a spray of aragonite crystals except the columns are in excess of 2 metres long in places and are composed of sparry calcite (Fig. 8). Cathode-luminescence was attempted to see if zoning could be observed in a cross-section of the columns. Results showed no zoning although the limestone did fluoresce a light blue colour instead of the usual orange for calcite (Koop, 1981). The anomalous fluorescence may be related to some cation

Figure 7. Isolated limestone block, on Bonaparte Reserve north of Cache Creek, B.C.

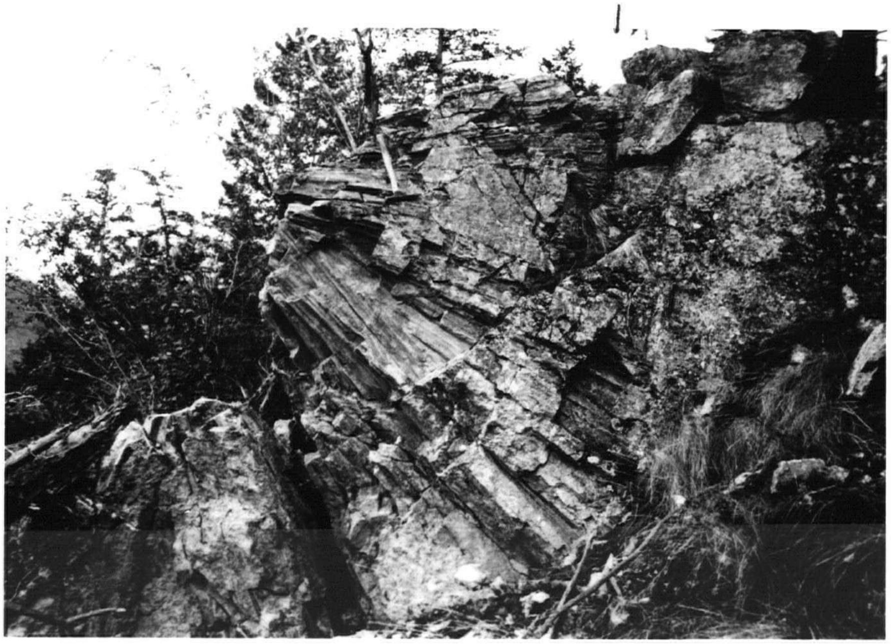

Figure 8. Radial structures in limestone block to west of Boston Flats

impurity in the calcite structure (Koop, 1981).

Ic) Greenstone Blocks

Blocks of greenstone are not common in the mélange unit. Blocks up to several tens of metres across were observed but most were less than ten metres in longest dimension. Colour of the greenstones is usually dark green to almost black. Typically the blocks are amygdaloidal and some show pillow structures. Greenstones in the mélange unit tend to be highly sheared and fresh surfaces are rare. Calcite and quartz veins up to 10 cm thick commonly crosscut the blocks.

Id) Nicola(?) Group Blocks

Light green volcaniclastic blocks occur scattered in the mélange unit, mainly in the vicinity of Cache Creek, B.C. Such blocks are similar in appearance and compostion to rocks of the Nicola(?) Group which is adjacent to the Cache Creek Group on the east. The light green volcaniclastic blocks are siliceous and contain a variety of clasts including felsic volcanics, quartz-eye porphyries, chert and fine-grained sedimentary rocks (Fig. 9). These volcaniclastic blocks are similar to Nicola(?) Group rocks cropping out along the Bonaparte River south of Cache Creek, which contain clasts of felsic volcanic rocks, siltstone and radiolarian chert (Fig. 10). Cache Creek Group volcaniclastic rocks contain only mafic volcanic and limestone clasts (Fig. 11). Some of the light green volcaniclastic blocks have well developed welded ash flow tuff textures (Fig. 12). Welded tuffs have been found in the Nicola Group by McMillan (1978) although such rocks have not been reported in the Cache Creek Group. All the light green blocks contain pyrite, locally up to several percent. Presence of pyrite is characteristic of Nicola rocks (McMillan, 1974) whereas pyrite is rare in the Cache Creek Group except within some ribbon cherts. The preceeding evidence strongly supports the correlation between the light green volcaniclastic blocks in the mélange unit and the Nicola(?) Group volcaniclastic rocks.

Partial alteration to clays and chlorite has rendered some of the Nicola(?) rocks incompetent and they form recessive rubbly outcrops. The volcanic and sedimentary clasts in these blocks range in composition from tuffs and agglomerates to volcanic greywackes. One of these breccia tuffs north of Cache Creek has developed rims of fibrous blue-lavender glaucophane around brown augite phenocrysts (Fig. 13).

AGE OF BLOCKS IN THE MELANGE UNIT

Fossil dates in the mélange unit have been obtained from radiolaria extracted from cherts and conodonts extracted from limestone blocks. The dates based on radiolaria range in age from probable Early Permian (D. Jones, written communication, 1981, United States Geological Survey) up to Late Triassic (Travers, 1978). Ages of blocks of limestone in the mélange are mostly Late Pennsylvanian to Early Permian based on conodonts

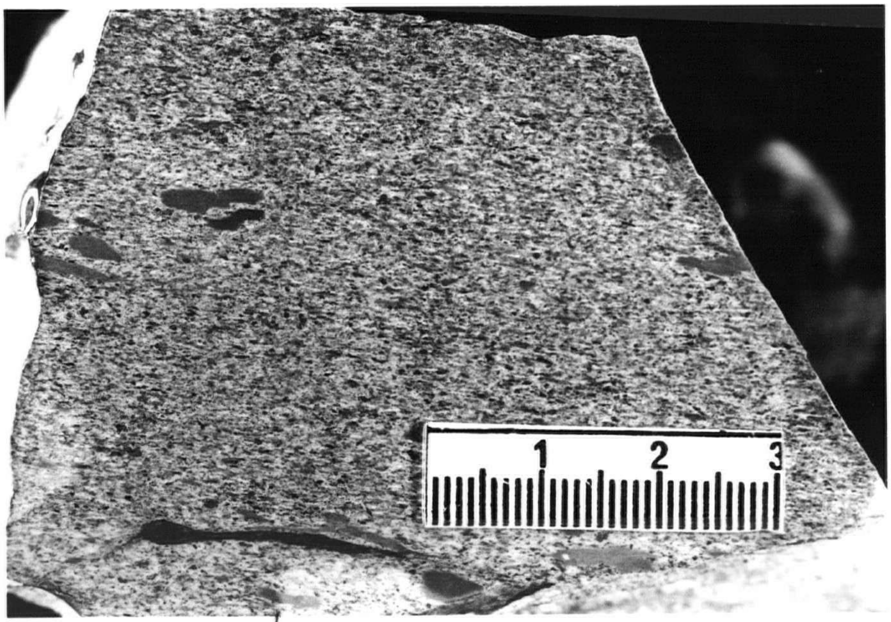

Figure 9. Nicola(?) block from 3 km north of Cache Creek, B.C. Showing volcaniclastic texture

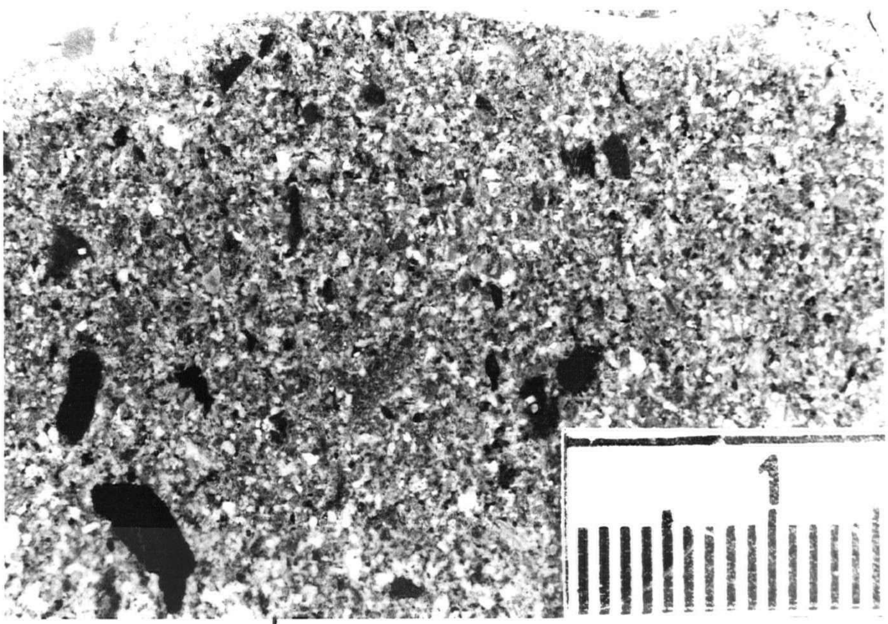

Figure 10. Nicola(?) Group volcaniclastic rock from vicinity of Woodburn Ranch

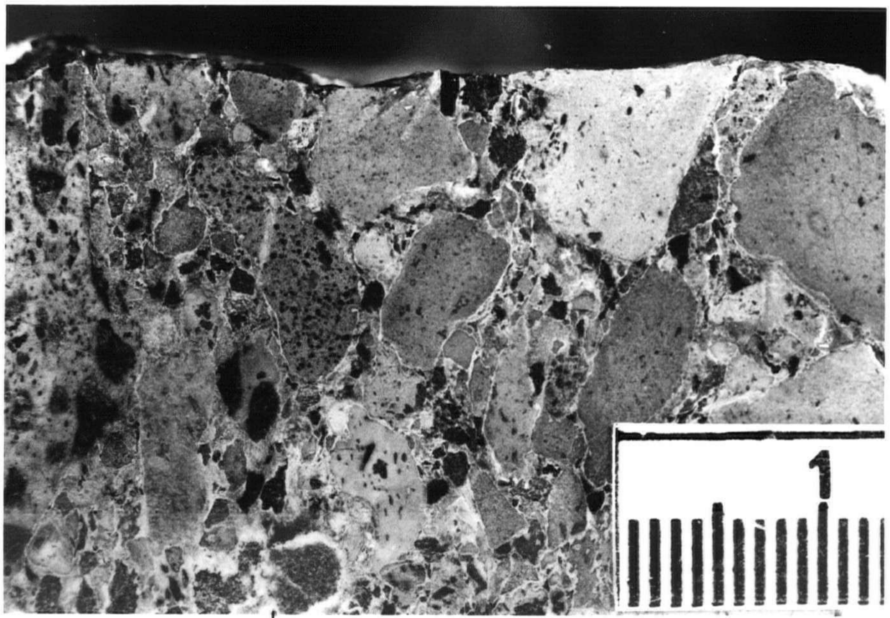

Figure 11. Cache Creek Group volcaniclastic rock from 3 km northwest of Carquile

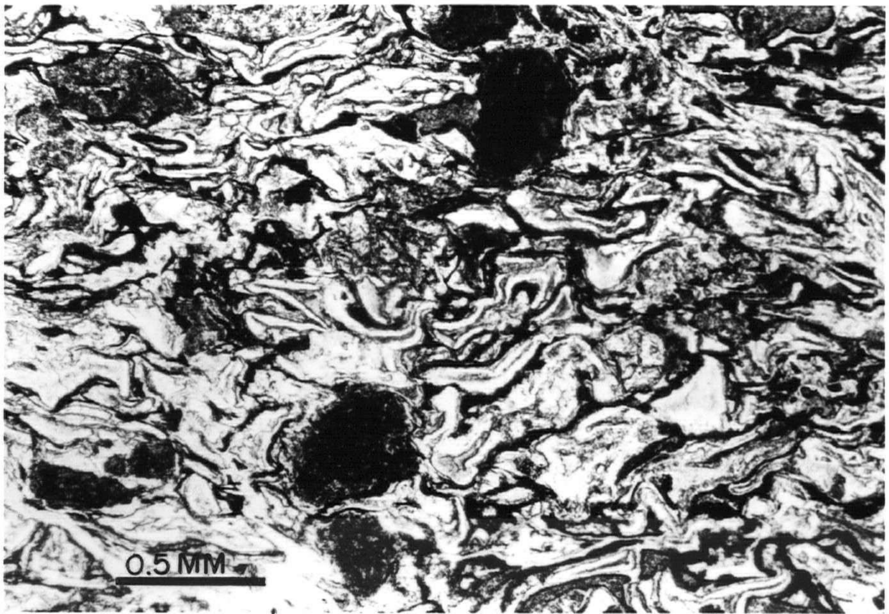

Figure 12. Photomicrograph of ashflow tuff block in Cache Creek Group mélange unit from near Boston Flats

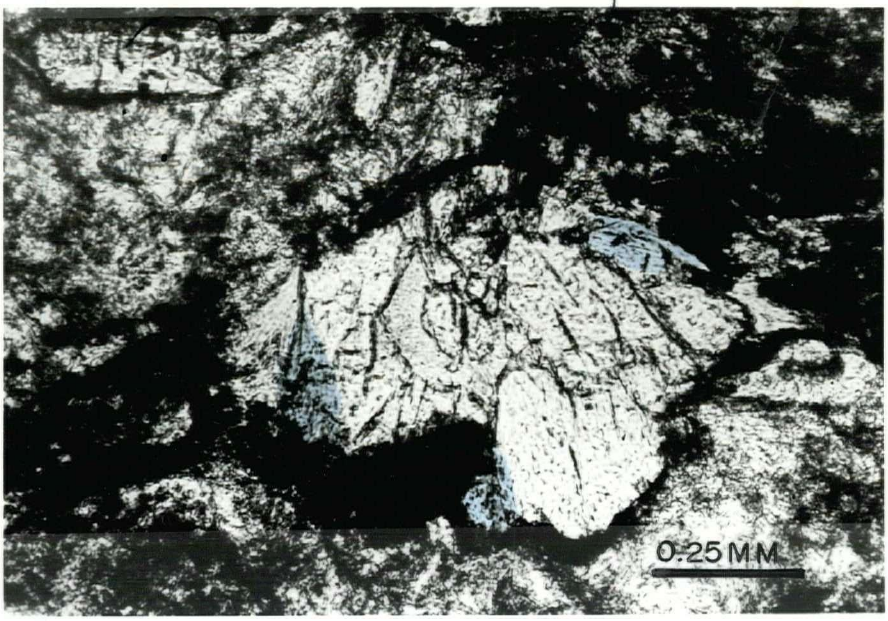

Figure 13. Photomicrograph showing augite phenocryst altering to glaucophane, from agglomerate block in mélange unit

(M. Orchard, written communication, 1981, Geological Survey of Canada). Therefore rocks in the mélange unit appear to have been deposited between Late Pennsylvanian to Late Triassic time. Deposition ceased sometime in the Late Triassic as no younger Cache Creek Group rocks have been found in the mélange unit.

II) <u>GREENSTONE UNIT</u>

The greenstone unit crops out mainly at higher topographic levels with best exposures along ridges above the Bonaparte River Valley especially on the west side north of Carquile. The greenstone unit overlies the mélange unit possibly along a relatively shallow dipping thrust fault (Fig. 14).

Amygdaloidal basalt is the most common lithology; it has a distinctive spotted look caused by small black spherical chlorite amygdules (<3 mm) in an aphanitic green matrix. Also common are volcaniclastic rocks which appear to be debris flow deposits; usually clasts are basalt and limestone. Degree of clast rounding and size of fragments is variable. These volcaniclastic rocks probably formed by submarine slumping of flows, as evidenced by poor sorting, lack of internal stratification except for alignment of fragments, multimodal clast size distribution and abrasive rounding of some clasts (Fisher, 1971). Other lithologies include basalt breccia, pillowed basalt (Fig. 15) and aphanitic basalt. Microscopically the basalts commonly have abundant plagioclase phenocrysts ranging from 0.1 to >10 mm in length. Augite phenocrysts were also observed sometimes with a brecciated appearance. Amygdaloidal infillings and alteration products include calcite, pumpellyite, stilpnomelane, quartz and chlorite. The chlorite commonly is a late stage mineral replacing calcite in some samples. Opaque minerals present include pyrite, hematite and magnetite(?).

Minor ribbon chert and phyllite are also included in the greenstone unit. Limestone is present as interpillow infillings and clasts in basalt tuff breccia. Approximately 3 km north of Carquile, interpillow limestones produced abundant fish teeth during processing for conodonts. The age of these teeth could

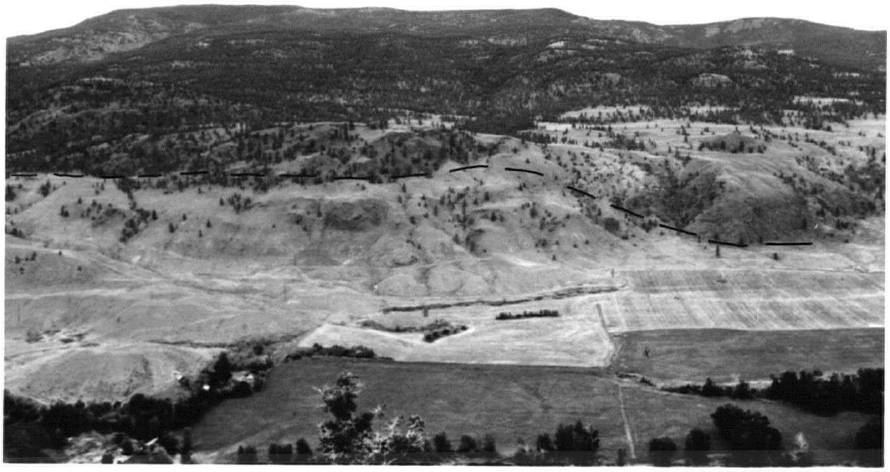

Figure 14. View looking eastward across Bonaparte Valley to the north of Cache Creek, B.C. Dashed line indicates contact of mélange unit with overlying greenstone unit

Figure 15. Basalt pillows in greenstone unit 3 km north of Carquile

not be determined and no conodonts were recovered.

Major element geochemistry was not attempted on any samples as extensive alteration made analyses suspect. Work done by others on the Cache Creek Group basalts in northern B.C., indicates that they straddle the alkaline-tholeiitic boundary (Souther, 1977). An effort to identify the original tectonic setting of these rocks was made using immobile element geochemistry. Elements were chosen which are relatively insensitive to alteration processes; these include Ti, Zr, Nb, and Y (Pearce and Cann, 1973). Results are presented in Fig. 16. Levels of Nb and Ti are substantially above normal ocean floor basalt and according to the Y/Nb ratio the samples plot mainly in the alkalic to transitional compositional field

(Fig. 17). When plotted on the discrimination diagram (Fig. 18), the samples fall mainly in the "within plate" or ocean island field, except for sample 103 which appears to be distinctly different than the other samples. Sample 103 is not anomalously enriched in Nb or Ti and appears similar to normal ocean floor basalt. It is the only sample from the mélange unit; all the other samples were from the greenstone unit or the Marble Canyon Formation.

This limited evidence suggests that the Cache Creek Group greenstones may be of two distinct types. The first type, enriched in Nb and Ti is of the ocean island variety. The second type has normal amounts of Nb and Ti as compared to the average of ocean floor basalts (Fig. 16). Geochemical differences between Cache Creek greenstones of the greenstone unit and Marble Canyon Formation versus normal ocean floor basalts are also manifested mineralogically. Clinopyroxene phenocrysts are common in the Cache Creek Group greenstones and in some samples the clinopyroxenes predominate over plagioclase. This is not typical of normal ocean floor basalt in which olivine and plagioclase are dominant, with rare clinopyroxene (Shilling, 1973). Shilling suggests that clinopyroxene-rich basalts are related to hot spot activity in the underlying mantle.

SAMPLE	Nb(ppm)	Ti(ppm)	Y(ppm)	Zr(ppm)
MVS-80-3a	48[2]	17100	26	172
MVS-80-22	37	15200	32	142
MVS-80-43a	29	17500	19	99
MVS-80-103	8	6800	38	25
MVS-80-171	77	28200	45	276
MVS-80-191b	27	16800	42	111
CACHE CREEK GREENSTONE MEAN	38	16933	34	138
OCEAN-FLOOR BASALT MEAN[1]	5	8350	30	92
OCEAN ISLAND BASALT MEAN[1]	32	16250	29	115

[1] (Pearce and Cann, 1973)

[2] (Values are ± maximum of 10%, Stanya Horsky, pers comm, 1981)

Figure 16. Trace element geochemistry of Cache Creek Group greenstones

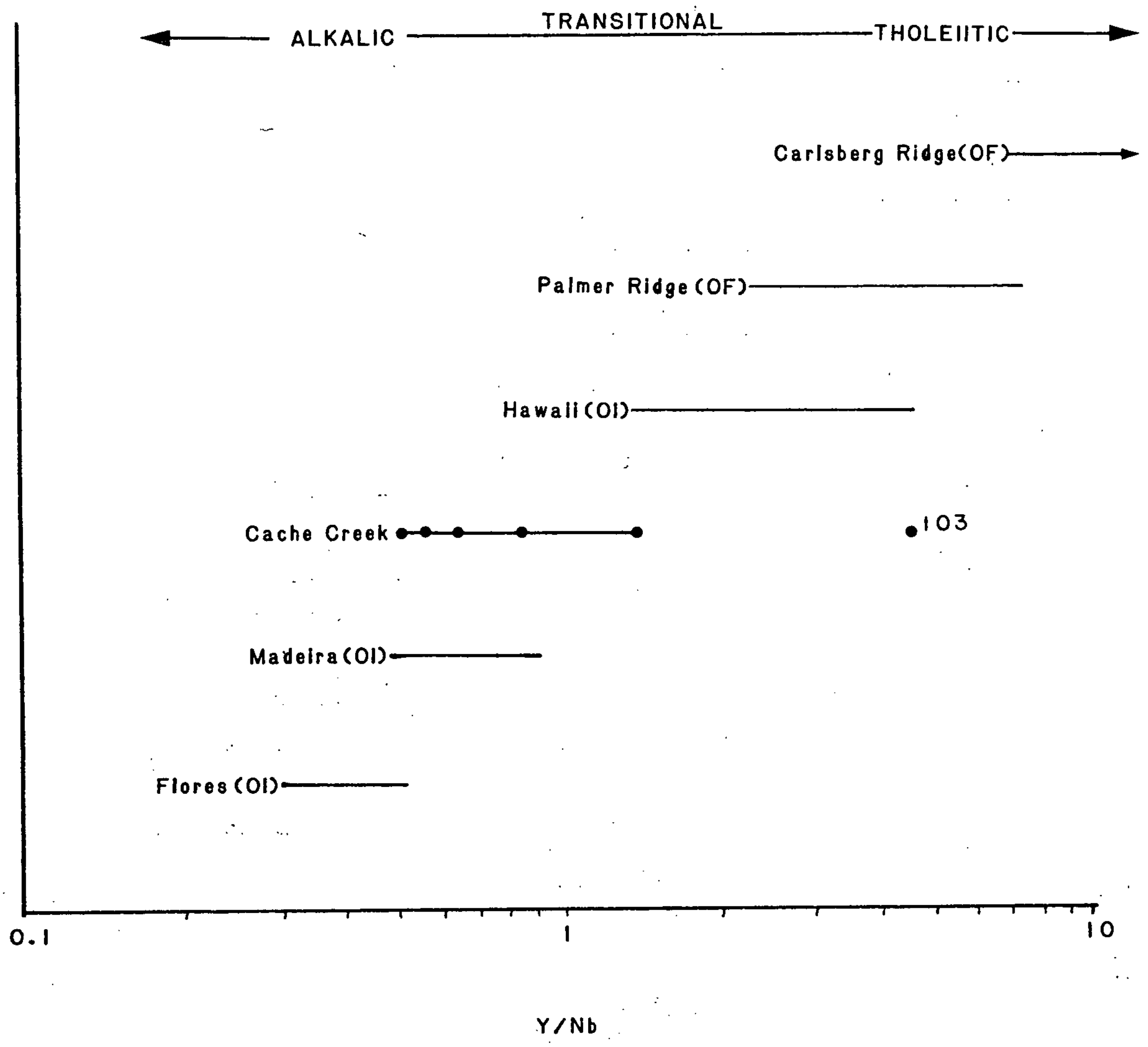

Figure 17. Alkalic to tholeiitic plot of Y/Nb, adapted from Pearce and Cann, 1973

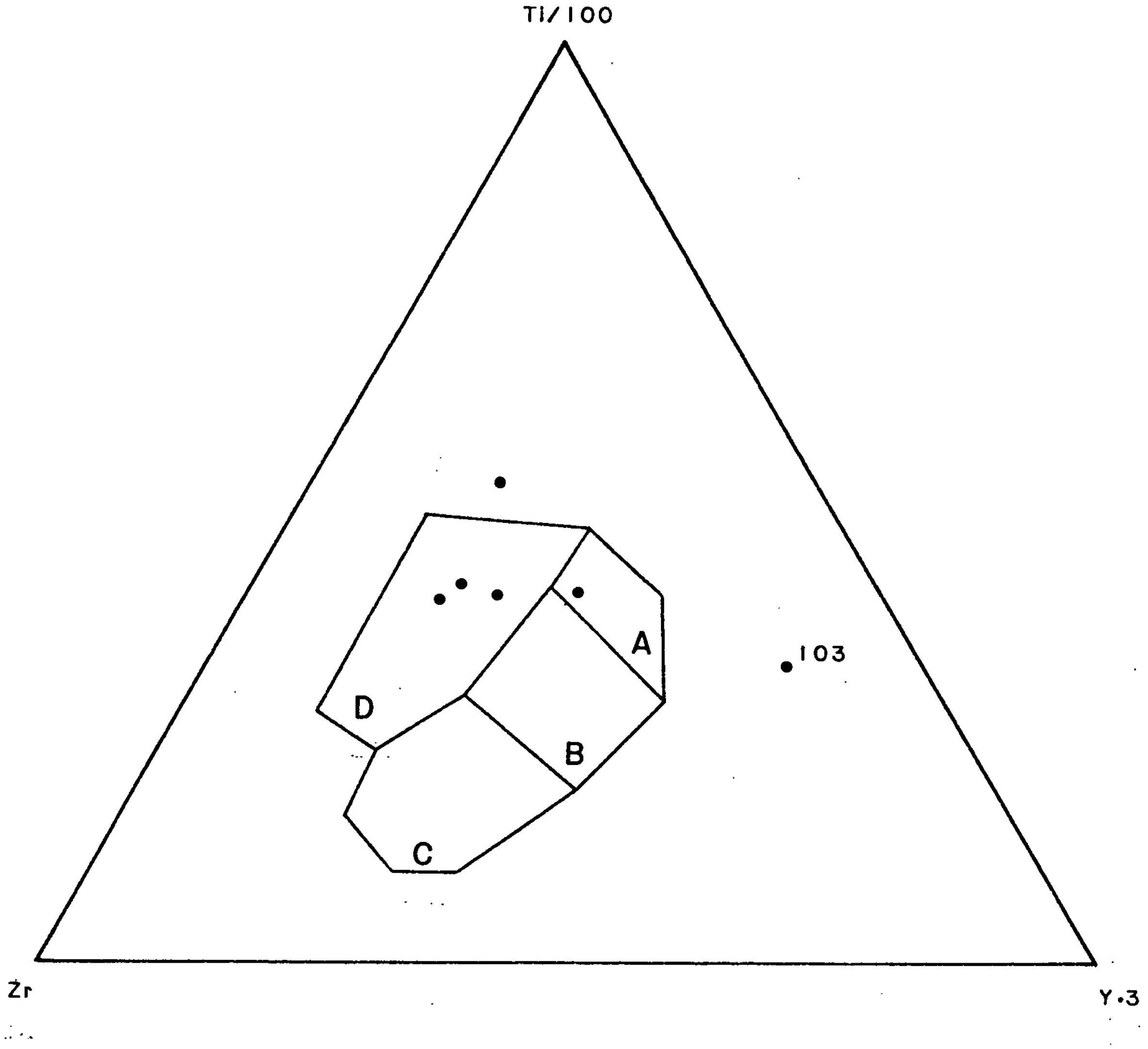

Figure 18. Discrimination diagram, adapted from Pearce and Cann, 1973. Field D = ocean island or continental basalt. Field A+B = low potassium tholeiites. Field C+B = calc-alkali basalt

AGE OF THE GREENSTONE UNIT

Dating the greenstone is difficult because of rarity of fossils. Fusulinid limestone clasts in a basalt volcaniclastic rock 3 km northwest of Carquile have been assigned an Early to Mid-Permian age by W.R. Danner (pers comm, 1981). A single conodont fragment found in a limestone clast in basalt 5 km south of Cache Creek has been identified as Upper Permian by M. Orchard (written communication, 1981). These two dates suggest that the greenstone unit was likely deposited in the Permian.

III) MARBLE CANYON FORMATION

The Marble Canyon Formation crops out mainly along the east side of Hat Creek valley and to the north in the Pavilion Mountains. Areas underlain by the Marble Canyon Formation can be distinguished on air photographs by the prominent white limestone cliffs which the unit tends to form. Caves and sinkholes and some tufa springs are found in the Marble Canyon Formation and are a reflection of its importance in the local groundwater circulation.

The Marble Canyon Formation as described by Duffell and McTaggart (1952) is predominantly limestone with less than 10% andesite, chert and argillite. However new exposures along logging road cuts in the area mapped as Marble Canyon Formation indicate that the amount of material other than limestone is substantially greater than 10%. Except for local areas that are almost all limestone such as the top of Cornwall Hills, Whiterock Cliffs and Marble Canyon itself the Marble Canyon Formation is composed of basaltic volcaniclastic rocks, limestone beds, radiolarian chert, argillite and minor serpentine in decreasing order of abundance. Because of its resistance to weathering in this area the limestone forms a higher percentage of natural outcrops, but in road-cuts it can be seen that limestone forms less than 50% of the Marble Canyon Formation.

The most common lithology among the limestones is a dark grey and white mottled variety which weathers light grey. It is commonly cross-cut with coarsely crystalline calcite veins up to several centimetres in width. Other varieties include tan limestone with black stringers (graphite?) and dolomitized limestone with small rhombs of white-orange dolomite (0.1-0.2 mm) forming up to 10% of the rock. Some limestone has been almost completely converted to dolomite.

One of the more fossiliferous rocks in the Marble Canyon Formation is a clastic rock with fragments of greenstone, micrite, fusulinids, crinoid columnals and other fossil debris in a fine grained tuffaceous(?) matrix (Fig. 19). Occasionally these clastic rocks are found interbedded with radiolarian chert (station #296, Fig. 30). It is unusual to find units with shallow water fossils such as fusulinids interbedded with radiolarian chert. Abrasive rounding of some of the clasts indicates transport of the fossil debris to the site of deposition. Turbidite transport or debris flow of the shallow water fossils would provide a mechanism for their emplacement in supposed deeper water sediments.

Another distinctive unit in the Marble Canyon Formation is an oolitic to pisolitic limestone which is best exposed on Cornwall Hills (Fig. 20). Dolomitization has been highly selective in these rocks sometimes replacing the cores of the oolites and sometimes the edges or even a few selected bands in the oolite. These limestones probably formed in shallow, warm and agitated seas, as these conditions are required for oolite formation.

As well as oolitic limestone, outcrops of thin bedded radiolarian limestone and tuff are also found on Cornwall Hills (Fig. 21). These rocks are interpreted as deep water facies because of their thin even bedding and lack of benthic organisms. Clasts of oolitic limestone are found in the tuff interbeds of the radiolarian limestone sequence. The presence of shallow water oolite clasts in the deep water radiolarian limestone and tuff indicates that the topgraphy on the seafloor must have been steep at this locality. Steep topography would allow the shallow water oolitic debris to slide down into the radiolarian limestone basin.

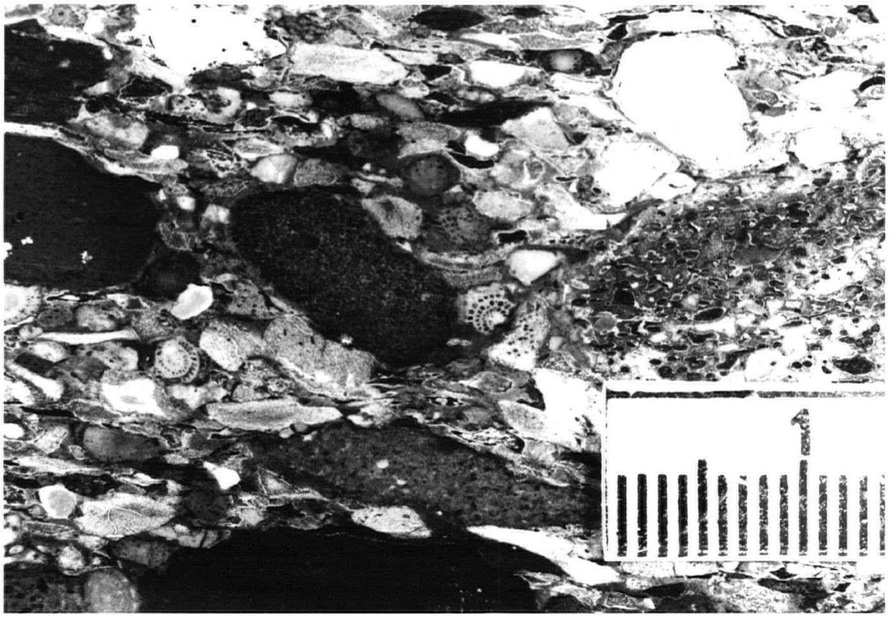

Figure 19. Basalt volcaniclastic rock with fusulinids. The fusulinids are visible as the round clasts with dark spots radiating out from their centres. From west side of Hat Creek Valley to the south of Medicine Creek

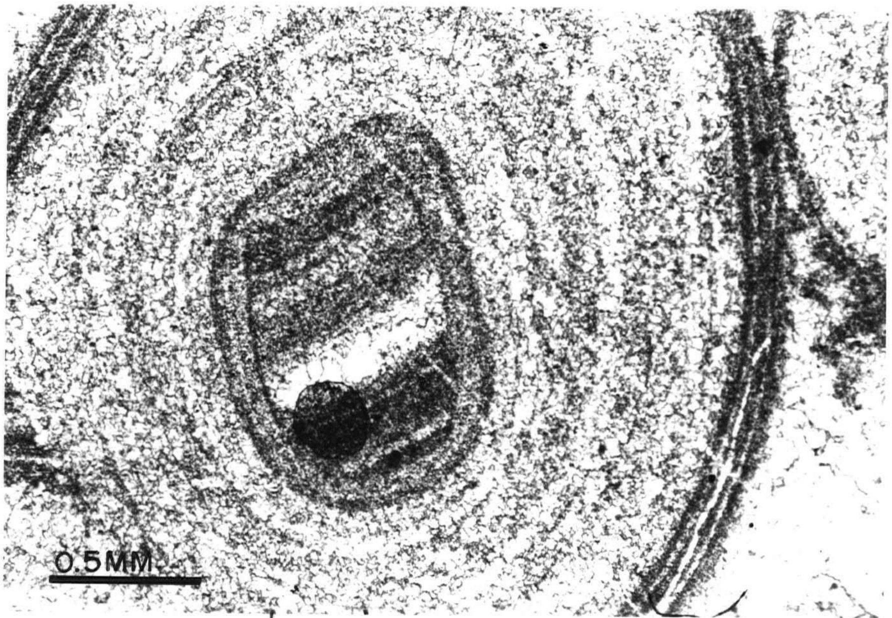

Figure 20. Compound pisolitic texture in limestone from top of Cornwall Hills at south end of map area

Figure 21. Interbedded radiolarian limestone and tuff from near top of Cormwalls Hills

AGE OF THE MARBLE CANYON FORMATION

Fusulinids found previously in limestones of the Marble Canyon Formation in southern B.C., range in age from Mid-Pennsylvanian to late Permian (Danner and Nestell, 1966). A Late Permian age was reported by Grette (1978) for fusulinids in the Marble Canyon Formation west of Venables valley and to the south of this map area. Ages in collections made during this study range from Early Permian to Middle Permian (W.R. Danner, pers comm, 1981). Samples were also processed for conodonts and ages determined range from probable Late Pennsylvanian to Late Triassic (M. Orchard, written communication, 1981). Two collections of radiolaria obtained from ribbon cherts in the Marble Canyon Formation near station #296 (Fig. 30) gave Early

Permian dates (D. Jones, written communication, 1981). W.R. Danner has collected thin shelled Halobia like Triassic pelecypods in limestones northwest of the lookout on Cornwall Hills (pers comm, 1981). Greenstone tuffs on Cornwall Hills have been assigned an Early Triassic age on the basis of conodonts in interbedded limestones (M. Orchard, written communication, 1981). These conodonts provide clear evidence for the continuation of Cache Creek volcanism into the Early Triassic; these are the youngest known Cache Creek Group volcanic rocks in the Canadian Cordillera.

Deposition of the Marble Canyon Formation was mainly during the Permian but extends from the Late Pennsylvanian to as young as the Late Triassic. In a regional perspective the Marble Canyon Formation appears to become progressively younger from northeast to southwest; most of the older Pennsylvanian to Early Permian limestones occur in the northeast, the Middle Permian is in the central part of the map area and the Late Permian to Triassic is found to the southwest.

IV) SERPENTINITE

Serpentinite is found as isolated outcrops in all the units of the Cache Creek Group. Normally there are abundant slickensided surfaces and fractures throughout the outcrops. Serpentinite usually crops out as a rubbly green talus slope

(Fig. 22) and commonly weathers recessively.

Figure 22. Serpentinite outcrop showing typical recessive nature from south side of Scottie Creek

Colour varies depending on amount of fracturing. Highly fractured samples tend to be light green to almost white whereas fresher relatively unfractured serpentine is dark green to almost black. Cross-cutting zones of white serpentinite alteration products are quite common. North of 16 Mile diorite dykes cut through the serpentinites along an easterly trend. Chalcedony and calcite veins usually <3 cm thick are also quite common in the serpentinites, often the chalcedony will weather out in raised relief giving a coarse mesh texture to the outcrops.

A common alteration product of the serpentinite bodies is a quartz, carbonate and fuchsite (chromian-mica) rock which is a distinctive orange-white colour with bright green speckles of fuchsite. The quartz-carbonate rock is resistant to weathering and tends to form ridge outcrops or circular knobs. This rock may be erroneously identified as malachite stained gossan material and is probably the quartz-carbonate with 2-3% chalcopyrite and malachite described by Ladd (1979) near Oregon Jack Creek (W. McMillan, pers comm, 1981) just to the south of the map area. Chromite was rarely observed in serpentinites in the field but in thin-section chromite occurs as small discrete brecciated crystals disseminated throughout the serpentinite.

The occurrence of serpentinite as a series of aligned bodies, together with its highly sheared nature and fault bounded outcrop margins indicate that emplacement of the serpentinites was likely related to fault activity. Most of the serpentinites are found along or near the Bonaparte Valley so probably this was an area of high fault activity. A recent discovery of serpentinites in the Marble Canyon Formation by H. Kim and A. Penner of B.C. Hydro was examined by the writer in January, 1981. It is located along the east side of Hat Creek Valley to the south of Medicine Creek in a logging road cut. It is variably sheared to fresh serpentinite in a sequence of limestone and basaltic volcaniclastic rocks, typical of the Marble Canyon Formation. This discovery means that the belt of serpentinite outcrops is over 20 km wide.

CORRELATION OF UNITS

Several outcrops in the field areas of Grette (1978) and Ladd(1979) were visited so a correlation could be made with the divisions of the Cache Creek Group established in this study. J. Grette divided the Cache Creek into three divisions, a lower clastic unit, a mafic volcanic unit and an upper clastic unit. J. Ladd divided the Cache Creek Group into a mélange unit and the Marble Canyon Formation. Areas of greenstone were interpreted by Ladd (1979) as large blocks in the mélange unit. The following correlations are suggested:

Cache Creek Group

(Shannon,1981)	(Grette,1978)	(Ladd,1979)
1. Marble Canyon Fm--	1. Upper Clastic Unit---	1. Marble Canyon Fm
2. Greenstone Unit---	2. Mafic Volcanic Unit--	2. Melange Unit
3. Melange Unit------	3. Lower Clastic Unit---	3. Melange Unit

NICOLA(?) GROUP

The Nicola(?) Group rocks are part of a package of felsic volcanic rocks and sediments which have been dated as Late Triassic by Grette(1978) and Travers(1978) and were correlated by them with the Nicola Group to the east. Similar rocks crop out immediately adjacent to the Guichon Batholith and are found as far south as Merritt (W.R. McMillan, pers comm, 1981 and Morrison, 1980). Rocks called Nicola(?) Group in this study are correlated with other Nicola Group rocks to the east strictly on lithostratigraphic grounds. Mapping was not sufficently detailed to outline the distribution of sub-units in the Nicola(?) Group rocks, but for descriptive purposes the Nicola(?) Group was divided into a felsic tuff unit and a volcaniclastic unit.

I) FELSIC TUFF UNIT

Best exposures of the felsic tuff unit are to the north of Cache Creek on Cattle Valley Ridge and also to the south of Red Hill along Highway 1. The felsic tuff unit consists mainly of a light green tuff with augens of quartz, plagioclase and chert in an aphanitic mica-chert matrix. Undulatory extinction was evident in some of the quartz grains. Extensive recrystallization has changed the chert grains to metamorphic quartz patches with highly sutured boundaries. Late stage carbonatization has replaced up to 15% of the rock with calcite.

Thinly laminated limestones up to several metres thick are found with these rocks. Abundant crinoid columnals were observed in these limestones which are dark grey on a fresh surface and weather a light grey to white. Included within this unit are minor amounts of coarser volcaniclastic debris.

II) <u>VOLCANICLASTIC UNIT</u>

The main exposures of the volcaniclastic unit are southwest of McLean Lake and along the Hat Creek road (station #19, Fig. 30). The volcaniclastic unit is characteristically blue green in colour and includes both pyroclastic and epiclastic rocks (mostly lapilli tuffs and volcanic sandstones, Fig. 23). A characteristic of the lapilli tuffs is their felsic nature; quartz "eyes" are very common and silicification is extensive. Chlorite, pumpellyite and stilpnomelane are found as alteration and replacement products. The blue green colour of the rocks is due to the extensive chloritization. Clast lithologies include amygdaloidal volcanic rocks, chert, fine-grained sediments, felsic intrusive rocks and limestone. Pyritization is very common in this unit with 1-3% pyrite in most samples.

Epiclastic rocks become more dominant higher in the Nicola(?) section and at the contact with the overlying Jurassic sediments the Nicola(?) is entirely sedimentary (Travers, 1978, Woodburn Ranch). The change in the Nicola(?) from dominantly volcanic to sedimentary is reflected in deposition of immature volcanic sandstones, siltstone and minor claystone in the upper Nicola(?) section.

Rocks of the Pavilion beds to the northwest (Trettin,1980) were examined in an effort to correlate Nicola(?) strata west to the Fraser River. Near Big Bar, along the Fraser River about 50 km northwest of Cache Creek, green volcanic sandstones were sampled. Colour, clast lithology and amount of silicification and pyritization were very similar to Nicola(?) rocks cropping out south of Cache Creek (Fig. 24). Conodonts recovered from nearby limestone interbeds gave a Late Triassic age (M. Orchard, written communication, 1981), which is the same age as the Nicola(?) Group rocks. Because of these similarities the Nicola(?) rocks have been correlated with the Pavilion beds. The correlation of Nicola(?) rocks and the Pavilion beds is significant as it extends the area of felsic volcaniclastic rocks west as far as the Fraser River. No rocks of Nicola(?) affinity have been found with the Marble Canyon Formation or greenstone unit of the Cache Creek Group between Big Bar and Cache Creek.

Felsic volcaniclastic blocks in the Cache Creek Group mélange unit have been correlated with the Nicola(?)Group. The main points of this correlation are as follows:

NICOLA(?) GROUP VOLCANICLASTICS	CACHE CREEK GROUP VOLCANICLASTICS	FELSIC VOLCANICLASTIC BLOCKS IN MELANGE
1. diverse lithology including siltstone felsic volcanics and chert.	1. basalt, limestone clasts only.	1. diverse lithology including siltstone felsic volcanics and chert.
2. contains felsic volcanic units such as ash flow tuffs and quartz-eye porphyries.	2. contains no felsic volcanic rocks.	2. contains felsic volcanic units such as ash flow tuffs and quartz-eye porphyries.
3. ubiquitous pyrite in this unit ranging from 1-3%.	3. pyrite is rare.	3. pyrite is present in all blocks usually >2%.

The above comparison suggests that the felsic volcaniclastic blocks are part of the Nicola(?) package and not the Cache Creek Group. The occurrence of Nicola(?) blocks in the Cache Creek mélange unit is significant. Such a relation would suggest that the Nicola(?) rocks were being deposited into the Cache Creek mélange unit as it was forming.

AGE OF THE NICOLA(?) GROUP

No diagnostic fossils were found in any units of the Nicola(?) Group in the thesis area. Thinly bedded limestones on Cattle Valley Ridge to the north of Cache Creek produced abundant fish teeth during conodont processing but no conodonts were found. Ammonite fossils found in Nicola(?) sediments southeast of Cache Creek are dated as Late Triassic (Travers,1978). A Late Triassic age based on conodonts is

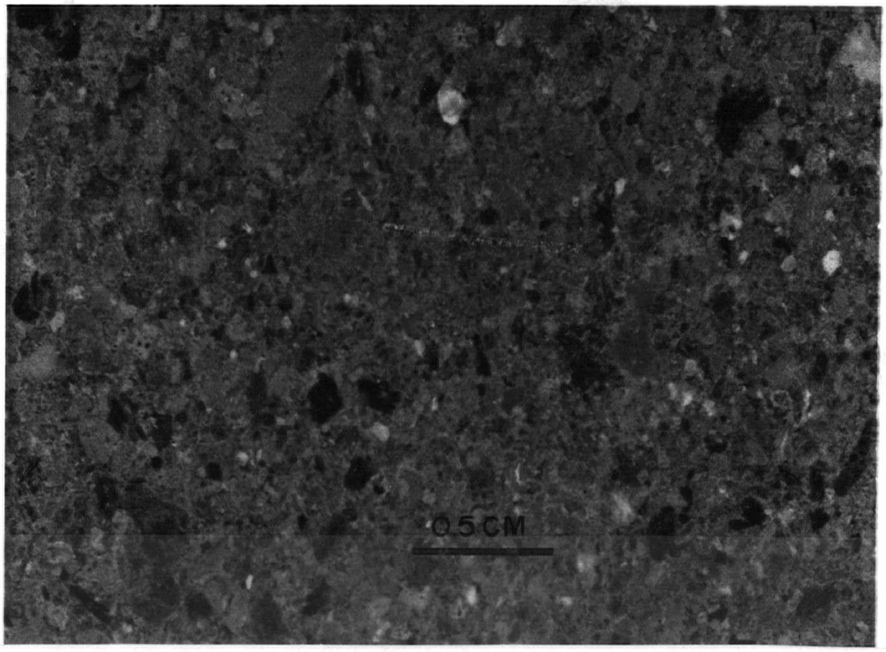

Figure 23. Nicola(?) volcaniclastic rock from along the Hat Creek road approximately 8 km west of Carquile

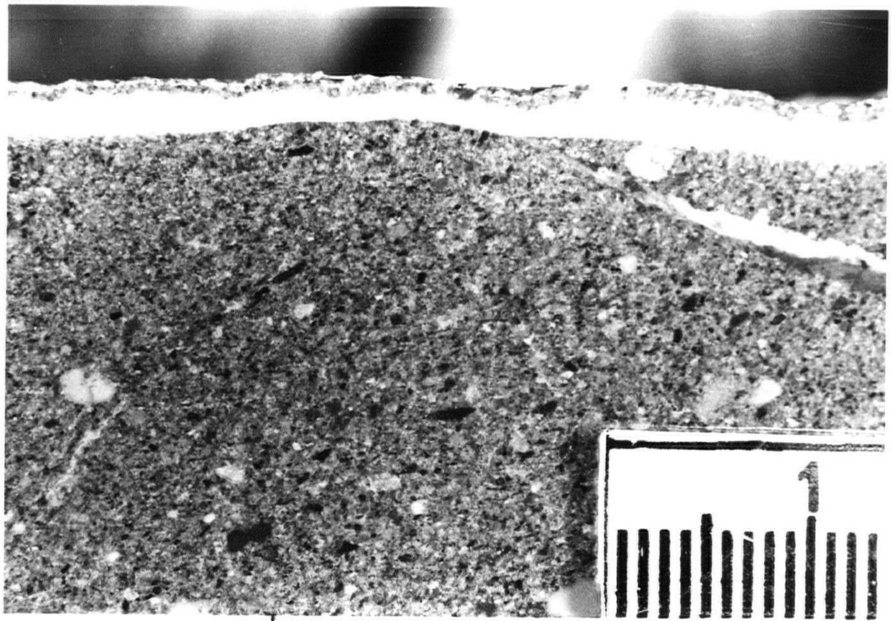

Figure 24. Pavilion bed volcaniclastic rock from along roadside approximately 6 km east of Big Bar

reported for Nicola limestones by Grette (1978). Volcanic rocks dated by Rb-Sr (Grette,1978) indicated a Late Triassic age as well. Limestones of the Pavilion beds which are correlated with the Nicola(?) rocks have produced Upper Triassic conodonts (M. Orchard, written communication, 1981).

Nicola(?) Group rocks represent a period of extensive Late Triassic volcanism with marine limestones present locally. Extensive erosion during the Late Triassic produced the volcanic sediments predominating in the upper part of the Nicola(?) Group.

ASHCROFT FORMATION

North of the Bonaparte Indian Reserve within the Cache Creek Group is a large area of brown to grey conglomerate and siltstone. Some areas of finer grained sediment show a weak foliation. No fossils were found in these rocks but on lithological grounds they are correlated with the Lower Jurassic Ashcroft Formation as described by Travers (1978) in the vicinity of Ashcroft, B.C. Outcrops of well foliated siltstone and sandstone with no conglomerate, which occur to the northwest of 20 Mile House extending to Clinton are tentatively correlated with the Ashcroft Formation.

Clasts in the conglomerate on the Bonaparte Indian reserve are extremely variable in size although usually not exceeding 10 cm in diameter. Clast lithologies are mostly intermediate to felsic intrusive rocks, quartz-feldspar porphyries and argillaceous sediments with minor gray micritic limestone and mafic volcanic rocks (Fig. 25). Well rounded clasts indicate that the conglomerate is quite mature but some of the argillaceous sediment clasts are quite angular; perhaps they were incorporated into the conglomerate close to the depositional site. Sand size matrix material usually exceeds

Figure 25. Ashcroft Formation conglomerate on the Bonaparte Reserve north of Cache Creek, B.C.

10% of the rock and appears to be mostly quartz. Cross-cutting calcite stringers are common.

Siltstone and minor argillite interbedded with the conglomerate have locally developed slaty cleavage. Sometimes this foliation is perpendicular to bedding but usually it is subparallel. Elsewhere in the map area outcrops of Ashcroft Formation are mainly siltstone and sandstone with no conglomerate. Foliation is usually present at low angles to bedding. An outcrop of Ashcroft Formation sandstones and siltstones along Lower Hat Creek is stratigraphically underneath Nicola(?) felsic volcanics and sediments. A single tops determination on Nicola(?) siltstones indicates that the unit is right side up, this would place Triassic rocks on Jurassic rocks. The most likely cause of such a stratigraphic anomaly is that the Jurassic rocks have been faulted into place against the Nicola(?).

RED CONGLOMERATE SANDSTONE UNIT

A few outcrops of red conglomerate and sandstone are visible along and north of the lower Hat Creek Road. Clast lithology is quite variable including limestone, chert, green to white felsic volcanic rocks, argillaceous sediments, serpentine and quartz, usually in a sparry white calcite cement. Clasts are subrounded to subangular and range up to 20 cm across. Abundant bright red clasts are distinctive and include siltstone, jasper and red chert. An outcrop close to the Marble Canyon Formation on the Hat Creek Road contains fusulinid limestone clasts; another about 4 km west of Carquile contains abundant chromite-serpentine clasts.

The correlation between Cache Creek bedrock type and clast lithology in the conglomerate, the poorly sorted coarse nature of the deposits, presence of minor crossbedding and the limited extent of the unit all indicate an alluvial fan depositional environment for the conglomerate unit (Friedman and Saunders, 1978). Age of the red conglomerate sandstone unit is unknown although it appears to underlie a mid- Cretaceous chert pebble conglomerate at station #271 (Fig. 30).

CHERT PEBBLE CONGLOMERATE UNIT

A chert pebble conglomerate unit is found along Lower Hat Creek. Outcrops continue both to the south and north along strike. G. Dawson (1895a) mapped the chert pebble conglomerate unit as the Coldwater Formation of Oligocene age. Subsequent workers assigned a Tertiary or Eocene age to the Coldwater, including Duffell and McTaggart (1952) and Church (1975).

Although sandstones and conglomerates are the main lithologies in the unit it also contains minor siltstone layers. The most common clast lithology in the conglomerates is grey to black chert pebbles (usually >50%) which contain visible radiolaria. Other clasts include aphanitic volcanic rocks, argillaceous sediments, high grade metamorphic rocks (with sutured quartz grains) and distinctive felsic tuffs and ash. A high level of maturity is indicated by the preponderance of well rounded chert and quartz clasts, usually less than 3 cm in diameter. Incompetent rounded white ash clasts found throughout this unit are anomalous in such a mature sediment. Likely volcanism during the Cretaceous which produced the Spences Bridge Group to the south and west has contributed ash to the chert pebble conglomerate.

The conglomerate is often cemented with sparry calcite composing up to 5% of some samples. In thin-section it can be seen that thin Fe-oxide rims have formed around many clasts, probably as a result of alteration from groundwater flowing through this permeable unit. Most of the sandstones are composed chiefly of small chert grains and quartz fragments. Tops structures such as truncated crossbedding indicate that the beds are right side up. Paleoenvironmental indicators include mostly planar and massive bedding with little cross-bedding; thick layers of coarse sediments and sand with local fining upward sequences; large carbonized logs up to 60 cm in diameter; an absence of fine grained sediments and lack of marine fossils. These are indicative of braided river deposits (Friedman and Saunders, 1978).

AGE OF THE CHERT PEBBLE CONGLOMERATE UNIT

Previously these continental rocks were assigned an Tertiary age based on lithological correlation (Dawson, 1895, Duffell and McTaggart, 1952 and Church, 1975). Palynomorphs collected at station #280 (Fig. 30) were examined independantly by G. Rouse (University of B.C.) and W.S. Hopkins (Geological Survey of Canada) and assigned a Late Albian or Cenomanian age. Correlation with the Eocene Coldwater Group and the Eocene Hat Creek rocks is therefore invalid. The chert pebble conglomerate unit is probably correlative with the Pasayten Group to the south (Monger, 1981).

KAMLOOPS GROUP

The Kamloops Group consists mainly of agglomerates, lahars and vesicular basalt and andesite. The lahars have sub-angular to sub-rounded clasts which can exceed 30 cm in diameter set in a fine grained silty matrix. Clast lithologies include light coloured andesite and dacite and black glassy basalt. The Kamloops Group crops out mainly to the east of the Bonaparte Valley but also occurs as isolated knobs scattered throughout the map area. This is the youngest unit in the map area and has been assigned an Eocene age by Church (1975) based on radiometric dating. A prominent basalt outcrop north of the Oregon Jack Creek road and west of the road leading up to the Cornwall Hills forestry lookout has a K-Ar age of 48 Ma (W.R. Danner, pers comm, 1980).

Chalcedony and minor opal veinlets commonly cross-cut the volcanic units and vuggy cavities lined with small crystals of quartz and calcite are common. Some of the volcanic units are fairly incompetent and north of Carquile a few large caves were observed in cliffs of Kamloops Group volcanic rocks. Large areas of white rhyolite cropping out northwest of McLean Lake and north of White Rock cliffs are also included in the Kamloops Group and have been dated as Eocene (51 Ma) by Church (1979). Tuffs and ash units containing clasts of serpentinite were found in the Kamloops Group in some outcrops to the northeast of the Bonaparte Indian Reserve. Minor sandstones and siltstones are also found in the Kamloops Group. Kamloops Group rocks unconformably overlie Cache Creek Group greenstones at #265 (Fig. 30) but in some places they are in fault contact.

STRUCTURAL GEOLOGY

There are two dominant structural trends in the map area, the oldest strikes 140 degrees and parallels the strike of much of the Cordillera. It is reflected by an elongate distribution of map units (see Fig. 3). A pronounced feature associated with this trend is a foliation reconized in most pre-mid-Cretaceous rocks. The younger structural trend strikes northeast and is reflected by numerous linear river valleys and lakes.

These two dominant structural features are truncated by a later one that strikes north. These north striking structures are thought to have controlled the development of Eocene basins in the map area which formed in grabens (eg. Hat Creek, Church, 1975).

Reactivation of faults has occured throughout the region as evident from the fault juxtaposition of older rocks such as the Cache Creek Group against younger rocks such as the chert pebble conglomerate and Kamloops Group. Faulted contacts appear to be characteristic of the units in this region and extensive faulting has led to the development of isolated fault bounded blocks.

STRUCTURAL STYLE OF INDUVIDUAL UNITS

A penetrative deformation, recognized by a micaceous foliation and shear fabric has affected both Cache Creek and

Nicola(?) Group rocks. A planar foliation consisting of aligned argillaceous partings is seen in radiolarian cherts, elsewhere the cherts may be highly brecciated as a result of the extensive shearing. The absence of a pronounced planar mineral fabric within the Cache Creek Group limestones is due mainly to a lack of platy mineral grains. Whilst fusulinids within the limestone near the Marble Canyon entrance are distorted, most of the strain effects have been destroyed as a result of post-deformational recrystallization.

A mylonitic fabric developed within Nicola(?) Group rocks is best seen in the quartz-eye tuff unit on Cattle Valley Ridge, to the north of Cache Creek. Quartz augens (0.1-0.5 mm diam) showing undulatory extinction occur in an aphanitic matrix of sericite and microcrystalline quartz which wraps around the quartz augens in a flaser texture.

In both the Cache Creek Group and Nicola(?) Group foliations are parallel or sub-parallel to bedding and have a strike direction of 140 degrees (Figs. 26 and 27). Minor exceptions to this foliation orientation strike northeasterly, almost perpendicular to the major strike direction. The general conformity of foliation to bedding is best explained by the presence of large isoclinal folds. This hypothesis is supported by the orientation of bedding which is predominantly steep and dips to the southwest except within anomalous zones in which the bedding usually dips northeast. These anomalous zones are interpreted to be structurally located in the hinge zones of the large isoclinal folds. Large isoclinal folds (limb lengths in

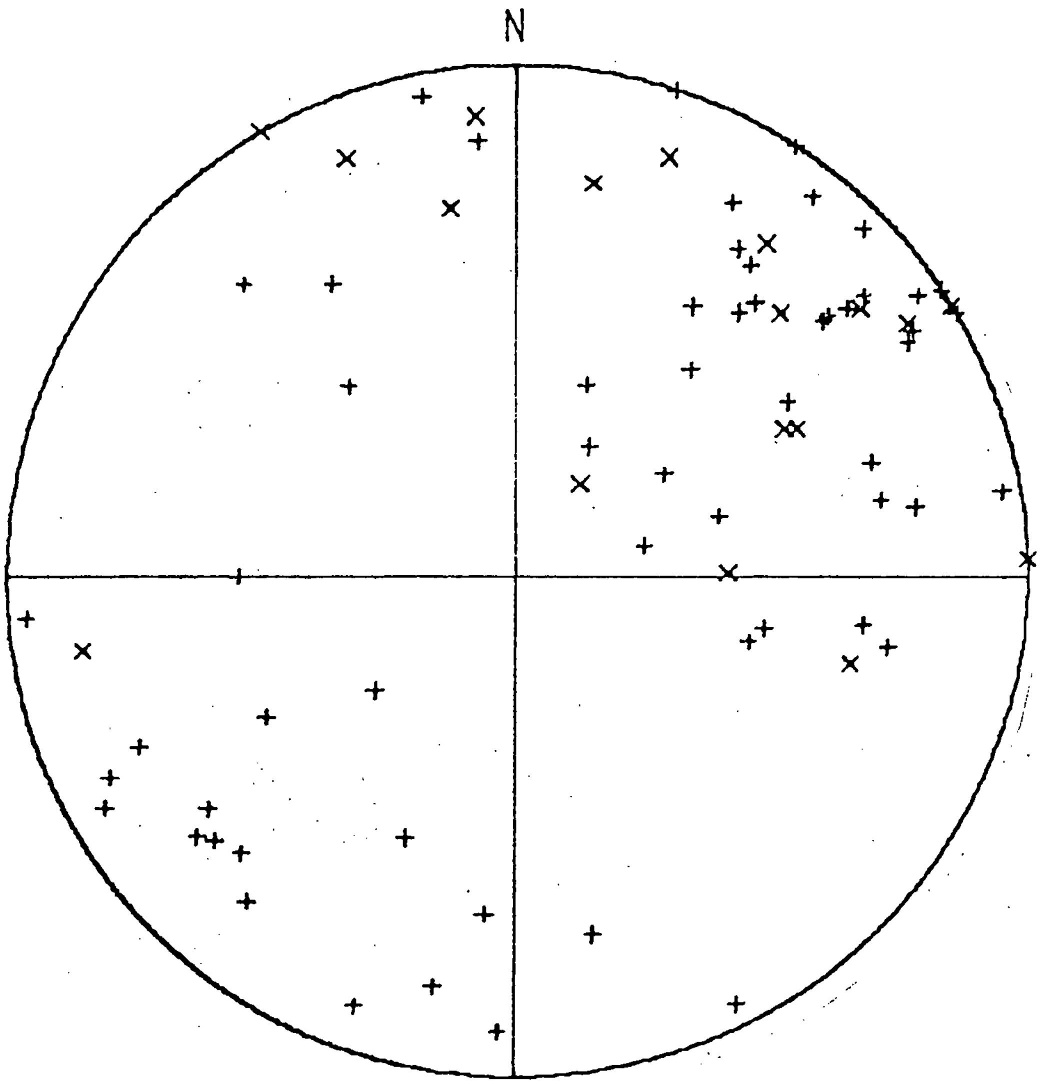

Figure 26. Stereoplot of poles to bedding and foliation, Cache Creek Group, foliation(+), bedding(X)

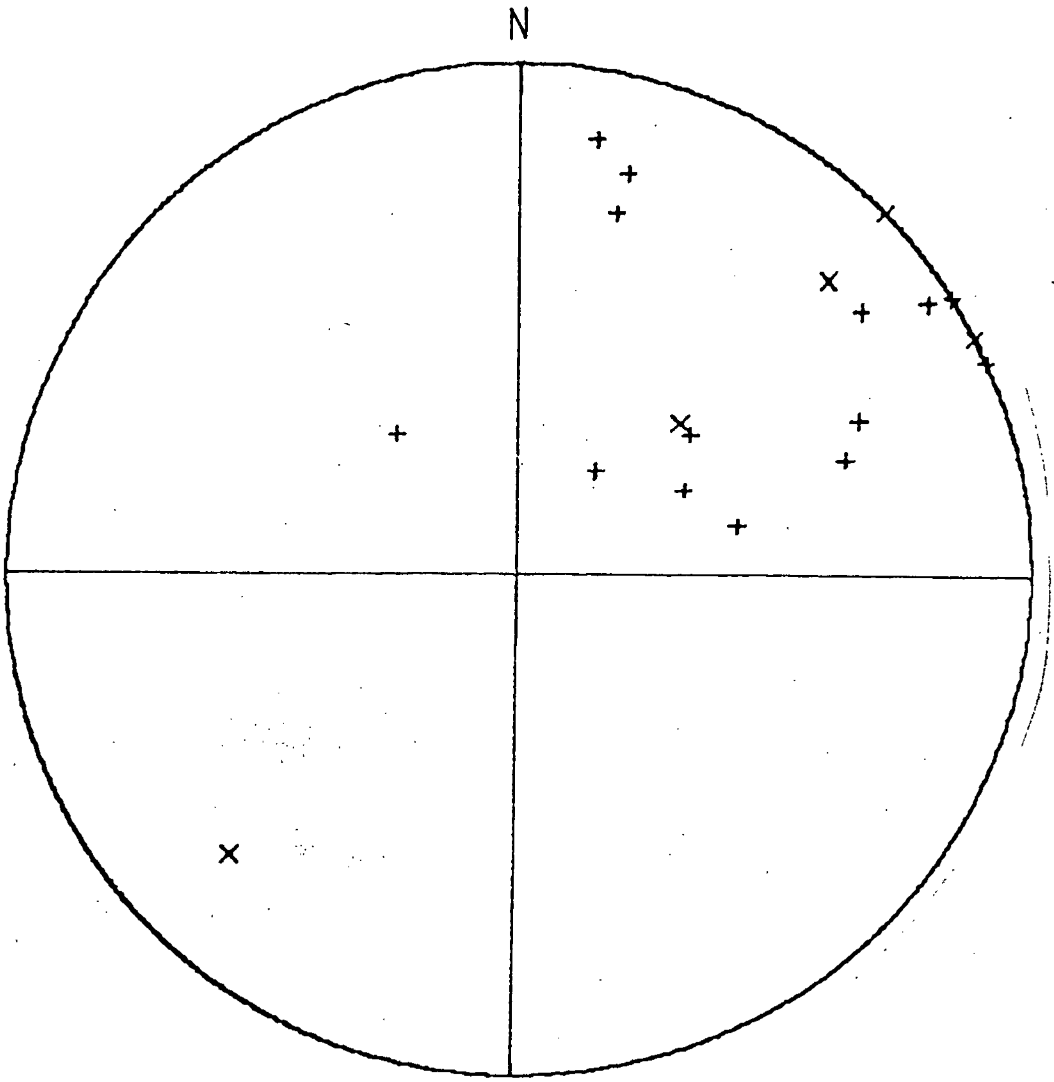

Figure 27. Stereoplot of poles to bedding and foliation, Nicola(?) Group, foliation(+), bedding(X)

excess of 1 km) have been reported in the Marble Canyon Formation by Trettin (1980) and W.B. Travers (pers comm, 1980). Slaty cleavage within the Early to Mid-Jurassic Ashcroft Formation also has a pronounced northwest-southeast strike, W. Travers (1978) reported a modal value of 136 degrees strike and a southwesterly dip of 32 degrees. W. Travers also presents evidence of soft sediment deformation features in the Ashcroft Formation. These soft sediment features include lack of fractures in tight fold hinges and thin wispy pull-apart structures in sandstone layers. The presence of soft sediment deformation structures in the Ashcroft Formation indicates that formation of the 140 degree foliation occured when the sediments had not yet been lithified. In as much as the 140 degree foliation developed in mid-Jurassic strata and not in post-mid-Cretaceous strata, development of the 140 degree foliation must then be post-mid-Jurassic and pre-mid-Cretaceous. Soft sediment deformation structures in the Ashcroft Formation suggest that the deformation was close to mid-Jurassic time.

Because of repeated reactivation of the faults the original contacts between units have been modified (eg. the contact between the Cache Creek Group mélange unit and the Nicola(?) Group). Clasts of presumably Cache Creek Group radiolarian chert are found in volcanic greywackes of the Nicola(?) Group south of Cache Creek. The presence of clasts of Cache Creek rocks in Nicola(?) sediments indicates that the contact between the two units is probably an unconformity and at least locally the Cache Creek mélange rocks were being uplifted in Triassic time. The best exposed contact is a steep fault on the Woodburn Ranch south of Cache Creek (Travers, 1978). Nicola(?) sedimentary rocks probably have an unconformable relationship with the mélange unit, but nowhere are they seen to occur unconformably on the greenstone unit or Marble Canyon Formation. The fact that the Nicola(?) Group rocks are not found unconformably with respect to the greenstone unit or Marble Canyon Formation is a very significant factor in tectonic modelling for the area. This aspect will be covered in more detail in the chapter on tectonic history.

The Nicola(?) Group-Ashcroft Formation contact appears to be a faulted one throughout most of the map area. North of the Bonaparte Indian Reserve steeply southwest dipping Nicola(?) strata abutt gently dipping Ashcroft conglomerates along a linear depression trending across the hillside. This feature has a 140 degree trend and is probably a fault. Along the Hat Creek Road, near station #19 (Fig. 30) Nicola(?) rocks overlie Ashcroft siltstones and sandstones. Differing orientation of the units suggests a fault contact. To the south Travers (1978) reported the contact both as an unconformity and as a thrust fault, the thrusting post-dates the unconformity.

Such complexly faulted interelationships continue into Eocene time. At station #265 (Fig. 30) immature sandstones of the Eocene Kamloops Group unconformably overlie greenstones of the Cache Creek Group. About 3 km to the north the contact is a vertical fault striking north-south which contains serpentine bodies cropping out along the contact. The varied nature of the stratigraphic contacts reflects the deformational history of this area between Triassic and Eocene time.

PALEOENVIRONMENTAL RECONSTRUCTION

The association of radiolarian ribbon chert, pillowed basalt, gabbro, ultramafic rock and limestone suggest an oceanic environment for deposition of Cache Creek Group rocks. A variety of specific enviroments has been proposed including a mid-ocean ridge as well as volcanic seamounts (Monger, 1977). Geochemical evidence of high concentrations of Nb and Ti suggest an ocean island or continental environment (Pearce and Cann, 1973). The occurrence of abundant shallow water faunas such as fusulinids and calcareous algae suggest a shallow marine environment. Together the geochemistry and paleontology suggest a large oceanic island or oceanic plateau environment as the most likely depositional site.

Shallow water indicators in the limestones such as fusulinids, oolites and algal laminations show that most of the Cache Creek oceanic plateau must have been covered by shallow warm seas. Conditions were tropical as is supported by the growth of large fusulinids which probably grazed on algae and other organic debris on carbonate banks (W.R. Danner, pers comm, 1980). Evidence for minor sub-areal exposure has been reported in the Cache Creek Group near Dease Lake, B.C. (Morrow, 1967).

This Cache Creek plateau was mainly composed of mafic volcanic and volcaniclastic rocks and limestone. Intermixing of limestone and mafic volcanic rocks is common in the Cache Creek Group in southern B.C. In northern B.C. the Cache Creek Group usually has distinct areas of limestone and volcanic rocks with little interbedding of the two (Monger,1977).

Both adjacent to and within the plateau were deeper water areas of pelagic deposition. Argillite and chert were most common in these areas. Topographic relief on the plateau and its margins led to the sedimentation of both carbonate and chert debris-flow deposits into the surrounding pelagic sediments. From time to time large blocks of limestone were broken off the plateau and slid into the deeper water radiolarian chert and argillite sediments. Almost all the limestone blocks in the mélange unit of the Cache Creek Group contain the same or similar Permian conodont fauna (M. Orchard, pers comm, 1981). The limestone blocks were probably dislodged by cataclysmic events such as hurricanes or earthquakes and emplaced as submarine talus and slide deposits. A similar explanation for limestone blocks interbedded with radiolarian chert in the Cache Creek Group in northern B.C., has been proposed by J. Monger (1977).

Felsic tuffs, agglomerates and flows with some basaltic rocks characterize the lower Nicola(?) while the upper part is mainly water-lain volcanic sediments (Travers, 1978). Limestones are found sporadically throughout the section and contain crinoids, brachiopods and other marine fossils. This sequence of rocks could have been deposited in a maturing island arc setting, where extensive erosion occurs as volcanism wanes, as proposed by Travers (1978). Granitic rocks of the underlying comagmatic Guichon Batholith would provide the plutonic roots for the system (McMillan, 1976).

TECTONIC MODELS AND HISTORY

A model has been developed in an effort to unite models put forth by previous authors (Monger, 1977), (Travers, 1978) and (Ladd, 1979) with new geological and paleontological information collected in this study. In the model proposed here the older rocks are divided into four groups.

4) Ashcroft Formation
3) Nicola(?) Group (Island Arc)
2) Greenstone Unit and Marble Canyon Formation (Oceanic Plateau)
1) Melange Unit (Subduction Complex)

On Fig. 28 the oceanic plateau is shown as approaching the arc. The plateau is composed of the greenstone unit and the Marble Canyon Formation. Formation of a subduction complex occurs at the trench and occasional arc debris slumps out to the ocean; where it is incorporated into the ocean sediments and eventually the mélange. Radiolarian chert and argillite scraped off the ocean floor are the main constituents of the mélange in the subduction complex. Also included are blocks which have slid off the nearby plateau and minor volcanic and sedimentary rocks from the Nicola(?) island arc. Late Triassic Nicola(?) rocks and Early to Mid-Jurassic Ashcroft Formation sediments are deposited out over the mélange. These rocks are represented by the Nicola(?) volcanic and sedimentary rocks south of Cache

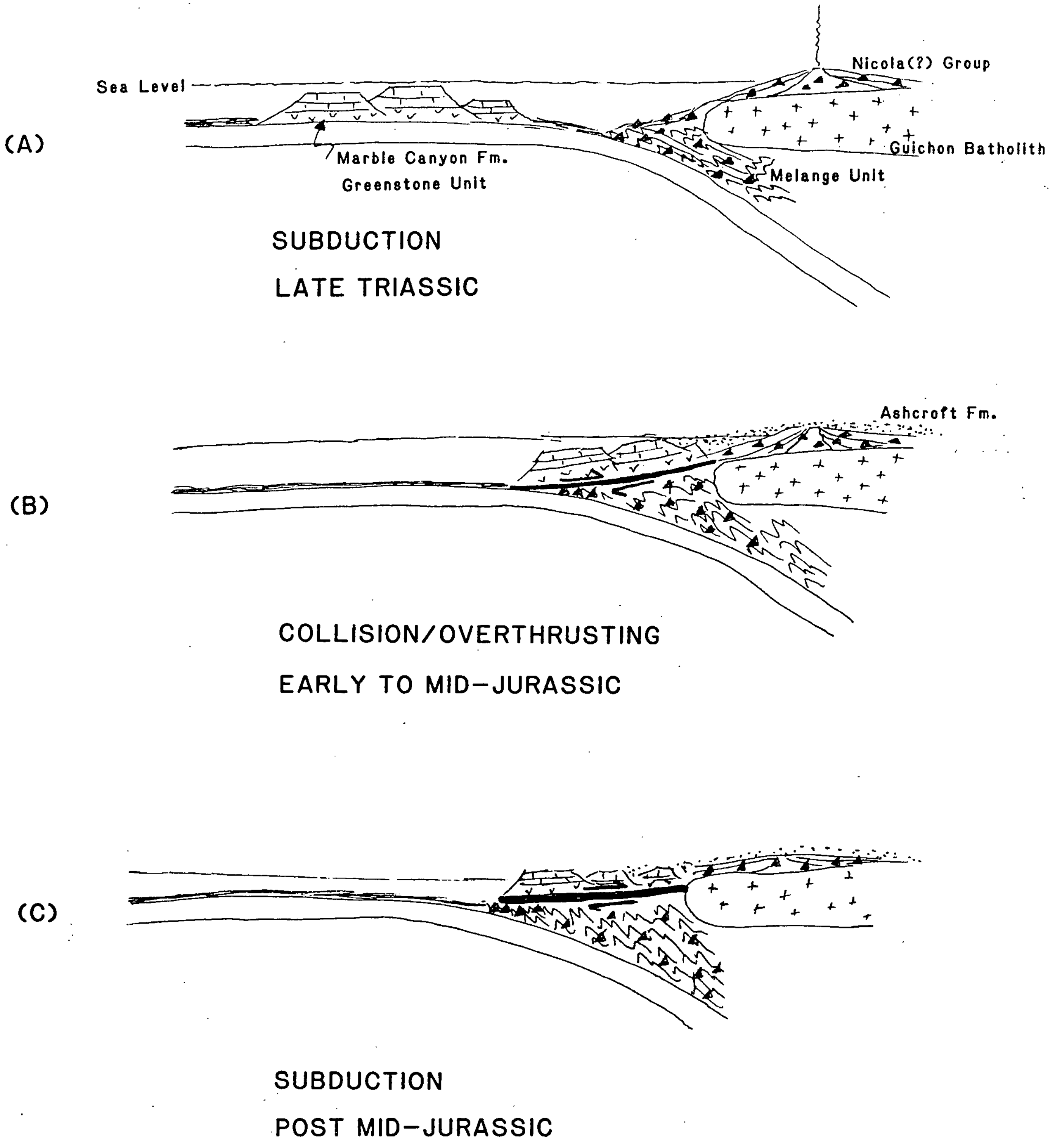

Figure 28. Tectonic model for Cache Creek Group

Creek, west of McLean Lake and west of the Bonaparte Indian Reserve; and Ashcroft Formation rocks south of Cache Creek, west of the Bonaparte Indian Reserve and along the Lower Hat Creek road. The Ashcroft Formation is composed mainly of eroded remanents of the extinct Nicola(?) island arc and associated plutonic basement.

As the ocean plateau collides (Fig 28b) it is thrust up over the mélange-arc unit for a minimum distance of 40 km, coming to a rest only a few kilometers from the batholithic core of the island arc (Fig 28c). This obduction may be the source of the predominant 140 degree southwest dipping foliation common in the pre-mid-Cretaceous rocks throughout the map area. Early to Mid-Jurassic rocks overlying the Nicola(?) Group rocks are involved in this deformation as discussed in the structural geology section. Because this deformation has no obvious effect on the mid-Cretaceous chert pebble conglomerate unit it must predate deposition of these rocks.

Later block faulting along the 140 degree and NS trends has brought all units into contact mainly along block boundaries. This effect has been quite dramatic west of Carquile in the chert pebble conglomerate unit. Rocks which originally were deposited in a broad flat river valley have now been tilted into two opposing half-grabens. Along the upthrown center portion of the two half-grabens are discontinuous pods of serpentinite and rocks from the Nicola(?) Group and Ashcroft Formation. This block faulting has continued until at least Eocene time as Kamloops Group rocks are locally faulted against Cache Creek

Group rocks.

ECONOMIC GEOLOGY

Metallic mineral deposits in the map area include the Cache Creek, Scotty Creek, Ferguson Creek and Cornwall Creek chromite occurrences (Duffell and McTaggart, 1952). The chromite is found as small pods and disseminations in serpentinites of the Cache Creek Group. Due to the erratic low-grade nature of much of the mineralization these occurrences have not been explored in recent years.

The Maggie Mine is a low-grade porphyry copper-molybdenum deposit with about 200 MT of reserves grading 0.4% copper equivalent (B.C. Dept of Mines, G.E.M., 1971, p 304), located about 3 km north of Carquile. Regional geochemical sampling for further examples of this kind of mineralization have been carried out by Bethlehem Copper and other companies but no new discoveries have been made.

Small quartz veins in Cache Creek Group and Nicola Group rocks carry minor amounts of chalcopyrite, galena and sphalerite throughout the map area. South of Cache Creek near Boston Flats, ribbon chert blocks were found with malachite and azurite coating fracture surfaces. None of these small occurrences appear to be large enough to warrant furthur exploration.

Altered serpentinites which form resistant outcrops of quartz, carbonate and fuchsite rock may be hosts to large-tonnage low-grade gold deposits. The association of quartz-carbonate rocks and gold deposits is documented in recent literature (Boyle, 1980). A grab sample of quartz, carbonate and fuchsite rock from west of McLean Lake gave values of over

300 ppb Au and 18 ppm Ag. However mineralization is erratic and nearby outcrops contained no gold or silver values. Detailed sampling over large areas of quartz, carbonate and fuchsite rock would have to be carried out to locate gold and silver-rich zones.

There is good potential in the Nicola(?) Group rocks for volcanogenic massive sulphide deposits. Nicola(?) Group rocks 15 km south of Cache Creek at Red Hill apparently contain massive chalcopyrite which appears volcanogenic in origin (Albrechtsons, 1981). New areas of Nicola(?) type rocks were discovered in the course of mapping for this project; these could be examined for extensions of Red Hill-type massive sulphide mineralization.

G. Dawson (1895) mentions reports of gold in the chert pebble conglomerate unit (Coldwater Formation) occuring as paleo-placer mineralization. Prospecting for this kind of deposit could be done by regional geochemistry in areas of favourable stratigraphy. Special attention should be focused on coarse gravel deposits which may indicate channel bottoms and could contain placer accumulations of gold.

Adjacent to the map area on the west is Hat Creek Valley which contains one of the worlds thickest single deposits of coal. Estimates of total reserves have exceeded 10 Billion tons (H. Kim, pers comm, 1980). Tertiary rocks with comparable stratigraphy were not found in the map area so the potential for coal deposits of the same type is very low.

CONCLUSIONS

1. The Cache Creek Group rocks of the eastern and central belts in southern B.C. (Duffell and McTaggart, 1952), can be divided into a lower mélange unit and a structurally overlying greenstone unit and Marble Canyon Formation.

2. Thinly laminated chert-argillite of the mélange unit is interpreted as representing a deeper water environment because of lack of carbonate (except as blocks) and evidence of pelagic sedimentation(radiolaria and thin rhythmic bedding of argillite between chert layers). Limestone blocks in the mélange unit contain fusulinids and algal structures indicating shallow water provenance. Greenstone blocks in the mélange unit contain clasts of fusulinid limestone as well as interpillow carbonate (but no deeper water chert-argillite), indicating deposition of the greenstone in relatively shallow water. Therefore the mélange probably formed by blocks of shallow water facies rocks sliding into deeper water where deposition of chert and argillite was predominant. A term for mélange formed in this manner would be talus mélange. Olistostrome would imply sedimentary transport of the chert-argillite matrix which does not appear to have occured. Later tectonism has sheared the mélange unit and caused rotation of blocks in the mélange.

3. Limited geochemical evidence from immobile elements such as Nb, Y and Ti indicates that the Cache Creek greenstones formed partly in an intra-plate ocean plateau environment (Pearce and Cann, 1973). Most greenstones in the Cache Creek Group in southern B.C. are highly enriched in Nb and Ti compared

to normal ocean floor basalts. Values up to 77 ppm Nb and 276 ppm Ti were recorded. One sample of greenstone had concentrations of Nb and Ti similar to ocean floor basalts indicating that there may have been more than one magma source for the Cache Creek Group greenstones. A modern analogue for this environment is Iceland (Schilling, 1973). Most of the rocks were alkalic to transitional and not tholeiitic according to the Y/Nb ratios(Pearce and Cann, 1973).

4. Discovery of probable Nicola(?) rocks apparently occurring as blocks in the Cache Creek Group mélange unit has several implications. First, the Cache Creek Group and Nicola(?) Group were juxtaposed by Late Triassic time and the Nicola(?) was shedding detritus into the Cache Creek mélange. As the Nicola(?) blocks contain glaucophane they presumably have been subjected to pressure and temperature conditions similar to the rest of the mélange which is reported to contain blue amphiboles (Grette, 1978). Since the Nicola(?) blocks have developed blueschist mineralogy they could not have been introduced into the mélange unit as later fault slices.

5. Radiolarian chert clasts found in the Nicola(?) greywackes along the Bonaparte River south of Cache Creek are probably derived from Cache Creek Group cherts and provide furthur evidence that the two units were together by Late Triassic time. This is disputed by W.R. Danner who maintains the radiolarian clasts may have come from cherts in the Nicola(?) Group. Radiolarian cherts are not presently known to occur in the Nicola(?) Group. Since Cache Creek Group

radiolarian cherts are as young as Late Triassic (Travers, 1978), the possibility exists that Nicola(?) Group radiolarian cherts may be discovered.

6. Superposition of the predominantly Permo-Triassic Marble Canyon Formation-greenstone unit and the Permo-Triassic mélange unit is probably along a large shallow-dipping thrust fault. Minimum displacement can be estimated by measuring from the furthest west Cache Creek mélange type rocks (along the Fraser River near Moran) to the easternmost edge of the greenstone unit north of Cache Creek; this provides a figure of at least 40 km displacement. Trettin (1980) has proposed the existence of similar flat lying thrust faults in the Cache Creek Group in the Marble Range to the north. An alternative explanation suggested by J. Monger (pers comm, 1981) is that the areas of greenstone and limestone which appear to overlie the mélange unit are enormous blocks. If this is true then Nicola(?) Group rocks should be found sitting unconformably above the greenstone unit and Marble Canyon Formation because Nicola(?) Group blocks are found in the mélange unit. However no Nicola(?) rocks are observed on the Marble Canyon Formation or the greenstone unit.

7. Radiolarian chert clasts presumably derived from the Cache Creek Group mélange unit rocks are found in Nicola(?) greywackes south of Cache Creek. However no limestones of Cache Creek Group origin have been found in these rocks (W.R. Danner, pers comm, 1981), which indicates that the mélange unit was in contact with the Nicola(?) Group in the Late Triassic but the

Marble Canyon Formation was not. The lack of Marble Canyon Formation debris in the Nicola(?) Group provides further support to the suggestion that the Marble Canyon Formation and greenstone unit were emplaced in their position after deposition of the Nicola(?) volcanic greywackes.

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