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DEPARTMENT OF ENERGY, MINES AND RESOURCES

MEMOIR 363

GEOLOGY OF BONAPARTE LAKE MAP-AREA, BRITISH COLUMBIA

R. B. Campbell and H. W. Tipper

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By
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PREFACE

Although this region is extensively drift-covered, some parts appear to have considerable potential for mineral exploration. It has many similarities with the Princeton-Merritt-Kamloops copper-producing area, in particular the fracture patterns which are here expressed as topographic lineaments. The Boss Mountain molybdenum mine and several significant copper properties occur northwest of Bonaparte Lake map-area. Those areas underlain by Triassic and Jurassic volcanic and sedimentary rocks and intruded by plutonic rocks of various ages appear to offer the most interesting possibilities for mineral exploration.

Y. O. FORTIER,
Director, Geological Survey of Canada

OTTAWA, February 27, 1969

MEMOIR 363 — Kartenblatt Bonaparte Lakes (Britisch-Kolumbien)

Von R. B. Campbell und H. W. Tipper

Dieses Gebiet spät-präkambrischer bis recenter Gesteine in den kanadischen Kordilleren umfaßt drei tektonische Hauptelemente. Es liegt dicht nördlich von einem Kupferabbaugebiet und bietet die Potentialität einer wirtschaftlichen Auswertung seiner Mineralien.

МЕМУАР 363 — Картографированная территория Бонапарт Лейкс, Британская Колумбия

Р. Б. Кампбелл и Х. В. Типпер

Территория эта периода от поздне докембрийских до современных пород в Канадских Кордильерах включает три главных тектонических элемента. Расположена она на север от места добычи меди и имеет экономически выгодный потенциал залежей минералов.

CONTENTS

CHAPTER I

PAGE

INTRODUCTION 1
- Location and accessibility 1
- Previous geological work 1
- Present field work and sources of information 2
- Acknowledgments 2
- Geological stage names used in this report 2

CHAPTER II

PHYSICAL FEATURES 4
- Physiography 4
  - Fraser Plateau 5
  - Thompson Plateau 5
  - Quesnel and Shuswap Highlands 5
- Glaciation 5

CHAPTER III

GENERAL GEOLOGY 8
- Table of formations 9
- Layered rocks 8
  - Shuswap Metamorphic Complex (map-unit A) 8
  - Kaza or Cariboo Group (map-unit 1) 8
  - Slide Mountain Group 14
    - Fennell Formation (map-unit 2) 14
  - Cache Creek Group (map-units 3–6) 18
    - Eastern part of Cache Creek Group (map-unit 3) 19
    - Western part of Cache Creek Group (map-units 4–6) 23
  - Pavilion Group (map-units 7 and 8) 29
  - Map-unit 10 30

PAGE

GENERAL GEOLOGY (*cont.*)

Nicola Group (map-unit 11) 33
Map-unit 12 36
Sinemurian to (?) Middle Jurassic rocks (map-units 15 and 16) 39
Map-unit 15 39
Map-unit 16 42
Origin of the Jurassic volcanic clastic rocks 44
Jurassic (?) rocks near Clinton (map-units 17 and 18) 44
Jackass Mountain Group (map-unit 19) 45
Kamloops Group (map-units 21 and 22) 46
Chu Chua Formation (map-unit 21) 46
Skull Hill Formation (map-unit 22) 50
History and correlation of the Kamloops Group 51
Oligocene volcanic and sedimentary rocks along Fraser River (map-unit 23) 54
Miocene and Pliocene sediments and volcanics (map-units 24 and 25) 56
Deadman River Formation (map-unit 24) 56
Plateau lavas (map-unit 25) 62
Pliocene or Pleistocene volcanic deposits (map-unit 26) 64
Map-unit 26a 65
Map-unit 26b 66
Pleistocene or Recent cinder cone (map-unit 27) 66
Recent volcanic rocks (map-unit 29) 67

Intrusive rocks 67
Serpentinite (map-unit 9) 67
Rhaetian or Hettangian granitic rocks (map-units 13 and 14) 68
Syenite and monzonite (map-unit 13) 68
Thuya and Takomkane batholiths and related intrusions (map-units 14, 14a, 14b) 68
Cretaceous granitic rocks (map-units 20, 20a, 20b) 72
Raft and Baldy batholiths and related intrusions (map-unit 20) 72
Granitic rocks near Fraser River (map-unit 20a) 75
Granitic intrusion near Tintlhohtan Lake (map-unit 20b) 76

CHAPTER IV

STRUCTURAL GEOLOGY 77
Faulting along North Thompson River valley 77
Block faulting in Eakin Creek region 77
Deformation in the Marble Range 79

PAGE

CHAPTER V

ECONOMIC GEOLOGY 82
Description of properties 82
Placer deposits 82
Gold, silver, copper, molybdenum, lead, and zinc properties 83
Chromite occurrence 88
Nickel deposit 88
Manganese deposits 88
Chrysotile occurrences 89
Coal 89
Saline lakes 90
Hydromagnesite deposits 90
Magnesite occurrences 91
Travertine deposit 92
Gypsum 92
Volcanic ash 92
Muscovite 93

BIBLIOGRAPHY 94

INDEX 97

Table I. Stage names of the Pennsylvanian to Early Cretaceous periods used in this report 3
II. Correlation of the middle Eocene to Pliocene formations and rock units of Kamloops and Bonaparte River areas 55
III. Modal analyses of Thuya and Takomkane batholiths 70
IV. Modal analyses of Raft and Baldy batholiths 74

ILLUSTRATIONS

Map 1278A. Geology of Bonaparte Lake map-area, British Columbia ..... *In pocket*

Figure 1. Physiographic subdivisions of Bonaparte Lake map-area (after Holland) 4
2. Direction of glacial flow in Bonaparte Lake map-area 6
3. Plot of modal data for Thuya and Takomkane batholiths 72
4. Plot of modal data for Raft and Baldy batholiths 73
5. Pattern of block faulting in Eakin Creek region (northeast part) and normal faults in Marble Range (southwest part) 78
6. Index map of properties in Bonaparte Lake map-area 83

GEOLOGY OF BONAPARTE LAKE MAP-AREA, BRITISH COLUMBIA

Abstract

Bonaparte Lake map-area comprises about 6,000 square miles and includes parts of several subsidiary plateau and highland divisions of the Interior Plateau of British Columbia. The region was entirely covered by the last major Pleistocene ice sheet flowing from the Cariboo Mountains which are to the north and northeast.

The rocks of the map-area range in age from late Precambrian to Recent. Parts of three major tectonic elements are represented; the relatively little deformed thick Mesozoic rocks of the Quesnel Trough are flanked on the east by the metamorphosed and highly deformed late Precambrian to late Paleozoic rocks of the Omineca Geanticline, and on the west by the folded late Paleozoic rocks of the Pinchi Geanticline.

Granitic rocks were emplaced in two major episodes. Hornblende-bearing granodiorite and quartz diorite batholiths are about 190 million years old and non-hornblendic quartz monzonite and granodiorite intrusions are about 100 million years old. Syenitic rocks are evidently related to the older intrusions.

Cenozoic rocks, particularly undeformed Miocene basaltic plateau lavas, cover a large part of the map-area. Middle Eocene volcanic rocks lie unconformably beneath the plateau lavas. Sequences of sedimentary rocks locally underlie each Tertiary volcanic formation. Pleistocene and Recent basaltic volcanic deposits are prominent near the northeast corner.

The Mesozoic rocks of the Quesnel Trough and associated granitic batholiths and minor intrusions reflect many of the relationships that characterize the copper-producing area to the south.

Résumé

La région du lac Bonaparte comprend environ 6,000 milles carrés et englobe certaines parties du plateau secondaire et des hautes-terres du plateau Intérieur de la Colombie-Britannique. La région a subi la dernière grande avancée glaciaire du Pléistocène issue des chaînons Cariboo en direction nord et nord-est.

L'âge des roches de la région s'échelonne de la fin du Précambrien à nos jours. Certaines parties de trois principaux éléments tectoniques se trouvent représentées: les roches mésozoïques épaisses et relativement peu déformées du synclinal Quesnel sont flanquées à l'est par les roches métamorphisées et très déformées, du Précambrien récent à la fin du Paléozoïque, du géanticlinal Omineca, et à l'ouest par les roches plissées du Paléozoïque récent du géanticlinal Pinchi.

Les roches granitiques ont été mises en place au cours de deux étapes principales. Les batholites de granodiorite à hornblende et de diorite quartzifère ont environ

190 millions d'années et les intrusions de monzonite quartzifère sans hornblende et de granodiorite ont environ 100 millions d'années. Les roches syénitiques se trouvent évidemment apparentées aux intrusions les plus anciennes.

Les roches du Cénozoïque, notamment les laves non déformées du plateau basaltique du Miocène, recouvrent une grande partie de la région. Les roches volcaniques de l'Éocène moyen reposent en discordance sous les laves de plateau. Des successions de roches sédimentaires s'étendent par endroits sous chaque formation volcanique tertiaire. D'importants dépôts volcaniques basaltiques du Pléistocène et de l'époque récente occupent l'angle nord-est.

Les roches mésozoïques du synclinal Quesnel, les batholites granitiques associés et des intrusions mineures reflètent un grand nombre des relations qui caractérisent la région cuprifère située au sud.

Chapter I

INTRODUCTION

Location and Accessibility

Bonaparte Lake map-area, comprising approximately 6,000 square miles centrally located in southern British Columbia, is bounded by longitudes 120° and 122°W and by latitudes 51° and 52°N. The city of Kamloops is about 22 miles south of the east half of the area. The village of Clinton in the southwest quarter is 145 miles northeast of Vancouver or about 239 miles by highway.

The area is readily accessible. The main line of the Canadian National Railways and Highway 5 follow the North Thompson River in the eastern part, and the Pacific Great Eastern Railway and Highway 97 cross the west half in a north-south direction. Highways 5 and 97 are paved routes. Branching from these highways are many secondary, gravelled, all-weather roads which in turn lead to mining, farm and logging roads, some passable only to four-wheel-drive vehicles. This road system reaches into most parts of the area. Many lakes, particularly in the east half, are suitable for landings by float-equipped aircraft.

Previous Geological Work

Several geologists have examined parts of the Bonaparte Lake map-area during the last 100 years. Selwyn (1872) crossed the map-area in 1871 during an exploratory geological investigation through south-central British Columbia. He briefly described the North Thompson Valley and the area around Clinton. In 1877 Dawson (1879) made preliminary examinations of the strata near the North Thompson Valley and around Clinton. He followed this preliminary work with a study (1895 a, b) of the Kamloops map-area in 1887, 1889, and 1890. The published map was on a scale of 4 miles to 1 inch and included the southern one-third of the present Bonaparte Lake map-area. In 1921 Uglow (1922) mapped an irregular belt extending from the southern edge of the area 35 miles along the North Thompson Valley. In 1930 Walker (1931) extended this mapping northward to about latitude 51°45′ N. From 1957 to 1959 Trettin (1961) studied the Fraser River valley from Lillooet to Big Bar Creek including part of the present Bonaparte Lake map-area, namely the Marble Range and the area to the southwest. In 1964 and 1965 he undertook further work in the Marble Range (Trettin, 1965, 1966).

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In addition to areal mapping, several short reports deal with certain aspects of the geology of the map-area, mainly mineral occurrences. In 1917 Camsell (1919) discussed a magnesite deposit near Lac la Hache. In 1918 Reinecke (1920) reported on mineral occurrences in the western half of the map-area. Cockfield and Walker (1933) described an occurrence of magnesite near Clinton in 1932. In 1934 Cockfield (1935) examined the mineralized area around Vidette Lake. In 1926 Berry (1926) reported on Tertiary flora collected by Uglow from the Chu Chua Formation. Other reports on mineral properties contained in the British Columbia Minister of Mines Reports are referred to in Chapter V.

Present Field Work and Sources of Information

The field work on which this report is based, was carried out from 1963 to 1965. The information contained herein was obtained in part from airphoto interpretation and aerial reconnaissance by helicopter but mostly from many ground traverses concentrated in areas of complex geology. The information in the southwest quarter is derived mainly from Trettin's report (1961). Some differences from Trettin's work result from new information or different interpretations of the same information but the responsibility for the conclusions stated herein rests with the writers.

The map-areas adjoining the Bonaparte Lake map-area have all been studied geologically and maps, either preliminary or final, are available. The writers recently mapped the areas to the north, east, and west (Campbell, 1961, 1963a and 1963b; and Tipper, 1959, 1963) whereas the areas to the south were mapped earlier by officers of the Geological Survey of Canada (Duffell and McTaggart, 1952; Cockfield, 1948). The information obtained and the conclusions drawn in these adjoining areas have permitted a fuller understanding of the geological relationships in the largely drift-covered Bonaparte Lake map-area. This report, therefore, represents the conclusions and the interpretations based on stratigraphic and structural information drawn from many sources.

Acknowledgments

The writers received many courtesies and much assistance from residents of the map-area. Efficient assistance was rendered in the field by T. M. Gordon, B. E. Lowes, R.B. Farquaharson, U. Upitis, K. Domai, C. A. Giovanella, M. A. Smith, K. V. Campbell, and numerous other summer student assistants. Helicopter services were provided by Associated Helicopters of Edmonton, Alberta, and by Bullock Helicopters of Calgary, Alberta.

Geological Stage Names used in this Report

Stage names have been used throughout this report whenever paleontological evidence permitted that degree of refinement. The stage names used are listed in Table I.

TABLE I *Stage names of the Pennsylvanian to Early Cretaceous periods as used in this report.*

Cretaceous	Early	Albian Aptian Barremian Hauterivian Valanginian Berriasian
Jurassic	Late	Upper Tithonian Portlandian Kimmeridgian Oxfordian
	Middle	Callovian Bathonian Bajocian
	Early	Toarcian Pliensbachian Sinemurian Hettangian
Triassic	Late	Rhaetian Norian Karnian
	Middle	Ladinian Anisian
	Early	Spathian Smithian Dienerian Griesbachian
Permian	Late	Ochoan Guadalupian
	Early	Leonardian Wolfcampian
Pennsylvanian	Late	Virgilian Missourian
	Middle	Desmoinesian Atokan
	Early	Morrowan Springeran

Chapter II

PHYSICAL FEATURES

Physiography

Bonaparte Lake map-area is part of the Interior Plateau and may be subdivided following Holland's system (1964) into several plateaux and highland regions. These subdivisions are outlined in Figure 1.

FIGURE 1. Physiographic subdivisions of Bonaparte Lake map-area (after Holland).

Fraser Plateau

This subdivision, comprising about three-quarters of the map-area (mainly the western part), is essentially a flat or gently rolling region lying between 4,000 and 5,000 feet elevation. It is a plateau region that changes gradually from a flat lava surface in the central west half to rolling uplands and rounded hills in the east half. In the southwest quarter the Marble Range rises abruptly to elevations of 7,500 feet, and bears little resemblance to the otherwise flat Fraser Plateau of which it is a subunit. Although its steep ridges and sharp peaks set it apart from all other physiographic units of the region, it is included in the Fraser Plateau because of its small area. Several other ranges to the northwest have similarly been included in the Fraser Plateau (Holland, 1964, p. 70).

The flattest part of the plateau, in the west half, is underlain by flat-lying Pliocene and/or Miocene lavas and although the plateau may not coincide with the original lava surface, erosion has apparently removed material mainly layer by layer, maintaining the level surface. Farther east along the margin of the lava field, shallow dissection of the edge and erosion along the normal faults that cut the pre-late Miocene rocks have developed a hilly terrane. Even where local relief increases most of the hills and ridges of this region are broad and rounded.

Thompson Plateau

This subdivision of the Interior Plateau was established by Holland (1964, p. 71) and is distinguished from Fraser Plateau by slightly greater relief, somewhat greater dissection, and absence of extensive flat lava areas. In Bonaparte Lake area, north of Clinton, the boundary with Fraser Plateau has been drawn arbitrarily at or near the edge of the flat lava plains. To the east the boundary marks the transition from rounded hills and rolling uplands to distinctly rougher topography. The eastern boundary of Thompson Plateau is approximately the North Thompson Valley.

Thompson Plateau in this area is underlain by folded and block faulted late Paleozoic, Mesozoic, and early Tertiary volcanic, sedimentary, and granitic rocks. Differing resistance to erosion of these rocks has resulted in a moderately dissected, irregular surface between 3,500 and 5,000 feet elevation.

Quesnel and Shuswap Highlands

These two subdivisions abut the Fraser and Thompson Plateaux on the east along a line from the southeast corner of the map-area, along North Thompson River valley to Little Fort and thence northwesterly to the east end of Canim Lake. This region, and the area immediately to the east of the map-area, is characterized by broad, rounded mountains up to 7,000 feet separated by deep valleys as low as 2,500 feet elevation. These highlands are remnants of a dissected, upwarped, erosion surface that becomes progressively lower to the south and west.

This area is underlain mainly by folded and metamorphosed Paleozoic rocks with lesser amounts of Mesozoic rocks. Igneous intrusions of Cretaceous (?) age commonly form the prominent ridges of the mountains.

Glaciation

The entire map-area was overridden by glacial ice. Glacial features and deposits are conspicuous in all parts of the area. Evidence in this and adjoining regions indicates that a dividing line between northward and southward flowing ice was situated in the map-area.

As may be seen on airphotos, drumlins and till grooves are moderately well developed in the central part of the area from Timothy and Canim Lakes southward. The northwest

quarter is characterized by extensive kettle topography with irregular depressions up to one mile in diameter. Numerous ice-margin meltwater channels parallel the northeast flank of Marble Range, and others of less prominence appear on the sides of many hills. Major glacial streams carried great volumes of meltwater through the Canim-Mahood-Clearwater-North Thompson, the Bonaparte River, and the Bridge Lake-Lac des Roches-Eakin Creek systems. Many eskers are associated with these drainage systems but they are better developed on the plateau surface where they are related to smaller meltwater channels that were formed by direct discharge from the melting front of the ice.

Glacial deposits, although widespread, are not deep. Over the plateau in the west half of the area drift is generally one to five feet deep except where filling preglacial gullies and valleys. The hillier parts of the area, particularly those underlain by granite, have a thinner cover of glacial material, yet it is distributed in such a manner as to obscure most of the bedrock. Some of the major valleys such as the North Thompson have thick deposits of glacial silts into which present streams have cut deeply.

Except for the area west of Marble Range, the last glacial ice to cover the area issued from the Cariboo Mountains. Available information suggests that ice advanced from east to west along the north boundary of the area from where it fanned out northward and southward. The southward flowing ice sheet moved southwesterly and southerly in the western part of the area, but near the central and southern parts, it flowed southerly and southeasterly (Fig. 2).

FIGURE 2. Direction of glacial flow in Bonaparte Lake map-area.

Direction of ice movement is deduced from a few glacial striae and the alignment of drumlins and glacial grooves. These, however, indicate only the last movements when the ice was thinning and topographical influence on flow patterns was increasing. Little is known about earlier ice movements, when thickness was greatest, beyond the fact that ice covered all parts of the area including the highest hills and mountains as is indicated by glacial grooves and erratics. Available evidence suggests that ice moved from the Coast Mountains into the extreme southwest corner of the area southwest of Marble Range. During the glacial maximum ice from the Coast Mountains may have moved over and around the Marble Range into the central part of the Bonaparte Lake area.

Chapter III

GENERAL GEOLOGY

Bonaparte Lake map-area is underlain by rocks ranging in age from late Precambrian to Recent. The map-area straddles the Quesnel Trough, a basin of early Mesozoic eugeosynclinal deposition situated between the Omineca Geanticline in Columbia Mountains to the east and the Pinchi Geanticline to the west.

Late Precambrian and/or early Paleozoic strata are widely exposed in the Omineca Geanticline. These, together with late Paleozoic rocks, lie along the eastern edge of the map-area and mark the western extremity of the eastern fold belt of which the Shuswap Metamorphic Complex is an integral part. Late Paleozoic rocks of the Pinchi Geanticline are restricted to the western part of the map-area. Between the geanticlines is a great thickness of late Triassic and early Jurassic primarily volcanic clastic rocks intruded by large granitic batholiths. Tertiary volcanic rocks obscure the older rocks of the trough over wide areas but the Mesozoic rocks apparently have not undergone the systematic and penetrative deformation that affected the Omineca and to a lesser extent the Pinchi Geanticline.

Layered Rocks

Shuswap Metamorphic Complex (Map-unit A)

Rocks assigned to the Shuswap Metamorphic Complex underlie a small area along the eastern boundary of the map-area in Clearwater River valley. Exposures are small and widely scattered but farther east on Trophy Mountain in Adams Lake map-area (Campbell, 1963b) outcrops are more extensive. The rocks are dominantly quartzofeldspathic biotite gneiss and schist, containing garnet and sillimanite, and minor amphibolite, quartzite, marble, and 15 to 25 per cent pegmatite. They are intensely and complexly deformed. The age of the rocks incorporated in the Shuswap Metamorphic Complex is not definitely known, but in Quesnel Lake and Canoe River map-areas to the north, Campbell has some evidence that Kaza Group and possibly younger strata are involved.

Kaza or Cariboo Group (Map-unit 1)

Distribution

Map-unit 1 lies in the northeastern part of the map-area near the eastern end of Mahood Lake. It is continuous with rocks mapped as the Snowshoe Formation of the Cariboo Group in Quesnel Lake map-area (Campbell, 1961 and 1963a) and was thus labelled on the preliminary map of the Bonaparte River map-area (Campbell and Tipper, 1966). Subsequent work (Campbell, 1968) suggests that the Snowshoe Formation may be equivalent to part of the Kaza Group and therefore Proterozoic rather than post-Lower Cambrian. As the problem is not yet solved the rocks in Bonaparte Lake map-area are assigned to the Kaza or Cariboo Group.

Table of Formations

ERA	PERIOD	EPOCH	GROUP	FORMATION	MAP-UNIT	LITHOLOGY
CENOZOIC	Quaternary	Recent			29	Blocky basalt flows
		Pleistocene and Recent			28	Till, gravel, clay, silt, alluvium
		Pleistocene or Recent			27	Basaltic cinder cone (Pyramid Mountain)
	Tertiary or Quaternary	Pliocene or Pleistocene			26	Basaltic arenite, conglomerate, breccia and rubble, basaltic flows, cinder deposits, cones
	Erosional interval in part					
	Tertiary	Late Miocene and/or Pliocene			25	Olivine basalt, andesite, related ash and breccia, minor plugs
		Late Miocene		Deadman River Formation	24	Shale, sandstone, tuff, diatomite, conglomerate, breccia
	Unconformity					
		Oligocene			23	Andesite, dacite, felsite, related tuff and breccia, greywacke, shale, minor lignite and conglomerate
	Not in contact					
		Eocene and (?) Oligocene	Kamloops Group	Skull Hill Formation	22	Dacite, trachyte, basalt, andesite, rhyolite and related breccia
				Chu Chua Formation	21	Conglomerate, sandy shale, arkose, coal

Unconformity

MESOZOIC	Cretaceous		Raft and Baldy batholiths and other granitic rocks		20	Biotite quartz monzonite, granodiorite, hornblende diorite, quartz diorite, aplite, pegmatite, leuco-quartz monzonite	
		Not in contact, intrusive into Jurassic and older rocks					
		Aptian and/or Albian	Jackass Mountain Group		19	Greywacke, shale, siltstone, minor arkose and lenses of pebble-conglomerate	
	Not in contact						
	Jurassic(?)				18	Shale and grit	
						Fault contact	
					17	Chert-pebble conglomerate and greywacke	
	Not in contact						
	Jurassic	Sinemurian to (?) Middle Jurassic			15, 16	Andesitic arenite, siltstone grit, breccia, and tuff; minor argillite and flows (map-unit 15) (all or in part contemporaneous with map-unit 16)	Porphyritic augite andesite breccia and conglomerate minor andesitic arenite, tuff, argillite, and flows (map-unit 16)
						Boulder and cobble conglomerate grit, greywacke (base of map-unit 15)	
	Triassic or Jurassic	Rhaetian or Hettangian	Thuya and Takomkane batholiths, other granite rocks, and syenite		13, 14	Hornblende-biotite quartz diorite and granodiorite, hornblende diorite, monzonite, syenite, syenodiorite, and hornblendite	
	Intrusive contact						
	Triassic	Karnian and Norian	Nicola Group		11	Andesitic flows and breccia, tuff, argillite, greywacke, grey limestone	
			Not in contact, in part correlative				
					10	Black shale, argillite, phyllite, siltstone, black limestone	

Table of Formations (cont.)

ERA	PERIOD	EPOCH	GROUP	FORMATION	MAP-UNIT	LITHOLOGY
		Relations uncertain				
PALEOZOIC and/or MESOZOIC	Permian and/or Triassic				9	Serpentinite and serpentinized peridotite
		Not in contact				
			Pavilion Group		8	Tuff, chert, argillite, limestone, greywacke and basaltic flows
					7	Chert, argillite, siltstone; minor tuff, and limestone
		Fault contact, relations otherwise uncertain				
PALEOZOIC	Permian	Guadalupian	Cache Creek Group	Marble Canyon Formation	6	Massive limestone, limestone breccia, chert, minor argillite, tuff, and andesitic and basaltic flows
		Wolfcampian to Guadalupian			5	Argillite, basaltic flows, tuff, chert, limestone
					4	Basic volcanic flows, tuff, ribbon chert, limestone, argillite
		Not in contact				
	Pennsylvanian and Permian	Morrowan to Guadalupian	Cache Creek Group		3	Volcanic arenite, greenstone, argillite, phyllite; minor quartz-mica schist, limestone, basaltic and andesitic flows, amphibolite, conglomerate and breccia
		Fault contact, relations otherwise uncertain				
	Mississippian and/or later		Slide Mountain Group	Fennell Formation	2	Pillow lava flows, greenstone, foliated greenstone, greenschist, argillite, chert, minor amphibolite, limestone, and breccia

Fault contact, relations otherwise uncertain						
PROTEROZOIC or PALEOZOIC	Windermere or Cambrian and later		Kaza or Cariboo Group		1	Feldspathic quartz-mica schist, locally garnetiferous, micaceous quartzite, black siliceous phyllite, quartz-hornblende-mica schist, marble, chlorite schist, greenstone, and amphibolite
Relations unknown						
UNKNOWN			Shuswap Metamorphic Complex		A	Micaceous quartzo-feldspathic gneiss, quartz-mica schist, amphibolite, micaceous quartzite, and pegmatite

Lithology

Map-unit 1 comprises quartz-mica schist and micaceous quartzite with minor amounts of black phyllite, quartz-hornblende-mica schist and marble. Chlorite schist and greenstone are restricted to a small area on the north end of Green Mountain.

The quartzose rocks are fine grained, drab brown to grey, and well foliated. They vary from very fine grained, black quartzite with scattered flakes of sericite and streaks of dusty carbonaceous material, to lighter coloured quartz-mica schist which contains quartz, muscovite, red-brown biotite, minor chlorite, plagioclase (about An_{30}) and, in places, potash feldspar. The rocks are commonly feldspathic, particularly where mica is abundant. Mica is partly concentrated in streaks and much of it displays a strong preferred orientation, though some biotite grains lie athwart the cleavage. Locally the foliation is contorted. Some rocks contain scattered tiny grains of epidote, and in others apatite is fairly abundant. A relatively rare schist comprises quartz, plagioclase (An_{40}), hornblende in long slender needles, biotite, and chlorite. Garnet is not abundant but was found at several places, where it forms irregular patches and streaks. A single specimen from close to the contact of Raft batholith was found to contain irregular, elongate grains of andalusite and patches of extremely fine fibrous sillimanite. Both these minerals are restricted to mica-rich streaks. Minor black, siliceous phyllite and grey finely crystalline marble are interlayered with the quartzose rocks.

Chlorite schist and more massive greenstone are restricted to the northern part of Green Mountain. These rocks consist of chlorite, plagioclase, epidote and amphibole.

Structural Relations

Internal structural relations. The rocks of map-unit 1 are poorly exposed but evidently highly deformed. All are strongly foliated and in the foliation planes they commonly exhibit a lineation produced by mica streaks and microcrenulation. Some of the phyllite is cut by a fracture cleavage at a large angle to the foliation.

The few folds observed are isoclinal or nearly so; they deform both the metamorphic foliation and the compositional layering. The trends of the observed linear structures are erratic but north of the map-area where the rocks are better exposed, fold axes plunge at moderate angles to the northwest (Campbell, 1963a). The attitude of the foliation also is erratic; the general trend is north-northeasterly to northwest with northeasterly dips but reversals of dips were noted and near the contact of Raft batholith east and northeast strikes are dominant.

The structure of the unit, evidently complex, is further complicated by bending near the contact of Raft batholith. Principal northwest and southeast fold trends are suspected but unconfirmed.

External structural relations. The Fennell Formation appears to underlie the rocks of map-unit 1 near the eastern end of Mahood Lake but is believed to be younger. There the foliation in the Fennell Formation and in the older rocks is generally parallel indicating that both units were subjected together to at least one period of deformation. These circumstances, coupled with a lack of evidence supporting major overturning, suggest that map-unit 1 is thrust westward over the Fennell Formation.

The rocks of map-unit 1 are intruded by the quartz monzonite of Raft batholith and a smaller body north of Mahood Lake. These granitic rocks cut and warp structures within the layered rocks and apparently were intruded following the deformation. The metamorphic rocks are overlain unconformably by clastic sediments presumably of Eocene age; these contain abundant fragments of the older rocks. Volcanic rocks that range in age from Miocene

to Recent also unconformably overlie rocks of map-unit 1. The relation of the rocks of map-unit 1 to the Shuswap Metamorphic Complex (map-unit A) is not known as the contact is not exposed. It may be a fault.

Age and Correlation

The strata of map-unit 1 apparently pass into the Snowshoe Formation where this unit was originally defined as the uppermost member of the Cariboo Group by Holland (1964). Following the work of Sutherland Brown (1957 and 1963), however, it was regarded as early Cambrian. Recent work by Campbell (1968) indicates that the Snowshoe Formation may be part of the Proterozoic (Windermere) Kaza Group and that it is older than the remaining units of the Cariboo Group. Unquestionably the rocks are older than the early Mississippian limestone and overlying Antler Formation of the Slide Mountain Group (Sutherland Brown, 1957 and 1963 and Campbell, 1968) and hence older than the correlative Fennell Formation.

Slide Mountain Group

Fennell Formation (Map-unit 2)

Name and Distribution

The Fennell Formation was named by Uglow (1922, p. 77A) for a mass of extrusive and intrusive greenstone and minor chert along North Thompson River valley near Barrière. Greenstone south of Barrière near Louis Creek and North Thompson River was included with the formation by Uglow but is placed in the Cache Creek Group by the present writers. The formation, as defined herein, also includes rocks called the "Fennell batholith" by Walker (1931, p. 132A) who regarded the greenstone as an intrusive mass—an interpretation with which the writers do not agree. They have little doubt that the formation is correlative with the Antler Formation of the Slide Mountain Group (Sutherland Brown, 1957 and 1963) and hence have included it in that group.

The Fennell Formation is restricted to the eastern part of the map-area where it extends northerly from Barrière River to beyond Mahood Lake. It forms prominent brown outcrops along the east side of North Thompson Valley between Barrière and Little Fort and along both sides of the valley from Little Fort to Blackpool. It is well exposed in the canyon of Joseph Creek, on Clearwater Peak and Grizzly Mountain, and on the shore of Mahood Lake.

Lithology

The Fennell Formation consists mainly of greenstone with minor argillite and phyllite, bedded chert, and breccia. The greenstone is medium grey to grey-green and is characteristically aphanitic or very fine grained; constituent minerals are rarely visible to the naked eye. Pillow structures are common but by no means universal features. Coarser greenstone is relatively rare and is most common on the upper slopes of Baldy Mountain, on Chu Chua Mountain, and near the headwaters of Joseph Creek where it is interspersed with more typical fine-grained rocks and associated sedimentary layers. In the coarser rock black amphibole grains range up to 3 mm but most are less than 1 mm in length. Some of the coarser rocks are dykes and some may be sills; others may be the result of recrystallization of fine-grained rocks near the contact of Baldy batholith. On the south shore of Mahood Lake and on the east boundary of the map-area just north of Joseph Creek the greenstone is foliated. At the latter place coarser rocks are fine-grained, weakly foliated diorite. On the shores of Mahood Lake the Fennell Formation consists of fine-grained amphibolite, diorite and greenstone.

Microscopic study of thin sections of the greenstone reveals that it is a metamorphic or completely altered rock. Most of the very fine grained and aphanitic grey and grey-green greenstone that forms the bulk of the Fennell Formation consists of a mosaic of tiny, colourless, brown or yellow-green hornblende needles, scattered grains of epidote and zoisite, and small laths of turgid plagioclase that commonly are rich in inclusions of hornblende, epidote, and possibly zeolites, a white opaque mineral, possibly leucoxene, and black opaque minerals. Carbonate and chlorite are common but not always present. The composition of the plagioclase cannot be precisely determined but judging from the refractive index it appears to range from An_{20} to An_{40} though in a few sections it is more sodic. Fine-grained carbonate forms veinlets and irregular patches, and pale green chlorite which is not common, forms patches and streaks of tiny flakes. Coarser grained rocks, including those with distinct foliation, are mineralogically identical to the rocks described above but in them hornblende forms crystals up to 3 mm long. Foliated rocks north of Joseph Creek near the east boundary of the map-area have a weak preferred orientation of hornblende and chlorite and those exposed on the shores of Mahood Lake have also very thin compositional layering alternately rich in hornblende and in plagioclase.

The original character of the greenstone prior to its alteration is obscure except in rocks from near Grizzly Mountain and Clearwater Peak*. There the rocks contain relicts of clinopyroxene, now partly replaced by hornblende, and distinct laths of turgid plagioclase. These minerals, originally about 1 mm in size, lie in a matrix of very fine grained amphibole, chlorite, and epidote. The pyroxene is replaced either by a mass of fine hornblende or by single grains. Apparently the rock originally consisted of clinopyroxene and plagioclase crystals in a fine-grained or glassy matrix. The larger hornblende crystals in coarser grained greenstone may be primary, particularly in the dioritic-looking rocks, but some may represent replaced pyroxene.

Details of pillow structures in greenstone of the Fennell Formation are well illustrated by Uglow (1922, Pl. IV). He described the pillows (op. cit. p. 77A) as follows:

> 'The outer parts of the "pillows" are dark bluish green dense, and minutely fractured. The spaces between the broken parts of the peripheries and between adjacent "pillows" are filled with chert or chalcedonic quartz . . . The cores of the "pillows" are slightly less dense than the outsides, and show concentric rings of much altered greenish amygdules. Coarse-grained calcite is associated here and there with the chert of the inter-pillow spaces.'

The writers saw neither the chert fillings nor the amygdules described by Uglow but found the pillows to fit tightly together with little or no inter-pillow space. They are rimmed, however, by dense bluish grey material as mentioned by Uglow.

Pillow structures were observed only in the western part of the Fennell Formation near North Thompson River and Dunn Lake valleys. Pillows are particularly well exposed in road-cuts along the new highway for the first five miles north of Little Fort. They are common, also, east of North Thompson River between Barrière and Blackpool and on Clearwater Peak. Pillows are most obvious in road and railway cuts and are difficult to see in natural exposures. They may be more common and widespread than observations indicate.

Breccia composed entirely of fragments of greenstone is exposed along the east side of Lemieux Creek valley between 3 and 5 miles north of Little Fort. The fragments are angular or subangular and range up to about 5 inches across. The fragments are closely packed with little or no matrix.

*Subsequent to completion of this report, similar locally unaltered greenstone was noted along Highway 5 north of Little Fort by K. V. Campbell (pers. comm., 1970).

Dark grey to black argillite and phyllite of the Fennell Formation are interlayered with and intruded by greenstone of the same formation. These rocks are restricted to the eastern part of the unit and are best exposed in cuts along the road between Clearwater and Blackpool east of North Thompson River but are found also in the region just north of Joseph Creek and on the ridge east of Chu Chua Mountain. The foliation in these rocks varies from an irregular cleavage to a penetrative schistosity. The foliation surfaces have a slight sheen. The rocks are very fine grained and consist mainly of quartz, white mica, and dusty carbonaceous material. Quartz grains are flattened and micas are strongly oriented in the plane of foliation. Some of the argillaceous rocks have a small quantity of fine carbonate. One highly schistose specimen from near the contact of the granitic rocks on Baldy Mountain is composed of quartz, green biotite, and white mica.

Chert, like the argillaceous rocks, is restricted mainly to the eastern part of the Fennell Formation. It is exposed in the hills east of North Thompson River between Clearwater Station and Barrière River interlayered with greenstone and argillaceous rocks and locally intruded by greenstone dykes and sills. The chert is mostly light coloured in shades of creamy white, buff, pale to medium greyish green, and medium grey. Some creamy white and buff coloured chert found near the eastern boundary of the map-area southeast of Clearwater Station is apparently unbedded, and superficially resembles siliceous aphanitic igneous rock. Most of the chert, however, has prominent beds ranging from 1 inch to 6 inches thick and commonly separated by thin argillaceous partings. Although bedded chert varies in colour it is most commonly pale to medium greyish green. The best exposures of bedded chert observed by the writers are 1.5 miles east of McCarthy Lake but those in the canyon of Joseph Creek, on Baldy Mountain, and on the ridge east of Chu Chua Mountain are also good. Uglow (1922, p. 77A) mentioned lenticular masses of thinly bedded chert in association with the pillow lavas and Walker (1931, p. 130A) also discussed the close association of chert and greenstone though he believed the greenstone to be entirely intrusive.

The chert, in all thin sections examined, consists of extremely fine-grained quartz and white mica. The mica has distinct preferred orientation. Streaks of dusty carbonaceous material were noted in some thin sections; one contained minute grains of carbonate, and one from near the east boundary north of Joseph Creek contained a small amount of chlorite and green biotite.

At the Blackpool microwave station 3 miles east and a little north of McCarthy Lake is a large exposure of breccia. Angular to subrounded fragments range up to 6 inches across and are poorly sorted. They are commonly flat or lenticular and are imbricated. Fragments consist of chert, greenstone, and argillite. The matrix, which is a very small proportion of the rock, consists of the same materials as the fragments. The breccia overlies beds of chert, cherty quartzite, and argillite. Chert and argillaceous fragments in the breccia do not display any obvious foliation or preferred orientation of minerals. A similar breccia, but with a more argillaceous matrix, outcrops on the ridge east of Chu Chua Mountain.

Structural Relations

Internal structural relations. The structure within the Fennell Formation is imperfectly known. Most of the exposures are greenstone which is monotonously uniform over large areas and from which no reliable structural data could be obtained. Pillow structures generally show that the section is not overturned but seldom reveal sufficient features to permit the determination of attitudes. Structural data obtained from sedimentary rocks found in widely scattered small exposures are insufficient to permit any interpretation of the structure within the formation as a whole. Some of the bedded rocks, particularly chert, exhibit

complexly superposed folds that seem to reflect local deformation rather than folding of the formation as a whole.

The preponderance of pillowed rocks in the western part of the formation from near Barrière to Clearwater Peak and the restriction of sedimentary rocks to the eastern part where they are associated with coarser grained and at least some intrusive phases of the greenstone suggests that a crude stratigraphic division of the formation can be made and that the western part overlies the eastern. This conforms with what is perhaps partly an intuitive feeling of the writers that major units in the formation dip to the west and that the rocks become progressively younger in that direction. A general westerly dip is displayed by rather vague stratification on the north side of the canyon of Joseph Creek. On the other hand the formation as a whole appears to dip eastwards at Mahood Lake. Metamorphic foliation in rocks of the Fennell Formation is restricted to the vicinity of Mahood Lake and to a small area near Joseph Creek along the eastern boundary of the map-area. East of the map-area near Joseph Creek the rocks are most strongly foliated and dip northeast in general conformity with metasedimentary rocks still farther east. Within Bonaparte Lake map-area the metamorphic foliation is mainly restricted to sedimentary rocks interlayered with greenstone, but it is somewhat erratic in attitude and not strongly developed. These rocks do not appear to have been penetratively deformed; the foliation in the sedimentary layers is attributed to slippage between confining sheets of massive greenstone.

Near Mahood Lake greenstone of the Fennell Formation is well foliated as are the metasedimentary rocks (map-units 1 and 10) on either side of it. The attitude of the foliation varies but maintains a general conformity with the foliation and contacts of the adjacent rocks. Rocks of the Fennell Formation, of the older map-unit 1, and the younger black phyllite (map-unit 10) were apparently deformed together producing a well-defined foliation throughout. Other than foliation, structures within the greenstone are rare or absent; no indications of intense folding were observed. The associated metasedimentary rocks, however, are lineated and folded. Although the mechanism that produced the foliation in the Fennell Formation near Mahood Lake is not known, possible thrusting of rocks of map-unit 1 westerly over the greenstone and the greenstone, in turn, over the black phyllite unit may have been accompanied by pervasive shearing.

External structural relations. Most of the contacts of the formation are either not exposed or are confused and complicated by the superimposed effects of metamorphism and the development of secondary foliation. Unquestionably the formation is intruded by granitic rocks of Baldy batholith and is overlain unconformably by the Eocene Chu Chua and Skull Hill Formations and by late Tertiary basaltic flows. The southern contact lies in the alluvium-filled valley of Barrière River where a fault is inferred. Similarly a fault is believed to form the western contact from Barrière to Lower Lemieux Creek but here again it is covered by continuous alluvium in North Thompson River and Lemieux Creek valleys. Between the lower reaches of Lemieux Creek and Mahood Lake exposures are small and scattered and the contact was not observed but may be a fault.

Except where it is formed by Baldy batholith, the eastern contact south from Clearwater Station, lies mainly in Adams Lake map-area to the east where it is obscured and has not been observed. Near the eastern contact, between Clearwater Station and Baldy batholith, the rocks of the Fennell Formation display a foliation which in most places is parallel with that in adjoining metasedimentary rocks. Both groups of rocks evidently were deformed together and possibly the deformation involved faulting. This might account for the relatively narrow band of penetrative deformation within the formation. The possibility cannot be discounted, however, that the Fennell Formation rests, perhaps unconformably, on the rocks

to the east. South from Baldy batholith to Barrière River the contact, which there separates unfoliated greenstone from well-foliated metasedimentary rocks to the east, lies in a heavily drift-covered area and little is known about it. Foliation, mappable lithological units, and fold axes in the metasedimentary rocks to the east would be intersected by the contact which thus may be a fault or an unconformity. North of Clearwater Station the Fennell Formation is intruded by the Raft batholith. Near Mahood Lake foliated greenstone of the formation apparently underlies strata of the older Kaza or Cariboo Group (map-unit 1) and overlies the younger rocks of map-unit 10. Both contacts may thus be easterly dipping thrust faults, or the entire section may be part of the overturned limb of a large fold. The former seems the more probable, but is unproved.

Origin

Uglow (1922, p. 77A) believed that greenstone of the Fennell Formation as defined herein was partly intrusive but that the bulk was composed of pillow lava. Walker (1931, p. 132A) thought it to be mainly intrusive and regarded the sedimentary rocks within it as remnants of country rock. The writers agree with Uglow and find little to support Walker's belief. The difficulty of explaining the development of pillow structures in an intrusive mass appears insurmountable; the pillows seem clearly to have originated in extrusive lava flows. The breccia capping the hill at the microwave station about three miles east of McCarthy Lake is associated with other sedimentary rocks within the greenstone mass and contains fragments of chert, argillite, and greenstone. The breccia appears to be of sedimentary origin and to be part of a substantial sedimentary section. The greenstone fragments in the breccia are easily explained if the greenstone is at least partly extrusive.

Age and Correlation

As no fossils were found in the Fennell Formation its age is uncertain. Possibly equivalent rocks outcrop in small areas in Vernon map-area to the southeast where they were named the Tsalkom Formation of the Mount Ida Group thought by Jones (1959) to be Archean or later.

The authors have mapped the Antler Formation of the Slide Mountain Group far to the north in Prince George (Tipper, 1960) and McBride (Campbell, 1968) map-areas. This formation was redefined and described by Sutherland Brown (1957 and 1963). The Antler Formation is characterized by pillow lava and in other respects also closely resembles the Fennell Formation. Campbell found early Mississippian fossils in the Guyet Formation immediately below the base of the Antler Formation which is thus early Mississippian or later. Both the Antler and Fennell Formations are locally in contact with and apparently older than dark Karnian shale and limestone units and are thus seemingly pre-Late Triassic. As similar rocks are unknown in the Pennsylvanian and Permian Cache Creek Group, the Fennell Formation may be regarded tentatively as early Mississippian or later and early Pennsylvanian or older, that is, mainly Mississippian.

Cache Creek Group (Map-units 3–6)

Introduction

The Cache Creek Group was named by A. R. C. Selwyn in 1871 from its type locality near Cache Creek (Selwyn, 1872, pp. 54, 60–62). He divided the sequence into a Lower Group of limestone, shale, volcanic rock, schist, and minor serpentine, and an Upper Group of limestone and minor shale. In 1875 Selwyn correlated the massive limestone at Fort St. James with that at the type area 280 miles to the southeast. G. M. Dawson re-examined the Cache Creek Group in the type area (1879) and in the Kamloops area (1895a) and concluded that the strata were of Carboniferous age. Later workers recognized equivalent rocks farther

north and south (Lord, 1948, pp. 13–15; Aitken, 1959, pp. 18–31; Armstrong, 1949, pp. 32–51; Duffell and McTaggart, 1952, pp. 15–24; Trettin, 1961, pp. 11–19) and showed that Pennsylvanian as well as Permian rocks are part of the Cache Creek Group. Several other assemblages of similar lithology, age, and complex structure are known by different names throughout the western Cordillera. Danner studied parts of the Cache Creek Group and many other late Paleozoic groups and concluded that they are mainly Pennsylvanian and Permian but include some Middle Devonian rocks. These lithologically and structurally similar rocks he proposes to call the Cache Creek Complex (Danner, 1968, p. 273). Brief histories of the Cache Creek Group, its age and application, were described by Armstrong (1949, pp. 32–51) and Duffell and McTaggart (1952, pp. 15–24).

Eastern Part of Cache Creek Group (Map-unit 3)

Name and Distribution

Rocks assigned to the eastern part of the Cache Creek Group underlie a large area flanking North Thompson Valley in the southeastern section of the map-area. South of Barrière they form a belt that is more than 15 miles wide and bounded on the east by Louis Creek. North of the town a narrower belt lies entirely west of North Thompson River. Rocks believed to belong to the Cache Creek Group outcrop near Little Fort, west of North Thompson River and Lemieux Creek. South of Friendly Lake they also comprise at least a small part of the rocks of map-unit 11 regarded as mainly Mesozoic. A small triangular area of Permian rocks two miles southwest of Windy Mountain is in fault contact with Mesozoic rocks.

The rocks here regarded as belonging to the eastern part of the Cache Creek Group were divided by Uglow (1922, pp. 76A–77A) into two formations of Precambrian or Paleozoic age. The Badger Creek Formation was supposed to consist mainly of sedimentary rocks and the greenstone (actually mainly clastic rock) was thought to be part of the volcanic Fennell Formation. Dawson, who conducted the first geological work in the region, believed most of the rocks west of North Thompson River belonged to the Carboniferous Cache Creek Formation (Dawson, 1895a, pp. 44B–46B; Map 1895b), but placed those close to and east of the river (Dawson, 1895b; 1898) in two Cambrian divisions, the Nisconlith and Adams Lake Series.

Cockfield (1948, pp. 6–11), in Nicola map-area immediately south of the east half of Bonaparte Lake map-area, did not follow Dawson's Carboniferous and Cambrian divisions but placed both in the Cache Creek Group in which he found fossils of definite Pennsylvanian and Permian ages. All the rocks in the northwest corner of Vernon map-area (immediately southeast of Bonaparte Lake map-area) were placed by Jones (1959, pp. 38–47) in the Carboniferous (?) and Permian Cache Creek Group. The present writers have mapped the rocks continuously northward from those mapped by Cockfield and can find no adequate basis for dividing them as was done by either Uglow (1922) or Dawson (1895b; 1898). The name Cache Creek Group, therefore, has been retained.

Lithology

The eastern part of Cache Creek Group is composed mainly of clastic rocks and minor carbonate; basic and intermediate flows may be important locally. The entire assemblage has been subjected to low-grade metamorphism. The most common clastic rocks are dull grey or grey-green volcanic arenite and greywacke; siliceous argillaceous rocks are subordinate but locally abundant.

Greenstone, as a general term, can be applied to the volcanic arenite, greywacke, and possible flow rocks. The origin of these rocks is not evident in many field exposures nor in some cases in thin sections. Most of the greenstone, however, displays obvious clastic textures, particularly in thin sections.

The typical grey to greenish grey greenstone is a fine-grained rock consisting of sodic plagioclase, chlorite, epidote, and quartz; carbonate, amphibole, and sericite may be present, but biotite is rare. The most common rock consists of grains up to 1 mm long of turgid, locally sericitized subhedra of plagioclase, about An_{20} in composition, with scattered grains of anhedral quartz and patches of very fine grained chlorite all set in a matrix of very fine grained epidote, chlorite, and possibly plagioclase and quartz. In some rocks, colourless to yellow-green amphibole forms grains up to 1 mm long and also finer grains in the matrix; where amphibole is abundant chlorite is absent or in small quantity. Carbonate is common and forms irregular patches and veinlets. Fine biotite was noted in the matrix in a few thin sections. Locally the rocks have a compositional layering in which layers rich in amphibole alternate with those rich in carbonate.

The clastic origin of most of the rocks can be recognized from the fragmental appearance of the plagioclase and quartz and because the rocks commonly lack any distinctive volcanic texture. Some rocks display no clear evidence of origin and a few exhibit a volcanic or igneous texture. The arenaceous rocks are regarded as having been derived from a volcanic source; those poor in quartz are called volcanic arenite and those with appreciable quartz are termed greywacke. Quartz is, however, nowhere abundant and its derivation from crystalline rocks or siliceous sediments should not be assumed; it could equally well be of volcanic origin.

Here and there the fine-grained arenites are interbedded with breccia and conglomerate in which fragments range up to 1 cm across. In addition to all the minerals of the arenites these rocks contain fragments of argillite, intermediate volcanic rocks and chert. The fragments are commonly flattened in the plane of the foliation.

In a few places highly schistose greenschist is associated with the greenstone. The schist is very fine grained and consists of sodic plagioclase, amphibole, epidote and chlorite. It may, perhaps, be the metamorphic derivative of tuffaceous layers.

The second most common rock types in the eastern part of the Cache Creek Group are dark grey to brownish grey slaty argillite, phyllite, and schist. These are most abundant just east of North Thompson River directly east of Skull Hill and are well exposed along Highway 5 but are common throughout the remainder of the group. These rocks are normally very fine grained and consist of quartz, sericite, and chlorite but along the highway east of Skull Hill they are metamorphosed to quartz-mica schist which contains both muscovite and biotite and, in at least one locality, small garnets.

Variations from argillite and phyllite to fine-grained arenite were found; these range from phyllite with a few scattered grains of plagioclase or quartz, or both, to rocks with more abundant coarser grains plus layers containing epidote and amphibole. The similarity to and gradation from the fine-grained greenstone to both finer and coarser sedimentary rocks indicates that most of the greenstone is itself of sedimentary origin.

Limestone is not common in Cache Creek Group rocks in this region and does not form the prominent thick masses prevalent elsewhere in the group. Grey or buff finely crystalline limestone in thin beds was found at scattered localities and a dark grey to black coquinoid limestone was noted about 2 miles south of the east end of Friendly Lake.

Chert, a common and characteristic rock in the Cache Creek Group in other regions, is rare or absent here. Cherty argillite and possibly true cherts were noted near the lower part of Eakin Creek. Fine-grained quartz phyllite near the highway about 2 miles south of Little Fort may have been chert originally.

The only other rock type of any significance found within the eastern part of the Cache Creek Group is a dark greenish grey material containing grains of black amphibole up to 5 mm long (map-unit 16a). In thin section the rock is seen to consist of large grains of deep green hornblende and plagioclase (about An_{30}) in a matrix of fine grains of the same minerals. The plagioclase is sericitized. This rock has an igneous texture but a volcanic origin cannot be ruled out. Several exposures were noted on the ridge between Louis Creek and North Thompson River and others were found south of Peterson Creek near Gorman Lake and near the lower part of Eakin Creek.

The small area of poorly exposed Permian strata southwest of Windy Mountain comprises interlayered blue-grey to dark grey limestone, limestone breccia with angular chert fragments, volcanic breccia, minor thin-bedded tuff, chert, argillite, and calcareous arenite. The rocks are irregularly bedded, poorly sorted, and beds may be lenticular.

Structural Relations

Internal structural relations. As the eastern part of the Cache Creek Group is poorly exposed and yields a minimum of structural data, the nature of the internal deformation is mainly unknown. The rocks are foliated but bedding is rarely apparent, particularly in the green arenaceous rocks. Minor folds and linear structures, though not common, can usually be found in argillite, phyllite, and schist and it is from these rocks that the character of folding in the entire unit may be inferred.

Where observed together, foliation or schistosity and bedding are commonly parallel or nearly so. Though folds are seldom seen, some isoclinal minor folds were observed and in a few localities where the folds are not so tight axial plane foliation intersecting bedding was recorded. The form of the folds probably varies, being more nearly isoclinal in the least competent rocks. A second phase of folding has warped the foliation on both a small and large scale. A large gentle anticline visible along Highway 5 directly east of the summit of Skull Hill was regarded by Uglow (1922, p. 76A) as a first-fold structure. In addition to this large fold there are smaller scale second folds that seem to vary from tight, nearly isoclinal structures to rather gentle warps; they do not seem to be systematically developed throughout the unit.

In the region east of North Thompson River and around Skull Hill and Mount Goudeau, both first and second folds trend about north- to north-northwest and plunge northerly. Farther west first folds at least, plunge mainly to the northeast except on Fishtrap Mountain where the trend is northerly. There no data on second folds were obtained. Near Little Fort fold trends are northerly.

Evidence of faults entirely within the eastern part of the Cache Creek Group is lacking or weak. A fault trending north-northeast may cut these rocks in the unusually straight, narrow valley immediately west of Skull Hill along the route of the oil pipeline. This possible fault may extend also southward down North Thompson River valley. The attitude of the foliation and the trend of folds appear to be distinctly different on opposite sides of the inferred fault.

External structural relations. An inferred fault forms almost the entire eastern contact of the eastern part of the Cache Creek Group from lower Lemieux Creek to Louis Creek valley. Along this fault the Cache Creek Group lies against the Fennell Formation as far south as Barrière River, and south from there against the rocks of map-unit 12. Though the rocks of the latter unit may be partly the same age as the Cache Creek Group, they differ in structural trend and locally in lithology across the line of the proposed fault. The relationship of the Cache Creek Group rocks to those of map-unit 16 at the southern boundary of the area in Louis Creek valley is unknown. South of Thuya batholith rocks of the Cache Creek Group

are unconformably overlain on the west by late Tertiary lavas (map-unit 25) and along North Thompson Valley by the Tertiary Skull Hill and Chu Chua Formations and by one small section of late Tertiary or Quaternary lava.

Rocks of the Cache Creek Group are invaded by several intrusive masses, including Thuya batholith and by small unmapped granitic and felsic dykes and by small bodies of very coarse hornblendite which may be related to map-unit 16a.

The nature of the contact of Cache Creek Group rocks to those of map-unit 11 is not known. Fossil evidence indicates that map-unit 11 contains at least some Cache Creek Group as well as younger rocks but these cannot be properly separated at present. North of Eakin Creek the conglomerate and breccia of map-unit 16 are probably in fault contact with the Cache Creek Group though they may rest unconformably upon it.

The Permian rocks southwest of Windy Mountain are in fault contact with rocks that are believed to be of Early Jurassic age. Thus the thick Upper Triassic section must be faulted out or the Lower Jurassic rocks may rest unconformably on the Permian strata in the area of Windy Mountain. Either interpretation is possible.

Age and Correlation

Fossils were collected from several localities in the eastern part of the Cache Creek Group in Nicola and Bonaparte Lake map-areas. The fusilinids were studied by Prof. C.A. Ross, Western Washington State College, Bellingham, Washington, and the corals, brachiopods, and other invertebrate fossils were identified by E.W. Bamber of the Geological Survey of Canada. Their identifications and comments are as follows:

GSC loc. 64811

South side of Windy Mountain, Bonaparte River Area, B.C. 51°40′ N., 120°36′ W.

Richthofenid brachiopod
Plerophyllid coral
Bryozoan indet.

Age: Permian

GSC loc. 64907

Cache Creek Group, 8½ miles east of Kamloops, 4 miles north of South Thompson River, 50°43′ N., 120°04′ W. Nicola map-area.

Echinoderm columnals

Age: Insufficient material for age determination

GSC loc. 64910

50°40′ N., 120°09′ W.; 7 miles east of Kamloops, 1 mile north of South Thompson River. Nicola map-area.

Productid brachiopods
Bryozoan indet.

Age: Carboniferous or Permian

GSC loc. 64911

51°32′ 50″ N., 120°25′ 25″ W.; 125 yards northwest of east end of 'L'-shaped lake. (Included with map-unit 11)

Muirwoodia sp.
Scacchinellid brachiopod
Spiriferella sp.
? *Cleiothyridina* sp.
Plerophyllid coral

Age: Permian, probably Leonardian or Wordian

GSC loc. 64915
50°41′ N., 120°04′ W., 8½ miles east of Kamloops, 3 miles north of South Thompson River. Nicola map-area.
Echinoderm columnals
Productid brachiopods indet.
Age: No precise age determination can be made

GSC loc. 68128
Southwest ridge of Windy Mountain, 51°33′ N., 120°30½′ W.
Pseudofusulina sp.
Pseudofusulinella ? sp.
Age: Early Permian, Wolfcampian

GSC loc. 64915
50°41′ N., 120°04′ W., 8½ miles east of Kamloops, 3 miles north of South Thompson River. Nicola map-area.
Parafusulina (?) sp.
Age: Guadalupian, at least middle Wordian, perhaps even younger.

GSC loc. 64909
50°47′ N., 120°18′ W., three miles south of Rayleigh Station, south-central B.C., Nicola map-area.
Eostaffella sp.
Endothyra sp.
Age: Early Pennsylvanian, Morrowan

The fossils clearly indicate that the group includes rocks as old as Early Pennsylvanian (Morrowan) and as young as Late Permian (Guadalupian). How much of the intervening time is represented is unknown but at least some Early Permian (Wolfcampian) rocks are present.

Rocks of similar age and lithology have been mapped as Cache Creek Group throughout British Columbia. As mapped in the east half of this map-area the group is correlative in part with those rocks in the type area near Cache Creek in Marble Canyon. In addition the lower part may be correlative in part with the group as mapped in the Fort St. James map-area (Armstrong, 1949, p. 47) and with the Asitka Group in McConnell Creek map-area (Lord, 1948, p. 13). The Chilliwack Group and the Sicker Group are also correlative.

Western Part of Cache Creek Group (Map-units 4–6)

Name and Distribution

The type area of the Cache Creek Group lies south of the west half of the map-area and the rocks extending from the type area into Bonaparte Lake map-area are here referred to as the western part of Cache Creek Group. In this map-area the group has been divided into map-units 4 and 5 and the Marble Canyon Formation (map-unit 6). Map-unit 4, mainly greenstone, chert, argillite, and limestone, underlies Hart Ridge southeast of Clinton and the hills northwest of Meadow Lake. The Marble Canyon Formation, mainly massive limestone, underlies most of Marble Range and Tsilsalt Ridge. Map-unit 5, comprised of chert, argillite, basic volcanics and limestone, is of limited extent in the Marble Range southeast of Mount Soues and around Mount Kerr.

The western part of the Cache Creek Group in Bonaparte Lake map-area provides more stratigraphical, structural, and paleontological information about the group than

does the type area. The group was named and described by Selwyn in 1872 who divided it into two parts. The lower part was believed to range in age from earliest Devonian to latest Permian on the basis of contained brachiopods. The upper part, mainly the Marble Canyon limestone, was dated as Eocene or Cretaceous because of misidentification of foraminifera.

Dawson decided that the two parts were closely related, that the Eocene or Cretaceous foraminifera were erroneously dated, and that the group as a whole was mainly of Carboniferous age (Dawson, 1895a, pp. 37B–39B). He referred to the entire assemblage as a formation and to the Marble Canyon limestone as a member.

Further work on the fusilinids established the age of the Cache Creek Group in the type areas as Permian (Duffell and McTaggart, 1952, pp. 22–24). In other areas the age was extended to include Pennsylvanian (Armstrong, 1949, pp. 44–47) but only Permian fossils have been found in the type area.

In a restudy of the type area, Duffell and McTaggart used the term, Cache Creek Group, but no longer referred to an upper and lower part. The Marble Canyon limestone member was identified as the Marble Canyon Formation (Duffell and McTaggart, 1952, pp. 15–24). The rocks lying west of the Marble Canyon Formation in the type area were regarded by Duffell and McTaggart as possibly the youngest part of the group (1952, p. 17); subsequently these rocks were mapped as the Pavilion Group by Trettin (1961, p. 20).

Lithology

Map-unit 4. This map-unit is of varied lithology but is mainly greenstone, chert, limestone, and argillite. Owing apparently to rapid facies changes the hills northwest of Meadow Lake consist mainly of limestone but Hart Ridge consists mainly of greenstone, chert and minor limestone.

The limestone, forming massive beds northwest of Meadow Lake, is fine grained to coarsely crystalline, white to grey and blue-grey, and in places is obviously limestone breccia with calcite cement. Although exposure is poor, the beds appear relatively thick and massive. Interlayered with the limestones are thinner beds of argillite, green phyllite, green to dark green or black basaltic or andesitic flows, breccia, tuff, and minor ribbon chert.

On Hart Ridge and along Bonaparte River east of Clinton the succession comprises mainly basic volcanic rocks, chert, argillite, and minor limestone. The volcanic rocks are dark green to black, brecciated, sheared, and in places thoroughly chloritized and epidotized. Some of the volcanic rocks are flows but whether flows, breccia, or tuff predominate is unknown.

Chert in the ribbon chert sequence is commonly blue-black to dark grey or grey in bands 1 inch to 6 inches thick separated by sheared argillaceous partings up to ½ inch thick. Where present chert is predominant but relatively thick sections of sheared black argillite without associated chert were noted, although little is known about them because of intense shearing. Several limestone bands, 25 to 50 feet thick, are interlayered with the other rocks. The limestone is grey, fine grained, and lacks bedding features. Along Bonaparte River near Clinton Creek small bodies of serpentinite and peridotite are included with map-unit 4. They are not shown separately because they are small and poorly exposed.

Map-unit 5. Rocks of map-unit 5, though poorly exposed, are prominent in the Marble Range insofar as they contrast markedly with the massive limestone of the Marble Canyon Formation. Trettin (1961, p. 12) described them as the Mount Soues Division of the Cache Creek Group as follows:

> "On the southeast slope of Mount Soues ribbon chert, argillite, volcanic flow-rocks mostly of basic composition, tuff, and limestone are exposed. The assemblage differs

from rocks of the Pavilion Group in two respects: the presence of limestones that are interlaminated with ribbon chert, and the relative abundance of basic volcanic flows. The outcrop zone is about 2 miles wide and pinches out to the northwest. The thickness of the unit which is overlain conformably by the Marble Canyon Formation is estimated as approximately 1,500 feet. The rocks are folded and faulted and seem to occupy the core of an anticlinorium formed by the basal member of the Marble Canyon Formation . . . . "

On Mount Kerr, Trettin mapped a section of limestone and cherty limestone overlying a unit (Trettin's 2C) of volcanic rock, chert, and argillite and considered all to be part of the Marble Canyon Formation. This section was re-examined and the rocks at the base of the limestone (Trettin's 2C) were mapped separately as map-unit 5. The rocks are dark green to dark grey basaltic flows and tuff, maroon tuff, mottled green and mauve flows, minor black chert, and sheared argillite. They are believed to be equivalent to part of the Mount Soues Division which they resemble lithologically. The section is thicker than the other non-limestone units interbedded with the Marble Canyon Formation, and stratigraphically it underlies massive limestone with the typical Guadalupian *Yabeina* fauna. Nevertheless this unit could be a member of the Marble Canyon Formation as interpreted by Trettin.

Marble Canyon Formation (*Map-unit 6*). The prominent, massive limestone beds that characterize the Marble Range form the major part of the Marble Canyon Formation. Interbedded but of relatively minor importance are thin beds of ribbon chert, argillite, tuff, and volcanic flows.

Trettin (1961, p. 13) described the main limestone member, designated by him as Member III, as follows:

"*Member III*, is composed mainly of limestone but locally contains small amounts of interbedded chert and argillite. The member forms a high ridge, about 13 miles long, that culminates in Mount Bowman . . . ."

"Most of the limestone is pure and massive and shows no bedding. In some localities, however, alternating light grey and dark grey layers are visible that are from a few millimeters to one centimeter thick. Under the microscope the layers are seen to differ in grain size and in the proportion of minute inclusions in the carbonate. Some of the rocks are calcarenites and show graded bedding, ripple marks, and intraformational breccias. Breccias made up of fragments that range from a few millimeters to one inch in size locally occur within the massive limestone. In the northern part of the map-area (the Marble Range) some rocks that may be correlative with Member III contain oolites. Fossils are relatively rare; remains of colonial corals, of crinoids, echinoids, algae, and fusulinids have been found at a few localities.

"In the syncline on Mount Kerr the thick massive limestone of Member III is overlain by a bed of limestone, approximately 500 feet thick, that contains laminae of chert. A sheet of interlaminated limestone and chert forms the crest of the Marble Range between Mann Creek (north of Mount Kerr) and Jesmond Creek. Scattered outcrops of a similar type occur between Jesmond Creek and the northern extremity of the Marble Range . . . ."

The results of a study of the Marble Canyon Formation form an important part of a report by Trettin (1961) and subsequently he devoted several weeks from 1964 to 1967 to revising and clarifying the stratigraphy, structure, and petrography of the formation (Trettin,

1966). A final report on these studies is in preparation and the following quotation is taken from a brief preliminary statement on the subject (Trettin, 1966).

> "Three members are presently recognized in the formation. *Member A*, a limestone, is characterized by relatively low thickness, a high proportion of thinly interbedded chert, and locally associated tuffaceous matter. *Member B* consists of poorly exposed phyllitic chert and dark shale. *Member C* is a relatively thick, massive, slightly dolomitic limestone. Fusulinids of the *Yabeina* zone, echinoderm columnals, cup corals, gastropods, algal laminations, oolites, calcarenites, and breccias are locally represented. Only on Mount Kerr, and north of it, does the member contain a considerable proportion of regularly interbedded chert. West of Mount Soues, it is overlain by calcareous, tuffaceous phyllite . . . ."
>
> "Texturally, the limestones fall in the transition field between normal micrites and regionally metamorphosed marbles. Most are pseudobreccias of the replacement type, with remnants of microcrystalline limestone surrounded by coarser grained crystal aggregates, part of which show elongation and preferred orientation."

The writers have not recognized the three members described by Trettin, probably because insufficient time was devoted to a study of the formation. For the purposes of this report, it is sufficient to map the Marble Canyon Formation as one unit, though further subdivision into members is possible.

Structural Relations

Internal structural relations. The relation of the three map-units of the group is not clear. Map-unit 5 and the Marble Canyon Formation apparently are conformable in the Marble Range. Map-unit 4 is in fault contact with the Marble Canyon Formation on the east side of Tsilsalt Ridge but on the east side of the Marble Range the contact is covered. As will be explained in discussing the age of the group, map-units 4 and 5 may be in part correlative or identical.

A limestone bed in map-unit 4 thickens from 25 to 50 feet on Hart Ridge and along Bonaparte River to massive beds several hundred feet thick in the hills northwest of Meadow Lake. The chert, greenstone, and argillite strata of Hart Ridge either pinch out, thin, or are not exposed around Meadow Lake. The limestones contain faunas that indicate they are correlative.

External structural relations. The Cache Creek Group is in fault contact with the mainly younger Pavilion Group. Trettin has proposed that the lower part of the Pavilion Group may be correlative with the upper part of the Marble Canyon Formation and that the lithologic dissimilarity is a result of a facies change (Trettin, 1961, p. 23). This proposition has not been proven.

No rocks older than the Cache Creek Group are known in the western part of the map-area.

Age and Correlation

The group has yielded many collections of fossils, mainly fusilinids but also a few corals, brachiopods, echinoids, bryozoa and other invertebrates. The writers made several collections of fossils from map-unit 4 and the Marble Canyon Formation; map-unit 5 yielded no fossils. The fusilinid faunas were studied by C. A. Ross of Western Washington State College, Bellingham, Washington.

Trettin made several collections of fusilinids from the Marble Canyon Formation which were identified by Professor W. R. Danner of the University of British Columbia. These determinations are reported by Trettin (1961).

Professor Danner and Dr. M. K. Nestell have recently collected fusilinids from map-unit 4 both on Hart Ridge and in the hills northwest of Meadow Lake. Professor Danner has made available to the writers the results of their studies and our indebtedness for this information is gratefully acknowledged.

From map-unit 4 on Hart Ridge and east of Clinton fusilinids were collected. Professor Ross's identifications and comments are as follows:

GSC loc. 68103

Southwest quarter of lot 873, 7 miles from west end of Loon Lake, Bonaparte River area.

Clasts include fragments of a fairly large *Schwagerina*? or *Parafusulina*?

Age: The fusilinids appear similar to some Late Permian ones from other collections, but these may be as old as early Leonardian.

GSC loc. 68093

West side of Bonaparte River, on road one mile south of fiftyseven Creek, Bonaparte River area.

Pseudoschwagerina cf. *P. uddeni*
Schwagerina sp.
Pseudofusulina sp.

Age: Early Permian, Wolfcampian

From near these two localities and in the valley of Bonaparte River as far south as Loon Creek, Danner and Nestell collected fusilinids from thin limestone beds in map-unit 4. They report the presence of *Triticites* sp., *Schubertella* sp., *Schwagerina* sp., *Pseudofusulina* sp., and *Pseudoschwagerina* sp. of Early Permian, Wolfcampian age.

Near GSC loc. 68103 one collection was made by Danner and Nestell who identified *Pseudodoliolina* sp., *Schwagerina* sp. or *Parafusulina* sp., and *Schubertella* sp. On this collection they commented as follows:

> "This fauna is well preserved and very significant. The species of *Pseudodoliolina* is very similar to one described from the Arlington area of northwestern Washington. This association is definitely older than the Marble Canyon *Yabeina* fauna. The age is probably late Leonardian or early Guadalupian."

From the limestone of map-unit 4 northwest of Meadow Lake, the writers obtained only fragmentary fossils (algae (?), corals, gastropods) which were insufficient for age determination. Also in this area Danner and Nestell made collections on the road near the west end of Meadow Lake, on the hill 4 miles northwest of the west end of Meadow Lake, and 3 miles southeast of Clink Lake. They identified the following:

Pseudoschwagerina sp., *Pseudofusulina* sp., *Triticites* sp., *Quasifusulina* sp., *Schwagerina* sp., *Chalaroschwagerina* sp., *Schubertella* sp., and *Nankinella* sp. To all collections they assigned an Early Permian (Wolfcampian) age.

From the foregoing, it is apparent that map-unit 4 is mainly Early Permian (Wolfcampian) age. One collection by Danner and Nestell indicates that part of the unit on Hart Ridge may extend into late Leonardian or early Guadalupian. It is significant, however, that no definite Leonardian fossils have been identified.

The Marble Canyon Formation has provided many fossil collections. C. A. Ross's identifications and comments are as follows:

GSC loc. 68097

300 yards east of Mount Soues, Marble Range, Bonaparte River area.

Neoschwagerina sp.
Cancellina sp.
Boultonia sp.
Kahlerina sp.
Schwagerina sp.
Reichelina sp.
Chusenella sp.

Age: Late Permian, Guadalupian, probably Wordian

GSC loc. 68094

200 yards east of Mount Soues, Marble Range, Bonaparte River area.

Yabeina sp.
Neoschwagerina sp.
Schwagerina sp.
Chusenella sp.
Nankinella? sp.
Kahlerina? sp.

Age: Late Permian, Guadalupian

GSC loc. 68096

100 yards south of Forestry Lookout on mountain west of Clinton, B.C., Bonaparte River area.

Codonofusiella sp.
Neoschwagerina sp.
Schwagerina? sp. or *Parafusulina*? sp.
Kahlerina? sp.

Age: Late Permian, probably late Guadalupian

Trettin's collections (1961, pp. 17–19) indicate a Late Permian age for the upper members of the Marble Canyon Formation. He suggests that the lower members of the formation might be Middle Permian, but the collections by the writers are from Trettin's lower members and they indicate a Late Permian (Guadalupian) age. For these reasons, the Marble Canyon Formation is probably entirely of Late Permian (Guadalupian) age.

The age of map-unit 5 can only be deduced by inference. Collection GSC loc. 68097, assigned an age of Wordian (early Guadalupian), was obtained immediately above the unfossiliferous map-unit 5 and probably is near the base of the Marble Canyon Formation. Map-unit 5 can, therefore, be no younger than early Guadalupian if the age assignment is correct. The age of map-unit 4 was determined as possibly as young as early Guadalupian, presumably Wordian. Map-unit 5, therefore, may be correlative, wholly or partly with map-unit 4.

The western part of the Cache Creek Group ranges in age from Early Permian (Wolfcampian) to Late Permian (late Guadalupian). No definite Leonardian or Ochoan rocks are known in this map-area. The Permian age probably applies as well to the type area lying directly south and southeast. Elsewhere Pennsylvanian rocks have been included in the group, such as in the eastern part of the map-area (map-unit 3) and in the Fort St. James

map-area (Armstrong, 1949, pp. 45–47). The group is correlative as a whole or in part with the folded late Paleozoic limestone, chert, argillite and greenstone strata extending from the Yukon through central British Columbia into Washington, Oregon, and California.

Pavilion Group (Map-units 7 and 8)

Name and Distribution

The name Pavilion Group was applied by Trettin (1961, pp. 20–34) to a succession of sedimentary and volcanic rocks lying southwest of the Cache Creek Group with which it is closely related. He divided the group into Division I and Division II each with several lithologic subdivisions. Only Division I is represented in the Bonaparte River map-area and two of the subdivisions have been retained as map-units 7 and 8.

The writers did not make a detailed study of the group and except for a few additions and minor changes, accepted Trettin's work as a completely adequate description. The information presented here is essentially an adaptation of Trettin's work and for a more complete account of the group as a whole, the reader is referred to his report (1961).

The Pavilion Group is exposed in Fraser River valley and on the adjacent hills. Map-unit 7 (Trettin's map-unit 3A) underlies the Edge Hills and much of Fraser River valley. Map-unit 8 (Trettin's map-unit 3B) outcrops in irregular areas in Fraser River valley south of Butcher Creek and also on the west side of Big Bar Creek near the northwest end of Marble Range. The group is poorly exposed.

Lithology

Map-unit 7. Interbedded chert, argillite, and siltstone or fine sandstone comprise most of this map-unit but minor limestone beds and lenses and tuff beds occur in places. The chert varies from light grey, greenish grey to blue-black and is interlaminated with dark grey or blue-black argillite to form typical 'ribbon chert'. The beds of chert are commonly 1 inch to 3 inches thick and those of argillite are commonly less than ¼ inch thick. Buff to greenish buff and grey sandstone is interlayered with the argillites and cherts but is not predominant in any section. Graded bedding was noted locally. Coarse sediments are absent.

Locally thin beds of fine greenish grey to dark grey tuff are interlayered with argillite and sandstone. Fine volcanic breccia with angular fragments to ¼ inch diameter, is also interlayered and is the coarsest clastic rock noted in the section. Volcanic flows are rare.

Limestone in lenses and thin beds is present in some sections apparently at various stratigraphic levels. It is light grey to blue-grey, fine grained, and closely fractured. The lenses may be as much as 100 feet thick but thin in short distances.

Map-unit 8. This map-unit differs from map-unit 7 in that volcanic rocks predominate (tuff, fine breccia, and rare basaltic or andesitic flows). The sediments are interlayered but are generally darker coloured and probably are tuffaceous.

Structural Relations

Internal structural relations. The relation of map-unit 7 to map-unit 8 is not fully understood. In places map-unit 8 is apparently younger but as the structure is complex and exposure poor this is not certain.

The Pavilion Group in this area is deformed into northwest-trending folds. Trettin (1961, p. 26) suggested that the rocks west of this area in a younger part of the group are tightly folded and appear to be overturned to the southwest.

External structural relations. The Pavilion Group is faulted on the southwest side against map-unit 23 and on the northeast side is probably faulted against the Marble Canyon Forma-

tion (map-unit 6). Trettin suggested that part of the Pavilion Group in this map-area is partly correlative with the Marble Canyon Formation as a result of a westward facies change (Trettin, 1961, p. 23).

Age and Correlation

No fossils were found in the Pavilion Group within the map-area. Trettin found fossils, believed to be hexacorals, in the Ashcroft map-area in rocks assigned to a division younger than those in Bonaparte Lake map-area. They were assigned a Triassic age (Trettin, 1961, p. 34).

The section that yielded Trettin's fossils was re-examined and another collection made and submitted to E. W. Bamber of the Geological Survey of Canada who reported as follows:

GSC loc. 74834

From ridge north of Keatley Creek, about 2 miles east of Glen Fraser, Ashcroft map-area. 50°40′ N., 121°46′ W.

scleractinian corals, indeterminate

Age: Mesozoic or Cenozoic

The fossils indicate a post-Paleozoic age but the enclosing strata are lithologically unlike any Late Triassic or younger formations in central British Columbia, and moreover the Late Triassic and younger strata are believed to be mainly block faulted, tilted, and relatively gently folded, whereas the Pavilion Group appears to be tightly folded and locally overturned. For these reasons the Pavilion Group is thought to be older than Late Triassic. The younger part of the Pavilion Group (Trettin's Division II) is therefore believed to be Middle or Early Triassic in complete agreement with Trettin's age assignment.

Trettin believed that the rocks of map-unit 7 and 8 (Division I) are older than the fossiliferous part (Division II) of the Pavilion Group, and, if true, no younger than Middle Triassic. If Trettin's postulate is correct that these rocks may in part be a facies of the upper part of the Marble Canyon Formation, then map-units 7 and 8 could be partly Guadalupian in age.

The Pavilion Group is similar to parts of the Cache Creek Group that are known to be Permian or Pennsylvanian. Many unfossiliferous sections mapped as Cache Creek Group in Quesnel (Tipper, 1959), Prince George (Tipper, 1961) and Fort St. James (Armstrong, 1949) map-areas may be correlative in whole or in part with the Pavilion Group.

Map-unit 10

Distribution

Map-unit 10, comprising phyllite, argillite, shale, and limestone, extends from the valley of Lemieux Creek, about 2 miles north of Little Fort, north to Mahood Lake and beyond the border of the map-area. The beds are well exposed in the canyons of Lemieux Creek, in the valley of Mann Creek, and along the north shore of Mahood Lake; elsewhere exposures are sparse.

Lithology

Siliceous argillaceous rocks and their metamorphic derivatives dominate and characterize map-unit 10. Metamorphism is low grade and locally absent, as in Mann Creek valley and near the lower, south-flowing part of Lemieux Creek. Metamorphic effects are most pronounced north of the central part of Mahood Lake.

The rocks in Mann Creek valley are brownish weathering black and dark grey, thin-bedded shales or argillites and siltstones that exhibit crude bedding plane fissility. Intercalated with them are beds and scattered concretionary ovoids of brittle black limy material. The rocks consist of extremely fine-grained quartz with minute sericite and chlorite flakes and carbonaceous material. Carbonate may be absent or relatively abundant. The minerals show only a weak tendency to a preferred orientation, except near the Fennell Formation where the rocks are phyllitic.

Other than near Mann Creek the most common rocks are black and dark grey phyllite, slaty argillite, and siltstone which display a prominent plane of fissility and consist of quartz, sericite, chlorite and irregular grains and small rhombs of carbonate. Along the northern shore of Mahood Lake, and farther north near the two bodies of quartz monzonite, these rocks have been affected by a superposed contact metamorphism, apparently induced by the two intrusive masses. These rocks have a distinct bedding plane foliation marked by layers alternately rich in carbonaceous material and in quartz, and by the orientation of sericite. This foliation is intersected at a large angle and mildly deformed by a fracture cleavage. Most of the rocks are very fine grained but within carbonaceous layers andalusite grains reach about 1 mm in length. These crystals are elongate parallel with the first foliation but streaks of carbonaceous inclusions within undeformed andalusite grains show deformational patterns produced by the fracture cleavage. Deep brown fine-grained biotite is not well oriented nor deformed by the fracture cleavage. It crystallized during or after the development of the cleavage as did the andalusite. The contact metamorphism thus was a late episode subsequent to or during a late stage deformation.

About 200 feet of dark grey and black interbedded limestone and shale is exposed in a canyon of Lemieux Creek about 6 miles north of Little Fort. The rocks are well bedded and essentially unmetamorphosed. Limestone beds up to 18 inches thick are separated by 2- or 3-inch layers of black, fissile shale. Less well-bedded and more highly fractured limestone is exposed for about 2.5 miles in cuts along the Lemieux Creek road north from the mouth of Eakin Creek. Elsewhere limestone forms rare thin beds.

Structural Relations

The nature of the folding within map-unit 10 varies. The rocks south of Raft batholith are much less deformed and foliated than those to the north except those in the upper part of Lemieux Creek near Taweel Lake which are phyllitic and seem to be tightly folded.

Although the bedding is obscure in the limestone exposed in cuts along the Lemieux Creek road, the strata appear to dip steeply to the west whereas the well-bedded limestone in the canyon of Lemieux Creek dips uniformly to the west at moderate angles. Minor folds were not observed in these rocks. The phyllite along Lemieux Creek near Taweel Lake, on the other hand, is highly deformed. It displays minor folds, bedding-cleavage intersections —though in many instances these are parallel—and crenulated foliation surfaces. The foliation trends northwest and dips steeply. Folds plunge at low angles to the west-northwest. In the valley of Mann Creek the shaly rocks are deformed into asymmetrical folds that plunge gently to the south-southeast. Anticlines have a steep eastern limb and a flat western limb and the axial planes dip moderately to the southwest. The phyllitic rocks closest to the Fennell Formation are apparently more highly deformed.

The rocks of map-unit 10 near Mahood Lake are well foliated and tightly folded. As bedding and metamorphic foliation are parallel in many places isoclinal folding is suspected. The foliation dips eastward and trends so as to maintain a rough parallelism with the contact of the Fennell Formation and with the foliation within the Fennell Formation and the

Cariboo Group. The few observed folds plunge easterly or southeasterly. The rocks of the three units, the Cariboo Group, the Fennell Formation, and map-unit 10, appear to have been subjected simultaneously to at least one episode of deformation. This is thought to involve at least local westerly directed thrusting. No evidence of thrusting was noted south from Raft batholith. Little is known of the structure of the rocks of map-unit 10 in the region north and west of Pendleton Lakes where exposure is meagre.

The structure within the rocks of map-unit 10 varies appreciably from place to place. Local stresses apparently developed near faults and were influenced by adjoining more competent rock masses.

The contact of the rocks of map-unit 10 with those of the Fennell Formation was not actually observed though it may be exposed just north of Mahood Lake where it is believed to be an easterly dipping thrust fault. The unit is thought to overlie the Fennell Formation, possibly conformably, in Lemieux and Mann Creek valleys but the contacts cannot be seen—they may be faulted.

The contacts with map-units 15 and 16 are even more obscure and may be faults, an unconformity or a combination of the two. Were this not so the Nicola Group should separate the Jurassic rocks from those of map-unit 10.

Strata of map-unit 10 are cut by granitic rocks of the Raft batholith and related bodies, and overlain by late Tertiary basaltic lava.

Age and Correlation

In map-unit 10 fossils were found only in the limestone near Lemieux Creek. Walker's (1931, p. 131A) collection from this limestone contained some forms suggesting a Triassic age and some, rather more definitely, indicated a Carboniferous age. Several collections of poor material made by the writers were sufficient to allow conclusive determination of an Upper Triassic or Lower Jurassic age. The collections were examined by E.T. Tozer and J.A. Jeletzky of the Geological Survey of Canada whose reports follow:

GSC loc. 64912
Lemieux Creek canyon 6.5 miles N. of Little Fort 51°30′50″ N., 120°13′10″ W.
Bivalve fragments
Small globose ammonoid, possibly an Arcestid

Age: Probably Triassic

GSC loc. 68125
Same locality as 64912
Small fragmentary Ammonoids indet.
Pectenid indet.
A belemnoid

J.A. Jeletzky comments as follows regarding the belemnoid

"*Atractites* Guembel 1861 S. st. 1 =
Ausseites Flower 1944 = *Xiphoteuthis*
Huxley 1864 sp. indet.

Age and Correlation: Most likely Upper Triassic to Lower Jurassic (Lias). The genus *Atractites* as here interpreted occurs about equally commonly in the Upper Triassic (Karnian and Norian but (?) not Rhaetian stages) and Lower to Middle Lias (Hettangian to Pliensbachian Stages) of the Tethian province of Europe. It is not definitely known to range beneath the Karnian Stage but may occasionally range into the Middle or even early Upper (Oxfordian

Stage) Jurassic. In British Columbia it is already known from both Karnian-Norian and Hettangian-Sinemurian rocks."

GSC loc. 68127

Road-cut, Lemieux Creek road, 3.2 miles north of Little Fort, 51°28′10″ N., 120°12′55″ W.

Spiriferid brachiopods
Pentogonal crinoid columnals
A belemnoid

J.A. Jeletzky comments as follows regarding the belemnoid:

"An indeterminate aulaeoceratid."

"Age is probably as for lot 68125, but the earlier Triassic or late Palaeozoic age cannot be excluded in view of the very poor preservation of the specimen."

Other collections yielded brachiopod and bryozoan fragments for which no age could be determined.

The belemnoid from lot 68125 rules out the possibility of an age older than Upper Triassic and the lithology of map-unit 10 does not resemble that of rocks younger than Upper Triassic. The rocks of map-units 15 and 16 are known to be at least partly Lower Jurassic (Sinemurian) and in Quesnel Lake map-area (Campbell, 1961) may include Upper Triassic (Norian) as well. The rocks of these units lie adjacent to those of map-unit 10 for many miles but their lithologies are in such sharp contrast that they are probably of different ages. The age of the rocks of map-unit 10 is thus probably Karnian or early Norian.

The dark argillaceous rocks of map-unit 10 are continuous with similar rocks that can be traced through the Quesnel Lake map-area (Campbell, 1961 and 1963a). In that area the unit was thought to belong to the Cariboo Group and to be Paleozoic though the possibility of an early Mesozoic age was suggested (Campbell, 1963a).

Lithologically similar rocks are known in the Prince George map-area (Tipper, 1961) and fossil evidence indicates they are late Norian, early Norian, and Karnian. The time span represented by the rocks of map-unit 10 is not known precisely.

Nicola Group (Map-unit 11)

Name and Distribution

The Nicola Group was named by Dawson (1879, p. 74B) from the type area around Nicola Lake south of Kamloops and was described as essentially volcanic rocks and minor sediments. Nicola Group rocks have been recognized in the Princeton (Rice, 1947, pp. 9–15), Ashcroft (Duffell and McTaggart, 1952, pp. 29–31), Vernon (Jones, 1959, pp. 49–50), and Nicola (Cockfield, 1948, pp. 11–15) map-areas. They extend directly into the Bonaparte Lake map-area along Deadman River valley and underlie substantial areas east of Lac la Hache, east and west of Lac des Roches, northeast of Canim Lake, and several scattered small areas.

The Nicola Group, as applied in Nicola (Cockfield, 1948) and Princeton (Rice, 1947) map-areas to the south, is regarded as being entirely or mainly Late Triassic. This is also true of the rocks mapped as Nicola Group in Bonaparte Lake map-area with the exception of those along the northern contact of Thuya batholith, which are probably mainly Late Triassic but include some Permian north of Eakin Creek and possibly Lower Jurassic strata. Except where fossiliferous, rocks of different ages in the group cannot be distinguished.

Lithology

The most common rocks are dull, greenish grey, aphanitic or very fine grained 'greenstone'. Associated with them are dark grey to pale green laminated tuff, dark grey limestone, and possibly some argillite. Near Thuya batholith fine- to medium-grained dioritic rocks, interspersed with greenstone, are relatively abundant.

The greenstone is mainly aphanitic or very fine grained but small and rarely large pyroxene crystals can be identified in hand specimens. Though not everywhere apparent to the naked eye these rocks are dominantly if not entirely fine to moderately coarse volcanic clastics in which the matrix is indistinguishable in colour and composition from the fragments. No distinct non-fragmental flows were seen. Rocks lacking fragmental texture on the scale of a thin section, hand specimen, or small outcrop may be parts of single large fragments.

Most of the fragments are angular to subrounded and less than 1 cm across but range from less than 1 mm to several centimetres. Originally both fragments and matrix consisted of plagioclase, pyroxene, and vitreous or ultra fine-grained material. These have been all or partly converted by low-grade metamorphism to colourless or pale green amphibole, chlorite, epidote, carbonate, albite, sericite, and cloudy indeterminant material. Veinlets of carbonate, epidote, or quartz are fairly common. In one thin section veinlets of prehnite were observed.

Uniformly fine-grained fragmental rocks or tuff vary in appearance from relatively massive dark rocks resembling argillite to medium grey and green finely laminated varieties. These rocks are similar in composition to those described above. Medium-grained dioritic rocks near Thuya and Takomkane batholiths consist primarily of highly saussuritized plagioclase and clinopyroxene partly replaced by hornblende. The relationship of the diorite to the batholiths and to the greenstone is not known. Some of the diorite is probably in the form of dykes and sills but some may result from recrystallization of the andesitic greenstone.

Both Permian and Upper Triassic (Karnian) fossiliferous limestone is dark grey, fine grained, and shaly. Locally, dark argillite is interlayered with the greenstone.

The volcanic rocks along Deadman River are generally typical of the group. They are fragmental but bedding is not clearly discernible except in rare laminated tuff and thinly bedded argillite interbedded with the sequence of volcanic and clastic rocks. No thick section of bedded rocks was noted. The section is dominated by massive beds of unsorted, dark green or grey augite porphyry breccia.

Northeast of 100 Mile House the group underlies a wide, mostly drift and forest covered area. In the main the rocks are similar augite porphyry breccias and tuffaceous rocks, dark green-grey, or rarely reddish brown where they contain dark maroon fragments. Southwest of Succour Lake massive light blue-grey limestone, weathering light grey to brownish grey, forms a section over 100 feet thick. It is massive and fine grained, with beds as much as 10 feet thick commonly separated by thin shaly limestone. One or two beds are limestone breccias but fragments are difficult to distinguish.

Structural Relations

Few useful structural data were obtained from the rocks of the Nicola Group partly because of poor exposures but mainly because bedding or other foliation is rarely apparent. Beds strike northwesterly and dip close to vertical in the few attitudes that were obtained indicating possible tight folding although no minor folds were observed. The absence of a secondary foliation or cleavage implies that any deformation was not penetrative. The writers believe that relatively local folding and/or tilting developed primarily in response to movements on faults and that the Nicola Group rocks were not systematically folded by regional stresses.

The rocks of the Nicola Group seem to be in fault contact with all other units except Thuya and Takomkane batholiths, small syenite bodies, and overlying Tertiary volcanic rocks. The prominent array of topographic lineaments north of Eakin Creek, if they represent fault traces, indicate many more faults than shown on the map; these are concentrated in two trends, northwest and northeast. Probably the fossiliferous Permian rocks are separated from the Triassic strata by faults in this region.

Age and Correlation

Permian fossils near a small L-shaped lake 2.5 miles south-southeast of Friendly Lake are in dark, coquinoid, fetid limestone. This locality is about 2 miles southeast and almost exactly along trend of Upper Triassic fossiliferous, dark grey, silty limestone. Possibly the two localities are separated by a fault.

E. T. Tozer identified the Triassic fossils.

GSC loc. 68119
51°34′ N., 120°28′ W.; 1 mile south of Friendly Lake.
"*Arcestes*" sp.
Tropites sp. indet.
Hannaoceras? sp.
Halobia sp.

Age: Upper Karnian

GSC loc. 64914
51°34′ N., 120°28′ W.; same locality as 68119; South of Friendly Lake.
Halobiid fragments
Proarcestes sp.
Juvavites?? sp.

Age: Triassic, probably Karnian

GSC loc. 64814
51°34′ N., 120°30′ W.; 4,000 feet west of Pooytl Mountain
Halobiid indet.

Age: Probably Upper Triassic

GSC loc. 64815
51°37′ N., 120°30′ W.; 2 miles southwest of peak of Mount Heger.
Palaeocardita or *Septocardia* sp.
Isocrinus? sp.

Age: Triassic, probably Upper Triassic

GSC loc. 64820
$\frac{1}{2}$ mile west of Succour Lake, 7 miles north of 100 Mile House
Echinoids undet.
Gastropods undet.
Spondylospira sp.
Large terebratulids
Hexacorals undet.

Age: Upper Triassic, probably Norian

The fossil collections listed above show that the group is upper Karnian and probably Norian within the map-area but map-unit 11 also contains Permian fossils, hence includes equivalents of the Cache Creek Group. The probable area of Permian rocks is very small and is not indicated on the map. Present information does not permit separation of rocks of different ages nor give an indication of probable relative proportions. The writers believe the bulk of the unit is Upper Triassic.

The Nicola Group in Bonaparte Lake map-area includes correlatives of map-unit 10 and is apparently correlative with the Nicola Group to the south, with the Tyaughton Group to the west (Cairnes, 1943), with Late Triassic rocks of the Mount Waddington map-area (Tipper, 1969), and with the lower part of the Takla Group in Fort St. James map-area (Armstrong, 1949, pp. 51–62). Other Late Triassic groups throughout British Columbia and Yukon Territory are correlative with the Nicola Group.

Map-unit 12

Distribution

The metamorphic rocks of map-unit 12 are confined to the area along the south part of the eastern boundary of the map-area between Barrière River and Louis Creek. These rocks include most of the Barrière Formation of Uglow (1922, p. 78A–79A) who regarded them as Precambrian or Paleozoic. Dawson (1898) included them in his Nisconlith and Adams Lake Series of probable Cambrian age. The writers believe the unit may include rocks of a variety of ages and until more is known it should be left unnamed.

Lithology

Map-unit 12a. Quartzose metasedimentary rocks, dominant in map-unit 12a, range from fine-grained siliceous phyllite to quartz-granule and pebble-conglomerate. Also included are argillite, calcareous phyllite, greenstone, greenschist, and marble. Quartzite and quartz conglomerate, with marble and siliceous phyllite are most prominent on the western slopes of Barrière Mountain and Mount Dixon and on the summit ridges of Armour Mountain. Quartzite is minor among the rocks farther east and southeast where siliceous phyllite, calcareous phyllite, and argillite, with greenstone and greenschist, are dominant.

The quartzite and quartz-conglomerate form prominent light brown weathering outcrops. Well-displayed bedding is thin in the finer rocks and massive in the coarser. The rocks vary from shades of medium to light grey to greenish grey to brown and buff. They consist of rounded grains and granular aggregates of quartz from less than 1 mm to about 1 cm across set in a matrix of very fine grained quartz and sericite. The nature of the foliation varies with the grain size; coarse-grained rocks, granular quartzite and conglomerate, display a platy cleavage, ill-defined in conglomerates, whereas fine-grained rocks are well-foliated phyllites. Larger quartz grains are elongated in the plane of the foliation but the sericite in the matrix may not have a strong preferred orientation. The siliceous phyllite consists of fine-grained quartz and well-oriented sericite. Some of the quartzose rocks contain grains of turgid sodic plagioclase.

Carbonate rocks vary from finely crystalline grey and buff pure marble to calcareous quartzite in which fine, round, glassy, quartz grains are set in a matrix of fine-grained calcite. These rocks are most abundant along the foot of the western facing slope about 2 miles west of Barrière Mountain.

Phyllitic rocks are characteristic of the remainder of map-unit 12a, that is, the parts east and southeast of the prominent exposures of quartzite. Siliceous phyllite is most abundant but the assemblage includes dark slaty or phyllitic argillite, chloritic phyllite and calcareous

quartz phyllite, as well as quartzite, greenstone, and minor limestone. The siliceous phyllite and quartzite consist of quartz and sericite, locally with calcite and brown ankeritic carbonate. The argillite and green phyllite are made up of varying proportions of quartz, sericite, chlorite, and locally carbonate. The greenstone is composed of turgid sodic plagioclase, fine, green amphibole, epidote, chlorite, and carbonate. The fine-grained rocks have a strong schistosity which commonly intersects the bedding at a marked angle. The coarser quartzite and greenstone are less prominently foliated. A few exposures of dense, dark grey limestone were noted.

Map-unit 12b. In the southeast corner of the map-area, this unit primarily comprises dark grey and black argillite, siltstone, slaty argillite, and phyllite. These rocks consist of very fine grained quartz, sericite, and dusty carbonaceous material. Minor dark limestone contains carbonaceous streaks and patches. Most of the rocks are not strongly foliated but have a rather irregular cleavage that is commonly oblique to bedding planes. Near the contact with the rocks of map-unit 16 outcrops of argillite and phyllite are interspersed with those of sheared greenstone which is evidently the altered equivalent of the adjoining augite andesite (map-unit 16). In some places the greenstone appears to cut the bedding of the argillite and in one exposure the two types are combined in a fine breccia. The greenstone clearly displays uralitized remnants of the original augite phenocrysts enclosed by a matrix of altered sodic plagioclase, chlorite, epidote, and carbonate. The boundary between the two units is believed to be a major fault and the lack of a distinct contact is thought to result from complexities within the fault zone.

Structural Relations

Internal structural relations. The rocks of map-unit 12 are all more or less well foliated, the finer grained rocks having the strongest foliation. The foliation generally trends between west-northwest and locally strikes west; dips are northerly at moderate angles. Bedding seems to be roughly parallel with metamorphic foliation, but many small-scale examples were noted (mainly in loose material) in which bedding and cleavage intersect at large angles.

The few data on fold axes and other linear structures are consistent and indicate that folds plunge almost down the dip of the foliation on trends varying from north-northwest to north-northeast. The few folds observed are tight with axial planes parallel with the metamorphic foliation. The sparse available evidence suggests that the strata of map-unit 12 are deformed into essentially recumbent folds plunging northerly at moderate angles.

Quartzite and quartz conglomerate are concentrated in a roughly semicircular area centred on Armour Mountain. These rocks are thought to be the oldest of the unit and if so they may be exposed in the core of a large, essentially recumbent, northward plunging anticline or series of anticlines. This interpretation may be an oversimplification for, as discussed in a later section, the quartzose rocks may lie unconformably beneath those farther to the east hence their outcrop pattern may depend partly on the configuration of the unconformity.

External structural relations. The rocks of map-unit 12 are bounded on the west by an inferred fault which extends from North Thompson Valley across the southwestern slopes of Armour Mountain and into the valley of Louis Creek. This fault separates map-unit 12 from Cache Creek Group strata and from the andesite of map-unit 16. They are also apparently bounded by a fault in Barrière River valley where they abut against the Fennell Formation. Apart from these fault boundaries the rocks of map-unit 12 are not known to be in contact with any other rocks in Bonaparte River map-area.

Evidence for the fault extending from North Thompson Valley into Louis Creek valley is good. The trend of foliation changes abruptly across the proposed fault line from west-northwest on the east to north-northwest on the west, but the trend of fold axes and other

linear features does not seem to change significantly. More convincing is the abrupt change in lithology, particularly near Armour Mountain, where quartzite of map-unit 12a lies against Cache Creek Group greenstone. The assumption that a fault zone exists provides the best explanation of the complex relations between map-units 12b and 16. Lithologic and structural changes are pronounced across the line of the inferred fault in Barrière River valley.

Age and Correlation

The rocks of map-unit 12a were mapped by Uglow (1922, pp. 78A–79A) as the Barrière Formation which he thought was Precambrian and possibly Paleozoic. Dawson (1898) thought the rocks were Cambrian and divided them into two units, the older Nisconlith Series corresponding roughly to map-unit 12b, and the Adams Lake Series including map-unit 12a. The writers believe that map-unit 12 includes rocks of several ages.

The quartzite and quartz-conglomerate (part of unit 12a) on and around Armour Mountain are of unknown age. Together with the associated siliceous phyllite these rocks resemble parts of the Kaza or Cariboo Group (map-unit 1), and thus may be either late Precambrian or early Cambrian or they may be younger and be pre-Mississippian. If the quartzose rocks are equivalent to part of the Kaza or Cariboo Group then it is reasonable to suppose they lie beneath an undetected unconformity which would separate them from other rocks of map-unit 12a thought to be appreciably younger.

Rocks similar to parts of map-unit 12a can be traced continuously southeastward through Adams Lake map-area (Campbell, 1963b) into Vernon map-area where they appear to merge with the Eagle Bay Formation of the Mount Ida Group thought by Jones (1959, pp. 17–27) to be Archean or later. In Adams Lake map-area (Campbell, 1963b), a short distance to the east of Bonaparte Lake map-area and just south of Barrière River, fossil crinoid stems were found in a sequence that is continuous with map-unit 12a. Thus at least some of the rocks are post-Cambrian. The nearest rocks with similar fossils in the general region are part of the Pennsylvanian and Permian Cache Creek Group in Nicola (Cockfield, 1948), Vernon (Jones, 1959) and Bonaparte Lake map-areas. Much of Jones' Eagle Bay Formation and its continuation in Adams Lake and Bonaparte Lake map-areas is comprised of low-grade metamorphic rocks much like those of the Cache Creek Group. Thus evidence suggests that Cache Creek Group rocks form part of the Eagle Bay Formation and hence of map-unit 12a.

The argillaceous rocks of map-unit 12b can be followed continuously into the Mara Formation and possibly all or part of the Sicamous Formation of the Mount Ida Group (Jones, 1959) in Vernon map-area. In a more southerly direction the same rocks connect directly with Jones' argillite unit (Division A) of the Cache Creek Group, an apparently anomalous situation but one that supports the concept that Cache Creek Group rocks comprise part of the Mount Ida Group.

In Vernon map-area the argillaceous rocks are associated with volcanic rocks of the Tsalkom Formation of the Mount Ida Group (Jones, 1959). Campbell, who examined outcrops of the latter, noted that it closely resembles the Fennell Formation of Bonaparte Lake map-area though pillow structures were not found. North of Little Fort the Fennell Formation is associated with dark argillaceous rocks and limestone containing probable Upper Triassic fossils. The two argillaceous units may be equivalent.

A few observations by Campbell on the volcanic rocks of the Cache Creek Group (Division B) east of Louis Creek in Vernon map-area (Jones, 1959, pp. 40-42) revealed the similarity of some of this unit to the rocks of map-units 15 and 16 in Bonaparte Lake map-area. The latter are at least partly Early Jurassic and are unlikely to be older than Late Triassic. If these rocks in Vernon map-area are Early Mesozoic as seems likely, then the suggestion that the associated argillaceous rocks are Mesozoic is all the more reasonable.

The possible correlations mentioned above seem to be more than coincidental and one may have some confidence in the assertions that rocks of the Cache Creek Group form part of map-unit 12a and that the black argillaceous rocks of map-unit 12b are equivalent to those of map-unit 10 of probable Late Triassic age. Until diagnostic fossils are found, no definite conclusions can be reached regarding the age of the rocks of map-unit 12. Rocks as young as Upper Triassic may be involved and if so then at least one important and regional episode of metamorphism and deformation took place during or subsequent to the Late Triassic.

Sinemurian to (?) Middle Jurassic Rocks (Map-units 15 and 16)

Map-unit 15

Distribution

The rocks of map-unit 15 are confined to the northeastern quarter of the Bonaparte Lake map-area. They underlie a region that extends southeasterly from the north boundary across Canim Lake to the vicinity of English and Taweel Lakes. Similar rocks have been traced to the north in Quesnel Lake map-area (Campbell, 1961, map-unit 16; and 1963a, map-unit 10a) but have not been mapped separately in map-areas to the south if they occur there.

Lithology

Map-unit 15 includes grey and brown weathering, medium to dark grey and greenish grey, mainly very fine grained (less than 0.5 mm) clastic rocks that consist almost entirely of clasts of volcanic rocks and minerals. Coarser grained rocks of the same composition are common though subordinate in quantity. These consist of grit and breccia in which most of the fragments are less than 10 mm long; coarser breccia was noted but is rare. Bedding varies from delicate fine laminations to thick crude stratification but in many exposures bedding is absent. Near Windy Mountain thick conglomerate contains cobbles and boulders of a variety of rocks including granitic types.

On the eastern and southern slopes of Windy Mountain a prominent conglomerate sequence, believed to be the basal section of map-unit 15, underlies a succession of volcanic and clastic rocks typical of the remainder of the map-unit. The upper part of the conglomerate consists of coarse breccia made up of angular blocks and cobbles of light grey limestone, greenish volcanic rocks, and a few granitic pebbles and blocks up to 2 feet across, and minor intercalated beds of volcanic arenite and pebble-conglomerate. Near the top of the section marine fossils were found. The lower part of the section is mainly coarse cobble and boulder conglomerate with well-rounded clasts, up to 12 inches across, of granitic rocks, grey limestone, and volcanic rocks. These form beds up to 10 feet thick. Lower in the section the clasts are more angular and mainly volcanic so that the lowest beds exposed are mainly coarse volcanic breccia.

Some of the clasts that make up the conglomerate and breccia can be related to older formations. The grey limestone is typical of Norian limestone from the Nicola Group (map-unit 11) or limestone from the Cache Creek Group (map-unit 3). The granitic clasts are hornblende-biotite granodiorite similar to that of the Thuya batholith (map-unit 14) and the syenitic rocks resemble those exposed in small intrusions (map-unit 13) immediately southeast of Windy Mountain.

The basal conglomerate section is more than 600 feet thick on Windy Mountain with the base unexposed. Short distances west from Windy Mountain thin beds of mainly pebble-conglomerate, thought to be correlative, suggest a fairly rapid thinning. The conglomerate was not found elsewhere.

Fragments in the volcanic-clastic rocks are poorly sorted and display angular to subround shapes. The matrix is difficult to distinguish from the fragments. In many places no true matrix exists but the rocks are composed of a wide range of fragment sizes, even where the largest is very small. The fragments in some of the rocks are associated with murky devitrified glass or ultra fine grained clastic material which may form a true matrix.

The clasts are derived almost exclusively from pyroxene andesite and perhaps some basalt. They consist of both broken and intact crystals of plagioclase, augite, relatively rare hornblende, and rock fragments. The rock fragments include porphyritic types with phenocrysts of the same minerals that comprise the crystal fragments, extremely fine grained rocks in which microlites of plagioclase are visible, and indeterminate murky material resulting from the devitrification of glass. Some irregular patches of chlorite may be of detrital origin. Thin sections of rocks of the map-unit from Windy Mountain contain fragments of quartz, perthitic potash feldspar, and strongly zoned plagioclase, admixed with the more usual volcanic material. Clasts of limestone were observed in outcrops and in several thin sections one of which, from near Skwilkwakult Mountain, contains organic structure believed to be part of a crinoid. Other uncommon components include epidote and greenstone (altered volcanic rock).

Coarse breccia containing subangular to subrounded clasts of porphyritic andesite (augite phenocrysts) is interlayered here and there with the more common fine-grained rocks. It is similar in all respects to the breccia of map-unit 16. Non-fragmental volcanic rocks that exhibit only igneous textures were found in a few places but their relationships to the fine-grained fragmental strata is not apparent.

Only one of more than 35 thin sections made from rocks selected at random from Bonaparte Lake and Quesnel Lake map-areas reveals a significantly different rock type. The exceptional rock is from 2 miles north of the centre of Taweel Lake and is doubtfully assigned to map-unit 15; it may more properly belong with the dominantly argillaceous rocks of map-unit 10. This rock is a feldspathic siltstone in which the clasts consist of about equal amounts of quartz and plagioclase. The matrix consists of fine white mica and brown biotite.

With some exceptions, the rocks of map-unit 15 are unmetamorphosed or have barely reached the initial stages of the laumontite-prehnite-quartz facies as defined by Winkler (1965, p. 137A). Though the strata are locally steeply dipping and may be folded, they have not been penetratively deformed except locally possibly near faults. Alteration of these rocks seems mainly confined to diagenetic effects and the devitrification of glass. Near Raft batholith the rocks clearly show the effects of contact metamorphism.

In most rocks of the map-unit the ferromagnesian minerals, augite and relatively rare hornblende, are unaltered or at most are cut by carbonate veinlets. The most abundant mineral, plagioclase, is always altered and commonly highly altered. The alteration products of plagioclase are very difficult to determine microscopically and obscure the original nature of the feldspar. The original plagioclase, however, was apparently intermediate to calcic in composition. It is now partly or entirely albitized and commonly contains minute grains of probable white mica together with very fine grained cloudy brownish material, probably a zeolite. Devitrified glass contains plagioclase microlites and indistinct crystalline patches that may be a zeolite. In some rocks both plagioclase and lithic clasts are replaced and veined by carbonate. Irregular patches of chlorite are common. They apparently have not formed directly from ferromagnesian minerals but are possibly detrital or may have formed from glass.

Some of the rocks near Canim Lake, particularly those south of the lake, have been extensively prehnitized. The prehnite has evidently formed, with albite, from the alteration of the original plagioclase. A vaguely defined low birefringent mineral resulting from the

alteration of plagioclase and glassy fragments may be a zeolite. In these rocks pyroxene crystals are partly chloritized. There and also near Skwilkwakult Mountain veinlets of prehnite, quartz, and calcite cut the rocks. Prehnite was not observed in rocks from other parts of the map-unit but it could have been missed because of the distribution of samples examined in thin section.

Near the southern contact of Raft batholith east, north, and northwest of Coldscaur Lake contact metamorphism of the rocks of map-unit 15 has partly or completely altered the original pyroxene to a mozaic of very fine grained, pale green amphibole and brown biotite. Epidote is a common constituent and veinlets of epidote and quartz were seen in some thin sections. Plagioclase is sericitized. In spite of alteration the fragmental character of some of the rocks is apparent and volcanic clasts are recognizable.

Structural Relations

Internal structural relations. Owing to limited exposure, lack of recognizable marker units, and primarily from the lack of identifiable structural features at many individual outcrops, little is known of the structures within the rocks of map-unit 15. Though the rocks are well-bedded in places, commonly no stratification is apparent.

The strata commonly dip 40 to 60 degrees, in places up to 80 degrees. Tilting of such magnitude implies folding, yet no minor flexures or systematically developed cleavage that might be related to large-scale folds were observed. The high dips seem more likely a product of tilting and warping in response to fault movements than of folding by regional deformation. Some faults are known to cut the rocks of the unit and many more are suspected.

External structural relations. Although not well exposed most of the rocks of map-unit 15 seem to be in fault-bounded blocks.

The granite-bearing conglomerate near and on Windy Mountain is evidently at the base of the sequence and, though the relationships in that locality are complicated by faults, the conglomerate appears to rest unconformably on Cache Creek Group and Nicola Group rocks. Elsewhere in the map-area the unit appears to be faulted against all older strata, and the base is not known to be exposed.

The coarse volcanic clastics of map-unit 16 may be all or in part stratigraphically equivalent to the finer grained rocks of map-unit 15. This relationship is obscure because of the lack of structural data and the generally poor exposures.

The rocks of the map-unit are cut by Raft batholith and other granitic rocks and are overlain unconformably by Tertiary volcanic rocks.

Age and Correlation

Two collections of poorly preserved fossils were obtained on Windy Mountain from this map-unit. One, is from an arenite lens in the basal conglomerate beds, the other is from well-bedded shale, tuff and fine breccia overlying the basal beds. They were examined by H. Frebold of the Geological Survey of Canada.

GSC loc. 68605
Top of Windy Mountain at Triangulation Station, Bonaparte River area.
Ammonites of possible Lower Jurassic aspect

GSC loc. 68604
Windy Mountain, Bonaparte River area, south slope ½ mile south of top.
Arniotites (?) sp. indet.

Age: Sinemurian?

The basal beds of the map-unit are probably Sinemurian but the fossil evidence is not conclusive. Similar rocks can be traced northwestward through Quesnel Lake map-area (Campbell, 1961 and 1963a) where no fossils were found in them, though associated strata, probably of the same age, are at least partly Sinemurian. In Prince George map-area similar rocks are known to be Lower Jurassic and still farther to the northwest the Takla Group may be partly correlative as it contains Lower Jurassic fossils. The Sinemurian stage of the Early Jurassic is widely represented in many parts of British Columbia.*

Map-unit 16

Distribution

Augite porphyry breccia and conglomerate assigned to map-unit 16 are closely associated in the field with the finer grained rocks of map-unit 15. They outcrop intermittently from near Lemieux Creek in a northwesterly trending belt that passes between Canim and Mahood Lakes and also in a small area near the extreme southeast corner of the map-area.

Map-unit 16a encompasses several small bodies of hornblende porphyry in the southeastern part of the map-area. Two of these west of Barrière are sufficiently large to show on the map but many others associated with Cache Creek rocks (map-unit 2) are unmapped. They are possibly intrusions.

Lithology

The coarse fragmental volcanic rocks of map-unit 16 weather in shades of brown and grey and fresh surfaces are greenish varying from green-grey to a more common bluish green. Locally they form prominent, brown, lumpy outcrops such as the Sentinels, the hill west of Coldscaur Lake, and some of the prominences southeast of Taweel Lake. Elsewhere these rocks are not so well exposed and in some places they underlie areas of very little outcrop; for example, near Lemieux Creek.

Two features are characteristic of the rocks of map-unit 16; these are the coarse fragmental texture and the black pyroxene phenocrysts within the individual clasts. The rocks are made up almost entirely of fragments of porphyritic augite andesite and compositionally similar volcanic rocks. Distinct clasts range from one quarter inch or less to blocks 12 inches or more across; these vary in shape from angular to subround but most are probably subangular. Most of the matrix is finer grained but compositionally indentical to the clasts. Locally, no clear division in grain sizes exists between the matrix and the coarser fragments and one grades into the other. The coarse clastic texture is not always apparent on fresh or unweathered surfaces but is well displayed on most weathered surfaces.

Euhedral to subhedral augite phenocrysts in the volcanic clasts, and whole and broken crystals of augite in the matrix are so characteristic that the term 'augite porphyry conglomerate' was used during the mapping to identify the rocks of the map-unit. The augite varies from tiny, black, barely visible grains, to crystals a centimetre or more across, most being 0.5 to 3 mm. Other constituents are fine grained and rarely identifiable in hand specimen. Occasional plagioclase laths, some reaching 5 mm in length, can be discerned.

As seen in thin sections, the most common components of these rocks are augite, plagioclase, chlorite, and cloudy, brown, devitrified glass. Hornblende is rare. The matrix, similar to the rocks of map-unit 15, consists of crystals and fragments of augite and altered plagioclase interspersed with lithic and devitrified fragments with patches of chlorite and carbonate

*In 1970, V. A. G. Preto of the British Columbia Department of Mines collected Early Jurassic ammonites near Friendly Lake which suggest late Sinemurian or early Pliensbachian according to H. Frebold.

and possibly some indeterminate zeolite. The coarser clasts are formed of commonly amygdaloidal volcanic rocks. These vary from the most abundant types bearing augite and smaller altered plagioclase phenocrysts through those with altered plagioclase phenocrysts and little if any augite to mainly devitrified glassy rocks with plagioclase microlites. Round amygdules range from less than 1 mm to about 3 mm across. They are filled with chlorite and calcite, and less commonly with zeolites (heulandite or stilbite) and quartz; epidote fillings were noted in one thin section.

The amounts of primary minerals in the rocks are difficult to determine accurately or to estimate because of the variations from clast to clast and from clasts to matrix. Augite varies from 0 to about 20 per cent, plagioclase from about 10 to 50 per cent, hornblende from 0 to about 2 per cent, and devitrified glassy material in some clasts may amount to 90 per cent or more. Exceptional rocks, noted on the hill south of the west end of Mahood Lake, are composed of a very high proportion of augite and resemble pyroxenite. Their origin is unknown but they are thought to result from unusual crystal accumulations in a magma during the period of volcanism. They may be extrusive or shallow intrusions.

Augite and hornblende are little if at all altered. Plagioclase, on the other hand, is everywhere altered though the nature of the alteration is difficult to determine. The original plagioclase apparently varied from medium to very calcic varieties; in some grains highly calcic cores are surrounded by albite rims. Albitization of the plagioclase is common, but distinct, clear grains of albite are rare. Much of the plagioclase contains tiny grains of a mineral that petrographically resembles sericite. Much of the feldspar is altered to a brownish translucent material that may be a fine-grained zeolite mineral or a combination of minerals. A few larger grains have the optical properties of heulandite.

The devitrified glass is brown and cloudy. Chlorite and possibly zeolite appears to have formed from alteration of the glass. Veinlets and patches of carbonate commonly vein and replace the devitrified glass and the plagioclase.

Chlorite and carbonate form most of the amygdules. Some contain zeolite, either stilbite or heulandite, and rarely quartz and epidote.

The rocks of map-unit 16a underlie two small areas shown on the map near the southeast corner and many areas associated with the eastern part of Cache Creek Group that are too small to show on the map. The rocks are composed of medium grains of hornblende and sericitized plagioclase (about An_{30}) in a fine-grained matrix of the same minerals. The texture is igneous and all or part of the rocks may be intrusive. No evidence of volcanic origin was noted.

Structural Relations

Almost no useful structural data were obtained from the rocks of map-unit 16. Their distribution appears to be controlled by faulting; that is, the rocks are found in individual fault blocks, but may have accumulated in large masses with much the same distribution as they have at present.

Whether the rocks of map-unit 16 underlie or overlie those of map-unit 15 or whether the two units occupy all or part of the same stratigraphic interval is not known.

The rocks of map-unit 16 are cut by the Cretaceous Raft batholith and are overlain unconformably by Miocene and Pliocene lavas. Near Lemieux Creek they are in fault contact with the argillaceous rocks of map-unit 11. Their contact with the Cache Creek Group (map-unit 3) near Lemieux and Louis Creeks is not exposed and may be faulted or unconformable. Near Louis Creek the rocks are faulted against those of map-unit 12b.

Rocks included in map-unit 16a may be small intrusive bodies.

Age and Correlation

No fossils were found in these rocks but as they are believed to be facies equivalents of map-unit 15 they are thought to be at least partly Early Jurassic. Rocks of similar lithology contain Lower Jurassic fossils in the Quesnel Lake map-area to the northwest (Campbell, 1961) and Norian fossils in the Nicola area to the south (M. Schau, personal communication, 1968).

Origin of the Jurassic Volcanic Clastic Rocks

Though the dominantly fine-grained rocks of map-unit 15 are texturally very different from the mainly coarse-grained volcanic clastic rocks of map-unit 16, they are strikingly similar in composition, closely related in areal distribution, and probably are generally of the same age. These factors suggest that the rocks of the two map-units are closely related and originated under somewhat similar conditions.

The huge quantity of nearly monolithic clastic fragments distributed over an area many miles in extent is perhaps the main factor that must be accounted for by any origin proposed for these rocks. The normal processes of subaerial erosion followed by transportation and deposition scarcely seem to apply. The processes leading to the deposition of these rocks must be primarily volcanic in character.

The fragmental character and the monolithic nature of the fragments suggest that the rocks may have formed as sedimentary wedges derived from volcanic islands far from any land masses from which contaminating sedimentary material might have been derived. Pyroclastic material might also have contributed to the developing sedimentary pile. Under these conditions masses of coarse volcanic clastic rocks produced by wave erosion of volcanic flows would form around the peripheries of the islands and finer sediments would be deposited farther from the shorelines. True volcanic flows, then, might be expected to form the 'root' (the islands) for the masses of volcanic clastic rocks, but no such 'roots' have been found. Few, if any, flows are included with the rocks of map-units 15 and 16 in Bonaparte map-area or in their known equivalents to the north (Campbell, 1961 and 1963a). If normal flows provided the source material for the volcanic clastic rocks they have subsequently been removed by erosion.

The lack of true flows associated with the volcanic clastic rocks suggests that a rather special condition of volcanism must apply to the origin of these rocks. The original volcanism whether subaerial or submarine, evidently produced fragmental rocks almost exclusively. The masses of coarse fragmental rocks included in map-unit 16 would thus represent the 'root' or source areas and the finer clastics (map-unit 15) would be deposited farther afield. The fragmentation of the lava might have been the result of explosive activity, possibly induced by interaction of lava and water during submarine extrusions. The rarity of fossils and the absence of carbonate reef deposits suggest a completely submarine origin.

Jurassic (?) Rocks Near Clinton (Map-units 17 and 18)

Distribution

Two small areas of sediments extend southward from near Clinton along both sides of the highway to beyond the south margin of the map-area. The rocks to the west of the highway are conglomerate and greywacke (map-unit 17) and to the east are shale with minor sandy interbeds (map-unit 18). Dawson mapped the former as Coldwater Beds and the latter as Cache Creek Group (Dawson, 1895a).

Lithology

Map-unit 17 consists of interlayered buff to grey chert-pebble conglomerate, conglomeratic greywacke, and minor quartzose sandstone in beds up to more than 15 feet thick. The greywacke and sandstone form thick, massive beds, rarely displaying crossbedding. The conglomerate pebbles are mainly chert derived from the Cache Creek Group and rarely granitic rock. They are well sorted, well rounded and well cemented with calcite. No shale or siltstone was noted in the section and the sandstone and conglomerate do not appear to contain much fine detritus.

Map-unit 18 is mainly fine dark grey and blue-black shale with minor buff sandy interbeds. The strata are phyllitic and near faults are intensely sheared and crumpled. Where well exposed the rocks are seen to be well and evenly stratified in beds ¼ inch to 6 inches thick. The sand beds are a few inches thick and in places are gritty but no conglomerate was noted. In places the shales are limy.

Structural Relations

The two units are in fault contact so that the relative age of the two is in question. Both are also in fault contact with the Cache Creek Group (unit 5) to the east and west so that the stratigraphic relations with older rocks are unknown. The two units apparently form a graben in the Cache Creek strata. Map-unit 17 is overlain unconformably by Tertiary sediments provisionally mapped as the Deadman River Formation (map-unit 25).

Age and Correlation

No fossils were found within either map-unit. Lithologically they resemble the Callovian rocks mapped by Duffell and McTaggart (1952, pp. 31–33) near Ashcroft.

Map-unit 18 is similar to the shale near Ashcroft in that it has interbedded sandy layers, is of similar colour, and is similarly crumpled and distorted. It is unlike the phyllitic Cache Creek shaly rocks particularly those of map-unit 5 with which it is in contact. The shale sequence is tentatively thought to be related to map-unit 17 but even this is questionable.

Map-unit 17 was mapped by Dawson as Coldwater Beds and its extension south of the map-area was also mapped as Coldwater Beds by Duffell and McTaggart (1952, pp. 64–66). In Bonaparte Lake map-area, the writers have determined part of the unit mapped by Dawson to be Tertiary (map-unit 25). In Ashcroft map-area the rocks that are most readily recognized as Tertiary are the coal-bearing upper members of the sequence. The previous mapping of the Tertiary Coldwater Beds as a single unit is thought to have been an error. Further, in Bonaparte Lake map-area the Tertiary rocks (map-unit 25) are flat lying whereas some of the conglomerate beds dip up to 70 degrees. Thus map-unit 17 is believed to be pre-Tertiary.

Clasts in the conglomerate are mostly chert pebbles but some granitic pebbles were noted and the formation should therefore be younger than the oldest known body of similar granitic rock in the region, namely the Guichon Creek batholith of probable Early Jurassic age (Duffell and McTaggart, 1952, p. 79). Similar clasts were noted in Jurassic conglomerate near Ashcroft (op. cit. pp. 31–33), and in parts of the Jackass Mountain and Taylor Creek Groups in Taseko Lakes map-area (Jeletzky and Tipper, 1968). The map-unit is therefore believed to be Jurassic or Cretaceous. Map-units 17 and 18, considered together, closely resemble the Callovian rocks near Ashcroft.

Jackass Mountain Group (Map-unit 19)

The Jackass Mountain Group is best exposed in Ashcroft (Duffell and McTaggart, 1952, pp. 39–52) and Taseko Lakes map-areas, where it is a thick sequence of greywacke, conglomerate, arkose, shale, and siltstone of Lower Cretaceous age.

In Bonaparte Lake map-area the group underlies a very small area in the extreme southwest corner where it probably is in fault contact with map-unit 23. In this area little is known of the group and it has little bearing on the geology of the area as a whole; it is mentioned here only for completeness.

Kamloops Group (Map-units 21 and 22)

In Bonaparte Lake map-area, the Kamloops Group comprises the Chu Chua and the Skull Hill Formations. The former is entirely sedimentary and the latter is mainly volcanic.

Chu Chua Formation (Map-unit 21)

Distribution

The Chu Chua Formation is confined to the immediate vicinity of North Thompson and Clearwater Valleys, outcropping along Newhykulston Creek, north of Dunn Lake along Joseph Creek, along the railway west and south of Mount Fennell, and in the valley of Eakin Creek near Little Fort. It probably underlies the drift-covered area from Dunn Lake south to Newhykulston Creek. Uglow mapped a small area of the formation along Darlington Creek near Darfield, apparently underlying Skull Hill volcanics (Uglow, 1922) but the writers found only fragments in the drift to indicate it probably is present but no longer exposed. East of Green Mountain in the valley of Hemp Creek tilted early Tertiary strata beneath flat basaltic lava flows are included in the formation.

Lithology

The Chu Chua Formation was studied by Uglow (1922, pp. 82–86, 97–98) and his description follows.

> "This formation consists of a series of sedimentary beds ranging in composition from conglomerate through arkosic sandstone and highly feldspathic arkose to sandy shale, and containing coal seams. All the rocks are consolidated. The lowest member of the series is the basal conglomerate (or agglomerate). It consists of a heterogeneous mixture of rounded, sub-angular, and angular fragments of the older country rocks of the immediate vicinity. Some of these fragments are very large, whereas others resemble pebbles from stream gravels. The matrix of the fragments is a fine- to coarse-grained grit. Where the underlying rock is the Fennell greenstone, the larger part of the conglomerate is made up of large, irregular, talus-like pieces of that rock, associated with which are stream-rounded pebbles and boulders of granite and granodiorite. The basal portion of this conglomerate passes gradually by an increase in the quantity of fragments into the underlying rock, so that it is often difficult, if not impossible, to trace a definite contact surface between the two formations. The thickest section of the basal conglomerate exposed in any one place in the sheet is 150 feet (near Chu Chua station).
>
> "The intermediate and upper members of the formation consist of massive beds of coarse pebbly sandstone or fine-grained stratified conglomerate, and a considerable thickness of thin-bedded arkose and sandy shale. There is commonly an abrupt change in the grain in adjacent beds, and frequently a 3- to 4-inch layer shows fine-grained, sandy shale at its margins with fine-grained conglomerate at its centre. Several seams of sub-bituminous coal occur in the upper part of the formation, associated with the sandy shale and feldspathic sandstone.
>
> "The basal conglomerate is well consolidated and is grey to green in colour according to the relative abundance of the constituent fragments. The arkose and sandy shale

are as a rule greyish white. Where these sediments are capped by Miocene lava flows, by which they have been considerably indurated, the shales are buff to brown, very markedly banded, and quite coherent."

Along Joseph Creek north of Dunn Lake the formation is not thick. The following measured section is typical.

Section U-1-5TD on Joseph Creek at the bridge, ½ mile north of Dunn Lake.

Unit No.	Unit	Thickness in feet	Total from base
	Chu Chua Formation		
6	Siltstone with interbedded sandstone and minor pebble conglomerate; beds 2 to 6 inches thick and well defined; weathers orange to orange-brown; contains poorly preserved plant remains	5	58
5	Fine pebble-conglomerate like unit 1; contact with lower unit is undulatory	0.5	53
4	Shale, very fine grained and finely laminated with carbonaceous laminations, bedding is up to 2 inches thick; shale is hard and fissile; light to dark grey weathering orange grey in large platy fragments; 1 foot to 2 feet above base of unit are numerous well-preserved fossil leaves GSC loc. 7070	14	52.5
3	Boulder conglomerate with pebbles, cobbles, and boulders to 2 feet diameter; coarse clasts make up 45% to 55% of rock embedded in a yellowish grey fine sandy matrix; clasts are well-rounded but poorly sorted fragments of greenstone, black chert, quartzite, granite, and siltstone; rock is hard, resistant, massive and weathers orange-grey to greyish brown; matrix becomes more abundant near top of conglomerate, as much as 75%; contact with overlying shale is undulatory	24	38.5
2	Thinly and evenly bedded shale with laminae ¼ to 1/32 inch thick; mainly grey to dark grey interlaminated with less buff shale; thin carbonaceous laminae are rare; brittle, fissile, and recessive; contains fragmentary plant fossils	0.5	14.5
1	Fine pebble-conglomerate, mainly ¼ inch or less in diameter clasts of quartz, feldspar, grey to dark phyllite, and greenstone in a limonitic to kaolinitic matrix; pale yellow to orange or ochre-coloured, weathers grey to orange-grey; mainly massive with irregular silty bands; resembles weathered granitic debris.	14	14
	Base not exposed.		

Although the contacts are not well exposed, in the Joseph Creek area the formation is overlain by Skull Hill volcanic rocks and underlain by the Fennell Formation. No faulting is apparent.

South of Chu Chua the formation, exposed mainly along Newhykulston Creek, is chiefly shale and sandstone with coal seams; conglomerate forms a thick basal unit and several beds

up to 10 feet thick higher in the section. Exposure is poor with much slumping. No section was measured by the writers but that of Uglow (1922, pp. 97–98) adequately describes the formation at this locality. According to Uglow, the thickness of the formation along Newhykulston Creek is much thicker than along Joseph Creek and could be as much as 2,500 feet.

Other outcrops of the Chu Chua Formation are small and contribute little to the understanding of the formation. North of Chu Chua railway station the coarse, unsorted, talus-like basal conglomerate is exposed along the railway. Along Eakin Creek near its junction with Lemieux Creek, sandstone, shale, and conglomerate outcrop and probably underlie much of the drift-covered area along the lower part of Lemieux Creek. Conglomerate, sandstone, and shale with common plant remains form an unknown thickness in and near the valley of Hemp Creek.

Structural Relations

Internal structural relations. The Chu Chua Formation is essentially a conformable sequence deposited in a valley ancestral to the present North Thompson and Clearwater Rivers. Local unconformities may exist but evidently do not represent any extended breaks in sedimentation. The sedimentary material, as much as 2,500 feet thick, was derived from the local pre-Tertiary rocks and rapidly deposited under fluviatile and lacustrine conditions.

External structural relations. The relation with the underlying formations is everywhere unconformable. Apparently the unit was deposited in a valley eroded out of the pre-Tertiary rocks. The overlying Skull Hill Formation is essentially conformable but well-exposed contacts are seen in few places. The Skull Hill Formation is probably not contemporaneous even in part as no clasts of that lithology are found in the Chu Chua Formation. Although a hiatus may separate the two formations no angular discordance was noted.

Age

A well-preserved fossil flora and spores and pollen were obtained from Joseph Creek and Newhykulston Creek; those from near Hemp Creek were not useful. The fossil flora was identified by Dr. F. M. Hueber, Division of Paleobotany, Smithsonian Institution, Washington, D.C. and the microfossils were identified by Prof. G. E. Rouse of the University of British Columbia.

Rouse's identifications and comments on the age are as follows:

GSC loc. 7069
Locality: Newhykulston Creek, B.C., elevation 2,050 feet.
Identifications:

Ginkgo sp.
Taxodium hiatipites Wodehouse
Pinus strobipites Wodehouse
Polypodiisporites sp.
Deltoidospora diaphana Wilson and Webster
Alnus sp.
Myrica sp.
Carpinus sp.
Fagus granopollenites—Martin and Rouse
Osmundacidites primarius (Wolff) Couper
Lycopodium sp.
Verruscosisporites sp.

Age: Tertiary, likely middle Eocene.

GSC loc. 7070
Locality: Joseph Creek, North of Dunn Lake, by the bridge.
Identifications:

Myrica sp.
Alnus sp.
Carpinus sp.
Anemia sp.
Triplanosporites sp.
Podocarpus sp.
Pinus sp.
Picea sp.
Keteleeria sp.
Taxodium sp.

Age: middle Eocene.

Two small collections of fossil plants were studied by Hueber and his identifications and comments are as follows:

GSC loc. 7069
Locality: Newhykulston Creek, B.C., elevation 2,050 feet.
Identifications:

Metasequoia occidentalis (Newberry) Chaney
Ulmus sp.

Age: No date can be given to this collection.

GSC loc. 7070
Locality: Joseph Creek, North of Dunn Lake, by the bridge.
Identifications:

Picae sp. seed
Metasequoia occidentalis (Newberry) Chaney
Sequoia affinis Lesquereux
Ulmus sp.
Corylus macquarrii (Forbes) Heer
Crataegus sp.
Betula parvifolia Berry
Sassafras selwinii Dawson
? *Comptonia* sp.
Juglans sp.

Age: This florule is very probably of Eocene age.

Uglow collected from the Joseph Creek locality and from Newhykulston Creek but at a stratigraphically lower bed (1922, pp. 85–86). His collections were larger and included more genera than those of the writers. They were examined by Prof. D. W. Berry of Johns Hopkins University and an age of middle or upper Eocene was given to the Newhykulston flora and of upper Eocene to the Joseph Creek flora.

The fossil evidence indicates unquestionably that the Chu Chua Formation is Eocene. The palynology report by Rouse indicates a middle Eocene age is preferred, a common age for many early Tertiary formations in British Columbia.

Skull Hill Formation (Map-unit 22)

Name and Distribution

The name, Skull Hill Formation, was applied by Uglow (1922, pp. 86–88) to a "series of volcanic flows, minor amounts of flow breccia, and a few sills . . . ." along North Thompson Valley. The writers have extended this name to include those rocks of similar lithology and stratigraphic position in the central part of the map-area. The best exposures of the formation other than the type locality are around Loon Lake, north from Bonaparte Lake to Lac des Roches, and from Bridge Lake to Canim Lake. Smaller isolated outcrops suggest that only remnants remain of a former widespread volcanic sheet.

Lithology

The formation is more varied lithologically than suggested by Uglow (1922, p. 86) who described the group as mainly vesicular and amygdaloidal hornblende and augite andesite flows. His description is applicable to the exposures along North Thompson Valley but elsewhere basaltic and dacitic flows and breccias are interlayered with typical andesites. Grey, brown, reddish brown, dark grey and lavender colours predominate but pink, buff, greyish green and yellowish brown are also common. Coarse, unsorted breccia in beds up to one or two hundred feet thick is common in the upper part of the formation and is composed mainly of fragments of dark, glassy basalt, brown to blue-black vesicular and amygdaloidal fine-grained basalt, fine-grained, brick red scoriaceous basalt, and fine-grained to light grey andesite. Flows up to 40 or 50 feet thick of similar or identical lithology are interlayered with the breccias but in most places are thinner and subordinate in volume; they are in general thinner than the breccias. Amygdaloidal flows are common in which the vesicles are completely or partly filled with chalcedony, zeolites, calcite, opal, and rarely a little malachite.

At least locally the basal part is different lithologically from the bulk of the formation. Breccia and flows like those described probably predominate but form thinner units. Interlayered with these rocks are more siliceous flows, particularly a coarsely porphyritic grey to mauve dacite with large, glassy, lath-shaped plagioclase phenocrysts. Light grey, finely granular to aphanitic, siliceous, finely flow-banded rocks are locally common. A fine-grained reddish brown to dark grey flow with dark green euhedral phenocrysts of pyroxene and a grey plagioclase feldspar and hornblende porphyry are characteristic rocks of the type locality and elsewhere. In places this basal part of the formation displays a variety of bright colours, light yellowish grey, buff, mauve, bright green, reddish brown, or orange as well as the predominant dark grey, brown, and black. In places the formation resembles the more rhyolitic Tertiary formations of the interior of British Columbia, such as the Ootsa Lake Group (Duffell, 1959, pp. 67–73), although no true rhyolites were recognized in the Skull Hill Formation.

Around Loon Lake black vesicular flows and flow breccias, massive grey to dark grey fine-grained basalt, reddish scoriaceous breccias, and flow-banded grey andesite make up the formation. Light coloured flows, some with flow banding, outcrop here and there, particularly near the northeast end of the lake but are nowhere extensive.

The rocks of this formation lying between Bridge Lake, Lac des Roches, and Bonaparte Lake are chiefly andesite and basalt with some dacite. Breccia is common throughout and in several places near the base of the formation blocks of the underlying pre-Tertiary rocks are included.

Andesite and basalt breccia and flows, typical of the upper part of the formation, form the high hills north of Drewry Lake, west of Bowers Lake, and north of Deka Lake. These are mainly breccia in thick beds dipping 5 to 10 degrees.

Structural Relations

Internal structural relations. No unconformities were recognized within the formation. Possibly the more acidic volcanics represent a slightly older part that could be unconformably overlain by the andesite and basaltic rocks but this is not proven. The thickness varies depending on the underlying topography and the amount of the formation stripped away; the maximum thickness is about 2,500 feet south of Canim Lake and south of Loon Lake.

The formation is only slightly deformed. Loon Lake apparently lies along the northeast-trending axis of a broad anticline, the limbs of which dip at about 5 to 10 degrees but the structure is poorly exposed. No other folds involving this formation are known. Around Bridge Lake the Skull Hill Formation dips gently, about 5 to 20 degrees, but with no consistent direction. This is a result of closely spaced faults that have produced disoriented fault blocks which seem to have been only tilted.

External structural relations. The Skull Hill Formation appears to rest conformably on the Chu Chua Formation along North Thompson River valley but the contact is poorly exposed. Elsewhere in the area the formation rests unconformably on all pre-Tertiary rocks. The surface upon which the formation was deposited was irregular with local relief as much as 3,500 feet along North Thompson River and several hundred feet in the central part. Apparently valleys such as North Thompson were deeply incised in the pre-Eocene surface indicating a pre-Eocene development of the major drainage systems.

The plateau lavas (map-unit 25) in places rest, with up to 20 degrees of angular discordance directly on the Skull Hill Formation. Nowhere in the area is the latter in contact with the Deadman River Formation or any of the volcanic units younger than the plateau lavas.

Age

The Skull Hill Formation probably overlies middle Eocene Chu Chua Formation conformably and is overlain unconformably by the late Miocene and/or Pliocene plateau lavas. It is probably older than the late Miocene Deadman River Formation which is conformable with the plateau lavas. The apparent conformity with the middle Eocene sediments suggests that the formation is at least partly Eocene.

A potassium-argon age determination on biotite from a dacite flow on Rayfield River (51°23′N., 120°58′W.) gave a date of 40 ± 5 million years (Wanless, *et al.*, 1967, p. 28) suggesting an upper Eocene age according to the Geological Society of London's Phanerozoic time scale, 1964. Age dates on lithologically similar and possibly correlative volcanics in the Kamloops Lake region by Mathews and Rouse (1961, p. 1079) also indicate an Eocene age. The age of the formation is therefore probably Eocene but presumably the upper part could extend into the Oligocene or Miocene.

History and Correlation of the Kamloops Group

The Tertiary rocks of the Kamloops area were divided by Dawson (1895a, p. 173–4B) into six units which he described as follows:

"No. 6. Agglomerates, chiefly basaltic, with some basaltic and trachytic flows; all rudely bedded . . . .

No. 5. Tranquille beds; tuffaceous sandstones and shales, with some soft tuffaceous agglomerates, all more or less distinctly water-bedded; holding occasional plant remains, ...

No. 4. Dolerite rocks, representing flows of molten matter . . . .

No. 3. Tuffaceous shaly beds, generally in thin layers, holding obscure plant and fish remains . . . .

No. 2. Dolerite like No. 4 . . . .

No. 1. Coldwater group; conglomerates composed of pre-Tertiary material, with some sandstones . . . ."

Apparently Dawson felt that unit No. 3 was of local importance only and that Nos. 2 and 4 were actually a single unit. On his accompanying map he shows the Coldwater Group as Oligocene and the remainder as Miocene. The volcanic section consisted of an Upper Volcanic Group and a Lower Volcanic Group separated by the Tranquille Beds. The Coldwater Group was believed to antedate the Tertiary volcanic activity and possibly to be separated from it by an unconformity.

Drysdale (1914), in mapping the Thompson River valley below Kamloops Lake concurred with Dawson's use of Coldwater Group, but he introduced the name Kamloops Volcanic Group for the volcanic rocks of the area and included the Tranquille Beds as the basal unit. The basaltic lavas and agglomerates of Savona Mountain near Kamloops Lake were included in the Kamloops Volcanic Group, the same rocks that Dawson had included in his Upper Volcanic Group. Apparently therefore, the Kamloops Volcanic Group is the equivalent of the Upper Volcanic Group and Tranquille Beds of Dawson.

Rose (1914), in the Savona map-area at the west end of Kamloops Lake, retained the Coldwater Group as already defined but altered the name to Coldwater Series. The name Kamloops Series was proposed "to include the Lower Volcanic group, the Tranquille Beds, and the Upper Volcanic group of Dawson." This series was considered to be conformable throughout.

Uglow (1922, pp. 72–106) mapped the North Thompson Valley and introduced new names for two Tertiary formations, the Chu Chua Formation and the Skull Hill Formation. The Chu Chua Formation, considered to be upper Eocene, was described as "a series of sedimentary beds ranging in composition from conglomerate through arkosic sandstone and highly feldspathic arkose to sandy shale, and containing coal seams." Earlier, Dawson had correlated this unit with the Coldwater Group, apparently because of its relation to the volcanics which were thought to be younger (Dawson, 1895a, pp. 228–9). The Skull Hill Formation was said to consist "of a series of volcanic flows, minor amounts of flow breccia, ...". This formation was provisionally assigned to the Miocene. Uglow recognized that the faulting along North Thompson River was later than the Skull Hill Formation.

Walker (1931, p. 136) recognized the Skull Hill Formation farther north along North Thompson Valley but he also recognized younger lavas, the Mann Creek Formation, which were later than the shearing that affects the Skull Hill Formation. He believed that these lavas were much younger than the Skull Hill Formation although he still referred to them as Tertiary.

When Cockfield remapped the area around Kamloops Lake (Cockfield, 1948) he proposed the name Kamloops Group, "to include most of the recognizable Tertiary rocks within the map-area, including both the Coldwater and Tranquille beds as well as large accumulations of volcanic rocks". The Coldwater Beds consist of sandstone, shale, and conglomerate, with seams of coal and underlie volcanic rocks of the group unconformably. Cockfield concluded that the age of the Coldwater Beds was Oligocene or Lower Miocene, based on paleobotanical evidence obtained south of the Kamloops area. Furthermore, he questioned that the Coldwater and Tranquille Beds were of distinct ages and included the Coldwater Beds in the Kamloops Group. The Tranquille Beds were described as "sandstone, shale, and con-

glomerate, with tuff beds and, locally, thin seams of lignite". The age of these beds was thought to be Oligocene or lower Miocene, the same age as suggested for the Coldwater Beds. Unlike the Coldwater Beds, the Tranquille Beds were believed to be conformable with the overlying and underlying volcanic rocks. The Kamloops volcanic rocks are described as basalt, basalt breccia, rhyolite trachyte, and andesite with a great range of colour and texture. Cockfield did not attempt a subdivision of the volcanic rocks because he felt that the Tranquille Beds do not represent a single horizon. Apparently Cockfield interpreted the group as having the Coldwater Beds at the base antedating the volcanic activity, with the volcanic rocks overlying the Coldwater Beds, possibly unconformably, and the Tranquille Beds as being one or more horizons locally interbedded with the volcanics. He assumed that the group covered such a short time span that the flora of the Coldwater and Tranquille Beds indicated no appreciable time difference.

Mathews and Rouse recently have studied the Tertiary rocks of central British Columbia relating potassium-argon dates to paleontological evidence and have contributed greatly to the clarification of the Tertiary stratigraphy. A diabase flow or sill associated with the Tranquille Beds was dated as 49 million years and a trachyte flow on Savona Mountain was 45 million years (Mathews and Rouse, 1961). These dates indicate middle Eocene.

Mathews and Rouse (1963) pointed out also that the plateau lavas of central British Columbia "can be distinguished from the Middle Eocene succession on structural, lithologic, geomorphic, and paleobotanical grounds". A sedimentary section below the plateau lavas contains fossil leaves and plant microfossils indicating a late Miocene age. Potassium-argon dates on ash layers within the plateau lavas or on material from the underlying sediments were 12, 13 and 10 $\pm$ 2 million years. Mathews and Rouse considered these dates indicative of lowermost Pliocene according to Kulp's time scale (1961).

In mapping Bonaparte Lake map-area, the writers concurred with the separation of plateau lavas from earlier lavas. On the preliminary map of the area (Campbell and Tipper, 1966) the plateau lavas and the sediments beneath them were mapped separately from the Kamloops Group which in this area was considered to consist of two formations, Chu Chua and Skull Hill, of Eocene age.

The name Kamloops Group should be retained to include the pre-late Miocene volcanics and sediments of the Kamloops region. The name Kamloops Volcanic Group of Drysdale and Kamloops Series of Rose referred, apparently, to the supposed pre-late Miocene volcanics and Tranquille Beds near Kamloops Lake and on Savona Mountain, subsequently proven by Mathews and Rouse to be middle Eocene. Dawson's Tertiary units apparently referred to the pre-late Miocene volcanic and sedimentary rocks as he included the rocks of Savona Mountain in his youngest units, the Upper Volcanic Group. Admittedly Dawson included the flat-lying late Miocene plateau lavas north of Kamloops Valley with his Upper Volcanic Group, presumably because he did not recognize the two distinct groups, the late Tertiary sequence and the Eocene rocks. Similarly Cockfield inadvertently included some of the plateau lavas and Miocene sediments in the Kamloops Group, although most of the rocks he was considering for the group would be pre-late Miocene.

The formations of the Kamloops Group are not completely understood. According to Cockfield's definition in the Kamloops Lake area, the Tranquille Beds, the Coldwater Beds, and the Kamloops volcanic rocks comprise the Kamloops Group but a definition of each

formation and its relation to other units requires further study. The writers did not study the group and its formations in the type localities.

In Bonaparte Lake map-area the Kamloops Group is divisible into two units, the widespread Skull Hill Formation and the locally important Chu Chua Formation along North Thompson and Clearwater Rivers. The Skull Hill Formation may be further divisible locally if the more acidic volcanic rocks can be shown to be a distinct unit. Dawson correlated the Chu Chua Formation with the Coldwater Beds and as the former is known to be middle Eocene it corresponds with the age of the Kamloops Group. Lithologically the Chu Chua Formation and the Coldwater Beds are not identical but their lithologies are so varied that they are in part similar. One characteristic common to both is that they pre-date the volcanics and do not have Tertiary volcanic clasts in their sediments. As the Skull Hill Formation is lithologically similar to the volcanics of the Kamloops Group in the type locality it may be included with confidence in that group. The Skull Hill Formation, however, appears to be conformable with the Chu Chua Formation whereas the volcanics of the Kamloops Group are thought to be unconformable on the Coldwater Beds. This conformable relation of the Skull Hill Formation may be more apparent than real as the exposure of the contact is limited.

A proposed stratigraphic correlation of Tertiary formations and rock units of Bonaparte Lake and Kamloops areas is incorporated in Table II. The information for the Kamloops area is an interpretation based on the work of Cockfield (1948) and of Mathews and Rouse (1961, 1963).

Oligocene Volcanic and Sedimentary Rocks along Fraser River (Map-unit 23)

Distribution

A group of volcanic and sedimentary rocks west of Fraser River near the southwest corner of the map-area was referred to by Trettin (1961, pp. 70–71) as the Ward Creek Assemblage. In Bonaparte Lake map-area, the unit is poorly exposed and the information on the group is derived largely from exposures in the adjoining Taseko Lakes map-area.

Lithology

The sequence comprises felsite, dacite, rhyolite, andesite, basalt, and related thick beds of breccia and tuff. Interlayered with volcanics locally and forming a thick basal section are conglomerate, greywacke, soft clay, and lignite. The rocks are colourful, commonly bright red, green, yellow, orange, black, brown, and purple, although in Bonaparte Lake area they are mainly red. It is mainly a volcanic group that accumulated under non-marine conditions.

Structural Relations

The thickness of the group is unknown but probably is more than 2,000 feet. The fault relation with the older rocks precludes any interpretation of the stratigraphic relation with the older rocks. In Taseko Lakes area and in Ashcroft area (Trettin, 1961) plateau lavas are younger than the faults that disrupt map-unit 23. Trettin has interpreted this belt of rocks as a graben in the Fraser River fault zone (1961, p. 71).

Age and Correlation

About seven miles north-northwest of the southwest corner of Bonaparte Lake map-area, soft, carbonaceous sediments yielded spores and pollen that were studied by Prof.

G. E. Rouse, University of British Columbia. His identifications and comments are as follows:

TABLE II *Correlation of the middle Eocene to Pliocene formations and rock units of Kamloops and Bonaparte Lake areas.*

	BONAPARTE LAKE AREA		KAMLOOPS AREA	
MIOCENE, PLIOCENE, AND (?) LATER	Plateau Lavas Deadman River Formation		Plateau Lavas late Miocene sediments at Red Lake (Mathews and Rouse, 1963)	
	unconformity		unconformity	
MIDDLE EOCENE AND (?) LATER	KAMLOOPS GROUP	Skull Hill Formation	KAMLOOPS GROUP (COCKFIELD, 1948)	Kamloops volcanic rocks Tranquille Beds Kamloops volcanic rocks
		Chu Chua Formation		unconformity (?) Coldwater Beds

GSC

GSC loc. 7340

On the first creek north of Watson Bar Creek, west side of Fraser River, Taseko Lakes area, B.C.

Ulmus sp.
Osmunda sp.
Deltoidospora sp.
Pinus (*contorta-latifolia* type)

Age: Tertiary

GSC loc. 7330

On first creek north of Watson Bar Creek, west side of Fraser River, Taseko Lakes area, B.C. Same stratigraphic position as 7340.

Carya sp.
Engelhardtia sp.
Myrica sp.
Ulmus sp.
Juglans sp.
Cedrus perialata Martin and Rouse
Taxodium hiatipites Wodehouse
Osmundacidites primarium (Wolff) Couper
Glyptostrobus sp.

Age: Early Oligocene

This group may be partly correlative with the youngest beds of the Kamloops Group but this is speculative. It is correlative with rocks in Quesnel area (Tipper, 1959, units 5 and 6).

Miocene–Pliocene Sediments and Volcanics (Map-units 24 and 25)

Nearly half of the Bonaparte Lake map-area is underlain by Miocene–Pliocene, essentially flat-lying, sedimentary and volcanic rocks, particularly in the area of low relief in the central and western parts. The rocks are divisible into two mappable units, the Deadman River Formation (map-unit 24) a local sedimentary section occurring at the base, and map-unit 25, a widespread sheet of plateau lavas.

Deadman River Formation (Map-unit 24)

Distribution

The Deadman River Formation is typically developed in good exposures along the upper parts of Deadman River valley. The type section is exposed on the east side of Skookum Lake. Elsewhere in the area sections correlative with this formation are included in this map-unit but are not identical lithologically. Such areas are southeast of Clinton, southwest of Loon Lake, and south of Chasm Provincial Park. Where plateau lavas, map-unit 25, rest directly on older groups and formations, thin zones of breccias or conglomerates were often noted. These might be considered part of Deadman River Formation but as they are thin and of little consequence, they are not mapped separately.

Lithology

Typically the Deadman River Formation is a buff to yellowish brown weathering section of tuff, breccia, diatomite, diatomaceous siltstone, pebbly arenites and conglomerate. The rocks are lacustrine mainly and are soft, poorly consolidated sediments. Two sections were measured and are as follows:

Section 1-2TD-1964 measured on the east side of Deadman River valley at the north end of Skookum Lake.

Unit No.	Unit	Thickness in feet	Total from base
	Basalt of Map-unit 25		
30	Covered interval	5–10	422–427
29	Sandy and pebbly arenite, conglomeratic in places; matrix only about 25 per cent in places; lenticular beds, near top tuff thinly bedded, compact, bedding ¼ to 2 inches, wavy, irregular; weathers yellowish buff to grey; siliceous; rocks are baked near top, hard and brittle; resistant	8	417
28	Covered interval, sandy talus	46	409
27	Silty, gritty tuffaceous arenite; angular fragments of clear or milky quartz in a greyish yellow silty arenaceous matrix; some feldspar fragments; rock is slightly ferruginous and slightly porous, poorly sorted	3	363
26	Slightly recessive, poorly exposed sandy siltstone; buff coloured	12	360

Unit No.	Unit	Thickness in feet	Total from base
25	Coarse tuff, ferruginous, resistant some fine wavy interbeds of siltstone	3	348
24	Arenite similar to unit 27 but slightly recessive; about 10 to 50 per cent of rock in places composed of pebbles up to ¼ inch diameter of quartz, chert and rarely basalt; rock is porous	14	345
23	Slightly recessive tuffaceous arenite with ¼ inch pebbles scattered throughout; many lenses of pebbly sand and pebbly conglomerates or breccia; beds 2-4 feet thick; some ferruginous beds	35	331
22	Pebbly tuffaceous siltstone, pebbles up to 25 per cent of rock, sand size grains 20 per cent, remainder is silt size or finer; poorly indurated; ferruginous in part, porous; limonite gives rock speckled appearance; rock is mainly buff coloured; rock is very slightly calcareous	19	296
21	Covered interval; fine silt talus	18	277
20	Buff-coloured tuff and sandy siltstone, resistant; slightly wavy bedding	14	259
19	Poorly sorted sandy to conglomeratic rocks or breccia; lenticular beds of tuff and pebble-conglomerate; beds 2 to 4 feet thick; in places poorly developed crossbedding porous slightly ferruginous; weathers yellowish buff to slightly brownish yellow	22	245
18	Covered interval; probably siltstone, and tuff	11	223
17	Poorly sorted conglomerate with pebbles to ¼ inch diameter making up 50 per cent of volume set in a tuffaceous matrix; slightly ferruginous	4	212
16	Mainly a covered interval but probably is a siltstone or tuff	8	208
15	Pebbly tuff; resistant; ferruginous	1	200
14	Covered interval; probably a siltstone	16	199
13	Tuffaceous siltstone, weathers greenish yellow	4	183
12	Ferruginous coarse sandy tuff; speckled with limonite throughout; very resistant and weathers dark brown	0.5	179
11	Impure tuff, coarse-grained sandy particles with pebbles to ¼ inch diameter scattered throughout; in places sandy 2-inch thick lenses to six inches long; a few ferruginous nodular beds 1 inch to 3 inches thick; indistinct bedding in general; rock is soft and friable, powdery, siliceous	9	178.5
10	Pebbly tuff, ferruginous, poorly sorted, resistant; beds 2-to 4-inches thick, wavy, rare basalt fragment	2.5	169.5
9	Impure diatomite, sandy	6	167

Unit No.	Unit	Thickness in feet	Total from base
8	Poorly sorted sandstone to fine pebble conglomerate; very little matrix	0.5	161
7	Diatomite, clay-rich but with sand grains scattered throughout; weathers grey-brown to buff	6.5	160.5
6	Fine pebble conglomerate, sand size to ½-inch diameter; angular to well rounded, poorly sorted, little matrix; friable	1.5	154
5	Poorly sorted siltstone and tuff with large irregular masses to 4 or 5 inches of grey, ash-like material; rock is porous, resistant; weathers yellow brown	9.5	152.5
4	Covered interval	72	143
3	Light yellowish buff diatomaceous siltstone; fine grained, indistinct bedding; weathers light yellowish brown; slightly porous; few sand grains scattered throughout and a few large 3- to 4-inch fragments of basalt	16	71
2	Covered interval	50+	55
1	Buff sandy siltstone	5	5
	Base not exposed.		

Section 2-2TD-1964 measured on the east side of Deadman River valley east of Snohoosh Lake north of Sherwood Creek.

Unit No.	Unit	Thickness in feet	Total from base
18	Covered interval	24	367
17	Sandy and pebbly tuff; sand and pebbles make up about 30 per cent of rock; porous and vuggy in places	5	343
16	Mainly covered; coarse, pebbly talus	25	338
15	Coarse, pebbly tuff, resistant; 45 per cent pebbles, slightly iron-stained	5	313
14	Covered interval; talus is pebbly	33	308
13	Pebbly tuff with poorly indurated lenses of gritty sand and conglomerate; rounded and disc-shaped 1-inch diameter reddish ironstone concretions occur here and there; beds are 2 to 4 feet thick; some beds are ferruginous and resistant	66	275
12	Covered interval, pebbly talus	14	209

Unit No.	Unit	Thickness in feet	Total from base
11	Coarse, pebbly tuff, grey-weathering and iron stained; irregular bedding; porous	3	195
10	Covered interval	14	192
9	Fine-grained to sandy tuffaceous siltstone; grey to light yellowish buff coloured; less than 5 per cent pebbles here and there; bedding is 2 inches thick or in massive beds; weathers light grey; resistant slight iron staining	13	178
8	Mainly covered interval; pebbly talus	18	165
7	Pebbly tuff weathering light yellowish buff; 1½ inch concretions at base	2	147
6	Poorly sorted pebbly and sandy tuff with angular fragments; coarse fragments make up 25 per cent of rock	6.5	145
5	Light grey porous clay or silt; slightly vuggy	2.5	138.5
4	White, fine-grained diatomite; very uniform	5	136
3	Covered interval	35	131
2	Diatomite, white, fine grained, uniform, in beds ¼ inch to 6 feet; non-calcareous; weathers light grey to bright orange	9	96
1	Covered interval	87	87
	Base not exposed.		

The rocks are more diatomaceous and finer grained near base of the section, but this part, being soft and recessive, is not well represented in the sections measured. However, two road-cuts exposed soft, diatomaceous silt and diatomite, obviously of lacustrine origin, within about 50 feet of the base of the section but not near the sections measured. Fossil leaves were collected from these silty beds and presumably date the basal beds.

Four small areas around Clinton contain poorly exposed rocks that are included in the Deadman River Formation because of general lithologic similarity and apparent position below the plateau basalts. For about one mile south of Clinton are gravels and sands with some diatomaceous silts exposed in cuts along logging roads. About ½ mile east of Clinton is coarse, poorly sorted, poorly consolidated, and crudely bedded gravel. Approximately one mile southwest of the west end of Loon Lake soft Tertiary sands and silts are exposed along and south of Loon Creek. At the junction of Chasm Creek and Bonaparte River a fan-like deposit of buff-coloured, bedded breccia more than 300 feet thick slopes to the south. Clay and breccia are interbedded at the top, whereas to the east grit, breccia, conglomerate and sandstone overlie rocks of the Cache Creek Group and Skull Hill Formation. The fragments of the coarse clastic rocks are derived from the underlying rocks, mostly presumably contemporaneous basalts, but near the base the grits and sandstones are arkosic suggesting a nearby granitic source.

Structural Relations

The Deadman River Formation is essentially flat lying and undeformed. Any dip to the sediments can be attributed to original dips, slumping or differential compaction from the weight of the overlying plateau lavas. The formation rests unconformably on all older rocks and is overlain conformably by the plateau lavas of map-unit 25. The upper contact is sharp or gradational over a small thickness of volcanic breccias and tuffs.

The thickness of the formation is variable. In places it is as much as 500 feet thick but may thin to a few inches. The variation in thickness results from deposition on an irregular surface; the thickest deposits formed in valleys cut into the older surface which apparently had local relief of 500 feet or more in the area around Deadman River.

Age and Correlation

Two collections of fossil flora were obtained and were identified by Dr. F. M. Hueber of the Division of Paleobotany, Smithsonian Institution, Washington, D.C. Samples of spores and pollen were obtained from the same localities and were examined by Prof. G. E. Rouse, Department of Biology and Botany, University of British Columbia, Vancouver, British Columbia.

GSC loc. 7067

Deadman River valley, south of Snohoosh Lake

Melosira granulata (Ehrenberg) Ralfs
Metasequoia occidentalis (Newberry) Chaney
Sagitarria sp.
Quercus columbiana Chaney
Quercus hannibali Knowlton
Quercus dayana Knowlton
Fagus sp.
Liquidambar pachyphyllum Knowlton

GSC loc. 7068

Deadman River valley, near Deadman Lake in road-cut.

Melosira granulata (Ehrenberg) Ralfs
Liquidambar pachyphyllum Knowlton
Acer bendirei Lesquereux
Betula sp.
Ulmus sp.
Quercus dayana Knowlton

Regarding these two collections, Hueber comments:

"This florule is clearly of middle to late Miocene age."

Spores and pollen from the same two localities were reported on by Rouse.

GSC loc. 7067

Deadman River area, B.C., south of Snohoosh Lake, on road.
Identifications:

ANGIOSPERMS:

Ulmus sp. (heavy rugulae)
Juglans sp.
Salix sp. (weak reticules)
cf. *Quercus* sp.

CONIFERS:

Picea sp.
Pinus spp. –*strobus*-type
contorta-type
Tsuga spp.–*heterophylla*-type
canadensis-type
Taxodiaceae–cf. *Taxodium*
cf. *Cedrus* sp.
Larix or *Pseudotsuga* sp.

Age: Miocene, probably late Miocene, same age as late Tertiary sediments of the Chilcotin Plateau (Mathews and Rouse, 1963).

GSC loc. 7068

Deadman River area, B.C., near Deadman Lake, on road.
Identifications:

ANGIOSPERMS:

Corylus sp.
Salix 2 spp.
Betula sp.
Juglans sp.

CONIFERS:

Picea sp.
Abies sp.
Pinus spp.
Tsuga sp.–*heterophylla*-type
Cupressaceae–cf. *Chamaecypoaris*
cf. *Juniperus*
cf. *Taxodium* sp.
cf. *Cedrus* sp.

Age range: Miocene–Pliocene
Probable age: late Miocene, correlative with GSC 7067, and with sediments from Chilcotin Plateau.

The age of the Deadman River Formation is probably late Miocene. The formation is not thick and the span of time it represents is probably not great. As these collections are from near the base of the formation the upper part may extend into the Pliocene, but this is not considered likely by the writers.

The formation is correlative in whole or in part with late Miocene sediments of the interior of British Columbia. In the Taseko Lakes map-area the "middle or upper Miocene" sediments near Hanceville (Tipper, 1963, map-unit 16) are similar lithologically and contain a similar flora. In Anahim Lake map-area the sedimentary rocks of the "Oligocene (?), Miocene and (?) later" map-unit 7 and the sedimentary rocks of map-unit 6 (Tipper, 1957) are now known to contain flora of the same age as that of the Deadman River Formation. In the Quesnel map-area (Tipper, 1959), the sedimentary rocks of the "Miocene and (?) Pliocene" map-unit 7 are correlative with the Deadman River Formation. The "Miocene (?)" sediments (map-unit 12) of the Prince George area are correlative in part (Tipper, 1961).

Late Tertiary sediments are known in the Nicola map-area to the south (Cockfield, 1948) and later work by Mathews and Rouse has shown that these are late Miocene and hence correlative with the Deadman River Formation.

Plateau Lavas (Map-unit 25)

Distribution

Plateau lavas are widely distributed in the topographically subdued areas of the central and western parts of the map-area. To the east detached areas of the map-unit are the result of erosion or of flows being poured out in separated areas. The lavas were extruded onto an irregular surface which in the west was at an elevation of 3,000 to 3,500 feet and rose to elevations of 5,700 feet in the southeast quarter. The lavas spread over the low areas in the west and built up to elevations of nearly 4,500 feet; in the southeast quarter, elevations over 5,900 feet were reached. The latter area had a rolling upland surface of pre-plateau lava that was not deeply dissected. In contrast the northeast part was deeply incised prior to outpouring of the plateau lava and the valley bottoms were at elevations as low as 1,500 feet. In this area the lavas were confined to the valleys, particularly in those of Mahood Lake, Clearwater River, and Mann Creek and the tops of the hills and mountains were never covered. Although later dissection has occurred, the isolated areas in the eastern part mainly represent individual extrusion centres of plateau lavas which did not coalesce into a single sheet.

Lithology

Olivine basalt is by far the most abundant rock type. Pyroxene andesites are present but uncommon. Siliceous volcanic rocks such as trachyte or dacite have not been found in this formation in the map-area.

Most of the rocks are dark grey, grey, greenish grey, blue-black, brownish grey and light grey. They weather a rust brown, dark brownish black, or dark grey.

Although generally similar in composition certain characteristics of the flows are varied. Most flows are thin, about 5 to 50 feet thick; thicker flows may be a result of ponding of the lava in topographic depressions. The length and breadth of individual flows is also dependent on local topography as well as the viscosity of the lava. The flow along Mann Creek, for example, is believed to have been at least twenty miles long. Elsewhere exposures on cliff faces are not sufficient for determining the length of most individual flows.

Slightly vesicular to scoriaceous lavas are common, particularly in the upper parts of flows; amygdaloidal flows are rare. Massive fine-grained flows are encountered but even these are usually slightly vesicular at their margins. The flows are commonly separated by a thin layer of flow breccia but in general fragmental deposits are of minor importance. Columns vary from short and crudely developed to well-defined and 20 or 30 feet long. Pillow lavas were not noted.

The lavas are generally fine-grained but some are medium-grained feldspar porphyries. Small crystals of olivine up to 2 mm across are visible in many hand specimens. Coarse-grained porphyries are not characteristic.

The olivine basalt along Clearwater River and Mann Creek is similar throughout in mineralogy. Typically it has an inter-granular texture with anhedral to euhedral olivine in a matrix of labradorite laths with interstitial augite or pigeonite and magnetite. In a few flows the olivine phenocrysts have rims of iddingsite and the smaller grains are completely altered. Clinopyroxene is rare as phenocrysts but where present, is more abundant than olivine. Several flows, particularly near the top of the section, have abundant plagioclase feldspar laths and anhedral olivine grains set in a fine matrix of plagioclase, clinopyroxene

and magnetite. These light grey flows are distinctive in that they are the lightest coloured rock in the group.

Four olivine gabbro plugs genetically related to and believed to be vents for some of the plateau lavas have been included with them and designated as map-unit 25a. These plugs were studied by R. B. Farquaharson (1965) while working with the writers and subsequently at university where they were the subject of his Master of Science thesis, the abstract of which is as follows:

> "Four olivine gabbro plugs crop out on the basaltic plateau in the south Cariboo region of British Columbia. The plugs form elliptical knobs of unaltered gabbro which stand 100 to 200 feet above the plateau surface. They are 300 to 600 feet in greatest diameter, as seen in plan view. Two plugs, Mt. Begbie and Forestry Hill, are described in detail in this thesis.
>
> "Alignment of tabular feldspar grains resulting from the upward flow of magma, has produced a foliation in both Mt. Begbie and Forestry Hill plugs. Foliation dips toward the centre at moderate to steep angles in both plugs. Small, scattered lenses of leucogabbro and picritic gabbro lie approximately in the plane of foliation. Marginal foliation is assumed to be roughly parallel to the walls of the plug. Foliation trends indicate that both plugs are funnel-shaped, increasing in diameter toward the surface.
>
> "The essential minerals of the plugs are olivine, calcic-augite and plagioclase. They are strongly zoned indicating a disequilibrium environment of crystallization. From a consideration of mineralogical and chemical characteristics it is concluded that the original magma was an alkali basalt magma. Differentiation by fractional crystallization produced small volumes of marginal dolerite and pegmatitic gabbro in the outer portions of Mt. Begbie plug. The trend of differentiation leads to iron-enrichment in the marginal dolerite, and then to alkali-enrichment in the pegmatitic gabbro.
>
> "The four plugs occupy former volcanic vents which, in late Tertiary time, fed lava to the surrounding plateau. The exposed portions of the plugs crystallized possibly within 50 to 150 feet of the surface. General geological relationship, petrological similarity, and the close comparison of fused whole-rock powders suggest a definite kinship of the plugs to the surrounding basaltic lava."

Structural Relations

Internally the plateau lavas appear to be a structurally conformable map-unit. Local channelling and erosion may have occurred but do not represent a prolonged erosional period or suggest any widespread tectonic event. These rocks overlie the Deadman River Formation conformably and where that formation is absent, rest with angular discordance on the older rocks. No younger formation is known to overlie the plateau lavas except glacial deposits and alluvium and, locally, Pliocene to Recent volcanic rocks.

Between the laying down of the youngest plateau lavas and glacial material a period of erosion occurred. Broad valleys such as those of Horse Lake and Green Lake reflect a more mature erosion than the glacial erosion. The dissection of the area south of Bonaparte Lake producing the relatively rounded hills and broad valleys with gentle slopes similarly suggests a mature stage in a regional erosional cycle that antedates the Pleistocene glacial erosion. During the Pliocene, therefore, an unknown proportion of plateau lavas may have been dissected and stripped away. The margins of the plateau lavas have sharply incised valleys such as that along Chasm Creek northeast of Clinton but these are obviously a result of youthful stream erosion related to the meltwater channelling of the Pleistocene deglaciation.

The plateau lavas do not appear to have been tilted since their deposition. In Taseko Lakes map-area the western margin of the plateau lava field has been upwarped, presumably during the rise of the Coast Mountains (Tipper, 1963). Along the eastern margin in Bonaparte Lake map-area no evidence exists of a similar upwarping. A vertical rise of the whole area is a possibility. The increasing elevation of the upper surface of the plateau lavas from west to east reflects only a higher elevation of original deposition in the east rather than later upwarping as the attitude of the flows throughout the map-area remains essentially horizontal.

Origin

The plateau lavas represent a post-orogenic outpouring of basic lava in an extremely fluid state which allowed lateral spreading wherever possible and formation of thin sheets of fairly uniform thickness. No central cone was built but rather many centres were developed which may have been short-lived and may have been obscured by outpourings from adjacent centres. Basalt dykes are not common within the lavas nor dyke swarms in the older rocks.

The plugs at Mount Begbie and Lone Butte offer the simplest explanation. These as well as several other funnel- or cylinder-shaped plugs scattered around the map-area represent small centres of extrusion probably situated along some of the many normal faults that cut the pre-Miocene rocks. If these were short-lived and the lava was exceptionally fluid no topographic feature would be built to mark the site of eruption. The plugs mentioned above are recognized only because the core of the eruptive centre is resistant and the surrounding lavas have been stripped away.

The lavas along Mann Creek, along Clearwater River, and the main mass in the west half of the area are probably all part of the same eruptive episode although they formed in separate areas. They are similar or identical in lithology, structure, stratigraphic relations and form. Their distribution is thought to be accounted for by (a) topography that controlled the shape of the basin of accumulation in the eastern part, (b) the fact that the eastern part represents the eastern extremity of the extensive lava outpouring of central British Columbia, and (c) erosion that may have stripped away any direct connection between the areas. The small areas along Canim and Mahood Lakes and along North Thompson River may well be remnants of ribbons of lavas that occupied these valleys and were linked directly to the plateau lavas west of Canim Lake.

Age and Correlation

No fossils were found within the plateau lavas. The unit conformably overlies the Deadman River Formation of late Miocene age and the upper surface has been glaciated; none of it appears to be interglacial. The age is possibly as old as late Miocene and as young as Pliocene.

Undeformed plateau lavas of this general age are widespread in central British Columbia. Much of Taseko Lakes, Quesnel, and Anahim Lakes map-area (Tipper, 1963, 1959, 1957) are underlain by the direct extension of this map-unit. It is also correlative in part with the younger flows of the Kamloops Group as mapped in the Nicola (Cockfield, 1948) and Ashcroft (Duffell and McTaggart, 1952) areas. Other basaltic lavas are known throughout British Columbia but whether these are the same age, slightly older, or slightly younger has not been determined.

Pliocene or Pleistocene Volcanic Deposits (Map-unit 26)

Map-unit 26 is made up of crudely bedded basaltic sand and breccia with some flows (map-unit 26a) and two extinct volcanoes consisting of basaltic cinder and flows (map-unit 26b). Map-unit 26a lies along the eastern boundary about 9 miles north of Clearwater Station

and the two volcanoes straddle the northern boundary near the northeastern corner of the map-area. Valuable suggestions regarding interpretation of these volcanic accumulations was provided by J. G. Souther of the Geological Survey of Canada.

Map-unit 26a

Crudely stratified rocks, perhaps best described as basaltic rubble deposits, characterize map-unit 26a. The deposits lie on the western slopes of Trophy Mountain (*see* Adams Lake map-area to the east, Campbell, 1963b) and are well exposed in three deep, sharp canyons cut by small tributaries to Clearwater River. The exposures in these canyons were described by Walker (1931, pp. 137A–138A) who did not differentiate the bedded deposits from the flat-lying lavas (map-unit 25) beneath.

At roughly 4,500 feet above sea level an abrupt shoulder separates the steep walls of Clearwater River valley from gentle slopes that rise to the summit ridges of Trophy Mountain to the east. Flat-lying thin basaltic flows lie on the upper, gentler slope and outcrop at the break in slope. A cinder cone stands 300 feet above the upper gentle slope. Its base is at an elevation of 4,900 feet which is the above highest observed exposures of the flows, thus the cone may or may not rest directly on the flows. The rubble deposits outcrop on the steep slope and can be traced downward through a vertical distance of about 2,000 feet from the bottom of the upper flows to the surface of the flat-lying flows (map-unit 25) near the valley bottom which the rubble deposits overlie with angular discordance. The deposits apparently mantle the valley wall and attain no great thickness. The strata display initial dips to the west, or downslope of 20 degrees or more.

Characteristic of the rubble deposits are thick, crudely bedded basaltic conglomerate and breccia in which fragments of vesicular basalt up to 18 inches across, but probably averaging less than 8 inches, are enclosed in sandy basaltic material. In some places the fragments are rounded, in others they are angular. In a few localities delicately laminated basaltic vitric tuff is exposed. Pillow basalts and intensely jointed flows are locally interlayered with the fragmental rocks. The pillowed rocks appear to grade here and there into fragmental material. The individual overlying flows at the top of the exposures are thin (10 feet or less). The flow tops are highly vesicular and some exhibit ropy lava surfaces. The flows contain pods of fragmental material that become more prevalent towards the base. Columnar jointing is well developed in some flows. A few dykes of highly fractured olivine basalt cut the fragmental deposits.

Till mantles the basaltic deposits including the upper flows, but the cinder cone appears to be unglaciated, thus the cone may have formed long after the original eruptions.

The basaltic eruptions apparently took place from a fissure above the steep slopes and parallel with Clearwater Valley. The cinder cone may lie on such a fissure. Eruptions may also have occurred from fissures on the steep slope, forerunners, perhaps, of the basaltic dykes that cut the rubble deposits.

The presence of air- or water-lain tuff and the rarity of non-basaltic fragments in the deposits rule against the possibility that the valley was filled with ice during the eruptions, but possibly the valley was partly filled by a lake and snow formed a heavy mantle on the hillsides. Under these conditions eruptions from fissures might have produced piles of highly fragmental material that, periodically, cascaded down the steep slopes forming breccia deposits. Molten lava may have flowed down the slope and, where it entered water, formed pillows. Occasional explosive eruptions may have led to the deposition of glassy tuff beds.

In the final fissure eruptions highly fluid and mobile flows capped the fragmental deposits and presumably flowed down into the valley from where they have, subsequently, been removed by erosion.

During the last major Pleistocene glaciation, till was spread over the volcanic deposits. The last event, apparently postglacial, was the development of the cinder cone. Whether or not eruptions took place under the ice is not known. The main volcanism may have occurred in an interglacial or in pre-glacial time.

Map-unit 26b

Two extinct, basaltic volcanoes straddle the northern boundary of the map-area; one in the northeast corner and one just west of Clearwater River. Most of each of them is in Quesnel Lake map-area (Campbell, 1963a). Both are about 3 miles long, 2 miles wide, and roughly elliptical in plan. Both rise above the general surface of the flat-lying lava flows (map-unit 25) in Clearwater and Murtle River valleys; the eastern one stands more than 800 feet and the western one about 600 feet in height.

Exposures are meagre on the two volcanoes but they are evidently made up of both hard basaltic flows and layers of soft cindery material all of which was ejected from central orifices. At least one roughly concentric ring parallel with the outer circumference is displayed on both hills. Within the rings the topography of the summits is very irregular and consists of a series of hillocks and depressions of which some contain small lakes. The hills have been scoured by overriding ice and the rings and irregular topography are thought to result from differential resistance to glacial erosion of hard flows as opposed to soft fragmental material. The concentric rings are believed to represent the outcrop of a flow or series of flows that mantled the surface of the volcanoes at one stage of their development.

These two small volcanoes may have formed either during or prior to the Pleistocene. They are within a small region extending to the north (Campbell, 1963a) in which are many similar volcanic centres that range in age from possibly pre-Pleistocene to Recent. Some of these centres, including the two under discussion, may mark sources of the older flows (map-unit 25) which flooded the Clearwater and Murtle River valleys.

Pleistocene or Recent Cinder Cone (Map-unit 27)

Pyramid Mountain, overlooking Murtle River near the northern boundary of the map-area, is an almost perfectly symmetrical basaltic cinder cone, with a small subsidiary cone on its eastern flank, that rises abruptly about 800 feet above the flat lava surface of the Clearwater and Murtle River valleys.

The cone does not seem to be appreciably modified by glacial activity and is probably postglacial. Abandoned stream channels near the base on the northeastern side may have formed during the waning stages of the last major glacial advance hence the cone could have formed late in the Pleistocene.

The cone is composed mainly of fine rusty material containing nodules of vesicular, sometimes frothy, glassy, black basalt, together with pebbles and cobbles of black olivine basalt, and granitic and metamorphic rocks. The latter are well rounded and are definitely enclosed in, and coated by the basaltic cinder. The pebbles and cobbles were evidently blown from the vent during the eruption. Those that are weathered out and lie about on the surface might be mistakenly interpreted as glacial erratics. Though assuredly some could be

of that origin, presumably the foreign rocks were picked up from a layer of glacial or river gravel which lay on the surface upon which the cone is built. No flows attributable to the Pyramid Mountain vent have been recognized.

Recent Volcanic Rocks (Map-unit 29)

Blocky, basaltic flows of postglacial age lie on the floor of the valley of Spanish Creek along the northern boundary of the map-area about 18 miles from the northeastern corner. These flows originated from a vent now marked by a cinder cone in the Quesnel Lake map-area to the north (Campbell, 1963a). The longest flow reached a point almost 10 miles from the source.

The surface of the flows is hummocky and rough, consisting of piles of loose blocks which commonly form small arcuate ridges or lobes. The convex sides of the ridges face in the direction of flow. The rough, angular blocks range in size from a few inches to 18 inches or more. They are composed of black, vesicular basalt containing, in places, as much as 20 per cent of glassy green olivine crystals and crystal aggregates that range up to one half inch in diameter. The larger olivine grains are rounded but some of the smaller ones are more angular. The glassy groundmass contains microlites of plagioclase. Locally vesicles are flat and narrow rather than spherical; their long dimensions lie in a common plane. Rarely vesicles are filled with white zeolites.

Intrusive Rocks

Serpentinite was noted in two small bodies southwest and south of Little Fort. The remainder of the known intrusive rocks are granitoid and can be divided into two groups depending on age. In general hornblende-biotite quartz diorite and granodiorite with minor diorite, syenodiorite, and syenite are Late Triassic or Early Jurassic (Rhaetian or Hettangian) and biotite granodiorite and quartz monzonite are Cretaceous.

Serpentinite (Map-unit 9)

Serpentinite was found in sufficiently large masses to be mapped separately in only two places, one south and the other southwest of Little Fort on the margin of Thuya batholith. Small amounts of serpentinite associated with map-unit 4 of the western part of the Cache Creek Group were noted.

The serpentinite is very fine grained and commonly dark grey or black with green scaly serpentine on shear surfaces. In the thin sections examined all original minerals have been altered to serpentine though a semblance of their original outlines remains. Because of differing appearance of the serpentine in the relict grains it seems that at least two minerals have been replaced; presumably these were orthopyroxene and olivine. No significant quantity or quality of asbestos fibre was noted.

Between Thuya batholith and the more northerly of the serpentinite bodies near Little Fort is a zone of brown-weathering serpentinite, locally with veinlets of magnetite, and of foliated mafic phases of the batholith with sparse disseminated iron sulphide.

The age of the ultramafic rocks is not known. Much serpentinite in the interior of British Columbia is closely associated with Cache Creek Group volcanic rocks and is thought to be Permian. As some, however, intrude Triassic rocks the unit has been designated as Permian and/or Triassic.

Rhaetian or Hettangian Granitic Rocks (Map-units 13 and 14)

Syenite and Monzonite (Map-unit 13)

North and west of Friendly Lake several small intrusions range from narrow dykes to elongate masses 2 miles long by 0.5 mile wide (map-unit 13a). Three of these are sufficiently large to be shown on the map. The rocks contain pink, and less commonly creamy white phenocrysts set in a grey to creamy fine-grained matrix. Small quantities of very fine amphibole are the only apparent mafic constituent.

Petrographic study revealed the phenocrysts to be mainly euhedra of zoned, perthitic, potash feldspar. Albite forms phenocrysts, together with potash feldspar, in a thin dyke but otherwise seems to be uncommon. A deep green amphibole, apparently a soda variety, forms small euhedral phenocrysts and matrix grains. Only shredded bits of the mineral remain in thin sections, the remainder having been plucked out during grinding, and identification is difficult. The matrix consists of very fine grained perthitic potash feldspar, albite, quartz, and amphibole. Quartz may be in sufficient quantity to invalidate the use of the names monzonite and syenite but this was not determined.

A body of syenite (map-unit 13b) about 6 miles long and up to 1.5 miles wide is associated with Thuya batholith-type granitic rocks in a small area about 5 miles immediately west of the town of Barrière. This syenite is a cream to buff, medium- to coarse-grained rock consisting of more than 95 per cent alkali feldspar. Other minerals, except for rare small garnet, cannot be identified in hand specimen. Both sodic plagioclase and perthitic potash felsdpar are present and both form platy grains locally 3 cm or more across but only 2 or 3 mm thick. The plagioclase consists of albite or sodic oligoclase rendered turgid by alteration to fine-grained epidote, sericite, and clay minerals. The altered plagioclase is commonly rimmed by clear albite particularly along contacts with potash feldspar. Some potash feldspar displays distinct zoning and some appears to replace plagioclase. All is perthitic. A few fine grains of quartz and some chloritized biotite were noted.

Where coarse grained the feldspar plates are well oriented and thus produce a marked flow or fluidal texture. In finer grained varieties the orientation of the plates is more random.

The rocks of map-unit 13 are known to intrude only strata of the Nicola and Cache Creek Groups upon which they seem to have had little or no contact metamorphic effect. Fragments of rocks similar to those near Friendly Lake were noted in early Jurassic conglomerate on Windy Mountain hence the age designation of Rhaetian or Hettangian in common with the Thuya and Takomkane batholiths. The syenite west of Barrière evidently intrudes Cache Creek Group strata, hence is Permian or younger. Its age has not been more closely determined.

Thuya and Takomkane Batholiths and Related Intrusions (Map-units 14, 14a, 14b)

Names and Distribution

Thuya batholith is named for Thuya Creek, an easterly flowing stream that joins North Thompson River just south of Little Fort. Rocks typical of the batholith are reasonably well exposed near the creek.

Thuya batholith in the east-central part of the map-area is at least 40 miles long (east-west) and 25 miles wide (north-south). It may be much more extensive than presently known for most of the contacts of the western part are covered by Tertiary volcanic deposits. The batholith extends westerly from North Thompson River to Rayfield River, a branch of Bonaparte River, and northerly from 7 to possibly 14 miles south of Bonaparte Lake to about

4 miles beyond Eakin Creek. Much smaller masses of similar and apparently related rocks were found 4 to 6 miles west of Barrière and near the south boundary of the map-area about 10 miles west of McLure. A small intrusion of augite-hornblende diorite 9 miles northeast of Barrière is tentatively included with the map-unit as is a dyke of biotite quartz diorite near the highway just south of Little Fort.

Takomkane batholith is named for Takomkane Mountain[1] in Quesnel Lake map-area just to the north of Bonaparte Lake map-area where the rocks are particularly well exposed. The Boss Mountain molybdenum deposit is on the eastern slopes of Takomkane Mountain. Takomkane batholith straddles the centre of the northern boundary of the map-area with about as much lying in Quesnel Lake map-area (Campbell, 1961 and 1963a) as in Bonaparte Lake area. The crudely circular pluton, roughly 30 miles across, extends from near the village of Forest Grove west of Canim Lake to the north boundary and from Spout Lake on the west to near Hendrix Creek on the east.

Lithology

The bulk of the rocks of the Thuya and Takomkane batholiths and related intrusions (map-unit 14) are hornblende-biotite granodiorite and quartz diorite. Major variants are diorite and syenodiorite of Takomkane batholith (map-unit 14a) and leucogranodiorite and quartz monzonite of Thuya batholith (map-unit 14b).[2]

Map-unit 14. The main parts of the two batholiths are medium-grained rocks with scattered coarse phenocrysts of pinkish, inclusion-rich potash feldspar. Neither the abundance nor the prominence of the phenocrysts is such that the rocks generally would be termed porphyritic. The rocks are prominently speckled medium grey to brownish grey but locally have a greenish cast as a result of epidotic alteration. Mafic minerals vary from less than 5 per cent to more than 20 per cent and though most show little if any preferred orientation some are well oriented. Quartz varies from smoky grey to glassy rounded aggregates.

The composition of the main phases of the batholiths, averaged from 24 modal analyses, is approximately 50 per cent plagioclase, 15 per cent potash feldspar, 20 per cent quartz, 7 per cent hornblende, 3 per cent biotite, and 5 per cent accessory and alteration minerals. Modal data are listed in Table III and plotted in Figure 3.

Subhedral plagioclase grains commonly exhibit clear, narrow albite rims on altered cores that range from An_{30} to An_{60} probably averaging An_{35}. The cores display both normal and complex oscillatory zoning and are altered more or less intensely to sericite and epidote. Perthitic potash feldspar forms anhedral, inclusion-rich grains that are mostly untwinned but microcline twinning is not uncommon. The apparent replacement of other minerals, particularly plagioclase, by potash feldspar is a common feature.

Quartz forms aggregates of strained anhedral grains; yellow-green hornblende is commonly subhedral or anhedral and biotite forms shredded grains and locally pseudohexagonal crystals.

All the rocks have been altered to some degree; hornblende and particularly biotite may be changed to chlorite and epidote, plagioclase is almost invariably altered to epidote, sericite, clay minerals, and carbonate, and potash feldspar shows a dusting of clay minerals. Accessory minerals are sphene, apatite, zircon, and opaques.

Of the variations from the normal type the most striking is medium to coarse hornblendite found along the eastern side of Thuya batholith near North Thompson River. A partic-

[1]Takomkane Mountain is also known as Big Timothy Mountain.

[2]Subsequent to completion of the project the authors learned that Thuya batholith includes syenite and syendiorite near Rayfield River.

ularly large mass lies at the contact immediately west of Little Fort. This rock is rare and its relationship to the other rocks was not observed. Quartz-poor varieties, including pyroxene diorite and syenodiorite, are most common in the western part of Takomkane batholith near the area mapped separately as map-unit 14a but are found elsewhere. The large dyke near the highway south of Little Fort is fine- to medium-grained dark grey biotite quartz diorite.

Map-unit 14a. A strip along the western edge of Takomkane batholith consists of diorite and syenodiorite (map-unit 14a). Much information regarding this strip was provided by J. R. Woodcock of Vancouver. Some of the rocks resemble those of the remainder of the batholith but contain little if any quartz. One fairly common variety resembles larvikite; it contains dark potash and plagioclase feldspar, clinopyroxene, and olivine. Other rocks contain pyroxene, hornblende, and biotite as well as the two feldspars.

Nine miles northeast of Barrière a small intrusive body associated with the Fennell Formation consists of fine- and medium-grained augite-hornblende diorite. The plagioclase, in subhedral to euhedral crystals, is very heavily altered so that its composition could not be determined. Augite, both subhedral and anhedral, is partly replaced by hornblende. Epidote is a common and locally abundant alteration mineral.

Map-unit 14b. Leucogranodiorite and quartz monzonite (map-unit 14b) form the western phase of Thuya batholith. The rocks are similar to those of the eastern part of the batholith (map-unit 14) but contain much less mafic mineral, probably averaging less than 3 per cent. The plagioclase-potash feldspar-quartz ratio for 2 of 3 available modes falls within the range of those for the main parts of the two batholiths (*see* Table III and Figure 3). The third is richer in potash feldspar.

Structural Relations

The contacts of the Thuya and Takomkane batholiths and related intrusions are very poorly exposed and in places covered by extensive deposits of Tertiary rocks. On a broad scale the contacts are discordant with the layering of the invaded rocks but locally they are concordant.

TABLE III *Modal analyses of Thuya and Takomkane batholiths*

	Thuya batholith											
Spec.	1	2	3	4	5	6	7	8	9	10	11	12
Plagioclase	52	60	56	54	64	53	49	50	60	43	70	68
Potash feldspar	16	8	12	17	6	3	20	7	19	40	8	18
Quartz	20	18	16	12	15	14	15	19	17	13	19	13
Hornblende	7	1	8	13	11	7	11	4	2	1	1	1
Biotite	1	7	1		—	10	3	11	1	1	—	—
Accessory minerals	2	—	2	2	1	1	1	1	—	1	1	—
Alteration minerals	2	6	5	2	3	12	1	8	1	1	1	—

Note: 10, 11, 12 are leucocratic western phase (map-unit 14b)

Takomkane batholith																	
Spec.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
Plagioclase	61	46	47	53	52	47	63	50	48	48	47	57	44	57	57	64	54
Potash feldspar	12	15	19	14	20	17	7	9	36	9	37	16	20	6	10	11	24
Quartz	18	20	27	22	17	27	24	—	4	37	7	19	27	20	26	24	18
Hornblende	6	13	3	4	8	7	3	—	6	2	7	7	7	14	4	—	—
Biotite	—	2	1	3	2	1	1	4	4	3	—	—	—	—	1	—	3
Accessory minerals	2	2	1	2	1	1	1	3	1	1	2	1	1	3	2	1	1
Alteration minerals	1	2	2	2	—	—	1	2	—	—	—	—	1	—	—	—	—

Note: 8 contains 14% olivine and 18% clinopyroxene
9 contains 1% clinopyroxene
8, 9 are both map-unit 14a

Contacts with the Nicola Group are not sharply defined. A transition zone up to a mile wide contains rocks that are typical of the granitic batholiths, others typical of the Nicola Group or its metamorphic equivalents, and others that are rather hybrid-looking diorites that could belong to one side or the other of the contact. Locally the invaded rocks are very rich in augite, a phenomenon noted only near the contact of granitic masses with Nicola Group or Lower Jurassic rocks, and thus possibly a result of contact metamorphism. Cache Creek Group (map-unit 3) strata do not display obvious contact effects where cut by Thuya batholith or related rocks. Near Lupin Lakes and the head of Powder Creek quartzose hornblendic gneiss underlies a small area adjacent to the batholith but whether or not it is part of the Cache Creek Group is not known.

The age relations of the various phases of the batholiths are not known.

Thuya and Takomkane batholiths cut Upper Triassic and older rocks and are not known to cut younger sequences. The plutons are overlain by Eocene and Miocene or Pliocene volcanics; in some cases they are faulted against the former as well as against Lower Jurassic rocks.

Age and Correlation

From geological relationships mentioned previously the age of Thuya batholith is inferred to be Rhaetian or Hettangian, that is, very Late Triassic or very Early Jurassic. The compositional similarity of the Takomkane batholith and other minor intrusions to Thuya batholith indicates that they are contemporaneous.

Potassium-argon age determinations were made on two samples of Thuya batholith and one of Takomkane batholith. The latter is 187 m.y. for biotite (Leech, *et al.*, 1963, p. 42). One of the former, from the eastern or 'normal' phase of the batholith, is 194 ± 10 m.y. for biotite and 198 ± 28 m.y. for hornblende (R. K. Wanless, pers. com.); the other from the western leucocratic phase is 166 ± 11 m.y. for biotite (Wanless, *et al.*, 1967, p. 28). Three of the four ages are in excellent agreement and corroborate the geologically inferred age. The younger age is probably a result of argon loss from the biotite or it could represent the true age of a younger intrusive phase.

Cretaceous Granitic Rocks (Map-units 20, 20a, 20b)

Raft and Baldy Batholiths and Related Intrusions (Map-unit 20)

Names and Distribution

Raft batholith is named for Raft Mountain in Adams Lake map-area (Campbell, 1963b), just to the east of Bonaparte Lake map-area where it was first examined by Campbell. The batholith is 40 miles long in a west-northwesterly direction and a maximum of 10 miles wide. From its western end, near the eastern end of Canim Lake, it extends easterly to Clearwater River and beyond. North of Mahood Lake two oval-shaped bodies, 3 to 4 miles across, are texturally and compositionally similar to Raft batholith as is a small intrusion near the head of Canim Lake on the eastern shore and another just east of Hendrix Creek on the north boundary.

Baldy batholith, variously called Baldie granite, Baldie batholith, and Baldie biotite granodiorite and granite by Uglow (1922) is named for Baldy Mountain on the eastern boundary of the map-area east of Little Fort. The great bulk of the pluton is in Adams Lake

FIGURE 3. Plot of modal data for Thuya and Takomkane batholiths.

map-area (Campbell, 1963b); only its western end extends into Bonaparte River map-area. This batholith is about 25 miles long and reaches a maximum width of 15 miles. Like Raft batholith it is elongate in an east-west direction. It has a small satellite just north of Baldy Mountain.

Lithology

Most of the rocks of Raft and Baldy batholiths are granodiorite or quartz monzonite hence are appreciably more potassic than those of Thuya and Takomkane batholiths. They differ from the latter also in having less mafic mineral and a preponderance of biotite over hornblende.

The average of 22 modal analyses of samples of the two batholiths and related intrusions (with those for map-unit 14 in brackets) is 38 (50) per cent plagioclase, 25 (15) per cent potash feldspar, 30 (20) per cent quartz, 5 (3) per cent biotite, 1 (7) per cent hornblende, and 1 (5) per cent accessory and alteration minerals (*see* Tables III and IV and Figures 3 and 4).

Though Raft and Baldy batholiths have compositions significantly different from Thuya and Takomkane batholiths they differ little in texture except that the former are more dis-

FIGURE 4. Plot of modal data for Raft and Baldy batholiths.

tinctly porphyritic with pinkish, somewhat rectangular potash feldspar phenocrysts up to 1 cm long that are prominent and common though not ubiquitous.

Plagioclase displays prominent oscillatory zoning and albitic rims; it ranges widely in composition but most is probably about An_{25} to An_{30}. Potash feldspar seems to grade within single grains from twinned to untwinned varieties and characteristically forms large inclusion-rich grains of perthite. Quartz, biotite, and hornblende are not distinguished by unusual textures.

The compositions of the two batholiths seem to be fairly uniform but local variants were noted. There are narrow zones of hornblende diorite near the north contact of Raft batholith just west of Clearwater River. Aplitic and pegmatitic phases occur here and there but are not abundant. The body just east of Hendrix Creek on the north boundary is hornblendic and possibly should not be grouped with Raft and Baldy batholiths. It appears to intrude Lower Jurassic rocks.

TABLE IV *Modal analyses of Raft and Baldy batholiths*

Spec.	1	2	3	4	5	6	7	8	9	10
Plagioclase	42	50	45	59	53	40	38	36	35	50
Potash feldspar	20	8	17	14	8	30	20	21	18	16
Quartz	32	21	27	23	27	21	32	36	34	16
Hornblende	—	7	2	1	2	1	2	—	—	6
Biotite	5	13	7	2	9	8	6	7	12	10
Accessory minerals	1	1	2	1	1	—	1	—	1	2
Alteration minerals	—	—	—	—	—	—	1	—	—	—

Note: 8 and 9 from intrusions north of Mahood Lake.

	Baldy batholith											
Spec.	1	2	3	4	5	6	7	8	9	10	11	12
Plagioclase	21	45	33	34	24	38	34	39	45	14	25	40
Potash feldspar	40	22	31	29	33	26	9	23	18	34	53	20
Quartz	37	29	32	33	37	26	47	33	30	50	18	28
Hornblende	—	—	—	—	—	—	—	—	—	—	—	4
Biotite	1	4	4	3	6	9	9	3	4	2	3	2
Accessory minerals	1	—	—	1	—	1	1	1	1	—	1	1
Alteration minerals	—	—	—	—	—	—	—	1	2	—	—	5

Structural Relations

The contacts of Raft and Baldy batholiths are not well exposed. In the few places where they are seen they appear to be steep and discordant with respect to the layering or foliation of the surrounding rocks and this is consistent with the crosscutting relationships as seen on the scale of the map. The surrounding rocks are apparently only locally deformed by the emplacement of the plutons although they are metamorphosed commonly for only a few hundred yards but in some places up to several miles from the nearest granitic rock. Andalusite in the black phyllite of map-unit 10, sillimanite in the schist of map-unit 1 and biotite in rocks of map-unit 15 probably resulted from contact metamorphism related to Raft batholith. Pyroxene-rich rocks of map-unit 16 on the northern contact of Raft batholith may be the result of recrystallization in the contact zone.

Rocks that Uglow (1922) called pyroxenite and micropegmatite on Baldy Mountain are apparently mainly part of the Fennell Formation and seem to result from contact effects adjacent to Baldy batholith. In Adams Lake map-area metasedimentary rocks (phyllite) adjacent to Baldy batholith are converted to biotite schist and hornfels.

Raft batholith cuts rocks as young as early Jurassic and is overlain by plateau lavas (map-unit 25) and younger Tertiary volcanic deposits.

Age and Correlation

From geological relationships the rocks of map-unit 20 can be dated only as early Jurassic or later and pre-late Miocene although it seems almost certain that they were emplaced prior to the deposition of the Chu Chua beds and hence are pre-Eocene.

Potassium-argon age determinations on biotite were made from two samples from Raft batholith and two from Baldy batholith. The latter, both from the Adams Lake map-area, gave ages of 96 $\pm$ 5 m.y. and 80 $\pm$ 6 m.y. (Wanless, *et al.*, 1966, pp. 16-17) whereas the former gave 105 $\pm$ 9 m.y. and 140 $\pm$ 9 m.y. (Wanless, *et al.*, 1967, pp. 25-26). This encompasses the interval from Late Jurassic to mid-late Cretaceous. No explanation is apparent for the wide range in ages. It is interesting to note, however, that the oldest dates are from Raft batholith which is apparently less potassic, more calcic, and richer in mafics than Baldy batholith (*see* Fig. 4) and thus may be intermediate in both composition and age between the latter and the older Thuya and Takomkane batholiths.

Granitic Rocks near Fraser River (Map-unit 20a)

In the valley of Leon Creek southwest of Fraser River is a small area underlain by granitic rocks. These were not examined by the writers but were, together with other nearby intrusives, described by Trettin (1961) as follows:

> "The intrusions are composed of diorite, quartz diorite, granodiorite, and dacite. Quartz diorite is the commonest rock type. The plutonic rocks have a hypidiomorphic equigranular texture and are mostly medium grained. Many of the dyke rocks are porphyritic.
>
> "The essential minerals present are plagioclase, quartz, hornblende, and biotite; augite was noticed only in one specimen. "Iron ore" constitutes up to 2 per cent of the rock. Apatite is comparatively common as an accessory mineral, and zircon and sphene are rare.
>
> "That the quartz diorite has been emplaced by intrusion and not by processes of granitization is suggested by the cross-cutting relation of the granitic rocks and the very low grade of regional metamorphism in the country rocks suggesting shallow depth of emplacement."

Trettin, for various reasons, considers these intrusions to be "Early Lower Cretaceous or older" (Trettin, 1961, pp. 88–89) and no new evidence was obtained within this map-area to support or refute this idea. In Taseko Lakes map-area to the west Tipper (1963) found that the Coast Intrusions are of Late Cretaceous or Early Tertiary age. Also, less than twenty miles to the west, small granitic stocks intrude the Jackass Mountain Group of Early Cretaceous age. Furthermore, it has been established (Jeletzky and Tipper, 1968) that uninterrupted sedimentation in that area continued throughout Late Jurassic and most of Early Cretaceous time. For these reasons a Late Cretaceous or Tertiary age for these intrusions is probable. However, the possibility of some relation to the older granitic rocks of map-unit 14 cannot be ruled out.

Granitic Intrusion near Tintlhohtan Lake (Map-unit 20b)

Just northeast of Tintlhohtan Lake a small plug of leuco-quartz monzonite cuts the fragmental volcanic rocks of map-unit 16. The intrusive rock is light to medium grey and medium grained. Glassy to smoky, rounded quartz and fine biotite are scattered throughout the rock which consists mainly of light grey feldspar grains. In thin section the feldspar is seen to consist of albite and perthitic potash feldspar with the former being slightly more abundant. Scattered veinlets of smoky grey quartz carry molybdenite.

The age of this intrusive is not known other than that it cuts Lower Jurassic rocks. It may be of the same age as Raft batholith or it may be younger, equivalent, perhaps to the compositionally similar intrusive 50 miles to the southeast in Adams Lake map-area for which a potassium-argon age on biotite is 46 $\pm$ 5 m.y. (Wanless, *et al.*, 1966, p. 17).

Chapter IV

STRUCTURAL GEOLOGY

What is known of the structures of the rocks within and between individual map-units is discussed in the previous chapter. Three main elements of the structure, however, are mentioned here; major faulting in North Thompson River, Louis Creek and Lemieux Creek valleys; block faulting in the Eakin Creek region; and deformation in the Marble Range.

Faulting Along North Thompson River Valley

A major north-northwest trending fault extends from the southeast corner of the map-area down Louis Creek valley into North Thompson River valley and then into Lemieux Creek valley where it seems to splay into several branches. The general zone of faulting, however, may extend to Mahood Lake and beyond.

Though the actual fault or zone of faulting is not exposed its location can be fixed within very narrow limits in several places where prominent lithological or structural contrasts define its location such as, between map-units 12b and 16 in the southeast corner, between map-unit 12a and the Cache Creek Group on Armour Mountain, and possibly between the Fennell Formation and map-unit 10 along Lemieux Creek.

The southern part of the fault appears to be a single break or narrow zone but near Lemieux Creek it divides into several northwesterly trending branches. The principal branch is inferred to bring the Fennell Formation against the Cache Creek Group and map-unit 10. If this is so then the fault, which is evidently steep from Mann Creek south, apparently flattens and becomes a reverse or thrust fault near Mahood Lake. It must be emphasized, however, that compelling evidence of faulting between the Fennell Formation and map-unit 10 is lacking.

Jones (1959) showed several faults in and near Louis Creek valley to the southeast in Vernon map-area. One or all of these may be extensions of the fault discussed here. To the north in Quesnel Lake map-area (Campbell, 1961 and 1963a) the trace of the fault cannot be identified at present though this should be possible with further work. It may in some way continue into the fault that passes along Spanish Lake valley and thence northwestward to near the northwest corner of the Quesnel Lake map-area. The latter fault is thought to be a principal southward extension of the Pinchi Fault.

Block Faulting in Eakin Creek Region

Conspicuous on air photographs of the Eakin Creek region are the multitude of closely spaced topographic lineaments which, although some may be glacial, are largely a reflection of block-faulting, the main structural feature of this part of the map-area. These linear features are concentrated in an area between Bonaparte Lake and North Thompson River and northwestward through Canim Lake to Mount Timothy and Lac la Hache. The greatest

concentration is apparently north and south of Eakin Creek but this may be accounted for by thinner drift cover that permits a sharper topographic definition of the features. Elsewhere, as to the southeast around Mount Hagen where drift and forest cover are thicker the features are less prominent. The subduing of the features there may also be attributable to different rock types. These features apparently are confined to areas southwest and west of North Thompson fault and to the west they end abruptly at the margin of the plateau lavas (map-unit 25).

The distribution and orientation of these lineaments is illustrated in Figure 5. In the Eakin Creek area the preferred trend is northwest although north, northeast and east trends are noted. Around Canim Lake northeast trends are predominant and near Lac la Hache northwest trends are more common. In these areas the features with the dominant northwest trend are the longest uninterrupted and most deeply incised of all the lineaments. In Figure 5 only the obvious and largest lineaments are illustrated; between these, particularly around Eakin Creek, are literally hundreds of short linear features forming an intersecting network of faults or joints.

Unquestionably some joint systems when examined in outcrop are parallel with the major lineaments and no movement on these joints is indicated. However the major lineaments are oriented in so many directions it would be difficult to conceive of a joint set that

FIGURE 5. Pattern of block faulting in Eakin Creek region (northest part) and normal faults in Marble Range (southwest part).

was not parallel or subparallel with some of them. This is particularly true of Thuya batholith (map-unit 14) which appears to be shattered by thousands of closely spaced joints, fractures, and/or faults.

The writers believe these features are a result of erosion along a system of closely spaced faults to which the joint systems of the area may or may not be related. Admittedly some of these lineaments may result from erosion along prominent joints but these are few. The reasons for believing that block faulting is responsible for this topographic effect are as follows:

1. In many places the lineaments mark abrupt changes in lithology within one map-unit.
2. Rocks of different ages are in contact along these lineaments in several places.
3. In several places blocks of older or younger rocks are introduced into areas of younger or older rocks respectively and this can be explained most readily by block faulting.
4. Where the rocks along these lineaments are exposed, a narrow zone of brecciation, shearing, and slickensiding is present.

Although detailed information about the faults is lacking, most appear to be near vertical. No fault surfaces were sufficiently well exposed to provide reliable information on relative movement. The amount of displacement on these faults is not thought to be great. Mapping clearly shows that Jurassic and Triassic rocks are more thoroughly fractured by the faulting than the early Tertiary rocks which are cut by relatively few widely spaced faults. The Cretaceous Raft batholith does not exhibit the closely spaced fractures characteristic of the older Thuya and Takomkane batholiths.

This block faulting is the main or only deformation that has disrupted the Late Triassic and Early Jurassic rocks (map-units 10, 11, 15 and 16). Nowhere do these rocks give evidence of a widespread, systematic deformation by folding. They consist of numerous distinct blocks apparently with a single, consistent attitude throughout each single block, but completely disoriented with respect to one another. Certainly it is improbable that the Mesozoic rocks were tightly folded prior to block faulting.

The age of the block faulting can be established with reasonable assurance. The Deadman River Formation (map-unit 24) and map-unit 25 are not cut by any of these faults and so the faulting can be no younger than late Miocene. The Eocene and (?) Oligocene Skull Hill Formation is cut by the faults so that block faulting must have occurred between Eocene and late Miocene time. However, the Skull Hill Formation is much less fractured than the Early Jurassic and Late Triassic rocks suggesting that at least two episodes of faulting took place, one prior to the eruption of the Skull Hill Formation and one later, possibly a result of further movement on some earlier faults. In this way the difference in amount of fracturing of older and younger rocks can be explained.

When the earlier episode of block faulting occurred is not definitely known. Unquestionably it was in part later than Early Jurassic (Sinemurian) although it could have occurred repeatedly over a long period. Significantly Raft batholith does not show the intense fracturing characteristic of Thuya and Takomkane batholiths. Possibly the block faulting and the Raft batholith, are related to the same Cretaceous structural event.

Deformation in the Marble Range

The southwest part of the map-area is dominated by the Marble Range but includes the Edge Hills and other small ridges and hills. This structurally disturbed area is isolated from the deformed rocks of the eastern part of the area by the great expanse of flat-lying

lavas (map-unit 25) in the central plateau. Within the Marble Range and the surrounding hills the strata reveal an episode of folding and thrusting and an episode of normal faulting whose interpretation has a bearing on the structural history of the area and of the Cordillera as a whole.

Several pronounced lineaments (*see* Fig. 6) trend northwesterly parallel or subparallel to the trend of the Marble Range in an area bounded on the northeast by the basaltic plateau lavas (map-unit 25) and on the southwest by the Fraser River fault. These lineaments are believed to be normal faults related to the episode of block faulting in the eastern part of the area; beneath the lava cover, the two areas of faulting are thought to merge and be indistinguishable.

The fault between Edge Hills and Marble Range that apparently truncates the structure of the Edge Hills is a zone of intense shearing and brecciation. The faults cutting the Marble Range, where exposed, also exhibit much shearing. Between Tsilsalt Ridge and Hart Ridge, two Jurassic (?) units (map-units 17 and 18) have been downfaulted forming a graben in the Cache Creek Group (map-unit 4). Near the west end of Loon Lake the Cache Creek Group (map-unit 4) is in fault contact with the Skull Hill Formation (map-unit 22) as evidenced by a zone of shearing, brecciation, and alterations.

The sense of movement on these faults is not indicated by the fault zones themselves. The faults are near vertical and have a pattern similar to that in the Eakin Creek region. In the Marble Range vertical displacement does not appear to be great for none of the faults seem to disrupt greatly the fold pattern of the range, as shown by Trettin (1966, p. 101) in his section across Mount Soues. The sense of movement is thus not known, but is probably normal, and related in time to the faulting in the Eakin Creek region.

The faulting is later than the folding of the Pavilion and Cache Creek Group. Trettin, who recognized the folding in the Marble Range, described the structure as follows (Trettin, 1966, pp. 98–99):

> "The overall structure of the range is a northwesterly plunging anticlinorium *en echelon* with a synclinorium.... The structure of the synclinorium is complicated, and has not been studied in detail. In the central parts of the anticlinorium, folds formed in member A are relatively simple and shallow. On the flanks of the anticlinorium, they show complex drag-folding. In the western parts of the range, folds formed in member C change, in southwestward direction from open and upright to isoclinal and overturned. These changes in structural style can partly be attributed to changes in the thickness of the limestones, and partly to structural disturbances on the southwest (Fraser River fault zone)...."

From a study of the Mount Kerr section, Tipper concluded that the synclinorium is made up of the lower part of Marble Canyon Formation with map-unit 5 at the base and that these rocks have been thrust southwesterly onto the upper part of Marble Canyon Formation.

The Pavilion Group has also been folded and Trettin commented as follows (Trettin, 1961, p. 23):

> "In most localities the strata of Division I (map-units 7 and 8) strike northwesterly and dip steeply. Marker beds are scarce and stratigraphic tops could be determined only at a few localities. Judging from the well stratified and plastic nature of the rocks they are tightly folded...."

From the foregoing it is apparent that the Cache Creek Group in the western part of the area and the Pavilion Group were folded, possibly at the same time. As the Pavilion

Group is involved, the time of folding is not likely older than Middle or Early Triassic. Presumably the Cache Creek Group in the eastern part of the map-area was folded at the same time. In the discussion of the block faulting in the Eakin Creek region it was pointed out that the Late Triassic rocks (map-units 10 and 11) were not folded. If this lack of folding in Late Triassic and younger rocks is true also for the whole area then the folding of the Cache Creek and Pavilion Groups is no younger than Late Triassic and no older than Early or Middle Triassic.

A mid-Triassic orogeny has been recognized in northern British Columbia (Souther and Armstrong, 1966, pp. 173–174). Possibly the mid-Triassic folding in Bonaparte River map-area is a reflection of that orogeny.

Chapter V

ECONOMIC GEOLOGY

Some parts of the Bonaparte Lake map-area are believed to have considerable potential for mineral exploration. This applies particularly to the region underlain by Triassic and Jurassic volcanic and sedimentary assemblages intruded by plutonic rocks having a variety of ages. The main geological features of the Princeton-Merritt-Kamloops copper producing area seem to be duplicated in Bonaparte Lake map-area, including somewhat similar fracture patterns expressed by topographic lineaments (M. Schau, pers. com.; *see* discussion in Chapter IV). To the northwest the same general belt contains the Boss Mountain molybdenum mine and several significant copper properties. Known mineral occurrences, of which many are listed in the succeeding section, provide ample evidence that deposits of economic interest are to be found within the map-area.

In the writer's opinion both the plutonic and the intruded rocks merit careful search. The widespread though not necessarily thick cover of glacial and recent deposits suggest that geophysical and geochemical prospecting techniques should be useful.

Description of Properties

The location of properties is shown on the index map (Fig. 6). The number in the brackets following the name of each property corresponds to the number marking the location of the property on the index map.

Placer Deposits

Eakin or Three Mile Creek (1)

References: Uglow, W. L.: Geology of the North Thompson Valley Map-area, B.C.; Geol. Surv. Can., Sum. Rept. 1921, pp. 101A–102A (1922). Ann. Rept., Minister of Mines, B.C., 1931, p. A108 (1932).

Eakin Creek flows into Lemieux Creek, west of Mount Olie, on the North Thompson River. Recorded attempts to recover gold, present in gravels of this creek, took place in the early 1920s and 1930s and a small amount of coarse gold was obtained. This gold was derived, according to Uglow, from a boulder conglomerate of the Chu Chua Formation, which is located just upstream from the gold-bearing gravels.

Louis Creek Placer (2)

References: Ann. Rept., Minister of Mines, B.C., 1913, p. K207 (1914); 1931, p. 109A (1932). Uglow, W. L.: Geology of the North Thompson Valley Map-area, B.C.; Geol. Surv. Can., Sum. Rept. 1921, pp. 101A–102A (1922).

FIGURE 6. Index map of properties in Bonaparte Lake map-area.

Louis Creek flows into the North Thompson River about 37 miles north of Kamloops. Gold is present in the creek gravels and placer mining was carried out at this locality as early as 1861, and continued sporadically until about 1932. Small amounts of placer gold were recovered. Uglow considers that the gold was probably derived originally from quartz veinlets in schists of the Shuswap region.

McLure Mines (3)

Reference: Ann. Rept., Minister of Mines, B.C., 1931, p. A109 (1932).

Placer mining leases were obtained to exploit bench-ground at McLure on the North Thompson River, 28 miles north of Kamloops. Expected values did not materialize.

Gold, Silver, Copper, Molybdenum, Lead and Zinc Properties

Mahood Lake (4)

Reference: Ann. Rept., Minister of Mines, B.C., 1924, p. B153 (1925)

A sample of possible gold-silver ore from the south side of Mahood Lake was recorded in 1924.

Clearwater (5)

Reference: Robinson, W.C.: Ann. Rept., Minister of Mines, B.C., 1964, p. 99 (1965).

Molybdenum showings occur on the west side of the Clearwater River 6 miles north of Clearwater in granitic rocks of Raft batholith. Claims are held by Southwest Potash Corporation, Vancouver. Molybdenum mineralization is present mainly in a set of narrow, widely spaced quartz veinlets. In 1964, 2 holes totalling 1,414 feet were drilled.

Sands Creek (6)

References: Walker, J. F.: Clearwater River and Foghorn Creek Map-area, Kamloops District, British Columbia; Geol. Surv. Can., Sum. Rept. 1930, p. 153A (1931). Stevenson, J. S.: Molybdenum Deposits of British Columbia, B.C. Dept. Mines, Bull. 9, pp. 33–34 (1940). McCammon, J. W.: Ann. Rept., Minister of Mines, B.C., 1961, pp. 51–53 (1962).

Molybdenite has been reported since 1930 from Sands Creek, a small stream flowing into Clearwater River about 2 miles north of Clearwater Station on the Canadian National Railways.

Claims were located during 1959-1960 and exploration carried out in 1960-61 by the Calder Molybdenum Company Limited but no development has taken place.

Molybdenite is present both in quartz veins and pegmatitic dykes cutting granodiorite and also disseminated through the granodiorite.

Empire and Bluebird (7)

Reference: Ann. Rept., Minister of Mines, B.C., 1934, p. D26 (1935).

The properties were located 1 mile north of Clearwater Station on the Canadian National Railways. Pyrite, galena and sphalerite are in quartz veins in schists.

Lemieux Creek (8)

Reference: Ann. Rept., Minister of Mines, B.C., 1924, p. B152 (1925).

Silver-lead ore was reported in 1924 from a locality near the head of Lemieux Creek which enters the North Thompson River at Mount Olie.

Friendly Lake (9)

References: Robinson, W. C.: Ann. Rept., Minister of Mines, B.C., 1965, p. 159 (1966). Waterland, T. M.: Ann. Rept., Minister of Mines, B.C., 1966, p. 143 (1967).

Claims held by Anaconda American Brass, Limited, at Friendly Lake about 20 miles by road northeast of Bridge Lake consist of sulphides, including pyrite, galena, molybdenite, chalcopyrite and bornite disseminated and as seams and blebs in fractures in andesite and tuff.

Mann Creek (10)

Reference: Uglow, W. L.: Geology of the North Thompson Valley Map-area, B.C.; Geol. Surv. Can., Sum. Rept. 1921, p. 105A (1922).

This prospect is situated 1½ miles from the mouth of Mann Creek which enters the North Thompson River south of Black Pool.

Black graphitic schist associated with the Fennell Greenstone is stained with azurite and malachite at this locality.

Queen Bess (11)

References: Ann. Rept., Minister of Mines, B.C., 1895, p. 665 (1896); 1918, pp. K234–236 (1919); 1951, pp. A125–A128 (1952). Uglow, W. L.: Geology of the North Thompson Valley Map-area, B.C.; Geol. Surv. Can., Sum. Rept. 1921, pp. 102A–103A (1922). Walker, J. F.: Clearwater River and Foghorn Creek Map-area, Kamloops District, British Columbia; Geol. Surv. Can., Sum. Rept. 1930, pp. 140A–143A (1931).

The Queen Bess property is located on the east side of North Thompson River valley, 1,000 feet above the valley bottom and 3 miles south of the Canadian National Railways station at Black Pool.

Crown grants were issued for the Ironclad and Lone Prospector claims in 1895. Exploitation of this property by the Queen Bess Mines Company took place between 1917 and 1920, when underground work was carried out, a mill constructed, and a small amount of concentrates produced. Last reported work on the property was in 1927. In 1951, the Lone Prospector and Ironclad claims, covering most of the showings, were owned by G. F. McGregor of the Spar-Mac Ranch at Black Pool.

Erratic mineralization occurs mainly in three narrow fissures, the two main ones being known as the Cameron and Bigelow veins. These fissures are in greenstones of the Fennell Formation (map-unit 2). Mineralization consists of sphalerite, galena and minor tetrahedrite, with disseminated sulphides in quartz and quartz dolomite gangue in leaner parts of the veins.

The first mill run of 720 tons gave 27 tons of lead concentrates assaying 40 to 50 per cent lead, 12 per cent zinc and 48 ounces of silver per ton, and 78 tons of zinc concentrates assaying 48 per cent zinc, 7 to 8 per cent lead and 14 ounces of silver per ton.

Underground workings of this property have been examined and described in some detail by Uglow, Walker and McCammon (Ann. Rept., Minister of Mines, B.C., 1951, pp. A125–A128 (1952)).

Silver Lake (12)

References: Ann. Rept., Minister of Mines, B.C., 1926, p. A187 (1927); 1927, p. C192 (1928); 1930, p. A192 (1931).

This property is 20 miles northwest of Mount Olie, on the North Thompson River, exploration work was reported in 1926, 1927 and 1930.

Zinc, with some lead and silver are reported to occur in a mineralized shear zone in black argillite.

Tintlhohtan Lake (13)

References: Stevenson, J. S.: Molybdenum Deposits of British Columbia; B.C. Dept. Mines, Bull. 9, pp. 20–28 (1940). McCammon, J. W.: Ann. Rept., Minister of Mines, B.C., 1961, pp. 49–51 (1962). Robinson, W. C.: Ann. Rept., Minister of Mines. B.C., 1965, p. 160 (1966).

Molybdenite claims were staked both in 1938-1939 and in 1960-1961 northeast of Tintlhohtan Lake, 12 miles northwest of Little Fort in North Thompson River valley.

Investigation both in 1938-1939, when the ground was known as the Anticlimax property, and in 1960-1961 by the Calder Molybdenum Company Limited has not resulted in development. Molybdenite occurs in pegmatite and quartz veins and lenses in an alkali-granite stock.

The property is described in some detail by Stevenson and McCammon.

Nehalliston Creek (14)

Reference: Waterland, T. M.: Ann. Rept., Minister of Mines, B.C., 1966, p. 144 (1967).

Near the head of Nehalliston Creek on the southwest side of Silver (Deer) Lake copper-lead-zinc claims are held by the United Copper Corporation, Limited.

Little Fort (15)

Reference: Waterland, T. M.: Ann. Rept., Minister of Mines, B.C., 1966, p. 143 (1967).

Ten miles northwest of Little Fort on claims held by Anaconda American Brass, Limited, pyrite, magnetite, pyrrhotite, and chalcopyrite occur in fracture fillings in dioritic and volcanic rocks.

Lakeview (16)

References: Ann. Rept., Minister of Mines, B.C., 1930, pp. A191–192 (1931); 1931, p. A108 (1932). B.C. Dept. Mines, Bull. 1, pp. 68–69 (1932).

This property, situated 9 miles west of Mount Olie on the North Thompson River, was discovered in 1930. It was acquired by the Premier Gold Mining Company who carried out exploration during 1930-1931, but abandoned the property in 1931.

Gold is associated with arsenopyrite, in a massive pyrrhotite and magnetite replacement body in limestone.

Windpass–Gold Hill properties (17)

References: Ann. Rept., Minister of Mines, B.C., 1916, p. K266 (1917); 1917, pp. F219–221 (1918); Pt. A, 1925, pp. A167–A170 (1926); 1934, pp. D26–D27 (1935); 1961, p. 49 (1962). Uglow, W.L.: Geology of the North Thompson Valley Map-area, B.C.; Geol. Surv. Can., Sum. Rept., Pt. A, 1921, pp. 99A–100A (1922). B.C. Dept. Mines, Bull. 1, pp. 68–69 (1932).

This group of properties is west of Baldy Mountain, east of Dunn Lake, and about 8 miles north-northeast of Chu Chua.

Gold-bearing quartz was discovered in 1916 and a car-load sample was shipped from Windpass No. 1 claim. Additional claims, the Sweet Home, Gold Hill, Keystone and Red Top, were located nearby. Development work proceeded sporadically before and during early 1920s but ceased in 1925. The Windpass and Sweet Home properties were further developed by Windpass Gold Mining Company Limited in 1933 and subsequent years when a mill was constructed and concentrates produced. The mines were closed in 1939. Fort Reliance Minerals Limited now hold mineral leases covering the former Windpass properties.

On the Windpass property, the mineralization is in a quartz vein cutting a pyroxenite sill. Free gold, gold tellurides, bismuth chalcopyrite and magnetite are associated. On the Sweet Home claims a quartz vein, crossing the contact between the pyroxenite sill and banded chert of the Fennell Formation (map-unit 2) contains gold, chalcopyrite, pyrite and bismuth. Mineralization is in two shear zones in greenstones of the Fennell Formation on the Gold Hill property. These shear zones are altered to siliceous ferrodolomite, and cut by quartz stringers which contain free gold together with galena, chalcopyrite, pyrite and sphalerite.

Assays from shipments made in 1916 and 1917 are, respectively gold, 2.40 ounces per ton, silver, 0.90 ounce per ton, and copper 1.46 per cent; gold, 2.14 ounces per ton, silver, 1.40 ounces per ton and copper, 0.58 per cent.

Allies (18)

References: Uglow, W.L.: Geology of the North Thompson Valley Map-area, B.C.; Geol. Surv. Can., Sum. Rept., 1921, pp. 100A–101A (1922).

This prospect is on the west side of the North Thompson River, 2 miles north of Chinook Cove.

Quartzites and concordant feldspar porphyry and felsite dykes of the "Badger Creek Formation" (included in the Cache Creek Group in this report) contain quartz veins. Pyrite, galena and chalcopyrite are disseminated through the veins.

Fortuna Group; Skookum Claim (19)

References: Ann. Rept., Minister of Mines, B.C., 1908, p. J123 (1909); 1913, pp. K209–210 (1914); 1918, p. K236 (1919). Uglow, W.L.: Geology of the North Thompson Valley Map-area, B.C.; Geol. Surv. Can., Sum. Rept. 1921, pp. 104A–105A (1922).

The Fortuna Group was located about 8 miles southeast of the Canadian National Railways Station of Louis Creek. The Skookum claim is located about ½ mile north of the Fortuna.

The Fortuna property was worked in 1907–1908 by the Fraser River Copper Mining Company; no subsequent work has been reported.

Pyrite replacing a dolomite bed in argillaceous schists and quartzites of map-unit 12a form the main orebody. Traces of copper mineralization and minor amounts of galena are present. Gold, silver and copper have been reported both from this body, and from quartz stringers in the schists. Platinum was reported in small amounts in the pyrite although Uglow states that analyses of picked samples failed to show any trace of platinum.

The Skookum claim consists of a narrow zone of pyrite and chalcopyrite in quartzites of map-unit 12a.

Vidette Lake Area (20)

References: Stevenson, J.S.: Ann. Rept., Minister of Mines, B.C., 1931-1940 (1931-1941); especially 1936, pp. F36–F43 (1937). B.C. Dept. Mines, Bull. 1, p. 71 (1932). Cockfield, W.E.: Lode gold deposits of Fairview Camp, Camp McKinney, and Vidette Lake area, and the Dividend-Lakeview property near Osoyoos, B.C.; Geol. Surv. Can., Mem. 179, pp. 26–36 (1935).

Several properties, around the northern half of Vidette Lake on Deadman River, were owned by Vidette Gold Mines Ltd., Hamilton Creek Gold Mines Ltd., and Savona Gold Mines Ltd., the latter company owning the Last Chance–Sylvanite group of claims.

These properties were developed during the thirties, but the only one exploited extensively was owned by Vidette Gold Mines Ltd. This property was located in 1931, was subsequently developed, a mill constructed, and the mine remained in nearly continuous operation until 1940, when it was abandoned.

The ore deposits occur in narrow, fairly continuous quartz veins in greenstone of the Nicola Formation (map-unit 11). Mineralization consists of pyrite, chalcopyrite and reported tellurides, accompanied by gold.

Maximum recorded production for 1 year from the Vidette property was in 1936, when 12,202 tons of ore yielded 8,269 ounces of gold, 13,037 ounces of silver and 27,672 pounds of copper.

The workings have been described in detail by Cockfield and Stevenson.

70-Mile House (21)

Reference: Waterland, T.M.: Ann. Rept., Minister of Mines, B.C., 1966, pp. 135–136 (1967).

Bornite is reported in claims held by Cominco, Limited, 15 miles due east of 70-Mile House. It occurs as fracture fillings and minor disseminations in syenite (map-unit 14).

C-Soo Group (22)

Reference: Waterland, T.M.: Ann. Rept., Minister of Mines, B.C., 1966, pp. 135–136 (1967).

The C-Soo Group of claims east of 70-Mile House, at the head of Campeau Creek, is reported as a copper prospect. Copper Soo Mining Company Limited had geophysical and geochemical surveys conducted in 1966.

Lac la Hache (23)

Reference: Waterland, T.M.: Ann. Rept., Minister of Mines, B.C., 1966, p. 135 (1967).

Six miles northeast of Lac la Hache on claims owned by Anaconda American Brass Limited, veins carrying galena, chalcopyrite and sphalerite with associated malachite and azurite occur in andesite (map-unit 11).

North of Lac la Hache (24)

Reference: Waterland, T.M.: Ann. Rept., Minister of Mines, B.C., 1966, p. 135 (1967).

Twelve miles northeast of Lac la Hache, on claims held by Coranex Limited, Vancouver, chalcopyrite occurs as fracture fillings and as disseminations in Nicola volcanic rocks (map-unit 11).

Chromite Occurrence

North of Clinton (25)

References: Ann. Rept., Minister of Mines, B.C., 1932, p. A154 (1933).

On the west side of the Bonaparte River, 7 miles north of Clinton on claims owned by W.N.D. McKay, Clinton, in a serpentinized belt of dunite numerous nodules of high-grade float and narrow segregations of speckled chromite in place were reported.

Nickel Deposit

South of Clinton (26)

Reference: Reinecke, L.: Mineral Deposits between Lillooet and Prince George, British Columbia; Geol. Surv. Can., Mem. 118, p. 96 (1920).

Garnierite was reported about 4½ miles south of Clinton, ½ mile west of Highway 97. An assay reported 0.11 per cent nickel and 0.17 per cent chromium oxide, Cr_2O_3.

Manganese Deposits

Clinton (27)

References: Reinecke, L.: Mineral Deposits between Lillooet and Prince George, British Columbia; Geol. Surv. Can., Mem. 118, p. 95 (1920). Holland, S.S.: Ann. Rept., Minister of Mines, 1948, pp. 91–92 (1949).

Manganese occurs in three locations in the west half of the map-area. Near the base of the Marble Range, about 10 miles northwest of Clinton in argillites and cherts of the Cache Creek Group, a deposit, owned by W. Murray, New Westminster, contains psilomelane, manganite and pyrolusite. Assay results were manganese 7.59 per cent, silica 82.57 per cent, and phosphorus 0.018 per cent.

Just west of the Pacific Great Eastern Railway $3\frac{1}{2}$ miles southwest of Clinton, brick coloured cherty quartzite with thin films of black manganese along fracture surfaces assayed about 0.75 per cent manganese. In an open-cut, rock mineralized with pyrolusite in stringers assayed 15.8 per cent manganese.

On the southeast side of Hart Ridge, 4 miles southeast of Clinton, manganese oxides occur in narrow fractures in white- or yellow-stained quartzite.

Chrysotile Occurrences

Clinton (28)

References: Dawson, G.M.: Geol. Surv. Can., Ann. Rept. VII B, 1894, p. 345 (1896). Robinson, W.C.: Ann. Rept., Minister of Mines, B.C., 1960, pp. 130–132 (1961).

Across the road from the Mond Ranch, 6 miles by road northeast of Clinton, chrysotile in veinlets generally narrower than $\frac{1}{16}$ inch is abundant in a small serpentine mass.

Small veins of chrysotile or serpentine asbestos occur on the south side of Mount Soues, southeast of Clinton.

Coal

Chu Chua Coal Mining Syndicate (29)

References: Dawson, G.M.: Report on the area of the Kamloops map-sheet, British Columbia; Geol. Surv. Can., Ann. Rept. (New Series), vol. VII, 1894, p. 228B (1896). Ann. Rept., Minister of Mines, B.C., 1920, p. N168 (1921); 1922, p. N146 (1923). Uglow, W.L.: Geology of the North Thompson Valley Map-area, B.C.; Geol. Surv. Can., Sum. Rept., 1921, pp. 92A–98A (1922).

Coal occurs in the lower part of Newhykulston Creek, south of Chu Chua in the North Thompson River valley, about 50 miles north of Kamloops.

First recorded examination of the deposits was in 1877. Development and exploitation of the property was undertaken by the Chu Chua Coal Mining Syndicate and a small amount of coal produced. The property was shut down in 1923. The coal forms thin seams in shales and sandstones of the Eocene Chu Chua Formation and is classified as low-rank bituminous, or high-rank sub-bituminous.

A detailed report on the property is given by W.L. Uglow.

Canim Lake (30)

References: Ann. Rept., Minister of Mines, B.C., 1923, p. A168 (1924).

Annual Report of the B.C. Minister of Mines for 1923, notes that 'an occurrence of coal is reported in the vicinity of Canim Lake'.

Saline Lakes

Saline lakes have been known in the western half of the map-area for many years and these have been discussed by Reinecke (1920, pp. 51–62) and Cummings (1940, pp. 1–24, 30–32, 40–41, 60–61) and it is from their reports that the following information is taken. For complete information on these lakes and their history, the reader is referred to the reports by Reinecke and Cummings and the additional references mentioned there. So far as is known there has been no interest in these lakes in recent years.

The saline lakes are small and undrained in which the concentration of salts has occurred as a result of evaporation. The important dissolved salts are sodium carbonate, magnesium carbonate, sodium sulphate, and magnesium sulphate. The source of the salts is apparently the underlying rocks from which the material is leached and carried by surface drainage or springs into the lake basins. It has also been suggested that water from volcanic activity has been a direct source of the salts.

Soda Lakes (31)

References: Reinecke, L.: Mineral Deposits between Lillooet and Prince George, British Columbia; Geol. Surv. Can., Mem. 118, pp. 57–63 (1920). Cummings, J.M.: Saline and Hydromagnesite Deposits of British Columbia; B.C. Dept. Mines, Bull. 4, pp. 1–24 (1940).

Soda lakes contain brines with mainly dissolved sodium carbonate (Na_2CO_3) or sodium carbonate, magnesium carbonate ($MgCO_3$) and other salts in small quantities. In this area they are restricted entirely to areas of flat-lying plateau lavas (map-unit 25). The lakes are fed by surface drainage as well as by springs. Soda lakes are concentrated south, southeast and east of Meadow Lake, northwest, northeast and east of 70-Mile House, and near Mount Begbie. From some of these a small commercial production has been carried out.

Epsomite Lakes (32)

References: Reinecke, L.: Mineral Deposits between Lillooet and Prince George, British Columbia; Geol. Surv. Can., Mem. 118, pp. 51–57 (1920). Cummings, J.M.: Saline and Hydromagnesite Deposits of British Columbia; B.C. Dept. Mines, Bull. 4, pp. 40–41 (1940).

Two small lakes southeast of Clinton contain epsomite (magnesium sulphate). The lakes lie on Cache Creek Group rocks (map-unit 4) of which basic lavas are a major rock type. Presumably surface water and springs percolating through these rocks have leached magnesium sulphate which was concentrated by evaporation in these lakes.

Hydromagnesite Deposits

Deposits of hydromagnesite occur in four areas in the west half of the map-area. These deposits are small and have been described by Reinecke (1920, pp. 20–49) and Cummings (1940, pp. 102–129). Hydromagnesite deposits in this area are a mixture of hydrated magnesium carbonate, calcium carbonate and magnesium sulphate.

Meadow Lake (33)

References: Reinecke, L.: Mineral Deposits between Lillooet and Prince George, British Columbia; Geol. Surv. Can., Mem. 118, pp. 44–46 (1920). Cummings, J.M.: Saline and Hydromagnesite Deposits of British Columbia, B.C. Dept. Mines, Bull. 4, pp. 102–108 (1940).

The Meadow Lake deposits comprising about five areas of fairly pure hydromagnesite occur ½ to 2 miles east of Meadow Lake. They underlie an area calculated by Cummings (1940, p. 104) to be 244,000 square yards. Tonnage calculated by Cummings (1940, p. 105) was 114,200 tons.

Watson Lake (34)

References: Reinecke, L.: Mineral Deposits between Lillooet and Prince George, British Columbia; Geol. Surv. Can., Mem. 118, pp. 46–48 (1920). Cummings, J.M.: Saline and Hydromagnesite Deposits of British Columbia; B.C. Dept. Mines, Bull. 4, pp. 108–110 (1940).

The deposit is situated ¼ mile south of Watson Lake, a small lake about one mile east of Tatton station on the Pacific Great Eastern Railway, southeast of Lac la Hache. Several small areas totalling 26,000 square yards contain an estimated 23,500 tons of hydromagnesite (Cummings, 1940, p. 109).

Clinton (35)

References: Reinecke, L.: Mineral Deposits between Lillooet and Prince George, British Columbia; Geol. Surv. Can., Mem. 118, p. 44 (1920). Cummings, J.M.: Saline and Hydromagnesite Deposits of British Columbia; B.C. Dept. Mines, Bull. 4, pp. 112–113 (1940).

The Clinton deposits lie in the valley of Clinton Creek, about ½ mile east of Clinton. Three small hydromagnesite deposits have an area of 3,310 square yards and have a tonnage of 2,650 tons.

Sixtyone Creek (36)

Reference: Cummings, J.M.: Saline and Hydromagnesite Deposits of British Columbia; B.C. Dept. Mines, Bull. 4, pp. 113–114 (1940).

A deposit of hydromagnesite lies about 4 miles north of Chasm Provincial Park. Cummings (1940, p. 113) reported that it covers an area of 13,000 square yards and contains a probable 9,000 to 10,000 tons.

Magnesite Occurrences

Lac la Hache (37)

Reference: Camsell, C.: Note on the occurrences of diatomaceous earth, clay, and magnesite along the route of the Pacific Great Eastern Railway. Geol. Surv. Can., Sum. Rept., Pt. B, 1917, p. 25 (1918).

On the southwest side of Lac la Hache, hard, white, fine-grained magnesite is reported in volcanic rocks as a number of short, narrow veins. Chemical analysis showed the composition to be magnesium carbonate 70 per cent, calcium carbonate 27 per cent, and iron 2 per cent.

Clinton (38)

Reference: Cockfield, W.E., and Walker, J.F.: An occurrence of magnesite near Clinton, British Columbia; Geol. Surv. Can., Sum. Rept., Pt. AII, 1932, pp. 72–73 (1933). Ann. Rept., Minister of Mines, B.C., 1947, p. 220 (1948).

About 6 miles from Clinton and a mile east of the Mond Ranch, magnesite occurs in badly altered, basic rock, now consisting largely of serpentine. The magnesite apparently formed from surface alteration of this rock. Complete alteration produces a china-white, dense magnesite of good quality.

Travertine Deposit

Clinton (39)

References: Reinecke, L.: Mineral Deposits between Lillooet and Prince George, British Columbia; Geol. Surv. Can., Mem. 118, pp. 49–51 (1920). Merritt, J.E.: Ann. Rept., Minister of Mines, B.C., 1948, p. 188 (1949); 1949, p. 256 (1950); 1953, p. 191 (1954).

A dome-shaped deposit of travertine or calcareous tufa located 3 miles west of Clinton on the Pacific Great Eastern Railway is owned by Clinton Lime Holdings, Limited, Vancouver. The deposit is bedded and consists of firmly compacted rock. From 1947 to 1953 agricultural lime was produced.

Gypsum

Louis Creek Deposit (40)

Reference: Davis, A.W.: Ann. Rept., Minister of Mines, B.C., 1922, pp. N153–N154 (1923).

A small deposit of relatively pure 'gypsite' on the North Thompson River, near Louis Creek, about 40 miles north of Kamloops was judged capable of limited production by Davis but no subsequent development has been recorded.

Volcanic Ash

Deadman River (41)

References: Eardley-Wilmot, V.L.: Siliceous Abrasives; sandstones, quartz, tripoli, pumice, and volcanic dust; Mines Branch, Dept. Mines, Canada, No. 673, pp. 87–89 (1927). Ann. Rept., Minister of Mines, B.C., 1959, pp. 181–185 (1960). Roman Pozzolan in B.C.; Western Miner and Oil Review, p. 52 (1959).

Acid volcanic ash of late Tertiary age, which outcrops in the Deadman River valley near Snohoosh Lake, has been considered at different times as a possible source of abrasive material or of pozzolan. The ash is in flat-lying beds of irregular thickness, and large outcrops form steep bluffs on the sides of Deadman River valley. The commonest type is buff to grey or yellow and medium grained, but may be coarser. It consists mainly of devitrified glass, with quartz and feldspar fragments. Beds of white ash, within the buff ash, are extremely fine grained and uniform and composed of fragments of clear volcanic glass.

Prior to 1927, the white ash bed at Sherwood (Last Chance) Creek, a tributary flowing into Snohoosh Lake, was staked and about 1 ton of material removed. Later, ash staked by T.C. McAlpine as a source of pozzolan, was examined in March, 1959, by C. Riley, for Industrial Minerals Ltd., a privately owned company. Preliminary estimates of the deposits were placed at 15 million tons. Little development work had been done at this time (1959) and no subsequent development has been reported.

Muscovite

Mahood Lake (42)

Reference: Cummings, J.M.: Ann. Rept., Minister of Mines, B.C., 1947, p. 226 (1948).

Muscovite mica of possible commercial value is present near Mahood Lake, although, according to Cummings, the proportion of mica of marketable grade is too low to be exploited profitably.

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INDEX

PAGE

Adams Lake Series....19, 36, 38
albite....68, 76
alkali feldspar.... 68
amphibole....20, 34, 41, 68
andalusite....13, 31, 75
Antler Formation....14, 18
argillite.... 20
  Cache Creek Group.... 20
Armour Mountain.... 77
  rocks.... 36
arsenopyrite.... 86
Asitka Group.... 23
Associated Helicopters.... 2
augite....40, 43
augite porphyry breccia.... 42

Badger Creek Formation.... 19
Baldie batholith.... 72
Baldie biotite granodiorite.... 72
Baldie granite.... 72
Baldy batholith....17, 72
  modal analyses.... 74
Baldy Mountain....16, 72, 75
Bamber, E. W....22, 30
Barrière Formation....36, 38
basaltic cinder cone.... 66
basaltic sand and breccia.... 64
basaltic rubble deposits.... 65
basaltic volcanoes.... 66
Berry, D. W.... 49
biotite.... 69
Blackpool microwave station.... 16
block faulting....77, 79
  Eakin Creek Region.... 77
blocky basaltic flows.... 67
bornite....84, 88
Boss Mountain molybdenum deposit.... 69
breccia.... 15
  Fennell Formation.... 16
  Cache Creek Group.... 20
Bullock Helicopters.... 2

Cache Creek Group....18, 38, 39, 41, 43, 45, 67
  argillite.... 20
  breccia and conglomerate.... 20
  chert.... 20

PAGE

Cache Creek Group (*cont.*)
  eastern part (Map-unit 3).... 19
  folding.... 80
  foliation.... 21
  garnets.... 20
  graben.... 80
  greenstone.... 20
  Mount Soues Division....24, 25
  Windy Mountain....19, 21
  ribbon chert.... 24
  schistosity.... 21
  type area.... 23
  western part (Map-units 4–6).... 23
Campbell, K. V....2, 15
Canadian National Railways.... 1
Canim Lake.... 5
  lava near.... 64
Cariboo Group....8, 14, 18, 32
  Map-unit 1.... 8
Cariboo Mountains, source of ice.... 6
chalcopyrite....84, 86, 87, 88
chert.... 16
  Fennell Formation.... 16
  Cache Creek Group.... 20
  Pavilion Group.... 29
Chilliwack Group.... 23
chlorite schist.... 13
chromite.... 88
chrysotile occurrences.... 89
Chu Chua Coal Mining Syndicate.... 89
Chu Chua Formation....17, 46, 51, 52, 54, 82
cinder cone on Trophy Mountain.... 65
Clearwater River.... 62
  lava near....62, 64
Clearwater River valley.... 8
Clearwater Valleys, Tertiary beds.... 46
clinopyroxene....15, 34, 70
Clinton.... 1
coal.... 89
Coast Mountains....7, 64
  rise.... 64
  source of ice.... 7
Coldwater Beds....45, 53, 54
Coldwater Group.... 52
Coldwater Series.... 52
Columbia Mountains.... 8

PAGE

conglomerate....20, 39
Cache Creek Group....20
Map-unit 15....39
contact metamorphism (Map-unit 10)....31
copper....87
Cretaceous granitic rocks....72

Danner, W. R....27
Deadman River Formation....45, 56, 63
deformation in Marble Range....79
diatomite....56, 58, 59
diorite....69
direction of ice movement....7
Domai, K....2
drumlins....5, 7

Eagle Bay Formation....38
Eakin Creek....20
block faulting in....77
economic geology....82
epidote....13, 15, 20, 34, 41, 68
eskers....6
extinct volcanoes....64

Farquaharson, R. B....2, 63
Fennell batholith....14
Fennell Formation....13, 14, 17, 19, 31, 32, 37, 38
chert....16
Map-unit 2....13, 14
foliation....17
thrusting....17
folding....80
of Cache Creek Group....80
of Pavilion Group....80
foliation....13
Cache Creek Group....21
Fennell Formation....17
Map-unit 1....13
Map-unit 10....31
Map-unit 12....37
Fortuna Group....87
fossils near Lemieux Creek....32
Fraser Plateau....5
Fraser River....54
fault zone....54, 80
granitic rocks....75
oligocene volcanic and sedimentary rocks 54
Frebold, H....41
fusilinids....22, 27

galena....84, 85, 87, 88
garnet....8, 13, 68
Cache Creek Group....20
Giovanella, C. A....2
glacial deposits....6
glacial grooves....7
glacial silts....6
glacial streams....6
glacial striae....7
glaciation....5

PAGE

gold....82, 83, 86, 87
gold-silver ore....83
gold tellurides....86
Gordon, T. M....2
graben, in Cache Creek Group....80
granitic intrusion near Tintlhohtan Lake....76
granitic rocks near Fraser River....75
Green Mountain....13
greenstone....20
Cache Creek Group....20
Nicola Group....34
Guichon Creek....45
Guyet Formation....18
gypsum....92

Hamilton Creek Gold Mines Ltd....87
Hemp Creek....48
heulandite....43
hornblende....15, 40, 69
hornblende-biotite granodiorite....69
hornblende diorite....74
hornblende porphyry....42
hornblendic gneiss....71
hornblendite....22, 69
Hueber, F. M....48, 60

ice-margin meltwater channels....6
Interior Plateau....4, 5
intrusive rocks....67

Jackass Mountain Group....45
Jeletzky, J. A....32
Jurassic (?) rocks near Clinton....44
Jurassic volcanic clastic rocks, origin....44

Kamloops....1
Kamloops Group....46, 52, 53, 64
history and correlation....51
Kamloops Series....52, 53
Kamloops Volcanic Group....52, 53
Kaza or Cariboo Group (Map-unit 1)..8, 14, 18
kettle topography....6

larvikite....70
laumontite-prehnite-quartz facies....40
Lemieux Creek....30, 31
fossils....32
leucogranodiorite....69
leucoxene....15
limestone....25
Marble Canyon Formation....25
Pavilion Group....29
Little Fort....5
Lone Butte....64
Louis Creek valley....37
fault....37, 77
Lowes, B. E....2

magnesite....91
magnetite....86

PAGE

Mahood Lake....8, 30, 31
lava....62, 64
manganese deposits.... 88
Mann Creek.... 62
lava....62, 64
Mann Creek Formation.... 52
Map-unit 4.... 24
Map-unit 5.... 24
Map-unit 10....18, 30
contact metamorphism.... 31
foliation.... 31
Map-unit 12.... 36
Map-unit 15.... 39
conglomerate.... 39
volcanic-clastic rock.... 40
Map-unit 16.... 42
Map-unit 16a.... 43
Map-unit 26a.... 65
Map-unit 26b.... 66
Mara Formation.... 38
marble.... 13
Marble Canyon Formation....23, 25, 26, 27
limestone.... 25
Marble Range....5, 7, 25, 28, 79, 80
deformation.... 79
Mesozoic eugeosynclinal deposition.... 8
Miocene-Pliocene sediments and volcanics.. 56
micropegmatite.... 75
molybdenite....76, 84, 85
molybdenum.... 84
Mount Begbie....63, 64
Mount Ida Group....18, 38
Mount Kerr....25, 26
syncline.... 25
Mount Soues....24, 26, 28
Mount Soues Division.... 24
Cache Creek Group....24, 25

Nestell, M. K.... 27
Newhykulston Creek.... 89
nickel deposit.... 88
Nicola Group....33, 39, 41, 71
greenstone.... 34
Map-unit 11.... 33
Nisconlith Series....19, 36, 38
normal faulting.... 80
North Thompson River....1, 5
lava.... 64
North Thompson River valley.... 77
faulting.... 77
North Thompson Valley....37, 46
fault....37, 77
Tertiary beds.... 46

Oligocene volcanic and sedimentary rocks along Fraser River.... 54
olivine.... 70
olivine basalt.... 62
olivine crystals.... 67
olivine gabbro.... 63
Omineca Geanticline.... 8

PAGE

Pacific Great Eastern Railway.... 1
Pavilion Group.... 25
chert.... 29
folding.... 80
limestone.... 29
Map-units 7 and 8.... 29
pegmatite.... 8
perthitic potash feldspar.... 76
physiographic subdivisions.... 4
physiography.... 4
pillow structures, Fennell Formation.... 15
Pinchi Geanticline.... 8
placer deposits.... 82
plagioclase....69, 74
Plateau lava.... 62
platinum.... 87
Pleistocene or Recent cinder cone.... 66
Pliocene or Pleistocene volcanic deposits.... 64
potash feldspar....68, 69, 74
potassium-argon age determination....51, 71, 75, 76
pre-Eocene surface.... 51
prehnite....34, 40
near Skwilkwakult Mountain.... 41
Preto, V. A. G.... 42
Pyramid Mountain.... 66
pyrite....84, 86, 87
pyroxene andesites.... 62
pyroxene diorite.... 70
pyroxene phenocrysts.... 42
pyroxenite....43, 75
pyrrhotite.... 86

quartz diorite.... 69
quartz-hornblende-mica schist.... 13
quartz-mica schist.... 13
quartz monzonite.... 69
Queen Bess property.... 85
Quesnel Highlands.... 5
Quesnel Trough.... 8

Raft batholith....13, 18, 31, 32, 40, 41, 43, 72
contact.... 13
modal analyses.... 74
Raft Mountain.... 72
recent volcanic rocks.... 67
Rhaetian or Hettangian granitic rocks.... 68
ribbon chert in Cache Creek Group.... 24
Ross, C. A....22, 26, 28
Rouse, G. E....48, 55, 60

saline lakes.... 90
Sands Creek.... 84
Savona Gold Mines Ltd.... 87
Savona Mountain....52, 53
Schau, M.... 44
schistosity in Cache Creek Group.... 21
scoriaceous lavas.... 62
Sentinels, the.... 42
serpentinite.... 67

PAGE

Shuswap Highlands..... 5
Shuswap Metamorphic Complex.....8, 14
Sicamous Formation..... 38
Sicker Group..... 23
sillimanite.....8, 13, 75
silver..... 87
silver-lead ore..... 84
Skull Hill..... 20
Skull Hill Formation.....17, 48, 50, 52, 54
Skwilkwakult Mountain..... 41
Slide Mountain Group.....14, 18
Smith, M. A..... 2
Snowshoe Formation.....8, 14
Spanish Creek..... 67
sphalerite.....84, 85, 88
structural geology..... 77
syenite and monzonite..... 68
syenodiorite.....69, 70
syncline on Mount Kerr..... 25

Takla Group.....36, 42
Takomkane batholith.....34, 68
  modal analyses..... 70
Takomkane Mountain..... 69
Taylor Creek Group..... 45
tetrahedrite..... 85
Thompson Plateau..... 5
thrusting..... 80
Thuya batholith.....22, 33, 34, 39, 67, 68
  modal analyses..... 70

PAGE

Thuya Creek..... 68
till grooves..... 5
Tintlhohtan Lake, granitic intrusion near.... 76
topographic lineaments..... 77
Tozer, E. T.....32, 35
tranquille beds.....51, 52, 53
Trophy Mountain..... 8
  cinder cone..... 65
  lava..... 65
Tsalkom Formation.....18, 38
Tyaughton Group..... 36

Upitis, U..... 2

Vidette Gold Mines Ltd..... 87
Vidette Lake Area..... 87
volcanic ash..... 92

Ward Creek Assemblage..... 54
Windpass-Gold Bill properties..... 86
Windy Mountain.....19, 22, 39, 41
  Cache Creek Group.....19, 21
Woodcock, J. R..... 70

yellow-green hornblende..... 15

zeolites.....15, 67
zoisite..... 15

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