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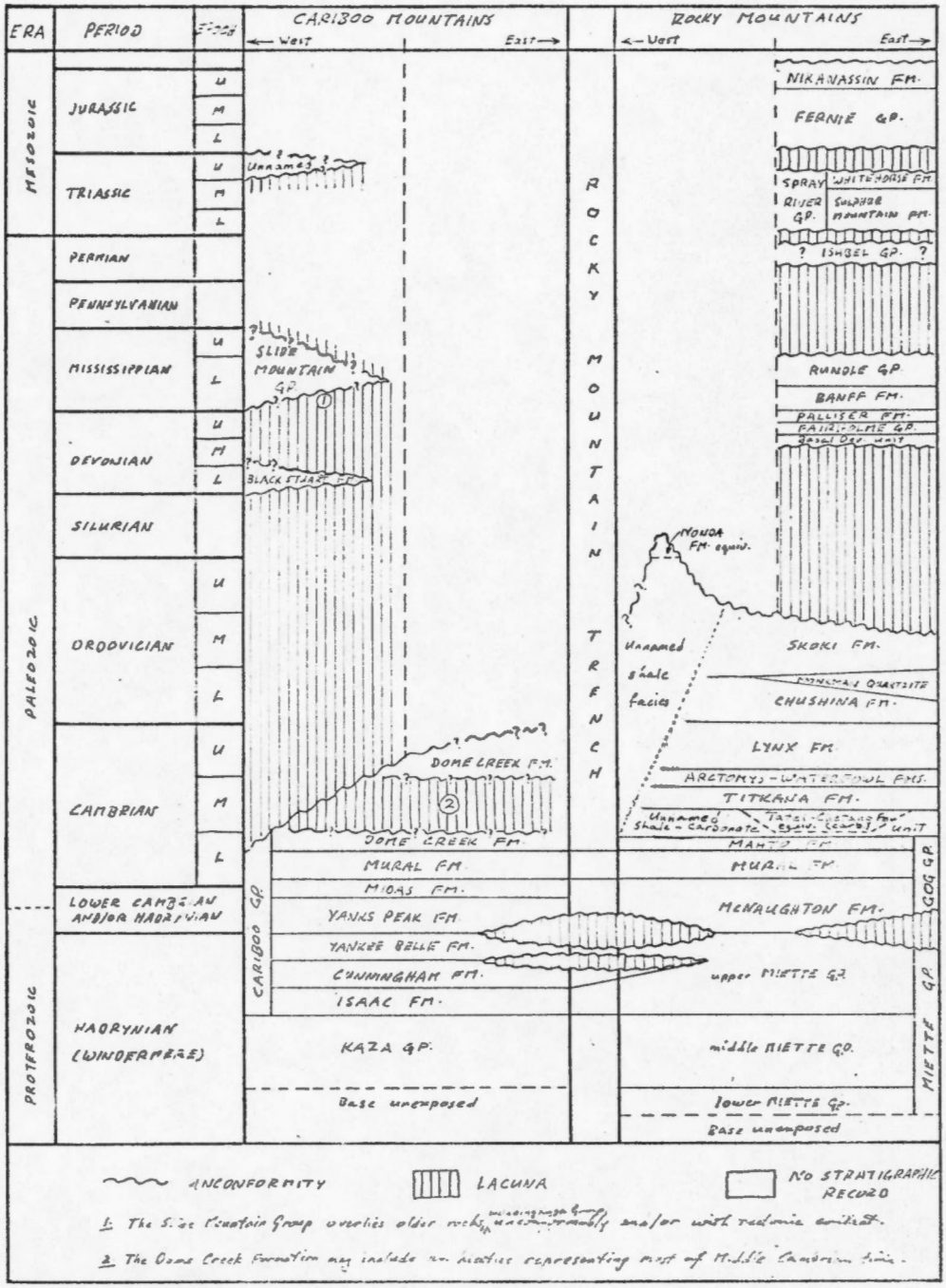

Figure 3. Correlation chart, McBride map-area, British Columbia

TABLE OF FORMATIONS (GALENA MINE'S & VICINITY PLATEAU)

CENOZOIC	QUATERNARY	GLACIAL MORAINE—GRAVELS, FLUVIO-GLACIAL SANDS, SILT, GRAVEL, RECENT ALLUVIUM; TILL?		
UNCONFORMITY				
MESOZOIC OR CENOZOIC	UPPER CRETACEOUS OR EARLY TERTIARY	BOWRON RIVER COAL MEASURES (0 - 2000' +)		CONGLOMERATE, BRECCIA, SANDSTONE, SHALE, COAL
UNCONFORMABLE CONTACT WITH SLIDE MOUNTAIN GROUP				
MESOZOIC	UPPER TRIASSIC	UNNAMED UNIT (THICKNESS UNKNOWN)		DARK GREY TO BLACK PHYLLITE & ARGILLITE, MINOR QUARTZITE AND LIMESTONE
RELATIONSHIP UNKNOWN				
PALEOZOIC	LOWER MISSISSIPPIAN AND/OR YOUNGER	SLIDE MOUNTAIN GROUP	ANTLER FORMATION (3-5000' +)	PILLOW BASALT, BRECCIA, TUFF, BEDDED CHERT, ARGILLITE, GREYWACKE
			CONFORMABLE CONTACT	
	LOWER MISSISSIPPIAN AND (?) OLDER		GUYET FORMATION 1100-1500'	CONGLOMERATE, SANDSTONE, ARGILLITE, BASALT, LIMESTONE
UNCONFORMITY ?				
	LOWER DEVONIAN AND (?) YOUNGER		BLACK STUMP FORMATION (0-2000')	ARGILLITE, CHERT, LIMESTONE, SANDSTONE, DOLOSTONE, BRECCIA.
UNCONFORMITY				
	UPPER & LOWER CAMBRIAN (MIDDLE CAMBRIAN MAY BE ABSENT)	CARIBOO GROUP	DONE CREEK FORMATION (0-4000'+)	SHALE, SILTSTONE, ARGILLITE, MINOR LIMESTONE
			GRADATIONAL CONTACT	
	LOWER CAMBRIAN		MURAL FM. (500-2000'+)	LIMESTONE, DOLOSTONES, SHALE, MINOR SILTSTONE
			CONFORMABLE CONTACT	
PALEOZOIC AND PROTEROZOIC	LOWER CAMBRIAN AND HADRYNIAN		NIDAS FM (300-1000'+)	SHALE, SILTSTONE, MINOR SANDSTONE
			CONTACT CONFORMABLE	
			YANK PEAK FM. (0-1900')	GREY, WHITE, PINK QUARTZITE, MINOR SILTY SHALE
			GRADATIONAL CONTACT	
PROTEROZOIC	HADRYNIAN (WINDERMERE)		YANKEE BELLE FM. (900-3000')	INTERBEDDED SHALE, SILTSTONE, LIMESTONE, MINOR SANDSTONE AND DOLOSTONE.
			GRADATIONAL TO DISCONFORMABLE CONTACT (?)	
			CHUNJINA FM. (?200-1600')	LIMESTONE, MINOR GREY SHALE, DOLOSTONE NEAR ROCKY MOUNTAIN TRENCH
			GRADATIONAL CONTACT	
			ISMAY FM (?300-500')	GREY TO BLACK PHYLLITE AND SHALE, MINOR SILTSTONE, SANDSTONE & LIMESTONE
		GRADATIONAL CONTACT		
		KASLO GROUP (INCLUDES SLOCAN FORMATION)		INTERTUNING UNITS OF FELDSPATHIC GRIT AND GREY PHYLLITE OR SCHIST
BASE NOT EXPOSED				

TABLE OF FORMATIONS (NOCKOLDS MTS)

CENOZOIC	QUATERNARY	GLACIAL MORAINE—GRAVELS FLUVIO-GLACIAL SANDS, SILT, GRAVEL, RECENT ALLUVIUM		
UNCONFORMITY				
MESOZOIC	UPPER JURASSIC AND LOWER CRETACEOUS	NIKANASSIN FORMATION (5-6000' ?)		QUARTZ ARENITE INTERBEDDED WITH SILTY SHALE
CONFORMABLE CONTACT				
	LOWER TO UPPER JURASSIC	FERNIE GROUP (1500 - 3000' ?)		BLACK TO GREY SHALE; MINOR SILTSTONE
UNCONFORMABLE CONTACT				
	MIDDLE TO UPPER TRIASSIC	WHITEHORSE FORMATION (1500 - 3000')		LIGHT GREY LIMESTONE AND DOLOSTONE; SANDY CARBONATES
CONFORMABLE CONTACT				
	LOWER AND MIDDLE TRIASSIC	SULPHUR MTN FORMATION (1500' ?)		SILTSTONE, SILTY LIMESTONE
UNCONFORMABLE CONTACT				
PALEOZOIC	PERMIAN	ISHBEL GROUP (PRENCE UNCERTAIN)		CHERT, SANDSTONE
DISCONFORMITY				
	LOWER TO UPPER MISSISSIPPIAN	RUNDLE GROUP (1000' ?)		CRINOIDAL, MICRITIC OR CHERTY LIMESTONES AND DOLOSTONES
CONFORMABLE CONTACT				
	LOWER MISSISSIPPIAN	BANFF FORMATION (EST. 700 - 1000')		ARGILLACEOUS SHALES, THIN-BEDDED LIMESTONE
CONFORMABLE CONTACT				
	UPPER DEVONIAN	PALLISER FORMATION (800 - 1000' ?)		DARK GREY MICRITIC LIMESTONE
CONFORMABLE CONTACT				
		ALEXO FORMATION (0-50')		RECESSIVE, LIGHT YELLOW-GREY ARGILLACEOUS CARBONATE (?) ROCKS
UNCERTAIN CONTACT RELATIONSHIP				
		FRASNIAN GROUP (APPROX. 1500')		LIMESTONE (SOUTHESK FM.) DARK SHALE (PEERIX-MT. HAW FM.) MICRITIC LIMESTONE, SHALE (FLUME FM.)
RELATIONSHIP TO SILURIAN UNKNOWN, UNCONFORM. ON ORDOVICIAN				
	SILURIAN	NONDA FM. (? 5000' +)		THIN-BEDDED LIMESTONE, CHERTY LIMESTONE; DOLOSTONE, QUARTZ ARENITE, SHALE
RELATIONSHIP UNKNOWN				
	LOWER TO MIDDLE ORDOVICIAN	SKOKI FORMATION (450 - 2000')		GREY TO BROWN DOLOSTONE SHALY FACIES ON BEARPAW RIDGE?
CONFORMABLE CONTACT				
	LOWER ORDOVICIAN	MONKMAN QUARTZITE (30 - 100')		WHITE WEATHERING QUARTZ ARENITE
CONFORMABLE CONTACT				
		CHUSHINA FORMATION (1500 - 1700')		LIMESTONE, SILTY DOLOSTONE, GREEN-GREY SHALE. SHALY FACIES ON BEARPAW RIDGE?
GRADATIONAL CONTACT				
	UPPER CAMBRIAN	LYNX FORMATION (1700 - 2000')		LIGHT GREY, WELL-BEDDED SILTY LIMESTONE AND DOLOSTONE SHALY FACIES ON BEARPAW RIDGE?
CONFORMABLE CONTACT				
	MIDDLE AND UPPER (?) CAMBRIAN	ARCTOMYS WHITEFOWL FORMATIONS (500 - 800')		RED AND YELLOW - WEATHERING SANDSTONE & ARGILLACEOUS DOLOSTONE, MINOR SILTSTONE & LIGHT GREY LIMESTONE SHALY FACIES ON BEARPAW RIDGE?
CONFORMABLE CONTACT				
	MIDDLE CAMBRIAN	TITKANA FORMATION (500 - 1000')		CLIFF-FORMING LIMESTONE AND DOLOSTONE DOLOSTONE ON BEARPAW RIDGE?
CONFORMABLE CONTACT				
	LOWER (?) TO MIDDLE CAMBRIAN	UNDIVIDED CARBONATE AND SHALE INTERVAL (200 - 1200')		BANDED SLATY SHALE, ARGILLACEOUS LIMESTONE, MICRITIC LIMESTONE, MAROON TO GREY-BROWN SHALE. SHALY FACIES ON BEARPAW RIDGE ?
CONFORMABLE CONTACT				
	LOWER CAMBRIAN	GOG GROUP	MAHTO FM (800-1000')	GREY TO PINK QUARTZITE, MINOR SILTSTONE AND SHALE
GRADATIONAL CONTACT				
			MURAL FM (700-1250')	LIMESTONE, DOLOSTONE, GREEN TO GREY SHALE, SANDSTONE, MINOR SILTSTONE
CONFORMABLE CONTACT				
PALEOZOIC AND PROTEROZOIC(?)	LOWER CAMBRIAN AND HADRYNIAN (?)		McWRIGHT FM. (2000-1500')	QUARTZITE, FELDSPATHIC AND PEBBLY AT BASE; INTERBEDDED SHALE AND FINE-GRAINED QUARTZITE (HOLMES RIVER MEMBER)
DISCONFORMITY WITH UPPER MIETTE FORMATION				
PROTEROZOIC	HADRYNIAN (WINDERMERE)	MIETTE GROUP		
			UPPER MIETTE (4-5000')	DARK GREY ARGILLITE AND PHYLLITIC SHALE; MINOR SILTSTONE AND FELDSPATHIC GRIT
CONFORMABLE CONTACT				
			MIDDLE MIETTE (?-9000 ?)	COARSE, ARKOSIC, PREDOMINANTLY PEBBLY SANDSTONE GRIT, GREY PHYLLITIC SHALE
CONFORMABLE CONTACT				
			LOWER MIETTE (2-3000'?)	BLACK, SLATY SHALE, MICRITIC LIMESTONE
BASE NOT EXPOSED				

GEOLOGY OF
McBRIDE MAP-AREA
BRITISH COLUMBIA

(93-H)

R.B. Campbell
E.W. Mountjoy
F.G. Young

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ABSTRACT

McBride map-area, about 5,800 square miles in east-central British Columbia, includes parts of the Interior Plateau, Cariboo Mountains, Rocky Mountain Trench, Rocky Mountains, and Foothills.

About 25,000 feet of Proterozoic (Windermere) and Lower Cambrian strata can be correlated in some detail from Rocky to Cariboo Mountains. The precision of the correlation, based partly on lithologic similarities, depends primarily on the obvious equivalence of the fossiliferous Lower Cambrian carbonate (Mural Formation) in each sequence.

The stratigraphy above the Lower Cambrian differs sharply from one side of the Trench to the other. In Rocky Mountains a carbonate-shale Cambro-Ordovician sequence, much like that at Mount Robson, becomes shaly near the Trench where overlying Silurian strata including volcanic rocks. The Upper Devonian to Permian and Mesozoic sedimentary rocks of the Front Range and Foothills are similar to those of the well-known Jasper-Banff region. West of the Trench Lower Cambrian beds pass upward to a Middle (?) and Upper Cambrian shale sequence that is unconformably overlain by Lower Devonian and (?) younger sedimentary rocks which in turn lie discordantly below conglomerate and basaltic pillow lava at least partly of Lower Mississippian age. These are followed by unconformably overlying Upper Triassic (?) phyllite and shale. The Upper Triassic and Lower Jurassic volcanic rocks of the Interior Plateau are just west of the map-area.

Minor dykes and sills and a small body of serpentinite are the only known intrusive rocks in the map-area.

Typical Rocky Mountain thrust faults are confined to the eastern Main Ranges, Front Ranges, and Foothills. Farther west in Rocky Mountains and also west of the Trench folding is prominent and recognizable faults are steeply dipping. In Cariboo Mountains folding in structurally deep beds apparently passes gradationally upward to a highly faulted and little folded terrane.

To date the only significant mineral production was from the gold placer and lode deposits near Barkerville. The Bowron River coal deposits have been extensively explored. Small copper showings are known near Dome Creek.

CHAPTER I

INTRODUCTION

Location and Access

McBride map-area comprises about 5800 square miles in east-central British Columbia between 53° and 54° N ~~latitudes~~ and 120° and 122° W ~~longitudes~~. Newly constructed Highway 16 and the Prince Rupert line of Canadian National Railways traverse the area diagonally from southeast to northwest. Prince George is about 30 miles west of the northwestern corner and Quesnel about 20 miles west of the southwestern corner. An all-weather road from Quesnel provides access to Wells, Barkerville, and Bowron Lake. Logging and mining roads extend into much of the western part of the area, principally west of Bowron River valley, but road-access off the main highway is limited in the mountainous central and eastern parts.

Precipitation is heavy; summers are usually cool and rain is common. In most years snow constitutes a serious handicap to travel above about 5,500 feet elevation until July 1st. Vegetation cover is dense and forest growth is extensive below timberline at about 6,000 feet elevation.

Physiography and Glaciation

Parts of four major physiographic divisions occupy McBride map-area - Rocky Mountains, Rocky Mountain Trench, Columbia Mountains, and Interior Plateau (See Fig. ~~4~~ 2). The Foothills of the Rocky Mountains cross the extreme northeastern corner of the map-area. The Front and Main Ranges of the Rockies, mainly part of the Park Ranges (Holland, 1964) extend from the Foothills to the Trench. Only in the northeast do these exhibit the topography characteristic of the Rocky Mountains in the Banff-Jasper region where gently to moderately-dipping cliff-forming strata alternate with recessive units. An example is the Mount Sir Alexander massif which resembles Mount Robson. South from McGregor River and Bastille Creek the geological control of topography is not so evidence and the mountains do not have a distinctive "Rocky Mountain" appearance but are similar to most parts of the adjacent Cariboo Mountains.

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At McBride the Rocky Mountain Trench is a flat-floored steep-walled valley but northward it becomes wider and major breaches in the valley walls are prevalent. Beyond the north end of Cariboo Mountains the southwestern wall no longer exists and the Trench merges with the Interior Plateau and loses its identity. It resumes on a different trend farther to the north where it is occupied by Parsnip River (Holland, 1964).

Cariboo Mountains constitute the most northerly range of Columbia Mountains. In both Cariboo and Rocky Mountains summit elevations range upwards from 7,000 feet except in the northwest near the Trench where summits are between 6,000 and 7,000 feet elevation. In general the mountain ranges do not display extensive, relatively flat ridge-crests or upper surfaces although locally, where they pass transitionally to the Interior Plateau, they do exhibit this character. Maximum relief is about 7,000 feet but generally is about 4,000 feet in the mountains.

The Interior Plateau is represented mainly by the Quesnel Highland in McBride map-area. As shown in Figure 4 the boundaries are modified from those established by Holland (1964). Summit elevations in the highland range from about 5,500 to 7,000 feet but most are close to 6,000 feet. Extensive, rolling, concordant surfaces characterize the ridge-tops although valley-sides are as steep as those in the mountains. Maximum relief is about 3,500 feet but the average is probably somewhat less than 2,500 feet.

The remainder of the Interior Plateau within the map-area includes Fraser Plateau and a small part of Fraser Basin (Fig. 4 and Holland, 1964). With rare exceptions summit elevations in Fraser Plateau are below 5,000 feet and relief generally is less than 2,000 feet. The broad, gently-rolling upper surface of the plateau is one of very low relief. Fraser Basin is an area of gently rolling topography mainly below 3,000 feet. The basin lies along the valleys of Fraser River and its major tributaries from which it passes into the surrounding plateau. The configuration of the basin suggests that the ancestral upper Fraser River drained to the north and presumably involved reverse or northward flow of a large part of the river south from Prince George (Holland, 1964).

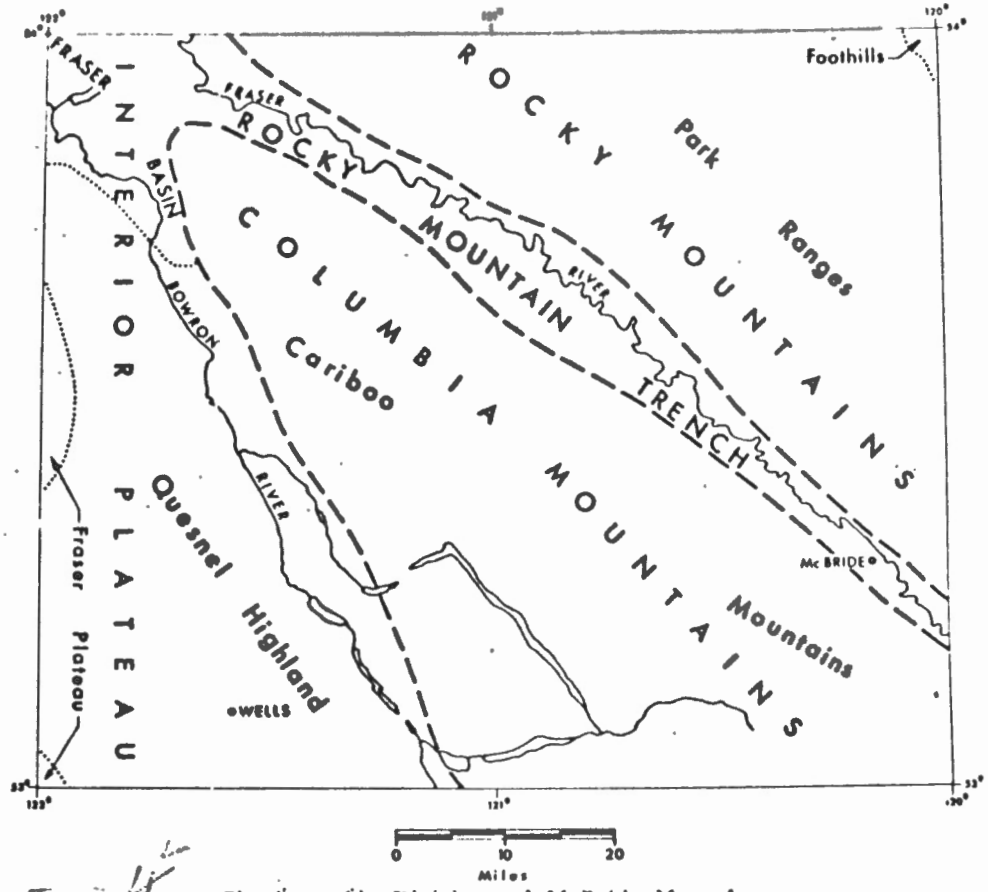

Fig. 4 — Physiographic Divisions of McBride Map-Area
Modified from Holland (1964)

Enlarge

During the last major glacial advance ice flowed north and northeast across the Interior Plateau in and near McBride map-area. Cariboo Mountains were apparently largely inundated by the last ice sheet but evidence of flow directions is not clear. Presumably ice flowed northerly and northeasterly but apparently did not flow over and through Rocky Mountains (Tipper, 1971). At some stage in late glacial history ice flowed northwesterly or westerly from northern Cariboo and/or adjacent Rocky Mountains because distinctive quartzite in drift on the Interior Plateau almost certainly originated from one or other of the adjacent mountain ranges.

Both Cariboo and Rocky Mountains supported extensive valley glaciers that developed from cirques and ice caps at elevations of 5,500 feet or higher. At present accumulation of ice occurs above about 7,500 feet.

Previous Work

The earliest systematic geological work in McBride map-area was that of Amos Bowman (1889) who conducted a remarkable reconnaissance in 1885 and 1886 around and south of the Cariboo gold-placer area centred on Barkerville. Johnston and Uglow (1926) published the results of an extensive study of the geology and placer and lode deposits of the Barkerville area. Much subsequent detailed work was restricted to that general area, for example Hanson (1938a ~~and 1938b)~~ and Holland (1948b). In two projects Sutherland Brown (1957 and 1963) studied a large region that overlapped the older work and extended eastward into Bowron Lake Provincial Park. His work was of great value to the writers.

No systematic studies were carried out in other parts of the map-area until recently. Malloch (1910) conducted a reconnaissance along the Rocky Mountain Trench between Tête Jaune Cache and Prince George. Sorensen (1955) reported on observations of the geology along part of the Trench, particularly in Cariboo Mountains near Goat River.

The geology of Rocky Mountains within the area was essentially unknown until Slind and Perkins (1966) published the results of their regional stratigraphic study of the Proterozoic and Lower Paleozoic rocks between Jasper and Pine Pass.

Many studies and brief examinations of the Bowron River coal basin have been reported over the years (e.g. Holland, 1948a; Sutherland Brown, 1967). Except in the Wells-Barkerville gold-producing region and the Bowron River coal district mineral discoveries have been rare hence little data is available from Annual Reports of the British Columbia Department of Mines and Petroleum Resources.

Present Work

Study of the geology of McBride map-area was undertaken by Campbell as an extension of his work in southern Cariboo Mountains in Quesnel Lake (1961, 1963; with K.V. Campbell, 1970; and with J.L. Mansy, 1970) and Canoe River (1968a) map-areas. He worked in the area during the summers of 1966 and 1967 (Campbell, 1967, 1968; Brown, 1968) and for about three weeks in 1968. Young spent two seasons (1967-68) studying the stratigraphy of the Lower Cambrian and part of the Proterozoic sequences (Young, 1968, 1969).

Mountjoy spent a short time in the field in 1967 and again in 1968. He greatly assisted with the mapping in Rocky Mountains and is solely responsible for the work in the eastern Main Ranges, Front Ranges, and Foothills (Mountjoy, 1970b). He also investigated the geology of Mount Robson west half map-area (Mountjoy, 1971) which lies to the east of McBride map-area. His field work was supplemented by extensive air-photograph interpretation. In 1968 Fritz (1969) made a detailed examination of the Lower to Upper Cambrian Dome Creek Formation in Cariboo Mountains.

Acknowledgements

The writers received many courtesies from residents of the area, particularly Mr. A. Wiltse and family of McBride and the staff of Cariboo Gold Quartz Mining Company Limited of Wells. They were ably assisted in the field by Anton Brown, K.V. Campbell, J.G. Buckingham, R.R. Culbert, many other student summer assistants and by E. Greyson who, for approximately the 44th and 45th time, made sure that a Geological Survey crew was well fed.

CHAPTER II

STRATIGRAPHY

INTRODUCTION

Early stratigraphic studies in McBride map-area were confined to the Cariboo gold district and to Bowron Lake Provincial Park. Bowman (1889) was the first to describe a stratigraphic succession which subsequently was refined by Johnston and Uglow (1926). Lang (1940) discovered Lower Cambrian fossils in the general region. Holland (1954) greatly modified the earlier concepts of the stratigraphy and his work was extended and enlarged upon by Sutherland Brown (1957 and 1963). The contributions of Holland and Sutherland Brown were a major advance and provided a solid starting point for the studies in this report. Modifications and revisions of some of the stratigraphic interpretations of Holland and Sutherland Brown reflects the fact that the earlier work was confined to a region of poor exposures, structural complexity, and incomplete sections, whereas the writers had access to well exposed sections over a broad area.

The excellent regional stratigraphic study of Slind and Perkins (1966) between Jasper and Pine Pass provided the first published information on the Proterozoic and Lower Paleozoic stratigraphy of the Rocky Mountains in and near McBride map-area and remains a major source of information that has been of much use to the authors. The region is not far removed from the Jasper and Mount Robson districts where some of the pioneer stratigraphic investigations in the Rocky Mountains were undertaken.

McBride map-area presents an opportunity, unique in the southern Cordillera, to study well-exposed late Proterozoic and Cambrian stratigraphy over broad regions on either side of the Rocky Mountain Trench. The stratigraphic relationships and the character of the rocks are not obscured by metamorphism or complicated by intense folding. The Proterozoic sequences on either side of the Trench are remarkably similar but the Cambrian successions, display facies differences (see correlation chart, Table 1).

Young (1969) examined in detail the Lower Cambrian and the upper part of the Proterozoic successions in both Cariboo and Rocky Mountains. Fritz (1969) carefully studied the Lower to Upper Cambrian Dome Creek Formation. Knowledge of the stratigraphy is otherwise dependent on earlier published work, airborne and spot observations, routine ground traverses, and study of air photographs.

In the following pages information on the Upper Miette, Gog, Cariboo, and Kaza Groups is provided by Young. All authors contributed data on the Lower and Middle Miette Group and Mountjoy compiled material on the Middle Cambrian to Jurassic stratigraphy of the Rocky Mountains. Information on the Silurian and associated rocks near the Trench northeast of Penny from Young, Campbell and Taylor. Campbell is responsible for the notes on the Slide Mountain Group and younger rocks in Cariboo Mountains and the Interior Plateau.

ROCKY MOUNTAINS

Proterozoic (Hadrynian or Windermere) to Jurassic rocks occur in various structural zones of Rocky Mountains. Mesozoic rocks, other than some Triassic strata at Intersection Mountain, are restricted to a small area in the Foothills in the northeast corner of the map-area. Upper Paleozoic (Carboniferous and Devonian) strata outcrop in the Front Ranges (Cecilia Thrust Sheet) and on the southern end of the Wallbridge Thrust Sheet within the Main Ranges. Relatively complete sequences of Ordovician and Cambrian strata dominate the Wallbridge and Sir Alexander Thrust Sheets of the eastern Main Ranges. In the western Main Ranges Proterozoic Miette Group strata underlie the Forgetmenot Zone and Proterozoic to Silurian rocks are found in the Mount Robson Synclinorium near the Trench.

Lower Mesozoic and upper Paleozoic strata have not been studied in detail, being observed mostly from the air except for one or two localities. The stratigraphic sequence is similar to that of adjoining areas to the north and east (Irish, 1965; Mountjoy, 1962, 1964) and for more detailed stratigraphic data pertinent references are included under each formation. Much of our present knowledge concerning the Ordovician and Upper and Middle Cambrian stratigraphy is derived from the summary for the Jasper-Pine pass region presented by Slind and Perkins (1966).

The Proterozoic Miette Group, comprising the lowest sequence of sedimentary rocks, is separated from the overlying Gog Group by an abrupt change in sedimentary regime and probably a disconformity (Aitken, 1969). The dominantly quartzitic sandstones of the Gog Group are in turn overlain conformably by mainly carbonate and shale units of Middle Cambrian to Middle Ordovician age, and perhaps younger. These grade to a shale facies in the northwest. Shale, carbonate, and volcanic rocks at least partly of Silurian age crop out on Bearpaw Ridge northeast of Penny. The thickness of the Proterozoic and lower Paleozoic rocks is in the order of 40,000 feet.

Upper Paleozoic strata of Middle (?) Devonian to Permian age comprise a sequence of about 4,500 feet of shallow-water shelf carbonates, interrupted by two somewhat deeper-water shale and argillaceous carbonate units (Devonian Fairholme Group and Lower Carboniferous Banff Formation), and terminated by sandstone, chert and cherty carbonate of the Permian-Pennsylvanian (?) Ishbel Group. Only the basal part of the Mesozoic succession outcrops in the northeast corner of the map-area. Other than the dominantly carbonate Whitehorse Formation, Mesozoic strata consist of siltstone, silty shale, and fine-grained sandstone, and in late Jurassic, form a part of a clastic wedge sequence derived from uplift in the western Rocky Mountains (Price and Mountjoy, 1970).

Proterozoic-Hadrynian (Windermere)

Miette Group

The Miette Group forms a thick succession of fine to coarse clastic rocks northeast of the Rocky Mountain Trench and include the oldest strata known in this part of the Rocky Mountains. The term Miette Formation was proposed by Walcott (1913) for about 2,000 feet of strata underlying Lower Cambrian quartz sandstones near Yellowhead Pass (Lat. 52° 52'N, Long. 118° 30'W). It was raised to group status in the Mount Robson and adjacent areas by Mountjoy (1962). Except for a belt of Miette strata on the east flank of the Mount Robson Synclinorium in the Park Ranges southwest of Cushing Creek, the Miette Group is generally folded and faulted making accurate thickness determinations and stratigraphic reconstruction

difficult. From data in this and surrounding areas ~~is~~ the Miette Group is over 10,000 feet thick and appears to be more than 15,000 feet thick along the east limb of the Mount Robson Synclinorium.

The Miette Group of the McBride area is divisible into three informally named map-units; ~~comprising~~ the lower, middle, and upper Miette. The lower and upper Miette are dominantly argillaceous sequences which form reasonably distinct and continuous units on the present scale of mapping. The upper Miette locally contains carbonate rocks overlain by quartzite and shale at the top of the section immediately below the Gog Group. These are correlated with the Cunningham and Yankee Belle Formations of the Cariboo Mountains. The Byng Formation (Slind and Perkins, 1966) was not recognized within the area (Young, 1972b). The middle Miette forms a series of resistant ribs of coarse-grained and conglomeratic sandstone (grit) separated by phyllite, which are elsewhere characteristic of Windermere strata in the Canadian Cordillera (Reesor, 1957). All units contain similar lithologies and are gradational. In the upper Miette a gradual erratic increase ~~towards the northeast~~ in the number and thickness of massive, coarse sandstone and conglomeratic units makes ~~it difficult to~~ map a consistent upper-middle Miette boundary difficult. Some areas mapped as middle Miette may contain upper Miette strata, especially in the area northeast of the Cushing Creek Fault. Lower Miette strata outcrop only near Cushing Creek and form a distinct sequence of dark grey to black phyllite and argillaceous limestone.

Lower Miette Group

The lower Miette Group outcrops only on the east flank of the Mount Robson Synclinorium adjacent to the Cushing Creek Fault. It is the oldest stratigraphic unit known in this part of the Rocky Mountains and on the basis of stratigraphic position is older than any of the units mapped in the Miette River valley by Charlesworth et al (1967). Relationships to strata of the Purcell System and the underlying Precambrian crystalline basement are not known.

On the ridges southwest of Cushing Creek between 2,000 and 4,000 feet (minimum) of folded and cleaved black shale, argillite, and micritic limestone form a distinct area of very dark and somewhat recessive weathering strata. The limestone

weathers grey to pale yellow. The contact with the overlying lighter colored and more resistant middle Miette strata is distinct and is easily distinguished on air photographs and is readily mapped from the air. No strata of similar lithologies are known to occur in the Kaza Group to the southwest or in adjacent areas in the Miette Group.

Middle Miette Group

The middle Miette Group is the thickest of the three informal map-units. About 9,000 feet of middle Miette strata were measured along the ridge crest between McKale River and East Twin Creek on the east limb of the Mount Robson Synclinorium, where these strata are well exposed and are not faulted. This succession together with the overlying upper Miette and underlying lower Miette is the best known reference section of the Miette Group.

About one third of the middle Miette consists of units 50 to 500 feet thick of coarse sandstone and pebbly sandstone ("grit"). Typically it is very immature, both texturally and chemically, being poorly sorted and containing up to 25 percent feldspar grains. It contains large amounts of green chloritic matrix. Quartz pebbles and feldspar granules are commonly concentrated in conglomeratic beds and lenses which grade into or are interbedded with thick beds of coarse-grained sandstone. These pebble beds commonly have sharp erosional basal contacts and grade upwards into argillaceous interbeds. They commonly contain large shale clasts and fragments and have some characteristics of proximal turbidite sequences. For additional petrographic information the reader is referred to the work of Charlesworth and his students (1967). Somewhat finer material varying from fine to coarse-grained immature sandstone also forms thick massive units, some of which are crossbedded.

The interbedded recessive weathering intervals consist of thin-bedded, pyritic, in part finely laminated argillaceous to sandy, quartz siltstone, and dark to light grey, greenish grey, or brown argillite, and are generally covered. The layering of alternating competent and incompetent units 50 to 500 or more feet thick is largely responsible for the tectonic style of the middle Miette. These strata have been folded into large and commonly overturned folds, near or between major faults.

Middle Miette strata are correlated with the Kaza Group southwest of the Rocky Mountain Trench on the basis of lithology, thickness, stratigraphic position, and correlation of overlying units. The middle Miette is approximately equivalent to the lower Wynd, the Old Fort Point, and the Meadow Creek Formations of Charlesworth et al (1967) which outcrop along the Miette River valley (Mountjoy, 1970). The middle Miette corresponds closely in lithology and stratigraphic position to the part of the lower Horsethief Creek Group of the Windermere Series of southeastern British Columbia.

Upper Miette Group

The upper Miette Group consists predominantly of grey to dark grey mudstone and silty argillite, generally cleaved and folded, and includes a variably thick zone of coarse clastic rocks whose base lies about 1,200 to 1,400 feet below the McNaughton Formation. The upper Miette is about 5,000 feet thick, and is typically recessive weathering.

Pelitic rocks of the lower part of the unit weather pale greenish grey to orange- and brown-grey. Small-scale ripples and very fine silt laminae are characteristic of most of the unit. Argillaceous siltstone or very fine-grained sandstone are interbedded and alternate with argillite to form distinct rhythmic changes upwards. Argillaceous intervals become increasingly silty and sandy upward, and are abruptly overlain by uniform phyllitic mudstone which repeat the rhythm. These coarsening upwards cycles are about 150 feet thick. A few interbeds of coarse-grained, immature sandstone and conglomeratic sandstone are present in most sections, and are noticeably lenticular.

The uppermost 1,000 to 2,000 feet of the Miette Group is relatively complex stratigraphically (Young, 1972b), and generally consists of a coarse phase followed by an argillaceous phase immediately below the Gog Group. The interval of coarse clastics is relatively thin, pebbly, and feldspathic near the northern border of the area, and becomes thicker, fine-grained, and quartzose towards the southeast. The base maintains a constant stratigraphic level hence as the interval thickens toward the southeast the upper beds are progressively closer to and ultimately pass

gradationally into the base of the Gog Group. There it weathers to a characteristic banded orange and dark grey due to interbedding of ferruginous sandstone and grey mudstone. Along the ridge including Holy Cross Mountain the coarse-clastic zone is represented by a 440-foot-thick unit of limestone, in part sandy, sandy dolostone, and interbedded mudstone, and an overlying unit of dominantly sandstone, 220 feet thick. These units greatly resemble respectively the Cunningham Formation and Zig-Zag Member of the Yankee Belle Formation of the Cariboo Group west of the Rocky Mountain Trench.

The uppermost argillaceous unit of the upper Miette varies considerably in character, due in part to the increase of sandy facies ~~facies changes with the sandy zone~~ towards the east. At Holy Cross Mountain it is a phyllitic greenish grey mudstone with minor amounts of limestone and limonitic fine-grained sandstone. There it greatly resembles the Yankee Belle Formation of the Cariboo Group, and, together with the close similarity of pairs of underlying units, can be correlated with the lower part of the Cariboo Group. Near Walker Creek this unit is medium to dark grey mudstone, in part sandy, with siltstone and calcareous sandstone interbeds near the top. Towards the east it becomes brown-grey, silty mudstone of fairly uniform character, and ranges from 500 to 600 feet thick.

No skeletal fossils have been found in the Miette Group but a variety of trace fossils occur in the uppermost 1,500 feet. These include:

(a) horizontal and oblique burrows of the Planolites type,

(b) digitate, angular markings, and

(c) curving, doubly furrowed, overlapping trails of undoubted metazoan origin classified as Didymaulichnus sp. (Young, 1972a).

The stratigraphy of the upper Miette Group is complex and requires a thorough investigation in McBride and Mount Robson map-areas before formal sub-divisions and correlations can be made. In general, the upper Miette is equivalent to the Isaac, Cunningham and Yankee Belle Formations of Cariboo Mountains, and to the lower Jasper and Wynd Formations of the Jasper area (Charlesworth et al, 1967).

The Sub-Gog Contact

Conglomeratic quartzite which forms a distinct member at the base of the Gog Group strongly contrasts with the upper Miette argillite. This contact

Insert on p. 11.

In particular, care must be exercised in correlating carbonate units. The relationship of the Cunningham Formation in Cariboo Mountains to the Byng Formation in Mount Robson map-area is uncertain though reconnaissance data suggest that the Byng Formation is stratigraphically lower than the Cunningham (Young, 1972b).

represents a marked and abrupt change in sedimentary facies and basin paleogeography. South of Holmes River in the Mount Robson Synclinorium the upper Miette is more sandy than elsewhere and grades subtly upward through an interval of over 500 feet into the McNaughton Formation suggesting continuous deposition. Elsewhere, the contact is abrupt and suggests the presence of a disconformity as Aitken (1966) has argued for much of the area between Banff and Jasper, southeast of the map-area.

Proterozoic and/or Lower Cambrian

Gog Group

The Gog Group is a sequence dominated by quartzite which overlies the Miette Group in the southern Rocky Mountains. The name Gog Formation was originally applied to 1,235 feet of quartzose sandstone near Mount Assiniboine by Diess (1940). Mountjoy (1962) raised the unit to group status in the Jasper Park area, where it includes, in ascending order, the McNaughton, Mural, and Mahto Formations. The Mural and Mahto Formations contain Early Cambrian trilobites.

The Gog Group thickens northwestward from 4,000 to 5,000 feet in the Jasper area to a maximum near 8,000 feet in the Mount Robson area (Mountjoy, 1964). Greatest thicknesses are generally attained in the most western ranges of the Rocky Mountains, where the unit consists of shale and siltstone as well as sandstone. In the McBride area the group ranges in thickness from 4,500 to 7,500 feet. Northwest of McBride map-area it gradually thins to 1,400 feet near Pine River (~~Lat.~~ 55° 20'N) (Slind and Perkins, 1966; G.C. Taylor, pers. comm., 1970).

McNaughton Formation

The McNaughton Formation was proposed by Walcott (1913) for quartzite outcropping on Mount McNaughton about 20 miles southeast of Mount Robson. Great cliffs of relatively monotonous, bedded quartzite characterize the McNaughton Formation in Jasper National Park and the northeastern corner of the McBride area. Three lithofacies include:

(a) a basal conglomeratic, feldspathic sandstone facies;

(b) a bedded, quartzose sandstone facies; and

(c) a burrowed, interbedded sandstone-shale facies.

In the western ranges of the Rocky Mountains the sandstone-shale facies constitutes a distinct, mappable unit within the McNaughton, here designated as the Holmes River Member.

Eastern, sandy developments of the McNaughton Formation are about 4,500 feet thick in McBride area, but become thinner northwestward to only 850 feet at Pine Pass (~~Lat.~~ 55° 20'N) (Slind and Perkins, 1966). The formation thickens westward in consonance with a facies change from sandstone to mudstone in the upper half ~~of the formation~~. Superimposed on this trend is a narrow, northeast-southwest trending zone of thinning. The thinnest McNaughton sequence in this zone occurs near Mount Rider, where the formation is only 1,900 feet thick. Just twenty-five miles southeast in the Holmes River area, along the structural trend, it thickens to about 6,800 feet. In the same distance to the northwest, it thickens to about 7,500 feet, as measured at the Walker Creek section (~~Lat.~~ 53° 54'N, ~~Long.~~ 120° 43'W).

In eastern sequences of the McNaughton Formation the basal conglomeratic sandstone grades upwards into the quartzite facies. The latter lies at the base of the formation in the west, and grades upward into and interfingers with the sandstone-shale facies. These relationships indicate that the quartzite facies lay between the conglomeratic sandstones and the sandstone-shale at any given time, and that these facies shifted towards the northeast in the early part of McNaughton deposition.

(a) Conglomeratic sandstone facies: Although absent in western ranges of the Rocky Mountains the conglomeratic sandstone is about 1,200 feet thick at "Quartzite Mountain", a few miles southwest of Mount Buchanan, and 1,000 feet thick at Horseshoe Lake, 15 miles north of McBride area. This facies is everywhere in sharp contact with underlying strata of the Miette Group, and grades subtly upwards into the quartzite.

The conglomerate facies consists of thick, lensoid to tabular units of quartz-pebble conglomerate and conglomeratic, granular, feldspathic sandstone, which interfinger with units of unfossiliferous, thinly bedded silty shale and sandstone. The rudaceous rocks are massively bedded, with sharp, mildly erosional basal

contacts. Internally, beds display graded bands, with sharp basal contacts, no cross-stratification, and rarely, phenoclasts of shale. The alternating units of shale and evenly bedded sandstones are up to 100 feet thick. The shale is in part sandy, contains minor silty streaks, and lacks organic traces.

Conglomeratic sandstone consists of a poorly sorted particulate fraction (80 - 85 percent) and a chlorite-sericite matrix (15 - 20 percent). Quartz, of which about 15 percent is fragmental quartzite, comprises the majority of the particulate component. Feldspar constitutes up to 15 percent of the rock, and in general decreases in abundance up-section. At least 20 percent of the feldspar is plagioclase, much of which is untwinned. Potash feldspar is most common in the grain-size range of 1 to 8 millimetres. A large proportion of the feldspar is white, seemingly due to both vacuolization and kaolinitization. As well, some grains of feldspar are relatively fresh, including those of plagioclase.

(b) Quartzite facies: The quartzite facies consists of a thick, nearly homogeneous sequence of bedded, submature quartzose sandstone. It occurs everywhere in the McNaughton Formation, either at the base in western sequences, or at the top in eastern sequences. In western Rocky Mountains, quartzites up to 2,100 feet thick form the base of the McNaughton. A thickness of 3,600 feet was measured at "Quartzite Mountain" (~~Lat.~~ 53° 53'N, ~~Long.~~ 120° 12'W).

The sandstone of this facies may be divided into three main categories, each representative of different depositional sites. These include:

(a) moderately sorted, submature sandstone, commonly cross-stratified, with sharp, undulose basal bedding contacts and diffuse upper contacts with minor intercalated siltstone and shale;

(b) well sorted, supermature, white, quartz-cemented sandstone, in part cross-stratified, commonly in very thick beds; and

(c) shale-parted, homogeneous, medium-grained or finer sandstone in thick beds, associated with burrowed, black shale.

The first type is most common, and is the type of rock into which the conglomeratic sandstone grades. Beds may be crudely banded or consist entirely of large tabular foresets. Distributions of the dip-directions of foresets are typically unimodal.

Granulometric analyses indicate that (a) modal sizes vary between fine- and coarse-grained; (b) grain-size distributions tend to be skewed towards the fine sizes; (c) sorting is poor to moderate; and (d) minor amounts of sericite matrix are present. The textural immaturity and grain size suggest deposition under fluvial conditions. The predominance of sand and abundance of planar cross-stratified beds indicative of lateral accretion suggest deposition on point-bars which migrated freely and rapidly because of the non-cohesive nature of the sandy alluvium (McGowen and Garner, 1969).

Sandstone of the second type occurs towards the top of the quartzite partly in association with burrowed shale and sandstone of the third type. The purity, the rounding, and good sorting exhibited by this sandstone reflects the constant re-working of the sand in beach and offshore bar environments.

The third type of sandstone is relatively uncommon, and is closely associated with the sandstone-shale facies in western sequences of the McNaughton. This sandstone is evenly laminated, and commonly interwoven by a network of irregular, thin shale partings, especially near bedding contacts with interbedded shale. Horizontal and vertical burrow structures are present and, with the associated shaly facies, suggest brackish or marine conditions, probably in shallow water.

(c) Holmes River Member: The interbedded sandstone-shale lithosome of the McNaughton Formation is here designated the Holmes River Member. This member is well developed in the ranges south of Holmes River in the Mount Robson Synclinorium. The type section occurs on the slopes of the mountain immediately south of the junction of the Holmes and Chalco Rivers, (~~Lat.~~ 53° 20'N, ~~Long.~~ 119° 49'W) where it is about 4,000 feet thick. It does not appear in eastern exposures of the McNaughton Formation, nor has it any exact equivalent in the Cariboo Group to the west.

The Holmes River Member lies gradationally above the quartzite facies which may form thick tongues within it as at the Walker Creek section.

This member is characterized by uneven and irregular, thin beds of alternating black shale and grey siltstone or very fine-grained sandstone. Stratification of both rock types is generally distorted due to early diagenetic slumping and in faunal burrowing. The horizontal casts (Planolites) of these burrows are common in relatively thick sections of the Holmes River Member.

Following is a brief description of the type section of the Holmes River Member:

Unit	Lithology	Thickness Unit	Thickness Above base
	Overlying beds: basal sandstone of Mural ~~Formation~~ McNaughton Formation - Holmes River Member		
9	Sandstone, very fine-grained, green-grey, thin bedded; shale, medium grey, pyritic, interbedded with sandstone	40	3,962
8	Shale, dark grey, irregularly interbedded with sandstone (40 percent) very fine grained, quartzose; poorly exposed with many covered intervals.....	247	3,922
	Covered interval, probably as above.....	300	3,675
7	Quartzite, light grey weathering, fine grained, thin to thick bedded, with variably thick shale or shaly intervals up to 700 feet thick, in part black, homogeneous, in part sandy, bioturbated, irregularly bedded.....	330	3,375

Unit	Lithology	Thickness Unit	Thickness Above base
6	Shale, black, silt-laminated, with sandstone interbeds displaying burrow structures in lower parts.....	50	3,045
	Covered, recessive interval.....	100	2,995
5	Sandstone, light grey weathering, very fine grained, silty, quartzose with minor heavy minerals, sericitic, bioturbated, laminated, thin bedded; interbedded with 50 percent shale, dark grey, burrowed, with minor silt-streaks.....	1,300	2,895
4	Quartzite, medium grey-brown, fine grained, quartzose with 5 percent dark, feromagnesian minerals, thick bedded to massive, bedding pinch-and-swell type with erosive basal contacts; 5 percent black shale interbeds....	80	1,595
3	Sandstone, quartzitic, light grey weathering, fine-grained, very sericitic, bioturbated in part, in part interlaced by a plexus of shale-partings; 30 percent interbedded shale, dark grey, silty, burrowed.....	205	1,515
2	Quartzite, light grey, fine grained, quartzose, medium to thick bedded, in part cross-stratified; minor grey shale intercalations.....	50	1,310

Unit	Lithology	Thickness Unit	Thickness Above base
1	Sandstone, light grey weathering, fine-grained, 30-70 percent, thin and unevenly bedded, in part intricately shale-parted; interbedded with shale, dark grey, in part silt-laminated, in part bioturbated and burrowed, in fine partings to thin, irregular beds.....	1,260	
	Underlying beds: quartzites (coarse-grained) ~~of quartzite facies~~ of McNaughton Formation		

Origin of McNaughton Formation

The various clastic facies of the McNaughton Formation in the McBride area suggest a wide range of depositional environments. The earlier discussed stratigraphic and areal distributions of the three component facies indicate that the quartzite lay between the sandstone-shall in the west and the conglomeratic sandstone in the east. The several kinds of sandstone described from the quartzite facies originated as shallow marine to alluvial ~~point-bar~~ deposits. The abundance of organic traces and the pelitic nature of the Holmes River Member indicate deposition occurred in quiet marine waters, hence this member represents deposition in a marine basin which lay to the west of a littoral zone represented by part of the quartzite facies. By inference, the conglomeratic sandstone may be placed in more proximal depositional sites than that of the quartzite lithosome, and are interpreted to be alluvial in origin. This interpretation is supported by the relative coarseness of the facies, its poor textural and mineralogical maturity, absence of trace fossils, and lensoid pebbly sandstone bodies which represent channel-fillings.

The abundance of very coarse particles, including easily fractured pebble-size grains of feldspar, and the various degrees of alteration of the feldspar suggest

a source-area of relatively high relief. The general coarsening of particles towards the northeast, and the abundance of materials indicating an igneous and metamorphic terrain suggest the source-area to be the western portion of the Canadian Shield, now buried by sedimentary rocks of the Interior Plains (Burwash and Petermann, et al, 1964).

Age and Correlation

No skeletal fossils were observed in the McNaughton Formation, and the only trace fossils in it in McBride area are abundant oblique burrows of the Planolites type. Elsewhere, the McNaughton has yielded many more trace fossils, especially in its uppermost few hundred feet (Young, 1972a). These were formed mainly by the activities of trilobites, and since the overlying Mural Formation is Early Cambrian in age, the uppermost part of the McNaughton Formation may also be considered Early Cambrian. However, the bulk of the formation may be immediately older than Cambrian judging by the lack of diversified trace fossils, in particular those formed by trilobites. Lack of fossils, of course, is not evidence of pre-Cambrian age and, as a matter of convenience, the base of the McNaughton Formation can be regarded as the base of the Cambrian as has been the practice elsewhere in Rocky Mountains (Mountjoy, 1962; Slind and Perkins, 1966; Price and Mountjoy, 1970). Such a designation, however, implies a precision regarding the Cambrian-Precambrian boundary that does not exist and furthermore it is unlikely that the base of the formation represents a "time line". The rocks below the quartzite contain trace fossils (metazoans) only (Young, 1972a) although they are of a lithological character in which skeletal fossils would be well preserved if present. For these reasons the writers take the view that the base of the Cambrian is probably within the McNaughton Formation but in recognition of the uncertainties of the age assigned is Lower Cambrian and/or Hadrynian (Windermere).

Units of the Cariboo Group that are probably correlative with the McNaughton Formation include the ~~Yankee Bell~~, Yanks Peak, and Midas Formations, which underlie the Mural Formation conformably in the Cariboo Mountains. Great thicknesses of sandstone in about the same stratigraphic position are common in western and northern North America. Formations which are largely correlative with

the McNaughton include the Hamill Group of southeastern British Columbia, the Gypsy Quartzite of Washington State, the Prospect Mountain Quartzite of southwestern United States, the lower unit of the Atan Group of northern British Columbia, and the Backbone Ranges Formation of Mackenzie Mountains.

Mural Formation

The Mural Formation outcrops in both the Rocky Mountains and the Cariboo Mountains in the map-area, and provides the key marker horizon between the Gog and Cariboo Groups. Its characteristics in the Rocky Mountains are discussed here.

Burling (1923) proposed the name Mural Formation to designate the dolomitic units above the McNaughton Formation in the Mount Robson area. According to Burling (1955) and Mountjoy it is equivalent to the Tah Formation of Walcott (1913). The Mural Formation is used here to include the dominantly carbonate rocks which overlie the McNaughton Formation, and is modified at the base to include a prominent, widespread quartz sandstone unit, and overlying argillaceous strata. These sandstone beds are believed to form the base of a widespread marine transgression, which led to the deposition of shallow-water sediments in the Mural.

The Mural Formation occurs sporadically near the crests of mountains immediately northeast of the Rocky Mountain Trench, and throughout the northern part of the map-area in the Rocky Mountains. From a maximum measured thickness of 1,800 feet near Walker Creek it becomes thinner and sandier to the east and north of the map-area, and finally disappears (Mountjoy, 1962; Slind and Perkins, 1966). From the north to the south side of Walker Creek the formation thins abruptly from 1,800 to 650 feet. Thinning occurs proportionately within individual members of the formation.

The Mural Formation may be subdivided into five informal members, including a basal sandstone member, a green calcareous mudstone member, a lower carbonate member, a medial shale member, and an upper carbonate member. The base of the Mural is marked by a massive sandstone unit which is generally more resistant to weathering than underlying quartzite and shale of the McNaughton

Formation. This unit varies in thickness from almost zero to fifty feet in the McBride area. At the Walker Creek section the basal sandstone member is replaced by a 15-foot-thick hematite iron-formation which contains trilobite fragments.

The basal sandstone member is overlain by the recessive-weathering calcareous mudstone member, which reaches a maximum thickness of 190 feet near Mount Rider. This unit consists of greenish grey calcareous mudstone which weathers to a characteristic "honeycomb" texture due to the presence of distorted, semi-connected, tabular nodules of limestone.

The lower carbonate member is typified by abundant oolitic limestone, which contains rounded intraclasts of oolitic calcarenite and accretionary grains resembling "grapestones". Limestone containing varying amounts of whole or fragmental skeletal remains are also common. The medial shale member is dominated by thin bedded limy shale, siltstone, and micrite. Oolitic and bioclastic limestone is rare in the upper carbonate member, in which massive beds of dolomitic, sparsely fossiliferous micrite predominate.

The abundance and widespread occurrence of filter-feeding forms of life, algal-coated grains, and oolites indicate that warm, shallow, well-agitated marine conditions prevailed over an extensive shelf during deposition of the Mural limestone. The influence of land-derived clastics was minor except for the widespread incursion of fine clastics represented by the medial shale member.

Fossils include trilobites, archaeocyathids, inarticulate brachiopods, hyolithelminths, algae, and echinoderms, and indicate an Early Cambrian age. The following collection made from the lower carbonate member was identified by Dr. W. H. Fritz of the Geological Survey.

Walker Creek (~~Lat.~~ 53° 54'N, ~~Long.~~ 120° 46'W) (GSC loc. 80691, 80692)

archaeocyathids

cf. Nevadella sp. or Judomia sp.

Nevadella sp.

olenellid, gen. & sp. undescribed

According to Fritz, these fossils indicate a middle Early Cambrian age, and correlate

with fossils found in the middle and upper part of the lower carbonate member of the Mural Formation in the Dome Creek section in Cariboo Mountains.

Mahto Formation.

The Mahto Formation lies in gradational contact above the Mural Formation, and consists dominantly of quartzose sandstone. The thickness of the Mahto varies from about 800 feet in the Mount Sir Alexander area to over 1,000 feet south of Walker Creek and at Mount Rider adjacent to the Rocky Mountain Trench. The Mahto Formation is distinguishable from the upper part of the McNaughton Formation mainly by the presence of the intervening Mural Formation.

In western ranges of the Rocky Mountains, the Mahto Formation comprises two large-scale sandstone-shale rhythms. The basal shale member is up to 450 feet thick, as measured south of Walker Creek, and grades upwards into a sandstone member by interbedding with burrowed, fine-grained quartz arenite. The sandstone member is 130 feet thick and consists of cross-stratified, well sorted quartz arenite displaying vertical Skolithos burrows. The upper rhythm is more condensed, and consists of a relatively thicker sandstone phase. Between the two rhythms a thin bed of sandy dolostone is present, which thickens northward in the Monkman Pass map-area. The shale parts of these rhythms probably represent eastern extensions of the shale facies (Dome Creek Formation) which overlies the Mural Formation in the Cariboo Mountains.

The sandstone is nearly purely quartzose, and consists of rounded, variably size-sorted grains of quartz, and rarely, highly altered feldspar, and pellets of glauconite. Some sandstone is stained by hematite. Size-sorting is variable, ranging from well sorted to poorly sorted. The poorly sorted sandstone consists of well rounded quartz grains, thus constituting a "textural inversion". These inversions may be due to highly turbulent conditions in the environment of deposition, or due to mixing of sediments by burrowing fauna.

The maturity of sand, and the rare presence of glauconite and trace fossils suggest sedimentation in littoral and shallow marine environments. The sandstone - shale rhythms may be interpreted as progradational clastic advances into the sea,

possibly culminating in alluvial sandstone at the tops of sandstone phases.

No skeletal fossils were observed in the Mahto Formation in McBride map-area. The basal beds are commonly riddled by closely spaced Skolithos burrows, which may be several feet long. An Early Cambrian age is assigned to the Mahto Formation because the units below and above it (Mural and Hota-Adolphus Formations) are Lower Cambrian (see Mountjoy, 1962), and Early Cambrian trilobites were recently recovered from the Mahto Formation just north of the map-area (W.H. Fritz, pers. comm., 1970).

Lower Paleozoic Carbonate Facies

Middle Cambrian

Middle Cambrian and Younger stratigraphic units were not investigated in detail during the course of mapping the McBride area, hence informal units are used wherever established formations seem inapplicable. In this report the Middle Cambrian is divided into three units, which include in ascending order:

1) an undivided carbonate-and-shale interval;
2) the Titkana Formation; and
3) the Arctomys-Waterfowl Formations.

Undivided Carbonate-and-Shale Interval

The stratigraphic interval between the Mahto and Titkana Formations consists of an eastern argillaceous facies in the Cecilia and Wallbridge Thrust Sheets, a medial carbonate-rich facies in the Sir Alexander Thrust Sheet, and a western argillaceous facies in the Walker Creek Area. This interval is more or less equivalent to the Hota-Adolphus and Tatei-Chetang Formations of the Mount Robson area, and Map-unit 3 of Mountjoy (1962) of the Front Ranges in northern Jasper National Park.

Cecilia and Wallbridge Thrust Sheets

The eastern argillaceous sequence consists of two or more resistant, dark grey limestone beds, 50 to 100 feet thick, separated by thin-bedded, recessive-weathering, argillaceous limestone and calcareous shale, nearly identical to the

successions represented by Map-unit 3 in the Snake Indian Thrust Sheet of the Mount Robson map-area to the southeast. Total thickness of this interval is about 200 to 500 feet in this structural element.

The basal portion forms light brownish grey-weathering talus-slopes between 300 and 400 feet thick which appear to be underlain by shale and thin-bedded argillaceous carbonate.

On the north spur of Wishaw Mountain a 200- to 300-foot unit at the top of the second limestone consists of interbedded maroon mudstone and argillaceous limestone which form a prominent marker horizon. This marker extends northward to Mount St. George and beyond. Slind and Perkins (1966, p. 454) noted two intervals of red beds which contain salt-crystal pseudomorphs 35 miles to the northwest at Horseshoe Lake. This red-bed unit is easily confused with the Arctomys Formation except that the former lies stratigraphically below rather than above massive carbonate of the Titkana Formation.

No fossils were obtained from this sequence in the McBride area, although to the southeast, Mountjoy (1962, and unpublished) and Slind and Perkins (1966) collected trilobites representative of the Middle Cambrian Albertella, Glossopleura and Bathyuriscus-Elrathina Zones.

Sir Alexander Thrust Sheet

A dominantly carbonate facies occurs in the Sir Alexander Thrust Sheet, where it forms resistant, grey-weathering, vertical cliffs on the south and west sides of the Mount Sir Alexander massif. Thin recessive zones exist near the base and top of this 1,000 to 1,500-foot-thick succession. The thickness is comparable to 1,200 feet at Mount St. George (Slind and Perkins, 1966) a few miles to the north, but is considerably less than the 2,100 feet near Mount Robson.

A thin basal carbonate, about 200 feet thick, rests directly upon the Mahto Formation, and may be equivalent to the Hota-Adolphus Formation. This is overlain by 300 to 400 feet of recessive-weathering light brownish grey argillaceous carbonate which is generally talus-covered. The main part of the unit consists of medium- to thick-bedded, moderately resistant grey carbonate. The upper part of this carbonate gradually becomes thinner bedded, and grades upwards into a 100- to 150-foot

recessive interval containing a few red beds. This uppermost interval may be equivalent to some part of the maroon beds in the argillaceous facies to the east. In the adjacent map-area to the north an additional red marker lies about two thirds of the way above the base of the Titkana Formation, according to G.C. Taylor (pers. comm., 1971). However, the red bed horizon at Mount Sir Alexander occurs lower in the succession and does not appear to be the horizon that Taylor observed within the Titkana.

The succession at Mount Sir Alexander is very similar to the one at Mount Robson, but until more stratigraphic studies are carried out, it is premature to apply the terminology erected at Mount Robson.

Walker Creek area

The most westerly outcrops of Middle Cambrian carbonate facies rocks are exposed near Walker Creek. The western argillaceous sequence observed in this area consists of a basal 30-foot sandy, dolomitic limestone member, overlain by about 80 feet of calcareous, partly sandy mudstone, followed upwards by about 1,300 feet of thin-bedded, slaty, grey- to brown-weathering micritic limestone and calcareous slaty shale similar in many respects to the Chancellor Formation near Field, B.C. (Cook, 1970).

The basal carbonate lies with gradational contact upon calcareous sandstone beds of the Mahto Formation, and contains oncoliths and ooliths. The recessive slaty shale and limestone unit grades into massive, resistant limestones of the overlying Titkana Formation. Fragments of the trilobite ?Ehmaniella were collected from the upper part of this sequence (GSC loc. 80710). According to Fritz, this trilobite belongs to the Bathyuriscus-Elrathina Zone of the Middle Cambrian. This unit continues to the northwest as far as Herrick Creek (G.C. Taylor, pers. comm., 1970), where it includes a basal carbonate-rich member of late Early Cambrian age.

The above three Middle Cambrian facies beneath the Titkana Formation clearly indicate the presence of a carbonate bank or shoal (Tatei-Chetang Formation) which separated on eastern and western argillaceous facies. This carbonate bank extends southward from Mount Sir Alexander into the Snake Indian Thrust Sheet at Mount Chown, and then to Mount Robson. Northward the carbonate facies is

absent and the eastern argillaceous facies can be traced into the western argillaceous facies (G.C. Taylor, pers. comm., 1970), therefore the northern margin of the carbonate facies occurs near Mount Sir Alexander.

Titkana Formation

The Titkana Formation forms prominent cliffs of dark grey micritic limestone with variable amounts of dolomitic mottling and interbeds. Local patches and masses of coarsely crystalline, light brown weathering dolomite are common in some areas. Near the top the Titkana becomes thinner bedded and more recessive weathering. The Pika Formation is poorly developed and could not be mapped separately except in the Cecilia Thrust Sheet. In the Cecilia Thrust Sheet the Titkana Formation is about 500 feet thick, on Wishaw Mountain about 700 feet, and in the Sir Alexander Thrust Sheet about 1,000 feet thick. In the more westerly Walker Creek section it is less massive, and consists of alternating units of grey-weathering oolitic and micritic limestone and orange-brown-weathering dolostone and dolomitic limestone. These units are about 150 to 200 feet thick, and the entire formation is over 800 feet thick.

No fossils were collected from this formation in the map-area, but collections obtained to the north and to the southeast in 1970 by W.H. Fritz of the Geological Survey (pers. comm., 1970) indicate that it is late Middle Cambrian in age.

Arctomys - Waterfowl Formations

The combined Arctomys and Waterfowl Formations form a widespread recessive marker unit consisting of bright red- and yellow-weathering sandstone and argillaceous dolostone with minor siltstone and limestone. Parts of the Arctomys Formation contain salt-crystal casts, ripple-marks, and mudcracks. Light grey carbonate interbeds increase in thickness and number upwards and commonly form a distinctive part near the top of the formation. This upper part appears to be equivalent to the Waterfowl Formation of the Rocky Mountains south of Jasper. At Mount Robson, Waterfowl strata appear to include part of the Arctomys Formation and the basal 250 feet of the Lynx Formation as previously mapped (Mountjoy, 1962,

1964). The immediately overlying 1,000 feet of Lynx Formation is probably equivalent to the Sullivan Formation. The addition of Waterfowl and Sullivan Formations and restriction of the Arctomys and Lynx Formations in the Mount Robson succession will be made in a future publication by Mountjoy (cf. Mountjoy, 1962). The Arctomys Formation (restricted) is about 500 feet thick, increasing to the southeast to about 800 feet in the Snake Indian Thrust Sheet near Blue Creek. Westward, the Arctomys interval loses its distinctive multicoloured character, contains more carbonate, and is only about 300 feet thick in the Walker Creek Syncline. The Waterfowl Formation appears to thin northwestward, decreasing from about 400 feet to between 100 and 200 feet. ~~Its~~ The light grey carbonate of the [illegible] is difficult to distinguish from the overlying Lynx Formation.

The age of the Arctomys Formation has been in doubt for many years but the occurrences of early Upper Cambrian trilobites in the Waterfowl Formation (Aitken and Greggs, 1967) and in the base of the Lynx Formation (Mountjoy, 1962) suggest that the Arctomys is Middle Cambrian except for the uppermost beds.

Upper Cambrian

Lynx Formation

The only Upper Cambrian formation which occurs in the northern part of the map-area is the Lynx Formation (Walcott, 1913), which was modified to exclude the distinctive Arctomys Formation (Mountjoy, 1962).

The Lynx consists of cliff-forming, medium-bedded, light grey- to yellow-grey weathering, silty limestone and dolostone. Beds of intraformational conglomerate occur near the top of the formation and in places stromatolites are present. The upper part ~~of the Lynx Formation~~ is more argillaceous but can be distinguished from the overlying pale greenish grey, recessive shales and argillaceous limestones of the Lower Ordovician Chushina Formation. The well-bedded character of the Lynx Formation distinguishes it from the underlying Titkana Formation.

The Lynx Formation is more than 1,700 feet thick on Mount Sir Alexander (top not present), between 1,700 and 2,000 feet thick on Mount Buchanan, and 2,000 feet on Broadview Mountain (Slind and Perkins, 1966). A minimum of 500

feet of Lynx strata occur in the core of the syncline north of McGregor River just east of the 121st meridian. This syncline plunges northwest into the Monkman Pass map-area where, at 54° 10', Ordovician Chushina strata appear in its core. There, the Lynx Formation is about 1,200 feet thick (G.C. Taylor, pers. comm., 1970).

Ordovician

The Ordovician succession is divisible into three formations on the basis of studies by Slind and Perkins (1966). From bottom to top these are the Chushina, Monkman and Skoki Formations. These formations are difficult to distinguish from the air because of their similar grey weathering character, especially when the Monkman quartzite is thin or absent. Ordovician strata outcrop in two areas: in the Cecilia Thrust Sheet between Kakwa Lake and Wallbridge Mountain, and Mount Buchanan.

Cuschina Formation

The Chushina Formation includes a basal 100 to 200 feet of light yellow-grey to putty grey weathering, greenish grey shale and calcareous shale. Dark grey limestone beds gradually increase in thickness and number upwards and exhibit pseudo-nodules and sedimentary boudinage structures. The limestone in the middle part of the Chushina Formation is 400 to 600 feet thick. The upper part of the formation consists of about 700 to 900 feet of well bedded, yellowish grey, silty dolostone and dolomitic siltstone.

The term Chushina was modified to include all the Ordovician strata lying above the Upper Cambrian Lynx Formation in northern Jasper Park by Mountjoy (1962) as no overlying Ordovician or Silurian units occur in that region. Slind and Perkins (1966, p.456) further defined the formation by placing a more definite upper limit, including in it all strata below the Ordovician Monkman Quartzite. The Chushina is of Early Ordovician age (zones A to J-K of Ross-Hintze).

In the McBride area the Chushina is between 1500 feet (estimate from Mount Buchanan) and 1700 feet thick at Broadview Mountain (Slind and Perkins, 1966, Fig. 2).

Monkman Quartzite

The Monkman Quartzite was only observed from the air. It was found to be a useful marker on Broadview and Wallbridge Mountains, but was recognized only with difficulty on Mount Buchanan because of its thinness. Northward in the Monkman Pass area it thickens to 400 feet and forms a distinctive formation. Slind and Perkins (1966) report thicknesses of about 100 feet from Broadview Mountain, and 50 feet from Wallbridge Mountain. It appears to be only about 20 feet thick on Mount Buchanan. Slind and Perkins (1966, p.458) reported that the sand is fine to medium grained, well sorted, rounded, frosted, and forms thick beds which are white weathering.

Skoki Formation

The Skoki Formation consists predominately of dolostone with some interbedded sandy dolostone and sandstone in the upper part. It can be distinguished from the Chushina Formation by its well-bedded and darker grey weathering character. The term Skoki was first used in this region by Slind and Perkins (1966) for the carbonates above the Monkman Quartzite and below the Beaverfoot Formation on the basis of stratigraphic and faunal correlation with the Skoki Formation in northern Banff National Park.

Slind and Perkins (1966) noted that the Skoki is divisible into three units, a basal dolostone with pisolites and gastropods, a middle barren dolomite, and an upper interbedded sandstone and dolostone. These units have been recognized over much of the Monkman Pass area to the north (G.C. Taylor, pers. comm., 1970). The middle dolostone weathers to an orange grey to brown color forming a distinctive unit recognizable in most sections.

The upper 500 feet of Skoki Formation on Mount Buchanan is not silty but consists of light to medium grey, aphanitic dolostone, which weathers light grey in distinct 1/2-to 3-feet beds. The upper part of this unit might represent the Beaverfoot Formation but the absence of sand beds, chert and silicified fossils suggests that the Beaverfoot Formation is in McBride area. The upper part of the Skoki Formation on Wallbridge Mountain has been described by Harker et al. (1954).

The Skoki contains Middle Ordovician fossils. The Skoki Formation is estimated to be about 2,000 feet thick on Mount Buchanan. Eastward it thins rapidly to 1,150 feet on Wallbridge Mountain and 450 feet at Broadview Mountain due to truncation by the sub-Devonian (middle Devonian through Silurian) unconformity.

Lower Paleozoic Shale Facies

Cambrian and Ordovician

Rocks presumed to constitute a shale facies, equivalents of Middle Cambrian to Ordovician rocks described above, outcrop along the northeast flank of Bearpaw Ridge in the northwesternmost part of Rocky Mountains within the map-area. The strata have not been adequately studied hence the following, taken from Taylor et al. (1972), is speculative at best.

The McNaughton and Mural Formations outcrop at the base of the ridge and in Torpy River Valley just north of the boundary of the map-area. Overlying these, to the southwest, is a sequence of dark limy shale and shale followed by a resistant carbonate unit tentatively correlated with the Titkana Formation. The rocks below the carbonate should thus be Middle and Lower Cambrian and may include equivalents of the Mahto Formation. Above the carbonate is a thick sequence of shale and shaly limestone which may represent the interval from late Middle Cambrian to Upper Ordovician. The precise location of the boundary between the presumed Ordovician rocks and the overlying Silurian strata is not known at present.

The thickness of the sequence may be in excess of 10,000 feet but unrecognized repetitions by folding and faulting are probable hence the true thickness and the verification of the existence of Cambrian and Ordovician rocks must await further study.

Silurian

In the uppermost beds on Bearpaw Ridge many Silurian fossils have been found in a folded succession that includes volcanic rocks and dykes and sills as well as prominent sugary white quartzite. The Silurian section, mainly dark dolomitic

and calcareous shale, dolostone, and limestone, contains no continuous prominent resistant beds other than the white quartzite mentioned above.

At the northern end of the ridge and extending northerly into Monkman Pass map-area dolostone is intercalated with distinctive, green, fragmental volcanic rocks including scoriaceous material. All variations from dolostone containing volcanic fragments to fragmental volcanic rocks with dolostone clasts were noted (Taylor et al, 1972). Apparently volcanism was contemporaneous with marine carbonate deposition. In Monkman Pass map-area the Silurian rocks are intruded by a very poorly exposed plutonic complex consisting of a variety of rocks including sodalite syenite, orthoclase syenite, gabbro, hornblendite, and porphyritic trachyte. The age of the plutonic rocks is not known.

All of the sedimentary and volcanic rocks are apparently Silurian. Fossils from above and below the quartzite and from dolostone interbedded with the volcanic rocks are of this age. Where more precise determinations are possible the fossils are probable late Early Silurian (Llandovery) which indicates a close correlation with the Nonda Formation of northeastern British Columbia (Norford et al. 1966).

The following lists compiled by Norford, who made the collections, typify the fauna found in the Silurian rocks of Bearpaw Ridge.

G.S.C. Locality No. C-10505

Southwest trending ridge: 54° 00N, 121° 30'W

echinoderm debris

indeterminate brachiopods

undetermined solitary corals

Catenipora sp.

Cystihalysites 2 spp.

Favosites 2 spp.

Favosites cf. F. favosus (Goldfuss)

Mesofavosites sp.

?Multisolenia sp.

G.S.C. Locality C-10506

About 50 yards north of triangulation point 5995 ft.;

54° 00N, 121° 28 1/2'W.

undetermined solitary corals

Cystihalysites sp.

Favosites sp.

?Favosites sp.

Pentamerus sp.

Norford assigns a late Early Silurian to early Middle Silurian age to these fossils and suggests they are probably late Llandovery.

Upper Paleozoic

Devonian

Devonian strata have been subdivided into the Fairholme Group, Alexo (?) Formation, and Palliser Formation. These units are best exposed in the Cecelia Thrust Sheet on Wallbridge Mountain and Mount Côté, and at the south end of the Wallbridge Thrust Sheet between Bastille Mountain and Mount Buchanan.

Fairholme Group

The Fairholme Group consists of the Flume, Perdrix, Mount Hawk and Southesk Formations in this area, and is about 1500 feet thick.

Flume Formation

The basal part of the Flume Formation was examined on the south slopes of Mount Buchanan and has been described by Harker et al. (1954) from the north spur of Wallbridge Mountain. The base consists of a variable thickness of white, fine-grained quartz sandstone and some siltstone which presumably were reworked from erosion of sandy Upper and Middle Ordovician strata. A chert conglomerate reported elsewhere by Harker was not observed. These strata generally weather brown to orange-brown in contrast to the grey colors of the underlying Ordovician strata. The sand is interbedded with brown shale and calcareous mudstone with interbeds of dark grey, micritic limestone. On Mount Buchanan these interbeds contain abundant

Thamnopora sp. and Emanuella sp. (GSC loc. C-1778) collected from between 50 and 70 feet above the base. This unit forms a recessive dark weathering sequence between the Skoki Formation and the overlying limestone.

The basal sandy unit is overlain by about 200 to 300 feet (to the core of a syncline) of thin-bedded, medium to dark grey, micritic limestone, containing at the base abundant brachiopods: Atrypa, sp. cf. A. oneidensis Beus, Schizophoria sp. indet., "Cyrtina" billingsi Meek, and an ambocoeliid indet. (GSC loc. C-1779). According to A.E.H. Pedder this collection is early Frasnian [Upper Devonian to 1α (Waterways) fauna] and occurs in the Flume Formation to the southeast. A few of the thicker interbeds contain corals and stromatoporoids. These strata are similar to the Flume Formation of northern Jasper National Park (Mountjoy, 1962, 1968).

Perdrix-Mount Hawk Formations

Argillaceous rocks referred to the Perdrix and Mount Hawk Formations are well exposed on the north spurs of Mount Côté and Wallbridge Mountain, and in the creeks which form the headwaters of Buchanan Creek. They were not examined in detail but aerial observations indicate that they comprise a thick sequence of dark weathering shaly beds. The Perdrix equivalent is a more recessive and darker weathering part at least 400 to 500 feet thick at the base; ~~and~~ an upper slightly more resistant and lighter weathering interval with some ribs of limestone 400 to 500 feet thick assigned to the Mount Hawk Formation.

Southesk Formation (Arcs(?) Member)

About 100 to 300 feet of coral- and stromatoporoid-bearing, light grey, medium- to thick-bedded, resistant limestone occurs above the Mount Hawk Formation and is assigned to the top of the Southesk Formation. These beds are presumably equivalent to the Arcs Member which commonly occurs in isolated patches above the Mount Hawk Formation. It represents small banks which developed during the late stages of the filling of the Fairholme basin (Mountjoy, 1965, 1968). On Wallbridge Mountain, where two limestone units, each about 100 feet thick, are separated by 50 feet of shale and argillaceous limestone, the Southesk Formation is about 250 to 300 feet thick.

Alexo Formation

A recessive, light yellow-grey to light brown sequence about 50 feet thick occurs on Wallbridge Mountain. It was not examined but appears to represent the Alexo Formation of the region to the southeast. However, the Alexo Formation is absent on Mount Hanington near Jarvis Lakes about 10 miles to the north in the Monkman Pass map-area. There the Palliser Formation rests directly on about 100 to 200 feet of Southesk limestone. Similarly in the Mount Robson map-area to the southeast the Alexo Formation is absent in the northernmost Devonian outcrops (Mountjoy, 1962).

Palliser Formation

The Palliser Formation forms a resistant succession of relatively massive grey limestone beds between 800 and 1,000 feet thick on Wallbridge Mountain. These carbonates are not as thick-bedded or resistant as the Palliser Formation in the region ~~of~~ to the southeast. This presumably marks the area in which the Palliser Formation begins a gradual ~~to~~ shale out northward. As elsewhere it consists of dark grey, micritic limestone.

Lower Carboniferous

Banff Formation

The Banff Formation forms a prominent recessive unit between the massive limestone cliffs of the Palliser Formation below and resistant ribs of the overlying Rundle Group. It consists of calcareous shale and thin-bedded limestone. The best exposures occur north of Sheep Pass near the Continental Divide. The base is generally covered but where exposed it is more shaly than higher beds. No black shales characteristic of the Exshaw Formation were observed at the base. Commonly crinoidal limestone about 100 feet thick occurs in the upper third of the formation and forms a distinctive mappable marker. The upper part of the formation contains prominent thin beds of limestone which give it a ribbed appearance. These limestones contain abundant scattered crinoid and brachiopod fragments. The formation was not measured but is between 700 and 1,000 feet thick. Similar thicknesses have been

reported from areas to the southeast (Irish, 1965; Mountjoy, 1962).

Rundle Group

The Rundle Group is about 1,000 feet thick and divisible into four formations: Pekisko, Shunda, Turner Valley and 'Mount Head', from bottom to top. The Pekisko and Turner Valley Formations form resistant units 100 to 300 feet thick, in contrast to the more recessive weathering and thinner bedded carbonates of the Shunda and 'Mount Head' Formations. The term Mound Head is used in an informal sense and probably is only partly equivalent to the type Mount Head. The upper part of this unit may also include some part of the Belcourt Formation. Until these strata have been studied in more detail they are tentatively assigned to the 'Mount Head' Formation.

The Pekisko Formation consists of at least two prominent massive limestone units consisting of crinoidal and coral bearing limestones about 100 to 150 feet thick. The Shunda Formation is about 300 feet thick and consists of micritic, pellettoid and fenestral thin-bedded limestone. The upper part of this formation is cherty and contains scattered coral fragments. Fossils collected from the Shunda at Mount Buchanan (GSC loc. C-1780) were identified by Dr. E.W. Bamber as Syringopora sp., ?Ekvasophyllum proteus Sutherland, and indeterminate productid brachiopods. The Turner Valley Formation mainly comprises coarse grained crinoidal carbonate with interbeds of fine grained partly cherty carbonate. The Turner Valley is about 200 to 300 feet thick. Another collection from the lower Turner Valley Formation or top of the Shunda at the same section as the above (GSC loc. C-1781) was identified as: Syringopora sp., ?Ekvasophyllum proteus Sutherland. Both collections indicate a late Tournaisian to early Visean age according to Bamber. The uppermost Rundle consists of 200 to 300 feet of slightly recessive, thin to medium bedded, light yellow-grey weathering, generally cherty dolomites. This unit can be confused with the Triassic Whitehorse Formation, which is more yellow-weathering and massive. No distinctive chert or sandstones of the Permian Ishbel Group were observed, but this thin unit may be covered by talus from the overlying Sulphur Mountain Formation.

Triassic

Spray River Group

~~The~~ Triassic strata are in general similar to outcrops exposed in the adjoining regions to the southeast which have been studied by Irish (1965) and Gibson (1965, 1968). Only the lower 1,000 feet of the Sulphur Mountain Formation is exposed on Intersection Mountain. This area, which continues into the adjoining Mount Robson map-area, is the most westerly outcrop of Triassic strata in the region. A brief reconnaissance examination of a small part of the sequence indicates that much of the Sulphur Mountain Formation consists of siltstone and silty limestone with a few ammonites. These strata appear to be more calcareous and lighter brown than sections to the east. Two miles immediately east of the map-area on Casket Mountain south of Sheep Creek the basal Whitehorse Formation is exposed. Sulphur Mountain strata are also exposed in the core of an anticline northeast of Cecilia Lake east of the Cecilia Fault. From the map pattern the Sulphur Mountain Formation is estimated to be at least 1,500 feet thick. For a more complete discussion of representative lithologies and sections in the region to the southeast see the reports of Gibson (1965, 1968).

The Whitehorse Formation outcrops only in one small area along the east boundary east and northeast of Cecilia Lake. It appears to consist of light grey to white limestone and dolostone and sandy carbonate with occasional red weathering horizons. The Whitehorse weathers to a brighter yellow grey colour than the upper part of the Rundle Group, with which it can be confused. No sections were measured in the map-area but judging from data in adjoining areas it should be between 1,500 and 2,000 feet thick (Gibson 1968, p.19). Gypsum of good quality in the order of 50 feet thick has been reported from about the middle part of the Whitehorse Formation 4 1/2 miles east of the map-area just north of Forgetmenot Pass (Govett, 1961). This area was being evaluated by drilling in 1968. Similar gypsum and anhydrite might be present in the area southeast of Cecilia Lake.

Jurassic

Fernie Group

The ~~Jurassic~~ Fernie Group forms a distinct, recessive, poorly exposed interval between carbonate of the Whitehorse Formation and overlying siltstone and sandstone of the Nikanassin Formation. The Fernie Group was only observed from the air and the following observations require ground checking. The Fernie Group consists of black to dark grey shale, and silty shale. The upper part of the formation contains more siltstone which occurs in thin beds that increase in number and thickness upwards to the first prominent sandstone of the Nikanassin Formation. This part of the Fernie Group is in the order of 700 feet thick. In the northeast corner of the map area the Fernie is approximately 3,000 feet thick (Stoff, 1972). On the basis of mapping in the west half of Mount Robson area the Fernie Group is estimated to be between 1,500 and 2,000 feet thick. Further southeast it is about 1,800 feet thick on the northeast side of Llama Mountain (Irish, 1965, p.142) and on the south fork of Sulphur River it is about 1,900 feet thick (Mountjoy, 1962, and unpublished). The Rock Creek sandstone appears to be absent in the more westerly sections (Irish, 1965 p.48) and are probably absent in the map-area as none were observed from the air.

Nikanassin Formation

The Nikanassin Formation consists of fine-grained quartz sandstone in 4-to 10-foot beds which weather buff to orange-brown. Dark grey silty shale and siltstone occur as interbeds between the sandstone beds. The base is arbitrarily selected at the first prominent sandstone above the Fernie Group. Only the basal 1,500 to 2,000 feet of the Nikanassin outcrops in the northeast corner of the map-area. Approximately 11 miles due north of these exposures on Mount Minnes, Ziegler and Peacock (1960) measured 6,300 feet of Nikanassin strata which they re-named Minnes Formation. To the southeast Thorsteinsson (1952) estimated that the Nikanassin Formation was at least 4,000 feet thick on Knife Mountain near ~~the~~ Smoky River. The Nikanassin Formation thickens westward and northwestward so that a complete thickness is in the order of 5,000 to 6,000 feet. The basal part of the Nikanassin

Formation contains Upper Jurassic Kimmeridgian to Portlandian Buchia (Irish, 1965; Mountjoy, 1962). Ziegler and Pocock (1960) suggested that the base of the Nikanassin became progressively older to the southwest but fossil data supporting this suggestion are lacking. Present data indicate that the age of the base of the Nikanassin is probably Kimmeridgian.

The term Nikanassin Formation is preferred to Minnes Formation because it has been used as a consistent lithological unit between the Fernie Group and Cadomin Formation by geologists mapping in the region to the southeast (MacKay, 1929a, 1929b; Irish, 1965 and earlier reports; Mountjoy, 1960, 1962, 1964) even though a type section is lacking. Ziegler and Pocock (1960) and Stott (1967) recommended the replacement of Nikanassin by Minnes because Nikanassin was poorly defined.

CARIBOO MOUNTAINS AND INTERIOR PLATEAU

Southwest of the Rocky Mountain Trench in Cariboo Mountains and Interior Plateau the rocks fall mostly into two contrasting sequences, the sedimentary Proterozoic to Cambrian Kaza and Cariboo Groups and the unconformably overlying volcanic and sedimentary Slide Mountain Group at least partly of Mississippian age. Between the two groups, apparently bounded by unconformities, is the sedimentary Black Stuart Formation of Lower Devonian and (?) younger age. Probable Triassic slaty and phyllitic rocks outcrop in the extreme southwest corner of the map-area and alluvium-covered Upper Cretaceous and/or Lower Tertiary coal-bearing clastic rocks underlie the northern part of Bowron River Valley. Other than narrow dykes and sills and a single small occurrence of serpentinite no intrusive rocks were noted in McBride map-area.

The Proterozoic (Hadrynian or Windermere) Kaza Group and Isaac Formation, totalling 15,000 feet or more in thickness, underlie broad areas in the southern part of the region where they are exposed in three major northwesterly-plunging anticli-noria. The Cunningham Formation and younger rocks of the Cariboo Group, 10,000 feet thick or more, are restricted to the intervening synclinoria and to the structurally higher "down plunge" parts of the anticlinoria in the central and northern parts of

the map-area. Kaza Group strata reappear in the northwest near Purden Lake. The section from Proterozoic to Upper Cambrian represented by the Kaza and Cariboo Groups is probably in excess of 25,000 feet thick; the base has not been observed and an unknown thickness of younger lower Paleozoic rocks may have been eroded from the top. The section is apparently conformable throughout though Middle Cambrian strata may be missing and a disconformity may separate the Cunningham and Yankee Belle Formations along the western margin of the Rocky Mountain Trench.

The Black Stuart Formation contains Lower Devonian fossils at its base which lies unconformably above Lower Cambrian Mural Formation and part of the Cambrian Dome Creek Formation. The formation is known only in the Black Stuart Synclinorium in the southwestern part of the map-area and is best exposed in Quesnel Lake map-area to the south (Mansy and Campbell, 1970).

The upper Paleozoic Slide Mountain Group, of unknown but substantial thickness, is confined to the Black Stuart Synclinorium where it rests apparently unconformably on older rocks. The masses of tholeiitic pillow basalt associated with ribbon chert and lithic sandstone is in marked contrast to the underlying sedimentary rocks of terriginous derivation whose source was the cratonal Precambrian Shield. They are strikingly dissimilar to the shelf deposits of equivalent ~~Upper~~ Paleozoic age in Rocky Mountains only 50 miles to the northeast. At least part of the Slide Mountain Group may be a huge thrust sheet that moved from the west during a late Paleozoic orogeny though evidence for this is inconclusive.

The dark phyllite and argillite of probable Upper Triassic age is known, from other areas, to lie unconformably on Slide Mountain Group and older rocks. No rocks similar to the extensive Pennsylvanian-Permian Cache Creek Group lie above the Slide Mountain Group in the map-area hence these were eroded prior to the Upper Triassic or were not deposited.

The rocks of the small late Cretaceous and/or early Tertiary coal basin are evidently of local derivation, perhaps within a fault controlled trough. Though tilted, these strata are little deformed in contrast to nearby older rocks.

The sequence of formations in the Cariboo Group, as established by Holland (1954) and Sutherland Brown (1957, 1963), has been revised. These workers

experienced great difficulties in establishing the stratigraphic succession in the structurally complex and poorly exposed Yanks Peak-Roundtop Mountain and Antler Creek areas. In 1966 a reconnaissance survey of Cariboo Mountains north and east of Bowron Lake Provincial Park indicated the presence of a second carbonate formation in the Cariboo Group (Campbell, 1967). The newly discovered, higher carbonate unit yielded archaeocyathids and trilobites and was correlated with the Lower Cambrian Mural Formation in Rocky Mountains. A follow-up study by Young (1968, 1969) provided a set of distinguishing characteristics between the two carbonate units. A revision of previous mapping in the Wells area became necessary, because mapping had been based on the assumption that only one carbonate unit, the Cunningham ~~Lime-stone~~ Formation, was present in that area.

The presence of a carbonate formation, succeeded by the shaly Dome Creek Formation, and directly overlying the Midas Formation, raises the problem of the position of the Snowshoe Formation (Holland, 1954; Sutherland Brown, 1957 and 1963) in the succession. The Snowshoe was placed directly above the Midas by the earlier workers, but the Snowshoe is very different in lithologic character from the Mural and overlying shale units. As discussed by Campbell (1968) the occurrence of the immature, feldspathic sandstone and pelitic rocks of the Snowshoe, which apparently occur in the same stratigraphic position as the shallow-water limestone of the Mural Formation only a few miles distant, may be explained in several ways. These explanations include: (1) the Snowshoe Formation results from deposition of material from a western source and represents a profoundly different facies than equivalent rocks to the east that have an eastern source; (2) the Snowshoe Formation lies above an unconformity and hence is younger than its apparent equivalents to the east; and (3) the Snowshoe Formation does not lie stratigraphically above the Midas Formation, is older than other units of the Cariboo Group, and is separated from the Cariboo Group in part by undetected strike faults, and in part lies in its normal lower stratigraphic position. The lack of fossils in the Snowshoe, its great resemblance to the Kaza Group, and revised mapping of the critical area all suggest the third explanation to be the correct one. If it is, the Snowshoe Formation is in reality but a western expression of the coarser immature sandstone of the Kaza Group.

In view of recent detailed studies by Mansy and Campbell (1970) immediately south of the map-area, revisions in the usage of the Midas Formation are also necessary. A Lower Devonian (?) and younger relatively thick black shale unit overlies the Cariboo Group unconformably in this area, and is herein named the Black Stuart Formation. This unit is much thicker than the Midas Formation, with which it was correlated by previous workers.

Proterozoic-Hadrynian (Windermere)

Kaza Group

The oldest rocks in the southwest segment of the map-area belong to the Kaza Group. These rocks are well exposed and probably least deformed within most of Bowron Lakes Provincial Park, which is the type area of the Kaza (Sutherland Brown, 1963). The Kaza also outcrops extensively in the southeastern part of the map-area where it becomes increasingly metamorphosed towards the southeast. An isolated area of Kaza outcroppings lies along the northern edge of the area immediately east and north of Purden Lake. The Snowshoe Formation, which is considered to be a western facies of the Kaza Group (see discussion above), outcrops in a northwest-trending strip that passes through Wells.

According to Sutherland Brown (1963) the Kaza Group is at least 12,000 feet thick in the Bowron Lake Park area. Deviations from this estimated thickness in other parts of the map-area are unknown.

The Kaza Group consists of alternating units of unsorted, feldspathic, gravelly sandstone or "grit" and greenish grey to dark grey phyllite and schist. For detailed aspects of the lithology and stratigraphy of the Kaza in the Bowron Lake Park area the reader is referred to Sutherland Brown (1963, p.13-19). At the Purden Lake outcrops, the Kaza consists of phyllite, micaceous quartzite, and minor schistose feldspathic "grit".

The Kaza Group is overlain conformably by slate and phyllite of the Isaac Formation. The contact between the two units is difficult to define in places, but it is generally placed at the top of the highest grit bed.

The lithology and thickness of the Kaza Group are about the same as those of the middle Miette Group on the opposite side of the Rocky Mountain Trench, and the two units are considered to be stratigraphic equivalents, hence, the Kaza, like the middle Miette, is Late Proterozoic in age. The Snowshoe Formation is also believed to be an equivalent of the Kaza Group. Although he carefully attempted to show their lithological differences, Sutherland Brown (1963, p.19) conceded that "The Kaza Group is in some ways similar to the Snowshoe Formation . . . a small outcrop could be difficult to identify positively as belonging to one unit or the other". The Snowshoe consists mainly of phyllitic siltstone, phyllite, and immature micaceous sandstone, and contains minor limestone and conglomerate.

Proterozoic and Cambrian

Cariboo Group

The Cariboo Group includes such diverse rock types as pebble conglomerate, feldspathic and quartzose sandstone, variously coloured argillaceous rocks, and many kinds of carbonate rocks. These rocks are subdivided stratigraphically into seven formations, which include in ascending order the Isaac, Cunningham, Yankee Bell, Yanks Peak, Midas, Mural, and Dome Creek Formations. The Dome Creek Formation is named and defined in this report.

The formations were deposited essentially without interruption, with the exception of a local disconformity between the Cunningham and Yankee Belle Formations near the Rocky Mountain Trench. The Cariboo Group attains a maximum thickness of about 17,000 feet in western Cariboo Mountains, and thins to about 12,000 feet eastward along the western rim of the Rocky Mountain Trench. In the southwestern part of the map-area structural deformation and a regional unconformity render an estimate of total thickness difficult. Nevertheless, the thickness of the group probably ranges between 8,000 and 10,000 feet in this area.

Cariboo Group strata range in age from Upper Proterozoic (?) (Hadrynian) to Upper Cambrian. At the base of the group, the Isaac Formation may be correlated with the upper Miette Group, a late Proterozoic unit in the Rocky Mountains. At the

top of the succession, the Dome Creek Formation contains fossils documented by Dr. W.H. Fritz of the Geological Survey as Upper Cambrian in age. This age range differs markedly from previous concepts (e.g. Sutherland Brown, 1963; Wheeler, 1966) and necessitates changes in the correlation of the Cariboo Group with other successions in the Eastern Cordillera.

Isaac Formation

The Isaac Formation was named by Sutherland Brown (1963) for the thick, recessive, argillaceous unit which underlies the Cunningham Formation in the Isaac Lake area. As measured by Young, the Isaac is 4,400 feet thick near its type area five miles east of the southern end of Isaac Lake. Sutherland Brown measured only 2,500 feet on the slopes immediately east of the lake. The discrepancy in measurements might be explained by the presence of a massive limestone unit (see below) within the Isaac at this locality, possibly mistaken for the base of the Cunningham by Sutherland Brown. Variations in the thickness of the Isaac are unknown because of its deformation over most of the map-area. It outcrops extensively in the Cariboo Mountains southeast of Goat River, where it is compressed into tight folds. It also occurs in scattered areas north of Goat River, in a large area north of Bowron Lake Park, and in the Wells area, where the Isaac phyllites were mapped previously as Midas Formation from Summit Creek to Roundtop Mountain (Sutherland Brown, 1963).

The Isaac Formation consists mainly of grey to black phyllite, and includes minor siltstone, sandstone, and limestone.

The basal half of the formation is mainly medium grey to black phyllite and argillite, which in part weather to a peculiar steel-blue colour, and commonly contain large crystals of pyrite. Within this sequence are calcareous siltstone and very fine-grained sandstone. Thinly bedded micritic limestone is minor.

In about the middle of the Isaac at its type section is a resistant-weathering, massive limestone conglomerate unit, which rests sharply upon recessive-weathering, dark grey shale. Similar units have not been observed elsewhere. This unit is distinctly lensoid, thinning from 100 feet to 50 feet in a distance of about 1,000 feet. Curved, tabular, angular phenoclasts of the underlying shale are common in the

basal part of the conglomerate. Fragments of limestone up to two feet in width were observed. Intraclasts are abundant, and consist in part of grain-supported, oncolitic and aggregate-grain limestone; many of these are dolomitic.

Above the conglomerate unit the Isaac is predominantly dark grey phyllitic shale, and includes minor argillaceous limestone. About 250 feet below the Cunningham Formation the shale is interbedded with microcrystalline limestone, which gradually increases in proportion upwards into the purely carbonate rocks of the Cunningham. (Plate VIII)

Eastward near the Rocky Mountain Trench, the upper 200 feet of the Isaac consists of grey phyllite with sparsely interbedded siltstone and limonitic fine-grained sandstone. The contact with the overlying Cunningham Formation is relatively abrupt.

Microscopic details of the lithology of the Isaac Formation may be found in the report by Sutherland Brown (1963).

The similar lithology, thickness, and stratigraphic position of the Isaac Formation with the upper Miette Group, together with the lithological equivalence of the Kaza and middle Miette Groups indicate the Isaac to be the western extension of the upper Miette Group. In its entirety this thick shale facies extends over the whole map-area, and represents the continuous sedimentation of silt and clay within a large marine basin possibly over a long period of time.

The only fossils observed in the Isaac Formation are "worm" trails on a single bedding surface in the upper half of the formation. Because the Isaac is correlative with the upper Miette Group, both contain trails of metazoan origins stratigraphically far below known Cambrian rocks, it is considered upper Proterozoic in age (Young, 1972a).

Cunningham Formation

The Cunningham Limestone was proposed by Holland (1954) to designate limestone beds which outcrop on the northeast side of Roundtop Mountain 16 miles southeast of Wells. Owing to structural complications and poor exposures in the type area, a reference section is suggested. This section forms well exposed cliffs

on the north side of Haggen Creek, opposite Clear Mountain in northern Cariboo Mountains. Also, the Cunningham is henceforth referred to as a "formation", as it is not entirely a limestone unit; for example it consists of dolostone and fine clastics near the Rocky Mountain Trench.

Reference Section of Cunningham Formation, Haggen Creek, northern Cariboo Mountains (Lat. 53° 28'N, Long. 121° 13'W).

Unit	Lithology	Thickness (feet) Unit	Above base
	Overlying beds: medium grey shale of Yankee Belle Formation Cunningham Formation		
11	Limestone, dark grey, light grey weathering, microcrystalline, thick-bedded, in part flecked with orange ankerite crystals, with minor thin-bedded, argillaceous limestone and limy shale.....	60	1,816
10	Limestone, medium to dark grey, light grey weathering, partly covered, very coarse-grained to pebbly, coated aggregate-grained calcirudite, fair to good sorting; resistant, massive.....	235	1,756
9	Limestone, medium grey, light grey weathering, microcrystalline, vaguely pelletal; gradational contact with Unit 10, resistant, massive.....	122	1,521

Unit	Lithology	Thickness (feet) Unit	Above base
8	Limestone, medium to dark grey, light grey weathering, 80 percent pellet/oidal calcarenite, coarse- to very coarse-grained, moderately well sorted, 20 percent micrite; moderately resistant, massive.....	158	1,399
7	Limestone, in abrupt contact with Unit 8, medium to dark grey, pale to light grey weathering, 90 percent granular calcirudite, intraclastic, pellet/oidal, possibly oolitic, ankeritic, and 10 percent micrite; relatively recessive at base, becoming more resistant upwards, thick-bedded.....	77	1,241
6	Limestone, pale brown to light orange-grey, light grey weathering, micrite at top, becoming dominantly very coarse-grained calcarenite, pellet/oidal, ankeritic, downsection; thick-bedded to massive, relatively recessive.....	194	1,164
5	Limestone, light to medium grey, pale grey weathering, mainly very coarse-grained, pebbly calcarenite, pellet/oidal and intraclastic, poorly sorted, and minor micrite; stylolites common, thick-bedded to massive, partly covered, in abrupt contact with Unit 6.	122	970

Unit	Lithology	Thickness (feet) Unit	Above base
4	Limestone, pale brown, light grey weathering, microcrystalline; very massive, resistant, in sharp contact with Unit 5, becoming less resistant downsection.....	178	848
3	Limestone, pale yellow- to red-grey weathering, mainly intraclastic, pelletfoidal calcirudite, unsorted with intraclasts elongated and rounded; interbedded with micrite and coarse-grained pelletal calcarenite; medium-to thick-bedded, resistant at top, in sharp contact with Unit 4, partly covered, includes 10-foot-thick diabase sill.....	215	670
2	Limestone, medium grey, pale brown weathering, in part silt-laminated, medium to thick-bedded; minor green limestone, microcrystalline, laminated, thin-bedded; partly covered, relatively recessive, in sharp contact with Unit 3.....	205	455
1	Limestone, dark grey, pale grey-brown weathering, micrite with fine-grained pellets in part, minor grey shale in mantling material, poorly exposed, relatively recessive with minor thick-bedded ledges protruding from slope.....	250	250

Unit	Lithology	Thickness (feet) Unit	Above base
	~~Covered interval~~	~~10~~	
	Underlying beds: dark grey shale (70 percent) and brown-weathering, microcrystalline limestone of Isaac Formation		

The Cunningham Formation attains its greatest thickness (more than 1,800 feet) and greatest limestone development at its reference section near Clear Mountain in northern Cariboo Mountains. In the south-central part of the map-area the Cunningham Formation limestone remains thick, but in the Wells area the formation apparently changes partly to shale. Near the Trench north of Goat River the Cunningham thins to 780 feet and is dominantly dolostone and shale. East of the Rocky Mountain Trench at Holy Cross Mountain, the Cunningham equivalent is 440 feet thick, and consists of interbedded limestone, dolostone, sandstone, and mudstone. It outcrops along the ridge towards the southeast, and disappears southeast of Morkill River. In the opinion of the writer (F.G.Y.) the Cunningham is younger than the type Byng Formation, which intertongues with feldspathic grits ~~of~~ tentative: assigned to the uppermost middle Miette Group (Young, 1972b).

The Cunningham Formation consists of limestone, dolostone, shale, siltstone, and sandstone. The limestone includes bedded or massive, mainly recrystallized micrite and non-skeletal calcarenite, which contain pisolites, oolites, pellets, algal-coated complex grains, intraclasts, and unidentified ovoid grains. In contrast with limestone which generally contains very minor quartz, the dolostone is commonly silty and sandy. Rounded quartz granules (2 - 4 mm diameter) were observed in some dolostone. Relict grains in the dolostone are commonly reddish toned due to hematite staining, and set in a grey or green dolmicrite matrix. These grains consist of pisolites and ovoid grains similar to those in the limestone. Rhythmic alterations between units of micrite or clastic rocks and units of calcarenite exist in some localities.

Recrystallization of limestone is manifested in varying degrees, but is mainly of the aggrading "neomorphic" type (Folk, 1964), by which true micrites are converted to microsparites (average diameter of crystallites 10 to 50 microns). This phenomenon plus dolomitization in eastern occurrences, causes much difficulty in the study of textures in these rocks.

The non-skeletal particles greatly resemble those forming presently on the Bahama Platform (Illing, 1954). Hence, the ? may be attributed to similar shallow marine conditions ~~may be attributed to the~~ origin of the Cunningham sediments. The presence of oolites, intraclasts, and cross-stratification indicate that currents were locally strong. The presence of quartz sand and a shale member in the northeastern sequences suggest that clastics entered the depositional sites from the northeast.

Distinction Between Cunningham and Mural Formations

The Cunningham and Mural Formations possess similar types of non-skeletal calcarenite. However, the Cunningham may be distinguished from the Mural by the following features:

(a) the Cunningham contains no skeletal fossils;

(b) carbonates of the Cunningham tend to be more ferruginous: crystals of ankerite and ferroan dolomite are common, as well as red, hematite-flecked, non-skeletal particles;

(c) the Cunningham is generally twice as thick as the Mural Formation in Cariboo Mountains; and

(d) the Mural is overlain by black shale, but the Cunningham may be overlain by greenish phyllite, siltstone, coarse-grained sandstone, and min or limestone.

The Yankee Belle Formation overlies the Cunningham with apparent conformity in the Wells area and western Cariboo Mountains. In the eastern Cariboo Mountains the basal sandstone member of the Yankee Belle Formation lies abruptly over Cunningham dolostones, which appear to be truncated along a disconformity near the Rocky Mountain Trench. In central parts of the northern Cariboo Mountains, the contact between the two formations is indistinct because of the limestones which dominate the base of the Yankee Belle in that area. For practical purposes in

mapping, the base of the Yankee Belle is picked at the base of the lowest, recessive-weathering, argillaceous unit above the resistant limestones of the Cunningham. However, dolostone-fragmental, feldspathic calcarenite near the top of the limestone sequence mapped as Cunningham in some places may lie above the disconformity which separates the two formations eastward, and be correlative with the basal sandstone (Zig-Zag Member) of the Yankee Belle Formation.

No skeletal fossils were found in the Cunningham Formation. Fossil collections described in Sutherland Brown's report (1963) in fact were taken from the Mural Formation. Many of the coated grains in the limestone suggest an algal origin, and small, domical stromatolites were rarely observed. Sorenson (1955) described and illustrated large, and well developed stromatolites from the top of the Cunningham ~~from~~ North of Goat River near the Trench. Future detailed studies of these algal structures may permit a refined age assignment to the Cunningham. For the present time, it is considered to be Late Proterozoic in age.

As the Cunningham was previously thought to be Lower Cambrian, it was incorrectly correlated with other Lower Cambrian formations in the Cordillera, such as the Badshot Limestone (Sutherland Brown 1963). However, the Cunningham probably correlates with upper parts of the "Windermere Series", such as the limestone and shale members of the Horsethief Creek Formation of the Selkirk Mountains.

Yankee Belle Formation

The type locality of the Yankee Belle Formation is on the Yankee Belle mineral property on Yanks Peak, about eighteen miles south of Wells (Holland, 1954). However, due to structural complications and poor exposure of bedrock, it is questionable that the phyllite at this locality belongs to the formation as currently used. A reference section for current usage of the Yankee Belle is located at the headwaters of Dome Creek in northern Cariboo Mountains (Lat. 53° 34'N, Long. 121° 07'W). Another complete but unmeasured section of the Yankee Belle occurs near Betty Wendle Creek east of Isaac Lake (Lat. 53° 13'N, Long. 120° 47'W). In the Wells area a good reference section is located along the bank of Summit Creek about four miles northeast of Wells (Lat. 53° 09'N, Long. 121° 31'W).

Near Wells the Yankee Belle Formation is 1,670 feet thick and consists dominantly of greenish grey argillite and phyllite. In northern Cariboo Mountains, the Yankee Belle is generally much thicker, and more calcareous, attaining a maximum measured thickness of 2,980 feet at the Dome Creek reference section. Along the northeast flank of the Cariboo Mountains the rocks are much sandier and the sequence thins to 1,300 feet at the ridge between Slim Creek and Fraser River.

The Yankee Belle consists mainly of alternating beds of shale, siltstone, fine-grained quartzite, and limestone. Some units of uniform argillite or shale up to 500 feet thick occur in the sequence. Along the northeastern flank of the Cariboo Mountains, a basal sandstone unit can be mapped, and is here designated the Zig-Zag Member after Zig-Zag Ridge near Goat River where it is well developed and exposed. This wide variety of rock types may be grouped into three facies which include:

(a) basal sandstone (Zig-Zag Member);

(b) rhythmic limestone-siltstone-shale; and

(c) shale-sandstone.

(a) Zig-Zag Member

Resting sharply upon Cunningham dolostone in the northeast Cariboo Mountains is a wedge of coarse sandstone and red shale, which thickens towards the Rocky Mountain Trench. Westward, the Zig-Zag Member intertongues with the limestone-shale lithosome, and gradually disappears. A maximum thickness of 317 feet was measured on Zig-Zag Ridge at the type section. The lithology of the Zig-Zag Member at the type section is as follows:

Unit	Lithology	Thickness Unit	Thickness Above base
	Overlying beds: blue-weathering phyllite with minor quartzite Zig-Zag Member, Yankee Belle Formation		

Unit	Lithology	Thickness Unit	Above base
4	Sandstone, greenish grey, coarse-grained, thin-bedded, with numerous green shale partings, moderately resistant.....	8	317
3	Sandstone, light grey, coarse-grained, quartzose, sericitic, cross-stratified with crude dark grey banding; medium-bedded, resistant.....	117	309
2	Siltstone, shale, and thin-bedded sandstone, partly covered, recessive.....	12	132
1	Sandstone, light grey, coarse- to very coarse-grained quartzose with up to 10 percent feldspar, sericitic, trace of green shale partings, thin- to thick-bedded, resistant, with sharp, slightly uneven contact over underlying dolostone.....	120	120
	Underlying beds: microcrystalline dolostone of Cunningham Formation		

Towards the northwest increasing proportions of red siltstone and shale appear, and the sandstone becomes more diverse in textural properties. On the ridge between Slim Creek and Fraser River (Lat. 53° 44'N, Long. 121° 11'W) the member consists of pebbly, coarse-grained, feldspathic sandstone and red, dessicated mudstone. Festoon cross-bedding is locally common. Thin interbeds of fine-grained sandstone in places contain rip-up clasts of shale, and may grade upward into red mudstone over 0.2-foot thick intervals. Towards the southwest where these rocks grade into 2 limestone-shale facies, increasing amounts of "calclithite", or limestone-fragment

sandstone, and dolomite-cemented sandstone occur at the base of the formation. These rocks, in places, grade into calcarenite with increasing proportions of pisolites and pellettoidal grains.

(b) Rhythmic limestone-siltstone-shale facies

The sequences of interbedded limestone, shale, and siltstone comprise two major cycles, the lower of which contains much more limestone than the upper. These cycles occur in the basal two-thirds of the Yankee Belle Formation over most of the northern Cariboo Mountains. Within these cycles are smaller order cycles which are mainly 100 to 200 feet thick. The basal part of each cycle is dominated by shale, and becomes richer in siltstone and fine-grained quartzite. At the top limestone predominates.

The limestone greatly resembles that of the Cunningham Formation, including microcrystalline limestone, and ankerite-flecked non-skeletal calcarenite of various types and grain sizes.

The clastics consist mainly of green-grey shale and argillite, laminated, thin-bedded siltstone, and very fine-grained, graded quartzitic sandstone. These components are typically interbedded. The siltstone and sandstone are generally evenly bedded, with sharp, locally undulatory, basal bedding contacts. Both rock types commonly grade into silty limestone. No sole markings characteristic of turbidites were observed. These rocks grade upward into the shale-sandstone facies and to the southwest into the latter and possibly the limestone lithosome of the Cunningham Formation.

(c) Shale-sandstone facies

Considered together in this lithosome are the sequences of dominantly greenish grey phyllitic shale in the Wells area, and the sandier shale and argillite units which underlie the Yanks Peak Formation in the northern Cariboo Mountains. In the latter area, the shale-sandstone unit commences over the limestone-siltstone-shale facies with green, red, maroon, or black argillite, which ranges from 100 to 500 feet thick.

The thickest development of this facies occurs on the ridge between Haggen Creek and Indian point Creek, where 1,500 feet of alternating dark grey shale and

very fine-grained sandstone beds lie above a massive limestone unit. Towards the north and east the facies thins, and sandstones become more abundant and coarser. The upper portion is replaced by the sandier facies of the Yanks Peak Formation with which it interfingers.

A great variety of sandstone occurs in this lithosome, but the majority are matrix-rich, limonitic, homogeneous, and contain minor amounts of plagioclase feldspar. Siltstone resembles the fine-grained sandstones in their comparable homogeneity, diversity of bedding thickness, and brown-weathering, limonitic character. Rarely they display bioturbated fabrics and rippled bedding surfaces.

Origin of Yankee Belle Formation

Environments of deposition of the Yankee Belle Formation range from the alluvial to deep marine. In the basal Zig-Zag Member, the textural immaturity, coarseness, and evidence of subaerial exposure (mud-cracks and hematite-staining) suggest a fluvial environment of deposition, possibly a deltaic flood-plain. Improved sorting of sandstone towards the southeast, plus the cross-stratification and parallel banding indicate energetic environments such as nearshore marine or littoral sites. The variety of rock types in the rhythmic limestone-shale facies, limestone of Bahamian character, widespread distribution, and lateral continuity with a sandy, littoral facies, indicate a marine environment situated adjacent to the littoral zone. A broad, relatively shallow shelf would accommodate the deposition of both fine clastics and particulate carbonates, which require sunlight and some water circulation for their development. In the shale-sandstone facies the predominance of mudstone, the gradation into shallow marine facies towards the northeast, and the rare organic traces indicate a neritic marine environment of deposition.

Reference section of Yankee Belle Formation, located at "Anticline Lake", northern Cariboo Mountains, B.C., Lat. 53° 34'N, Long. 121° 07'W.

Unit	Lithology	Thickness Unit	Above base
	Overlying unit: Yanks Peak Formation - White-weathering, resistant, medium grained quartzite		
	Yankee Belle Formation		
34	Sandstone, medium-grained, grading into Yanks Peak quartzites, interbedded with phyllite, 50 percent at base of unit.....	50	2,948
33	Interbedded shale, medium-grey, dolostone, dark red-brown weathering, and silty quartzite, shale-laminated; shale predominant.....	84	2,898
32	Sandstone, white-grey weathering at top, quartzose, coarse-grained, well sorted, in sharp contact with Unit 33, becoming more limonitic, finer grained downsection, red-grey weathering at base of unit.....	32	2,814
31	Siltstone, light grey weathering, green-grey, slightly sandy, medium- to thick-bedded, unevenly shale-laminated in part; interbedded with up to 50 percent shale, light green-grey.	221	2,782
30	Sandstone, deep red-brown weathering, hematitic, thick-bedded, homogeneous, recessive, in sharp contact with Unit 31.....	6	2,561

Unit	Lithology	Thickness Unit	Thickness Above base
29	Interbedded shale, olive, and siltstone, or very fine-grained sandstone, 30 percent, medium-bedded, evenly laminated, ripple-marked near top of unit.....	66	2,555
28	Shale, orange-brown weathering, light green-gray, fracture cleavage pronounced, recessive, minor siltstone, green-grey, limonitic.....	214	2,489
27	Argillite, light green-grey, becoming medium grey downsection, grading into red shale with rare shale-clast limestone beds, green shale, and green-shale-clast limestone, with cream matrix at base.....	56	2,275
26	Interbedded shale, olive to medium grey, siltstone, in part calcareous, sandstone, light grey weathering, very fine- to fine-grained, pyritic, and limestone, sandy, red-brown weathering, medium- to thick-bedded, minor	285	2,219
25	Limestone, red-brown weathering, sandy, platy and uneven beds, 50 percent inter-bedded shale, olive.....	55	1,934

Unit	Lithology	Thickness Unit	Above base
24	Shale, olive, in part grading to siltstone, or interbedded with siltstone, olive weathering, laminated, calcareous; rare beds of limestone, medium grey, micrite, and sandstone, white-grey weathering, fine-grained.....	175	1,879
23	Limestone, light grey weathering, medium grey, microcrystalline, 10 percent sandy content, in part ankeritic, becoming recessive, more thinly bedded downsection; topmost bed a sandy, ochre-weathering dolostone, in sharp contact with Unit 24.....	26	1,704
22	Shale, olive, 50 to 80 percent of unit, interbedded with siltstone, finely and evenly laminated, and limestone, sand-laminated, limonitic in part, recessive.....	181	1,678
21	Limestone, mainly pelletoidal, coarse-grained, in part silt-banded; with 20% interbedded shale; average resistance.....	26	1,507
20	Interbedded shale, medium to dark grey, in part silty; limestone, medium red-grey, limonitic, micrite, in part silty, laminated; and siltstone, calcareous; very thin to thick bedded.....	90	1,481

Unit	Lithology	Thickness Unit	Thickness Above base
19	Limestone, light grey weathering, pelletoidal, coarse-grained, well sorted, with ankeritic interiors common; 20 percent interbedded shale, olive.....	46	1,391
18	Interbedded shale, light grey, medium olive weathering; siltstone, laminated or homogeneous, evenly bedded; and minor sandstone, dark green-grey, very fine-grained, and limestone, sandy, thin-bedded.....	84	1,345
17	Interbedded siltstone, calcareous and silliceous varieties, and silty shale, 10 to 50 percent; limestone common in uppermost 20 feet, yellow-weathering, micritic, recessive, silty.....	63	1,261
16	Limestone, mainly pelletoidal, very coarse-grained, grain-supported, 70 percent; interbeds of shale and siltstone	26	1,198
15	Interbedded shale, medium olive-grey, 50 percent; and siltstone, medium grey in part calcareous, laminated.....	47	1,172
14	Limestone, medium grey, intraclastic calcirudite mainly; interbedded shale, medium grey, and sandstone, medium-grained, unevenly bedded, calcareous.....	20	1,125

Unit	Lithology	Thickness Unit	Thickness Above base
13	Shale, green-grey, yellow to red-brown weathering; with interbedded siltstone, medium grey, partly laminated, thin- to medium-bedded; minor limestone, micro-crystalline, in part pelletal, ankeritic, and sandstone, very fine-grained, limonitic.....	220	1,105
12	Interbedded limestone, micrite, unevenly bedded, and shale, medium grey.....	10	885
11	Limestone, medium grey, pelletoidal, intra-clastic, clasts dolomitic, medium-bedded to massive; up to 20 percent interbeds of shale, light olive-grey, and siltstone, green-grey, laminated, evenly bedded, calcareous.....	353	875
10	Interbedded shale, 70 percent, medium olive-grey; siltstone, dark green-grey; and sandstone, white-grey weathering, medium-grained.....	15	522
	Covered interval, recessive-weathering.....	28	507
9	Limestone, pelletoidal and intraclastic calcirudite, dolomitic clasts common, thick-bedded; minor interbedded silty limestone and shale.....	120	479

Unit	Lithology	Thickness Unit	Above base
8	Interbedded siltstone and shale, both medium to dark olive-grey, light brown weathering, with minor sandstone, brown-grey weathering, fine-grained, calcareous, recessive.....	25	359
7	Limestone, medium grey, vaguely pellet/oidal, medium-grained, thick-bedded; contains trace amounts of quartz sand up to granule size; minor intraclastic limestone, siltstone, green-grey calcareous.....	73	334
6	Interbedded shale and limestone, micrite, in part silt-laminated; thin-bedded, recessive, poorly exposed unit.....	26	261
5	Limestone, microcrystalline, vaguely pellet/al, silty or sandy (5 percent) with micro-cross-laminations, medium- to thick-bedded, minor dolomitic bands; minor interbeds of shale, olive-grey, recessive.....	51	235
4	Shale, medium olive-grey, recessive, with interbedded limestone, microcrystalline or pellet/oidal, ankeritic; poorly exposed.....	65	184
3	Limestone, light grey-weathering, pellet/oidal, partly calcirudite, medium to thick bedded, with minor shale interbeds.....	43	119

Unit	Lithology	Thickness Unit	Thickness Above base
2	Interbedded limestone, shale, sandstone, and sandy limestone; dolomitic intraclasts and quartz granules present; sandstone partly cross-stratified; thick-bedded.....	9	76
1	Interbedded shale, olive, and siltstone, green-grey, evenly textured, thin- to medium-bedded.....	12	67
	Covered, recessive, probably shaly interval.	55	55
	Underlying unit: Cunningham Formation - massive limestone, intraclastic and sandy at top		

Yanks Peak Formation

The quartzite on Yanks Peak after which the formation is named is structurally deformed and possibly not of the Yanks Peak Formation of present usage, hence, a reference section is designated for northern Cariboo Mountains where the unit is well exposed and much thicker than the quartzite of the type area. The section measured at the headwaters of Dome Creek is representative of the average thickness and lithology of the Yanks Peak Formation in the Cariboo Mountains. Here, the formation is 1,320 feet thick, and includes quartzite, shale, siltstone, and calcareous sandstone. It is recommended that the term "formation" be used when referring to the Yanks Peak as a unit instead of "quartzite" as in the original definition. A good reference section in the Wells area occurs on Summit Creek near its junction with Shepherd Creek, about four miles northeast of Wells. Here, 178 feet of quartzose sandstone is exposed without outcroppings of underlying or overlying units.

Southwest of the fault through and northwest of Isaac Lake the Yanks Peak Formation is apparently mainly less than 500 feet thick. Southward from Wells it appears to ~~feather out~~ grade into into argillaceous rocks, but in places it is represented by ~~the~~ lensoid ~~development~~ processes of quartzite. Immediately northeast of Isaac Lake near Betty Wendle Creek the formation reaches its maximum thickness of 1,900 feet. Northeastward it thins to only 800 feet at Zig-Zag Ridge north of Goat River near the Rocky Mountain Trench. In the Rocky Mountains the quartzite-shale couplet formed by the Yanks Peak and Midas Formations is generally not recognizable below the Mural Formation, except for one locality just northeast of McBride..

The Yanks Peak Formation is dominated by quartzitic sandstone that weathers to white and grey, and various shades of red and green. The sandstone is mainly medium to coarse grained and thickly bedded (Plate XI). Granular to pebbly sandstone is scarce, but exists in most sections studied in northern Cariboo Mountains. Fine-grained sandstone and siltstone are typically thin bedded, recessive weathering, limonitic, and olive or red in colour.

~~The~~ sandstone of the Yanks Peak are essentially quartzose. Rounded pebbles are mainly white, milky, vein-quartz; some quartzite pebbles may also be present. Particles of quartz sand are generally rounded, and cemented together by continuous quartz overgrowths, or by granulization of particle rims.

Although scarcely any feldspar is found in the formation in the southwestern part of the area (Sutherland Brown, 1963, p.32), potash feldspar constitutes up to 20 percent in the northern Cariboo Mountains. Accessory minerals include muscovite, magnetite, hornblende, leucoxene, rutile, albite, zircon, tourmaline, and garnet. This suite of minerals indicates derivation from a mixed igneous and metamorphic terrain, such as the Canadian Shield.

The grain-sizes of quartzitic sandstone range between fine to coarse grained mainly, and size-sorting varies from poor to moderate (Standard deviation: 0.70 to 2.0). Sparsely scattered granules and pebbles comprise a minor, secondary coarse mode in most of the quartzitic sandstone. Fine-grained sandstone and siltstone have strongly bimodal grain-size distributions, consisting of clay and coarse silt.

In most of the northern Cariboo Mountains the lower half of the formation contains minor amounts of shale and argillaceous sandstone in contrast with the uniform quartzitic sandstone of the upper half. Where the formation is thickest, it consists of a series of rhythmic alternations of sandstone units and argillaceous, recessive units. Southwest of Isaac Lake the formation is a single unit of sandstone, which grades above and below into strata of argillaceous sandstone and shale.

The Yanks Peak intertongues with the Yankee Belle Formation below, and the contact is placed at the base of the lowest resistant bed of white-weathering quartzite. The contact with the overlying Midas Formation is everywhere conformable, but varies from very sharp to gradational.

Reference section of the Yanks Peak Formation, northern Cariboo Mountains, B.C. at headwaters of Dome Creek (Lat. 53° 36N, Long. 121° 01W).

Unit	Lithology	Thickness Unit	Thickness Above base
	Overlying unit: Midas Formation - dark brown sandstone and dark grey shale interbedded		
	Yanks Peak Formation		
10	Sandstone, quartzitic, white fine to medium grained, well sorted; minor siltstone interbeds up to 0.5 feet thick; mainly very resistant, thick-bedded to massive, with rare cross-bedding.....	487	1,181
9	Sandstone, very coarse-grained to granular, moderately sorted, well rounded, white-weathering, medium- to thick-bedded; minor interbeds of red or green shale and shaly siltstone.....	87	694

Unit	Lithology	Thickness Unit	Above base
8	Sandstone, pink to maroon, fine-to coarse-grained, fairly well sorted, in part cross-stratified; up to 40 percent red shale and siltstone interbeds up to 0.5 ft. thick.....	211	607
7	Sandstone, pink, fine- to medium-grained, quartzose, well sorted, slightly limonitic, banded, medium- to thick-bedded; red-shale partings and coatings common.....	107	396
6	Sandstone, coarse-grained to granular, medium red, hematitic, slightly feldspathic, argillaceous, thick-bedded; interbedded with 20 percent siltstone and shale, red, up to 1.0 ft. thick.....	80	289
5	Sandstone, grading to conglomerate, medium-grained to granular, light grey feldspathic, thick-bedded to massive, very resistant, sharp upper and lower contacts.....	32	209
4	Sandstone, light grey, fine to medium grained, well sorted, limonitic, slightly feldspathic; minor shale and argillaceous sandstone inter-beds, very thin-bedded	27	177

Unit	Lithology	Thickness Unit	Thickness Above base
3	Sandstone, light grey weathering, medium grey-brown, fine-grained, quartzose, sericitic, limonitic; even, thick bedding, minor cross-lamination.....	76	150
2	Sandstone, light grey weathering, light brown coarse-grained, limonitic, quartzose, thin-bedded, shale partings common, black argillite phenoclasts common.....	51	74
1	Sandstone, white-weathering, medium grained, fairly well sorted, quartzose, siliceous, limonitic, resistant; minor dark grey shale inter-beds, very thin bedded.....	23	23
	Underlying beds: interbedded white sandstone and dark grey shale, unevenly bedded - Yankee Belle Formation		

Units of thin-bedded, fine-grained sandstone and shale in the Yanks Peak Formation contain fossil trails, indicating a marine origin. The alternations of these units with cross-stratified, moderately well-sorted sandstone strongly suggests that widespread progradations of paralic sand deposits alternated with periods of marine inundations during which fine clastics were deposited. This series of transgressions and regressions caused a multi-storey development of sandstones to accumulate in more landward sequences to the northeast, where the shale units gradually disappear. Towards the southwest in the Wells area, one progradational tongue appears to have advanced farther than any others, and formed the single thin ~~Yanks Peak quartz~~ite

unit of that area.

Several trends indicate a northern source-area and a north to south or southwest dispersal trend. First, lithofacies are aligned such that shale units increase in thickness and proportion towards the southwest, and coarse sandstones of probable fluvial origin increase towards the north. Maximum grain-sizes decrease from the north, where pebbles 45 millimeters in greatest diameter were observed near Slim Creek - Fraser River junction, towards the southwest to only 4 millimetres near Wells. North of the map-area the Miette Group exhibits a 10,000-foot-thick conglomerate sequence west and southwest of Monkman Lake (Slind and Perkins, 1966; Taylor, pers. comm., 1970); this is the closest underlying rock-unit which could have been uplifted and eroded to supply adequate coarse, Shield-like detritus to the Yanks Peak Formation.

No skeletal fossils were observed in the Yanks Peak Formation. Trace fossils were observed rarely, and include horizontal burrows and locomotion markings on bedding surfaces. One of the latter resembles a pin-wheel, consisting of three curving, tapering tracks, which are doubly furrowed and internally ribbed.

Midas Formation

The type locality of the Midas Formation is at Yanks Peak in an area of intense structural deformation, and, as in the case of the two underlying formations, it is uncertain that the type section represents the Midas of current usage. A reference section is therefore suggested. This section is at the Dome Creek locality (Lat. 53° 36'N, Long. 121° 01'W) continuous with the reference section of the Yanks Peak Formation. Another location in northern Cariboo Mountains where the Midas is well exposed, though not examined, is on the upper slopes of Mount Hammell (Lat. 53° 28'N, Long. 120° 55'W).

The Midas Formation occurs in numerous discontinuous outcroppings in northern Cariboo Mountains. Southeast of Wells it is generally poorly exposed due to its recessive-weathering nature, and is apt to be confused with similar shale units such as the Isaac, Yankee Belle, Dome Creek, and Black Stuart Formations (Mansy and Campbell, 1970).

The Midas Formation appears to thicken and thin in harmony with the overlying Mural Formation. It attains its maximum thickness on the ridge between Haggen and Indianpoint Creeks, where over 1,000 feet of phyllite and siltstone were directly measured, and about 2,000 feet are indicated by outcrop widths. However, internal folding or faulting may account for much of this apparent thickness. Eastward and northward the Midas becomes much thinner and richer in sandstone. At the reference section it is 487 feet thick. A minimum thickness of about 300 feet is developed in the area of Zig-Zag Ridge.

Characteristically, the Midas is a recessive- and dark-weathering argillaceous unit, consisting mainly of shale and siltstone with minor sandstone. In northern Cariboo Mountains fine-grained sandstone is commonly horizontally burrowed, and resembles strata in the Holmes River Member of the McNaughton Formation. Sandstones include quartzarenite, subarkose, and phosphate-quartz arenite, all of which are texturally immature. Collophane (phosphate) grains are well rounded, arenaceous, black, and constitute up to 25 percent of sandstones in the upper part of the Midas in northeastern occurrences. Beds of sandstones part irregularly, and are only rarely cross-stratified. Siltstone displays parallel laminations, small-scale scour-and-fill structures, and cross-laminations. The shale, phyllite, and argillite which dominate the formation are mostly dark grey or black, commonly silty, and orange-brown weathering.

In southwestern parts of the map-area where structural deformation is relatively intense, the Midas acts as an incompetent unit, and is commonly shear-folded and phyllitized. In northern Cariboo Mountains structural relationships with adjacent formations are generally uncomplicated, and argillaceous rocks range from well-indurated shale to phyllite.

The recessive Midas Formation typically contrasts sharply with the underlying resistant Yanks Peak Formation, along an abrupt, conformable contact. On the ridge where the Midas is thickest, however, the contact with the Yanks Peak Formation is gradational. Nearly everywhere the contact with the overlying Mural Formation is well defined, although in detail it is gradational. The Midas becomes increasingly silty or sandy near the contact, and grades into silty or sandy limestone

of the Mural Formation.

Following is the stratigraphic sequence in the reference section at the headwaters of the Dome Creek.

Unit	Lithology	Thickness Unit	Thickness Above base
	Overlying beds: Mural Formation (Lower Cambrian)		
	Midas Formation		
9	Interbedded shale, medium grey, and limestone, red-brown weathering, medium grey, sandy; very recessive, thin-bedded...	7	487
8	Siltstone, light grey-brown, very fine grained sandy, calcareous and siliceous varieties, beds wavy; in sharp contact with unit below.....	9	480
7	Shale, orange-brown weathering, medium green-grey, in part very silty; minor sandstone, very fine grained, thin-bedded, siliceous; trace fossils common.....	119	471
6	Sandstone, pale grey, very fine grained, limonitic, quartzose, laminated, thick-bedded, with abundant shale partings and intercalations.....	22	352

Unit	Lithology	Thickness Unit	Thickness Above base
5	Interbedded shale, dark grey-brown weathering, dark olive-grey, and sandstone, light grey, very fine grained, thin-bedded, in varying proportions throughout unit.....	87	330
4	Interbedded sandstone, light grey, fine-grained, quartzose, well sorted, thin to medium bedded, irregular shale partings common; and shale, 50 percent dark grey, in uneven layers.....	86	243
3	Sandstone, pale yellow-grey, medium to very coarse grained, quartzose, siliceous, thick bedded to massive, resistant, burrowed at top, in sharp contact with unit.....	10	157
2	Shale, dark grey, with interbedded sandstone, medium yellow-grey, very fine to fine grained, fairly well sorted, siliceous, medium to thick bedded.....	24	147
1	Sandstone, dark yellow-grey weathering, very fine- to very coarse-grained, quartzose, argillaceous, very thin-bedded, uneven, and intercalated by shale, dark grey; burrows and trails common; recessive, in sharp contact with underlying Yanks Peak ~~quartz~~ite.....	123	123

Unit	Lithology	Thickness Unit	Above base
	Underlying beds: Yanks Peak Formation (quartzite)		

The high proportion of darkly coloured fine clastics and evidence of organic life suggest calm, restricted, marine conditions of deposition. Because of the wide extent of facies, and its gradation westward into a thick black shale sequence, these conditions were probably associated with a deep shelf or basin, rather than a lagoon. The presence of phosphatic grains implies restricted circulation and low clastic supply, according to Pettijohn (1957, p.476).

Trace fossils are common in the Midas Formation, but no skeletal fossils have yet been found within it. Trace fossils include Scolicia (?) de Quatrefages, Planolites Nicholson, and an unnamed radiating burrow structure. Immediately above the contact with the Mural Formation, W.H. Fritz of the Geological Survey discovered the early Lower Cambrian trilobite Fallotaspis sp. Inasmuch as this contact is gradational, and the Midas is probably correlative with the uppermost McNaughton Formation which exhibits cruzionid trace fossils formed by trilobites, the Midas may be considered early Lower Cambrian in age.

Mural Formation

Characteristics of the Mural Formation in the Rocky Mountains are described in an earlier section of this report. In northern Cariboo Mountains, the Mural conformably overlies the Midas Formation, and consists of three members similar to the upper three members of the Mural in the Rocky Mountains. It is found throughout the Cariboo Mountains north of Bowron Lake Park, and forms the narrows at the Grand Canyon of the Fraser; it also comprises most of the Iltzul Ridge in western Bowron Lake Park, and is mappable southeast of Wells, where it has been previously lumped with the Cunningham Formation. For the southwestern half of the map-area a good reference section of the Mural Formation is situated at the head

of Dome Creek (Locality 7).

In the Cariboo Mountains the Mural is thinnest near the Rocky Mountain Trench where it is about 500 feet thick. It thickens gradually westward to a maximum of about 2,400 feet along a north-south thickening trend which runs from the Grand Canyon of the Fraser in the north to Turks Nose Mountain (Lat. 53° 02'N, Long. 121° 09'W) in the south. Westward of this trend the Mural is progressively truncated along an unconformity at the base of the black argillite of the Black Stuart Formation.

In this part of the area the Mural consists mainly of limestone, with lesser amounts of shale, siltstone, and quartzose sandstone. Within the zone of thickening the Mural consists entirely of limestone. Nearly everywhere else, however, a medial shale member provides its characteristic tripartite appearance (Pl. XII).

Pl. XII Cl. are

Limestones include oolitic calcarenite which is intraclastic in places, fragmental bioclastic calcarenite, micrites with scattered whole trilobites and archaeocyathids, and unfossiliferous dolomitic micrite. Where the Mural is thick oncolitic calcirudite occurs near the top ~~of the Mural in the thickened zone~~. In thin sections of calcarenites fragments of echinoderms and green algae are identifiable. Although no reefoid developments were observed, archaeocyathids of various types and sizes abound in the lower carbonate member of the Mural in Cariboo Mountains. Southeast of Wells the Mural is recrystallized into a banded grey marble at most localities. No fossils have been found in the Mural Formation in this area.

A typical sequence of rock types in the Mural Formation is expressed in this reference section at the head of Dome Creek.

Unit	Lithology	Thickness Unit	Thickness Above base
	Overlying beds: Dome Creek Formation - black shales and bituminous, thin-bedded limestones		
	Mural Formation		

Unit	Lithology	Thickness Unit	Above base
8	Limestone, light grey, in part trilobite-archaeocyathid biomicrite, in part dolomite-mottled, microcrystalline limestone; massive beds, resistant; the following fossils have been identified by W. Fritz: Aldonaia? sp., Bonnia sp., Bonnia tatondukensis? Palmer, Kutorgina sp., Paedeumias sp., Polliaxis sp., Onchocephalus cf. O. profectus Palmer, aff. Perimmella sp., aff. Clariondia sp., Kootenia sp., Ogygopsis sp., Protolenus? sp., ptychoparioid trilobite, archaeocyathids (GSC loc. 82787 to 82793) (late Lower Cambrian).....	98	666
7	Limestone, light grey, mainly bioclastic calcarenite, medium to coarse grained; minor dolomite-mottled micrite, mottling irregular, elongate parallel to bedding; identified fossils include cf. Fremontella sp., Olenellus sp., and archaeocyathids (GSC loc. 82784 to 82786) (late Lower Cambrian).	76	568

Unit	Lithology	Thickness Unit	Above base
6	Shale, medium olive, splintery, with minor silty shale, olive, and trilobite-bearing limestone, red-grey, very thinly bedded; recessive, in sharp contact with Unit 7; identified fossils include Olenellus sp., cf. Wanneria mexicana prima Lochman, and olenellid fragments (GSC loc. 82782, 82783, det. W.H. Fritz) (late Lower Cambrian)..	167	492
5	Interbedded shale, medium green-grey, siltstone, medium brown weathering, thin-bedded, and limestone, medium grey, trilobite biomicrite; bedding uneven, thin; limestone becomes predominant in basal 30 feet; recessive, partly covered; identified fossils include: Nevadella? sp., Nevadella cf. N. addyensis (Okulitch), Kutorgina? sp., and an olenellid provisionally named genus S. (GSC loc. 82779 to 82781, det. W.H. Fritz) (middle Lower Cambrian).....	131	325
4	Limestone light grey, micrite containing large, whole archaeocyathids, some bio-clastic calcarenite, fine to coarse grained; thick, uneven beds; resistant, in sharp contact with Unit 5; identified fossils include: archaeocyathids, olenellid trilobite fragments, Nevadella sp., and		

Unit	Lithology	Thickness Unit	Above base
	Judomia? sp. (GSC loc. 80715, 81776-82778, det. W.H. Fritz) middle Lower Cambrian)..	46	194
3	Limestone, medium grey to red-grey, coarse- to very coarse-grained bioclastic calcarenite; very minor shale interbeds, green-grey; beds uneven, medium to thick; resistant; identified fossils include: archaeocyathids, Judomia? sp., Nevadella sp., Kutorgina? sp., and trilobite fragment with Wanneria - like markings (GSC loc. 80689, 80690, 82769 to 82775, det. W.H. Fritz) (middle Lower Cambrian).....	78	148
2	Limestone, pale, grey, medium to very coarse-grained bioclastic calcarenite, quartz-sandy in stringers; thick bedded to massive; shale partings; resistant.....	14	70
1	Limestone, medium grey, oolitic calcarenite, medium-grained, in part cobbly intraclastic calcirudite, slightly sandy, about 25 percent quartz sand near base; minor dolomite, light yellow-brown, microcrystalline, in thin beds; medium-bedded to massive, average resistant; identified fossils include cf. Judomia sp. (GSC loc. 80709, det. W.H. Fritz) (middle Lower Cambrian); and from the base of unit, Fallotaspis sp. (GSC loc. 82768,		

Unit	Lithology	Thickness Unit	Above base
	W.H. Fritz) (early Lower Cambrian).....	56	56
	Underlying beds: Midas Formation		

The Mural Formation lies conformably above the Midas Formation, and grades at the top into dark grey shale and siltstone of the Dome Creek Formation. In western Cariboo Mountains, the appearance of limestone units in the lower parts of the Dome Creek Formation suggest that the thickening of the Mural farther west may in part be due to a facies change from shale to limestone in the basal Dome Creek.

The fossils collected by Fritz and Young at the Dome Creek section indicate the Mural Formation ranges in age from early to late Lower Cambrian. Archaeocyathids in these collections have not yet been identified. Those collected by Sutherland Brown and listed in his report (1963, p. 27, 28) under the Cunningham Limestone include:

Coscinocyathus sp.
Pycnoidocyathus sp.
Ajacicyathus sp.
Coscinocyathus dentocanius
Protopharetra? sp.

Identifications were made by V.J. Okulitch.

According to Fritz (written comm.) the trilobite Fallotaspis sp. is the oldest trilobite genus known in Canada, and occurs in the basal beds of the type Sekwi Formation, District of Mackenzie (handfield, 1968). The carbonate formation, like the Mural, ranges up into the upper Lower Cambrian, and is therefore closely correlative with the Mural Formation. Also according to Fritz, "the presence of Polliaxis in the uppermost limestone beds of the Mural Formation serves to correlate these beds with the Mural Formation on Mount Kerkeslin, Jasper Park, Alberta and with beds in the Adams Argillite of east-central Alaska" (written comm.). The

Badshot and Donald Formations (Wheeler, 1963) of the Selkirk and Dogtooth Mountains about 200 miles southeast of McBride carry Lower Cambrian faunas, and are ~~largely~~ all or partly correlative with the Mural Formation.

Dome Creek Formation

Overlying the Mural Formation in northern Cariboo Mountains is a dominantly black shale sequence with minor siltstone and thin, nodular limestone. The name Dome Creek Formation is here proposed for this unit, after the stream in whose drainage basin the formation is well exposed. The type section is continuous with the reference section of the Mural Formation (lat. 53° 35'N; Long. 121° 01'W). The Dome Creek Formation is up to 5,700 feet thick, and forms the highest stratigraphic unit of the northern Cariboo Mountains. To the southwest it is truncated by an unconformity over which lie beds of similar lithology - the Black Stuart Formation of Lower Devonian and (?) younger age.

The Dome Creek Formation is relatively restricted, outcropping discontinuously in the Cariboo Mountains only between Latitudes 53° 28' and 53° 40'N. About 5,700 feet of shales were measured in two different surveys at the type section in which partial repetition by small faults and folding may be present.

The Mural Formation grades into the Dome Creek shales through a zone of interbedding, in which uneven beds of bituminous, trilobite-bearing micrite alternate with beds of black, bituminous shale. Between 100 to 500 feet above the Mural, the shale grades into a unit of banded siltstone and silty argillite, several hundreds of feet thick, which commonly weathers to a characteristic yellow, flame-like colour at close range. Above the siltstone unit are black, siliceous argillite and dark grey shale which are unfossiliferous in the lowest 1,200 feet, but contain trilobites of Upper Cambrian age above the barren strata.

Much of the argillaceous siltstone displays fine, even laminations. Others are burrowed and include accumulations of trilobite fragments along some bedding planes. Silt is composed mainly of angular quartz, with minor contributions of muscovite, biotite, albite, and leucoxene. X-ray analyses indicate illite and quartz to be the dominant components of the shales. Bituminous matter probably

accounts for the blackness and petroliferous odour of the shales. Pyrite crystals occur sparsely throughout the unit.

The type section was measured and described by K.V. Campbell in 1967, and by W.H. Fritz in 1968.

Unit	Lithology	Thickness Unit	Above base
	Overlying beds: Yanks Peak Formation - quartzites, in faulted contact with Dome Creek Formation		
	Dome Creek Formation		
7	Shale, very dark grey, very hard, phyllitized in part.....	117	5,755
6	Shale, light to medium grey, slightly calcareous.....	139	5,638
	Covered, probably shale.....	69	5,499
5	Shale, very dark grey, hard, sheared, minor thin-bedded limestone, dark grey.....	170	5,430
	Snow covered interval, probably shale....	505	5,260
4	Shale, dark grey, slightly calcareous; recessive; faults suspected at 3,753 and 2,115 feet above base; six-inch bed of black chert at 2,017 feet above base of formation. Fossils found in interval between 1,510 - 3,950 feet, and identified by W.H.		

Unit	Lithology	Thickness Unit	Thickness Above base
	Fritz as: Taenicephalus sp., cf. Wilbernia sp., Pseudagnostus sp., Maustonia sp., and Lingulella sp. (GSC loc. 82810 to 82818) (Conaspis Zone, Upper Cambrian).....	3,270	4,755
3	Shale, dark grey, in part limy, with minor thin beds or argillaceous limestone, dark grey; minor black chert nodules near base; recessive.....	475	1,035
2	Siltstone, brown-grey, laminated in part, thin-bedded, interbedded calcareous and siliceous varieties, in part bored; well-indurated; relatively resistant.....	320	560
1	Shale, dark grey to black, dark brown weathering, in part silty, with minor limestone beds, thin, nodular to uneven, trilobite-bearing, becoming more abundant in basal 80 feet, grading into pure limestone of Mural Formation; fossils identified by W.H. Fritz as follows: Hyolithes sp., Bonnia sp., Ogygopsis sp., Paedeumias sp., Paterina sp., aff. Clariondia sp., Nisusia sp., Protolenus? sp., Olenellus sp. (GSC loc. 82793 to 82809) (late Lower Cambrian)..	240	240

Fossils collected from the Dome Creek Formation at its type section indicate that it ranges in age from late Lower Cambrian to at least as young as Upper Cambrian (Conaspis Zone). Only one fossil collection suggested a Middle Cambrian age for part of the unit, and this consisted entirely of the trilobite Ogygopsis sp. (GSC loc. 80713) at a locality about nine miles west of the type section.

Since the Mahto Formation interfingers with shales in its most western exposures, and is equivalent in age to the lowest part of the Dome Creek Formation in Cariboo Mountains, the lower Dome Creek shales probably represent the seaward facies of the Mahto sandstones. Also, the presence of pyrite and bitumen, and the fine laminations indicate deposition of the shales took place in quiet, restricted, marine waters. Similarly, the Middle and Upper Cambrian parts of the Dome Creek Formation comprise basinward facies with respect to carbonate units of the same age which lie above the Mahto Formation in the Rocky Mountains.

Devonian

Black Stuart Formation

Recent work in Quesnel Lake map-area (Mansy and Campbell, 1970) has shown that a hitherto unrecognized formation lies between the Cariboo Group and Slide Mountain Group. The name Black Stuart Formation is proposed for this unit which is best exposed on the ridges south of Kimball Creek and east of Cariboo River near Black Stuart Mountain in Quesnel Lake map-area. The general region from Black Stuart Mountain southeastward to the lowest beds of the formation in the keel of the Black Stuart Synclinorium is a general type locality.

The Black Stuart Formation is well exposed in Quesnel Lake map-area to the south but is poorly exposed in McBride map-area where it may be locally confused with the Dome Creek, Midas, or Isaac Formations. Dark argillaceous rocks between the Mural and Guyet Formations on the southwest flank of the Black Stuart Synclinorium can be traced continuously southeastward to the type locality of the formation as can the rocks on the small hill east of Mount Tinsdale. The formation is otherwise known only from exposures on the slopes of the hill south of

Haggen Creek overlooking Bowron River Valley and on the banks of Haggen Creek.

Thickness is probably less than the 2,800 feet initially reported (Mansy and Campbell, 1970). At the type locality the base of the formation is marked by a prominent though discontinuous unit of carbonate and chert that may be 300 feet thick locally but is probably mostly less than 150 feet. This basal unit together with the unconformably underlying Mural Formation was originally mapped as Yanks Peak Formation by Sutherland Brown (1963) and Campbell (1961). The unit contains breccia that presumably was originally entirely carbonate, possibly mainly limestone, but that is now largely chert with some dolomite. It also contains more massive dolostone and chert and some thinly bedded sandy limestone. Also in Quesnel Lake map-area immediately west of Cariboo River, on the edge of the slope to the canyon and about 300 feet north of Limestone Creek, is an outcrop of limestone conglomerate and well-bedded finer-grained clastic limestone all of which contains small grains of well rounded clear quartz. These rocks, which lie not far above the Mural Formation, are through to be equivalent to the basal unit of the Black Stuart Formation. They contain fossil corals and conodonts (GSC loc. 53024) that are definitely of Early Devonian age. The macrofossils (at 52° 58 1/2'N, 121° 13'W) were identified by A.E.H. Pedder as Favosites 2 spp. undet. and Spongophyllum(?) sp. ex. gr. S. (?)halysitoides Etheridge and the conodonts were examined by T.T. Uyeno who reported the presence of Icriodus pesaris Bischoff and Sannemann (1) and Spathognathodus inclinatus wurmi Bischoff and Sannemann (2). The macrofossils indicate a probable Early Devonian age confirmed by the conodonts as early Early Devonian (Gedinnian).

In McBride map-area the only rocks that resemble the basal unit of the Black Stuart Formation are massive chert stratigraphically above the Dome Creek Formation and not far above the Mural Formation on the west-facing slope south of Haggen Creek. Some of the rocks mapped as Yanks Peak Formation on the south slopes of Mount Guyet (Sutherland Brown, 1957) may also be part of this unit.

Above the basal unit of the Black Stuart Formation are 1,000 feet or more of dark siliceous argillite and phyllite interspersed with a few cherty layers. At the top are several hundred feet of sandy limestone, calcareous schist, and arkosic

sandstone interspersed with dark phyllite and argillite. The dark argillaceous rocks of the middle unit can be traced continuously to those on the southern and western slopes of Mount Guyet. They may reappear north of Antler Creek. Similar rocks underlie the hill just east of Mount Tinsdale and on the banks of Haggen Creek.

Upper Paleozoic

Slide Mountain Group

Originally named the Bear River Series by Bowman (1889) the Slide Mountain Group was renamed by Johnston and Uglow (1926). Their ~~divisions into~~ proposed formations were modified by Sutherland Brown (1957 and 1963) to the basal Guyet Formation, including the Greenberry Limestone Member, and the Antler Formation. No specific type sections were designated for the formations. Sutherland Brown (1963, p.35) suggests Mount Murray and/or Slide Mountain as the type locality for the Guyet and Antler Formations.

Guyet Formation

The Guyet Formation is exposed along the southwestern flank of the Black Stuart Synclinorium from the south slopes of Mount Tinsdale to the southwestern side of Two Sisters Mountain. It has not been recognized farther to the northwest and is known only from a single small outcrop at the north end of Spectacle Lake on the northeastern side of the synclinorium. The formation is evidently of limited extent; it may be pod-like or it may undergo rapid facies changes and become indistinguishable from the overlying Antler Formation. The base of the Guyet Formation appears to truncate beds of the Black Stuart Formation so that the latter are completely cut out a short distance north of Antler Creek on the southwestern side of the synclinorium. Farther northwest the Guyet rests directly on strata of the Cariboo Group. Because of very poor exposures in the entire area where it is known its contacts are unobserved and the relationships of the Guyet Formation to other units are speculative at best.

Sutherland Brown (1957, p.33) estimates the formation to be from 1,125 feet to 1,500 feet thick. It is characterized by pebble conglomerate though the clasts vary from boulders to granules from place to place. Lithic sandstone, argillite, basaltic flows and breccia, and crinoidal limestone comprise the remainder of the formation. The latter is confined to pods at the top of the unit and is designated the Greenberry Limestone Member (Sutherland Brown, 1957).

Sutherland Brown (1957, pp.33-37) presented much detail on the lithologies of the Guyet Formation and provided an additional summary (1963, pp.35-37) in a later publication. This material is not repeated here, though some discussion of the conglomerate is warranted. Sutherland Brown emphasized the profound unconformity between the Slide Mountain and Cariboo Groups. He maintained that the Guyet Formation is significantly less metamorphosed and deformed than the older rocks and that it does not display prominent secondary foliation in contrast to the underlying phyllitic rocks. He particularly emphasized that the conglomerate contained clasts of variously-oriented, foliated, metamorphic rocks in unfoliated matrix. The authors were unable to verify these observations.

Though an unconformity below the Slide Mountain Group seems certain, this does not appear to have resulted from intense pre-Slide Mountain deformation and metamorphism (see section on Structural Geology). Examination of a ~~very~~ large collection of conglomerate specimens together with study in the field at several localities failed to disclose clasts of variously oriented metamorphic rocks in unfoliated matrix. On the contrary, the rocks examined exhibit a distinct, throughgoing foliation in both matrix and clasts. The character of the foliation may vary from clast to clast and from clast to matrix; it is most prominent in pelitic rocks and may show distinct refraction between matrix and clast. Sutherland Brown described extensive silicification of the conglomerate whereby phyllitic clasts were converted to cherty-looking rocks. The authors believe these fragments were originally chert and that the conglomerate is composed dominantly of clasts of chert, greenstone, and argillite of which few, if any, resemble rocks of the Cariboo Group. Sutherland Brown examined many localities not seen by the writers and may thus have observed features not generally displayed. The writers'

observations, however, are consistent with their belief that the major episodes of deformation and metamorphism succeeded rather than preceded deposition of the Slide Mountain Group (see section on Structural Geology).

The age of the Guyet Formation is determined from fossils in the Greenberry Limestone Member on the southwest side of Two Sisters Mountain. A collection by Johnston and Uglow (1926, pp. 20-21) from the crinoidal limestone was examined by E.M. Kindle who, on the basis of a possible Spirifer Keokuk, suggested a tentative Mississippian age. Although the writers found numerous horn corals and brachiopod fragments E.W. Bamber could provide no more definite age designation than Carboniferous or Permian. The rock was found to contain conodonts (GSC loc. 76020) which were reported by Dr. Gilbert Klapper of Pan American Petroleum Corporation, Tulsa, Oklahoma, to be: Bactrognathus hamatus Branson and Mehl, Gnathodus texanus Roundy, and Spathognathodus sp. (cf. Thompson, 1967, Pl.1, Fig. 15) indicating a Lower Osage (Lower Mississippian) age. The fossils were found in the more southerly of the two limestone pods on the southwest slope of Two Sisters Mountain at 5,000 feet elevation (53° 10'N, 120° 32'W).

Antler Formation

The Antler Formation, characterized by pillow basalt, occupies a large area within the Black Stuart Synclinorium. It extends from Mount Tinsdale at the southern boundary to and beyond the western and northern borders of the map-area. It was mapped by Tipper (1961) in Prince George map-area to the west and by Muller and Tipper (1969) in McLeod Lake map-area to the northwest. Sutherland Brown (1957 and 1963) estimated the thickness of the formation to be 3,600 feet at Mount Murray and possibly thicker in the Palmer Mountains. The large and hitherto unknown areal extent of the unit suggests that it may be very much thicker than his estimate. The formation has no easily recognizable marker units and stratification is commonly not visible. Hence, the internal structure is largely unknown and no new meaningful estimate of thickness can be given with present data.

The Antler Formation seems to rest conformably upon the Guyet Formation but beyond the limited extent of the Guyet the Antler appears to lie unconformably directly upon strata of the Kaza and Cariboo Groups over a broad region. This unconformable contact is not clearly exposed and the possibility of fault relationships cannot be discounted. Indeed, the Antler and possibly the Guyet Formation might comprise a huge allocthonous sheet or sheets thrust from the west during a late Paleozoic orogenic event. Reasons for this speculation are given in the section on structural geology.

Sutherland Brown (1957 and 1963) gives much detailed information on the lithologies of the Antler Formation to which the reader is referred. The formation is dominated by basic volcanic rocks, chert, and argillite and includes some coarser sedimentary rocks. Pillow basalt is abundant and can be found in every part of the formation. Volcanic breccia, though not abundant, is widespread. It varies from fine-grained tuffaceous rocks to coarse, angular breccia. In many places the volcanic rocks are uniform and featureless aphanitic greenstone but locally they display distinct granularity and may be diabasic. In a few places medium-grained diorite and gabbro were noted. Some rocks of the volcanic suite are evidently intrusive (see Sutherland Brown, 1957 and 1963). Ribbon chert, argillite, and fine lithic sandstone, though subordinate, are scattered throughout the formation. Two small limestone outcrops were found near the eastern margin of the formation, one about four miles north and the other about four miles south of Highway 16.

As in the case of the Guyet Formation, Sutherland Brown (1963, p.38) emphasizes that the Antler Formation is not affected by regional metamorphism nor is it significantly deformed in contrast to the Cariboo Group. The authors disagree. Argillaceous rocks of the formation are commonly cleaved and locally phyllitic. The volcanic rocks contain pumpellyite and prehnite (e.g. on Slide Mountain and along Highway 16). Well-bedded rocks locally are much folded. These factors, when related to the metamorphism and deformation of the older rocks, appear to be consistent with the view that the principal metamorphism and deformation took place subsequent to the deposition of the Antler Formation. This view is strength-

ened by the substantial increase in metamorphic grade (greenstone becomes actinolitic amphibolite) near the west boundary of the map-area along Willow River Valley. This increase is paralleled by a similar change in the adjoining Snowshoe Forma (Kaza Group) rocks which contain garnet.

The base of the Antler Formation rests on the Greenberry Limestone Member of the Guyet Formation and is thus Lower Mississippian or younger. No fossils were found within the formation hence its upper age limit can only be inferred. An extensive dark-coloured argillaceous sequence that crosses the southwest corner of McBride map-area and that is thought to be Upper Triassic in age (Campbell and Tipper, 1970 and 1971), rests unconformably on the Slide Mountain Group and older strata. Thus, the age of the Antler Formation is apparently pre-Upper Triassic. The Pennsylvanian-Permian Cache Creek Group, though similar in some respects to the Slide Mountain Group (chert and basaltic rocks), differs substantially in general aspect; particularly, it does not include masses of pillow lava and it does include thick limestone sequences. This suggests but does not prove that the Antler Formation is pre-Cache Creek Group and substantially of Mississippian age.

The Antler Formation is similar to the Fennell Formation from near the valley of North Thompson River in Bonaparte River map-area (Campbell and Tipper, 1971) with which it is correlated. The Devono-Mississippian Sylvester Group of Northern British Columbia (Gabrielse, 1963) is probably at least partly equivalent to the Antler Formation.

Upper Triassic

Phyllitic Rocks

Dark phyllite and argillite underlies a small area in the extreme southwest corner of the map-area. These rocks can be traced nearly continuously from near Little Fort in Bonaparte River map-area (Campbell and Tipper, 1971) into Quesnel Lake map-area (Campbell, 1961 and 1963; Campbell and Campbell, 1970) in the south through the corner of the McBride map-area and on to Prince George map-area to the west (Tipper, 1971; Campbell and Tipper, 1970).

The rocks are dominantly dark phyllite within the map-area though elsewhere the unit includes shale, argillite, siltstone, and rarely dark limestone. They are well exposed in a road-cut southwest of Wingdam.

The age of the phyllitic rocks is problematical. Along their ~~trend~~ outcrop belt several Upper Triassic ~~(Karnian)~~ fossil collections have been made but nowhere can it be shown conclusively that the fossils are from the phyllite unit because of lack of critical exposures. Where fossils are found the rocks do not seem completely typical of the unit although they occur on trend with its outcrops. Near Crooked Lake in Quesnel Lake map-area (Campbell, 1969; Campbell and Campbell, 1970) the phyllitic rocks conformably underlie volcanic and sedimentary rocks of Upper Triassic and/or Lower Jurassic age. They apparently rest unconformably on Slide Mountain Group (in Prince George map-area) and older strata. All available evidence strongly favours an Upper Triassic age for the phyllitic rocks.

Cretaceous and Tertiary

Bowron River Coal Measures

Coal-bearing sedimentary rocks underlie part of Bowron River Valley south of Purden Lake. The rocks are exposed only in a few scattered outcrops along the river bank. Most information on the sedimentary sequence and structure comes from drill cores described in British Columbia Minister of Mines reports by Holland (1948) and Sutherland Brown (1967). The authors have no new information and the following is taken from the report of Sutherland Brown (1967).

The rocks occupy a northwesterly trending basin or trough, 8 miles or more in length and about 1 1/2 miles across, bounded on both sides by rocks of the Slide Mountain Group. The southwestern border is apparently a normal unconformable sedimentary contact where the beds dip about 45 degrees northeastward. Dips evidently flatten farther into the trough so that 1500 feet from the southwestern contact they are in the order of 10 degrees. Because of the northeasterly dip of the strata the northeastern contact is assumed to be a fault. Unfortunately neither contact is exposed.

The beds have a maximum thickness of more than 2,000 feet. Sutherland

Brown (1967, p.460) presents the log of a bore hole in which a true thickness of 1460 feet of strata were intersected. The section is dominated by sandstone and fine conglomerate displaying graded bedding and slump structures. Shale interbeds are mainly restricted to the lower half of the section and coal, apparently in three separate beds from 8 to 12 feet thick, is found only in the basal 200 feet. Black and amber resin is a constant constituent of the coal and is found in associated shale. The coal is reported to be of good quality.

In a basal conglomerate clasts up to 10 inches across reflect a local origin from the Slide Mountain Group (Holland, 1948, p.234). Sutherland Brown (1967) reports greenschist pebbles thus suggesting that deformation of the older rocks preceded deposition of the coal measures.

The age of the beds is uncertain; they may be late Cretaceous or early Tertiary. W.A. Bell of the Geological Survey of Canada examined macro-plant fossils collected in 1968 by P.A. Hacquebard of the Geological Survey from a dump near old workings on the west bank of the river (GSC loc. 8044). Bell believed the florule indicated an Upper Cretaceous age, probably Campanian but possibly Maestrichtian (P.A. Hacquebard, pers. comm., 1968). G.E. Rouse of the University of British Columbia examined a microflora from the same general locality and believes the age is not likely older than early Paleocene and may be younger (G.E. Rouse, pers. comm., 1969). Rouse states that more work is needed and points to his earlier designation of mid-Tertiary as reported by Sutherland Brown (1967, p.459) as evidence of the uncertainties involved.

ROCKY MOUNTAIN TRENCH

Bedrock in the Rocky Mountain Trench is commonly highly sheared and deformed along steeply oriented planes. There are few exposures, although the more resistant rocks form low ridges in the valley floor north of ~~Lat.~~ 53° 30'N, and recessive rocks are exposed in gorges of tributary streams and in road-cuts. Almost all rocks in the Trench may be assigned to the Cariboo Group. At Grand Canyon of the Fraser a normal succession of Cariboo Group units is fairly well exposed, including a very thick development of the Mural Formation.

The thick, resistant, pure limestone at Ptarmigan Falls (~~Lat.~~ 53° 41'N, ~~Long.~~ 120° 54'W), which is quarried for railroad ballast, is mapped as the Mural Formation. It may, however, be a higher carbonate unit since its textural properties are more similar to Middle or Upper Cambrian carbonates than normal Mural limestone.

Metaquartzites which form low bluffs along each side of the Rocky Mountain Trench near McBride are mapped as McNaughton Formation. These rocks may alternatively belong to the equivalent Yanks Peak Formation.

CORRELATIONS BETWEEN ROCKY MOUNTAINS AND CARIBOO MOUNTAINS

Thick successions of Upper Proterozoic and Cambrian rocks lie on both sides of the Rocky Mountain Trench; however, sequences of Ordovician and Silurian rocks which appear in Rocky Mountains are entirely absent a short distance westward in Cariboo Mountains.

In Rocky Mountains, within the map-area, Upper Devonian strata rest unconformably on Ordovician beds ("sub-Devonian" unconformity) whereas west of the Trench the Lower Devonian and ~~perhaps~~ (?) younger Black Stuart Formation lies unconformably on the Lower Cambrian. Northward in Rocky Mountains Middle Devonian rocks are unconformable on older strata (G.C. Taylor, 1971) and are themselves overlain unconformably by the Upper Devonian. Volcanic and sedimentary rocks of the Slide Mountain Group (Mississippian in part) of the Interior Plateau are partly equivalent in age to sediments of the Banff Formation, to which they bear little resemblance. These rocks apparently rest unconformably on all older strata and are themselves unconformably overlain by rocks thought to be Upper Triassic.

The above relationships attest to a history of repeated uplifts in the area immediately west of Rocky Mountains beginning possibly in the Siberian and continuing intermittently into the Mesozoic. Some of these episodes involved extensive areas and affected the sedimentation now observed in Rocky Mountains.

Correlations between the Cambrian sequences are based largely upon fossil zonation down to and including the basal part of the Mural Formation (Figures

1 3
~~8~~ and ~~5~~). The Mural Formation also acts as a regional lithologic marker on which to base correlations. Below the formation correlations are based on homotaxial relationships. The middle Miette Group and Kaza Group have similar thicknesses and lithologic characteristics, as do part of the overlying upper Miette Group and Isaac Formation. These similarities leave little doubt that they comprise two facies which are distributed over the entire map-area.

At Holy Cross Mountain the stratigraphic succession within and below the McNaughton Formation closely resembles that of the Cariboo Group fifteen miles to the southwest on the opposite side of the Rocky Mountain Trench. Particularly striking is the similarity of the greenish grey phyllitic mudstone unit which underlies the McNaughton quartzite to the Yankee Belle Formation of the Cariboo Group. This 1,000-foot-thick unit is in turn underlain by 220 feet of quartzitic sandstone, which is similar in thickness and position to the Zig-Zag Member of the Yankee Belle Formation. Below the sandstone is a dominantly carbonate formation, 440 feet thick, which is partly dolomitized and sandy, similar to the Cunningham Formation along the southwestern margin of the Rocky Mountain Trench. The basal McNaughton quartzite may be correlated with the Yanks Peak Formation of the Cariboo Group based on the similarity of underlying successions and on prevalence of green, feldspathic quartzites in the basal parts of both units. Because the Yanks Peak tends to be thicker than the basal quartzite of the McNaughton, and the overlying Midas Formation much thinner than the Holmes River Member of the McNaughton, it is likely that the upper part of the Yanks Peak shales out into the lower part of the Holmes River Member. Near Walker Creek in the northern part of the map-area the McNaughton Formation contains a second quartzite unit above the basal one, and it probably correlates with the upper part of the Yanks Peak Formation.

The upper Yanks Peak - Midas interval of the Cariboo Group does not have a similar counterpart in the Gog Group, and the correlation remains interpretive. The Holmes River Member of the McNaughton Formation is similar to the Midas in its shaly, recessive, brown-weathering, burrowed, fine sandstones, but is much thicker and does not abruptly overlie the McNaughton quartzites as the

Midas does the Yanks Peak Formation. Perhaps the thinning of the Midas Formation in the northern Cariboo Mountains is only a local feature resulting from slow sedimentation (supported by the abundant phosphate grains) over a relatively positive area in the basin.

Numerous thickness and facies changes along and across the Rocky Mountain Trench strongly support the existence of a positive arch-like feature ("McBride Arch") whose axis was located in the area now occupied by the Trench. This evidence consists of the following features:

(1) Every formation in the Cariboo Group except the Isaac and Dome Creek Formations thins toward the Rocky Mountain Trench;

(2) Lithologic correlations within the Cunningham Formation, plus the presence of dolostone fragments in the overlying Yankee Belle sandstones suggest that the Isaac - Cunningham sequence was locally uplifted and eroded at the end of Cunningham sedimentation, thus forming a land-mass in the area of the Rocky Mountain Trench near Latitude 53° 30'N.

(3) As the Yankee Belle Formation thins towards the Rocky Mountain Trench, the basal portion rapidly changes from marine to littoral and non-marine facies in the same direction;

(4) Differences in facies and thicknesses between the McNaughton Formation and correlative units of the Cariboo Group may be explained easily in terms of a positive tectonic element (arch) separating the two areas of deposition. The relative thinness of the McNaughton and Mural Formations of the Gog Group between Walker Creek and McKale River are manifestation of this arch in the adjacent Rocky Mountains. Rapid thickening of the McNaughton between McKale and Holmes Rivers and the Mural from the south to north sides of Walker Creek indicate that [illegible] area, [illegible] ~~step-like~~ flanks in places, possibly due to the influence of deep-seated faults.

CHAPTER II

STRUCTURAL GEOLOGY

INTRODUCTION

Much of McBride map-area provides good exposures and readily mappable stratigraphic units from the edge of the Interior Plateau of British Columbia across the northern end of Columbia Mountains to the Rocky Mountain Trench and into Rocky Mountains to the edge of the Foothills. It thus offers an excellent cross-section of the eastern Canadian Cordillera. Some aspects of the regional structure have been previously ~~briefly~~ reported (Brown, 1968; and Campbell, 1968 and 1970). Some information on the northeast corner was published ~~provided~~ by Slind and Perkins (1966). Much detailed data from the southwestern part of the area was presented by Sutherland Brown (1957 and 1963) who named many of the important structural features. Earlier studies were concentrated near Wells and Barkerville. Principal among these were the remarkable reconnaissance of Bowman (1889) and the more detailed work of Johnston and Uglow (1926).

McBride map-area extends across several major structural and tectonic elements of the Canadian Cordillera. It straddles the Core Zone of the Eastern Fold Belt (Wheeler, 1970a and 1970b) extending from the edge of the Intermontane Zone in the extreme southwest corner across the Rocky Mountain Trench and into the Marginal Zone (Thrust and Fold Belt) in Rocky Mountains to the edge of the Foothills in the extreme northeast corner. It thus includes parts of the Quesnel Trough, Omineca Geanticline, and the Alberta Trough (Wheeler, 1970a).

Structures typical of the Intermontane Zone are found just beyond the southwest corner of the map-area (Campbell and Tipper, 1970). Between the southwest corner and the Rocky Mountain Trench the fold structures of the Core Zone of the Eastern Fold Belt are apparently not significantly different from those in the western part of the Rocky Mountain Main Ranges southwest of the Snake Indian Fault (Brown, 1968). Only northeast of this fault are essentially unmetamorphosed and generally little folded rocks cut by thrust or reverse faults as in the classic Main and Front Ranges of the Banff-Jasper Region. In Mount Robson map-area (Mountjoy, 1971)

typical "Rocky Mountain" structures extend farther southwest to near the Trench.

The structures in Cariboo Mountains and Interior Plateau can be conveniently subdivided into a series of large anticlinoria and synclinoria that are generally well defined in the south, though complicated by faults, and are less obvious to the north where some of these structures flatten out and lose their identity. From southwest to northeast the major structures are the Lightning Creek Anticlinorium, Black Stuart Synclinorium (including Slide Mountain Trough as defined by Sutherland Brown, 1963), Lanezi Arch, Isaac Lake Synclinorium, and Premier Anticlinorium (Fig. 4 and map and sections in pocket) ~~(Figure 6)~~. The last is succeeded on the east by the Rocky Mountain Trench within which the structure is little known. The structural significance of the Trench is not known; a major fault or faults may underlie it but evidence is not conclusive. In the western part of the Rocky Mountains east of the Trench the Mount Robson Synclinorium follows the Premier Anticlinorium on the east and is the most easterly clearly defineable major fold structure (Fig. 4 ~~Figure 6~~). From a single syncline in the southeast it develops into a broad zone of faulted folds toward the northwest where no single major axis can be delineated. The northeastern limit of the Mount Robson Synclinorium is defined arbitrarily at the contact between the Upper and Middle Miette Group (though older strata are obviously part of it) that crosses the headwaters of McKale River, passes through Mount Bagg and the upper valley of Walker Creek, and extends into the McGregor River valley.

In the zone between the Mount Robson Synclinorium and the Snake Indian Fault the structure is transitional from the fold structures in the southwest to relatively little folded and gently to moderately dipping thrust sheets of the eastern Main Ranges, Front Ranges, and Foothills of the Rocky Mountains. This zone cannot be classified in terms of major fold structures, though folding is prominent; nor can it be designated as a single or group of thrust sheets though faults are locally prominent and the zone may be underlain by a major fault. The informal name "Forgetmenot Zone" is here proposed for this element which is the site of a regional structural culmination (Fig. 4 ~~Figure 6~~). (map and sections in pocket)

Northeast of the Forgetmenot Zone and the Snake Indian Fault the structures are typical of the well known Rocky Mountains in the Jasper-Banff region. The eastern Main Ranges, dominated by the Mount Sir Alexander massif, consist of

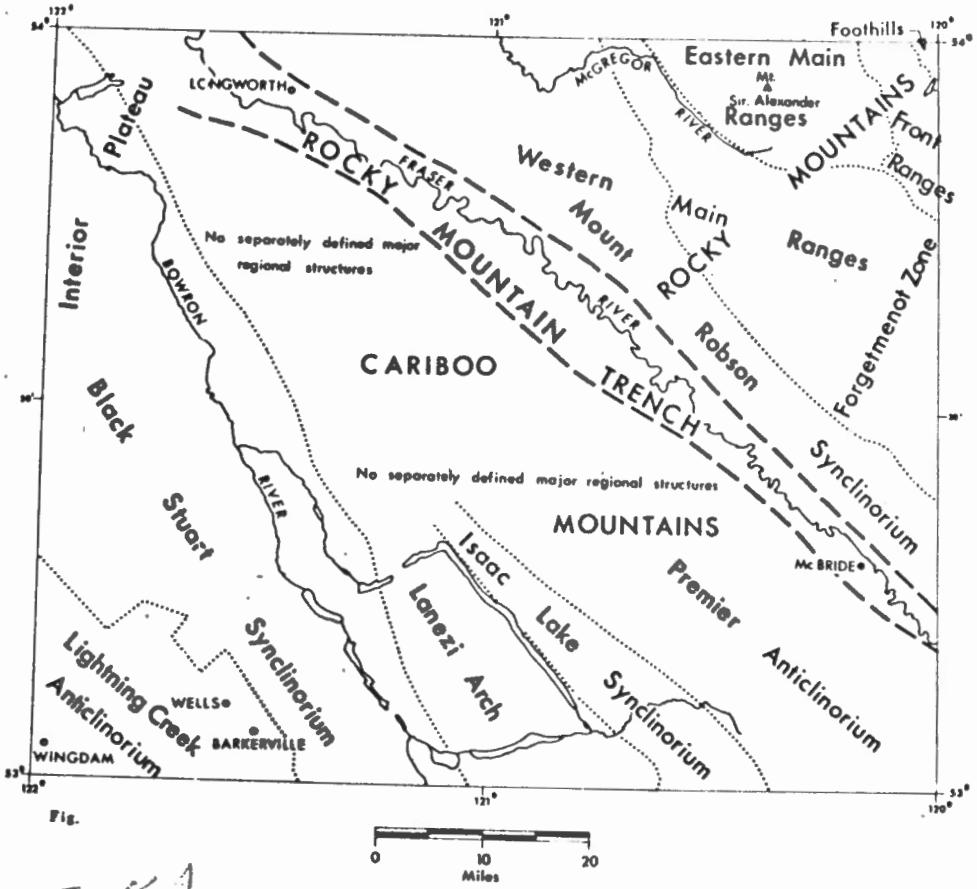

Fig. 1

Structural Elements and Physiographic Divisions in Mc Bride Map-Area

the Sir Alexander and Wallbridge Thrust Sheets made up principally of ~~early~~ lower Paleozoic strata. The Front Ranges are formed by Cambrian to Triassic strata of the Cecilia Thrust Sheet beyond which, in the extreme northeast corner, is a small area of Triassic and Jurassic rocks at the western margin of a wide Foothills structural subprovince (Figure 4). In the following sections the reader should refer to the map and structural cross-sections (in pocket).

ROCKY MOUNTAINS

Foothills

The Rocky Mountain Foothills are underlain mainly by middle and upper Mesozoic clastic sedimentary rocks. In McBride map-area the Foothills, bounded on the southwest by the Cecilia Fault, occupy a 2-to 3 mile-wide zone in the extreme northeast corner where Triassic and Jurassic strata are exposed in an anticline (Section E-E') on the western limb of the large Côte Creek syncline that extends about 17 miles southeastward to Sheep Creek (Mountjoy, 1971). Thrust sheets of the western Foothills give way, on trend to the southeast, to from three to five thrust sheets of the Front Ranges, dominated by upper Paleozoic rocks, between Smoky and Athabasca Rivers. Irish (1965) presented a summary of Foothills structure in a region to the east of 119° 30' west longitude (east of the map-area), Stott (1967) discussed the area to the north of the map-area, and Mountjoy (1971) briefly outlined the geology of the Mount Robson west half map-area to the east.

Front Ranges

The Front Ranges of the Rocky Mountains, conventionally defined as those ranges within which upper Paleozoic strata dominate major thrust sheets, are confined to a single unit in McBride map-area - the Cecilia Thrust Sheet (i.e. the thrust sheet or fault panel overlying or west of the Cecilia Fault and underlying or east of the Wallbridge and Snake Indian Faults) (Sections E-E' and F-F'). The Wallbridge, and the Snake Indian Fault, south of the junction with the Wallbridge, are thus the boundary between the Front and Main Ranges.

The Cecilia Thrust Sheet consists of a panel of southwesterly dipping Middle Cambrian to Triassic strata that strike more northwesterly than the northerly trending

bounding thrust faults. Thus Triassic strata are exposed in the south and Cambrian beds are confined to the north.

The sheet is complicated by small thrust faults that repeat the Ordovician succession, by two normal faults, and by east-west thrust faults near Bastille Mountain. The easternmost normal fault ~~is a listric structure; at least in part, it~~ apparently follows an older thrust fault for some distance but breaks away toward its northern end. This results in the normal fault (west side down) in the north merging with a thrust fault and finally, in the south, becoming a normal fault with the east side down. The structure cuts across the anticline near Intersection Mountain where it appears to join the Snake Indian Fault. Displacements are small ranging from 0 to 1000 feet. The fault may have some transcurrent movement.

The more westerly normal fault can be traced for 7 miles; it is partly responsible for the basin-like depression floored by recessive "off reef" Fairholme Group strata north of Wallbridge Mountain. Maximum displacement of 2000 to 2500 feet in the center of the fault decreased to zero toward each end. On the north face of Wallbridge Mountain the fault disappears into a small fold in Fairholme Group strata and it does not appear to break the overlying carbonate rocks of the Palliser Formation.

The faults near Bastille Mountain that trend at a high angle to the Wallbridge and Cecilia Faults are somewhat unusual. They are roughly parallel, however, with a nearby segment of the Snake Indian Fault and to small parts of other faults in the eastern Main Ranges. They have stratigraphic throws of 500 to 1200 feet (Alexo Formation thrust over Banff Formation) and dips are sub-parallel with the stratification.

Main Ranges

The Main Ranges are conventionally considered to be that part of the Rocky Mountains within which ~~early~~ lower Paleozoic strata are dominant although substantial areas of older and younger rocks may be present. In the classic Main Ranges between Jasper and Lake Louise the strata are relatively flat-lying within large thrust sheets though locally they dip appreciably. Post-Lower Cambrian strata are characterized by thick carbonate rock-units.

The Main Ranges in McBride map-area are divisible into eastern Main Ranges consisting of the Wallbridge and Sir Alexander Thrust Sheets and the western Main Ranges that include the Forgetmenot Zone and the Mount Robson Synclinorium (Fig. 4). The eastern segment contrasts sharply with the western; the former consists mainly of Cambrian and younger strata deformed dominantly by faulting though folding is locally prominent, and the latter includes large areas of late Proterozoic with some younger rocks deformed primarily by folding though faulting is locally important. These differences evidently result from variations in relative competence of the rocks. From east to west strain varied during deformation; in the east relatively brittle rocks yielded by faulting and concentric folding; in the west relatively more ductile or plastic rocks yielded by penetrative deformation with the development of schistosity and similar to composite folds. The reasons for the differences are stratigraphic but also involve temperature variations manifest by metamorphic grade. The differences may be attributed to: a) relative incompetence of Proterozoic rocks broadly exposed in the west (hence their deformational style is apparent at the surface); b) ~~great~~ increase in the thickness of Proterozoic rocks from east to west; c) probable facies changes from relatively competent carbonate rocks to incompetent shale in part of the Paleozoic section from east to west, and from thick sandstone to shale-sandstone in the Gog Group; d) gradual increase in temperature (hence effective decrease in competence) from east to west; and e) strongly anisotropic layering of the relatively competent Paleozoic rocks in the east as opposed to the more nearly isotropic character of the rocks in the west, particularly of the Proterozoic sequence.

Eastern Main Ranges

The eastern Main Ranges in McBride map-area consist of the Wallbridge Thrust Sheet bounded by the Wallbridge and Sir Alexander Faults and the Sir Alexander Thrust Sheet between the Sir Alexander and Snake Indian Faults. The Wallbridge and Sir Alexander Thrust Sheets each contain Cambrian sections, including the McNaughton Formation, that total more than 13,000 feet in thickness.

The Blue Creek Fault of Slind and Perkins (1966, Fig. 1) is apparently

continuous with and was earlier called the Snake Indian Fault farther to the south by Ziegler (1960) and Mountjoy (1962). One of the authors (E.W.M.) favours the view that the Snake Indian Fault extends down Bastille Creek and McGregor River valleys as shown on the accompanying map, whereas another (R.B.C.) believes that the Sir Alexander Fault is the extension of the Snake Indian Fault. The former view requires that the Wallbridge and Sir Alexander Thrust Sheets are new structures of the Main Ranges emerging from beneath the Snake Indian Thrust Fault which thus must be flat and have undergone very large displacement, as proposed for the similar faults of the Main Ranges to the southeast (Price and Mountjoy, 1970). The latter opinion implies that the Wallbridge and Sir Alexander Thrust Sheets are merely the continuation of typical eastern Main Ranges structures similar to the Snake Indian and Snaring Thrust Sheets to the southeast (Mountjoy, 1971) and separated from them by exposures of Miette Group rocks brought to a high level in the structural culmination of the Forgetmenot Zone. This view does not require that the Snake Indian Fault and its extension as the Sir Alexander Fault be uniformly flat with large displacement as it is interpreted in Mount Robson map-area (Mountjoy, 1971). On the contrary, the Sir Alexander Fault is known to die out within the Wallbridge Thrust Sheet north of the map-area (Slind and Perkins, 1966 and G.C. Taylor, pers. comm., 1970). The decrease in stratigraphic throw on the Sir Alexander Fault is compensated by an equipment increase on the Wallbridge Fault which replaces the southern Snake Indian - Sir Alexander Faults as the boundary structure between the Main and Front Ranges. If the Snake Indian Fault does extend into McGregor River valley it may then join to the north with the Back Range Fault of Slind and Perkins (1966). It would thus be about 300 miles long and would be one of the major faults of the Rocky Mountains extending from near Athabasca River (Mountjoy, 1964) to north of Pine Pass. Compilation resulting from current work by Taylor in Monkman Pass map-area should determine this connection and its significance.

The Snake Indian Fault must underlie part or all of the Forgetmenot Zone but the zone is not easily compared to nor divided into thrust sheets. To the southeast the Snake Indian Thrust Sheet consists of a narrow panel clearly defined by the bounding Snake Indian and Snaring Faults (Mountjoy, 1971, and 1964). The

designation of the zone as a thrust sheet implies the existence of underlying major flat faults. One of the authors (E.W.M.) approves of this configuration but another (R.B.C.) has serious reservations. The term Forgetmenot Zone is a compromise that avoids connotations regarding bounding structures and is used for convenience of description without structural implications.

Wallbridge Thrust Sheet

The Wallbridge Thrust Sheet (Section E-E'), as defined by the bounding faults, strikes more northerly than the enclosed strata which strike northwesterly and dip 20 to 40 degrees to the southwest. Thus, as in the Cecilia Thrust Sheet, the strata become younger to the south. Devonian strata of the Fairholme Group form the hanging wall of the Wallbridge Fault at its southern end where it apparently merges with the Snake Indian Fault in Bastille Creek valley. Strata of the Mississippian Banff Formation form the footwall. Hence the stratigraphic separation is relatively very small. At the northern boundary of the map-area, however, the separation is much greater; Lower Cambrian beds in the hanging wall lie against Devonian rocks. Coincident with the increased separation on the Wallbridge Fault toward the north, the separation on the Sir Alexander Fault decreases markedly. In the south Proterozoic and Lower Cambrian rocks are thrust over Carboniferous beds whereas at the north boundary the separation is between Lower and Middle Cambrian strata. Still farther north the Sir Alexander Fault is known to die out completely (Slind and Perkins, 1966 and G.C. Taylor, pers. comm., 1970). It is thus apparent that as the Sir Alexander Fault dies out its function as the easterly bounding fault of the Main Ranges (assuming it continues to the south as the Snake Indian Fault) is shifted to the Wallbridge Fault which carried on to the north. Because of the small throw on the Wallbridge Fault at its southern end, the rocks of the Wallbridge Thrust Sheet in the south are late Paleozoic similar to those of the Front Range Cecilia Thrust Sheet rather than the early Paleozoic of the typical Main Ranges. This situation changes to the north as the throw increases.

Sir Alexander Thrust Sheet

The Sir Alexander Thrust Sheet displays the structural and stratigraphic characteristics of the familiar Main Ranges in the Jasper - Lake Louise region. It is

dominated by a wide plate of relatively gently dipping Lower, Middle, and Upper Cambrian strata that are exposed in a massif with local relief of 7,000 feet and an elevation of more than 11,000 feet at the peak of Mount Sir Alexander (Sections D-D' and E-E').

The major structure within the sheet is a ~~ten~~ 10-mile-wide slightly asymetrical syncline in which the western limb dips moderately but more steeply than the eastern limb. Several small normal faults cut at right angles across the axis of the syncline on the northwest spur of Mount Sir Alexander. The eastern limb of the syncline is broken by a branch of the Sir Alexander Fault near Buchanan Creek and in the segment between the branch and the main fault an overturned anticline deforms Lower Cambrian strata. A steeply southwest dipping normal fault with 1,000 to 3,000 feet of relative displacement (southwest side down) cuts the strata on the southern spur of Mount Sir Alexander. A prominent recumbent anticline-syncline pair is associated with this fault and these folds die out in a short distance.

Western Main Ranges

The western and eastern Main Ranges of the Rocky Mountains in McBride map-area are separated by the Snake Indian Fault, a boundary between a fault-dominated regime in Lower Paleozoic rocks to the east and a fold-dominated regime in Proterozoic and lower Paleozoic rocks to the west. Along the Snake Indian Fault between its junction with the Sir Alexander and Wallbridge Faults in McBride map-area and the DeVeber Fault in Mount Robs on map-area (Mountjoy, 1971) the eastern Main Ranges, as defined herein, do not exist, and the western Main Ranges lie directly against the Front Ranges (Sections F-F').

Insofar as the western Main Ranges are bounded on the east by the Snake Indian Fault they could be classified as the Snake Indian Thrust Sheet in the same manner as other thrust sheets are named for the "underlying" fault, but this is not followed in this case because one of us (R.B.C) ~~is not convinced that such a fault exists because~~ believes that the western Main Ranges seem too large and structurally complicated to be classed as a single thrust sheet. Until structure at depth is better understood the western ranges are arbitrarily divided for convenience of discussion into the Mount Robson Synclinorium, relatively easily delineated though complicated by faults, and

the Forgetmenot Zone. The former is a simple syncline from near Mount Rider for a long distance southeastward to beyond Mount Robson, but it involves many folds broken by faults toward the northwest. This is the most northeasterly of a series of major fold structures that dominate Cariboo Mountains and apparently extent into Rocky Mountains. The Forgetmenot Zone, though characterized by folding, seems to provide a link between the folded and the faulted regimes.

The western and eastern Main Ranges are involved in a major structural culmination the crest of which is a wide, ill-defined, northeasterly trending zone extending from near the ~~mount~~ mouth of McKale River to about the headwaters of Forgetmenot Creek. If the Snake Indian Fault continues into McGregor River Valley as shown on the accompanying map then the Sir Alexander Thrust Sheet is not necessarily involved in the culmination but if the Sir Alexander Fault is the extension of the Snake Indian Fault then all of the eastern Main Ranges are involved. Fold structures plunge gently to the northwest and southeast away from this crestal zone. Miette Group strata are exposed along the crest and underlie wide areas on both sides but in each direction (NW and SE) progressively younger strata outcrop and the Miette Group is restricted to narrow strips or does not appear at the surface. To the southeast in Mount Robson map-area (Mountjoy, 1971~~b~~, ~~and~~ 1964) the younger rocks occupy a structural depression followed by a culmination near Yellowhead Pass (Price and Mountjoy, 1970). ~~To the northwest are similar depressions and culminations (Taylor, pers. comm., 1970)~~. These structures in the Main Ranges apparently are not reflected by similar culminations and depressions in the Front Ranges or Foothills as is the case with the culmination at Yellowhead Pass.

Forgetmenot Zone

The Forgetmenot Zone lies between the Snake Indian Fault on the northeast and the Mount Robson Synclinorium on the southwest. Although at least part of the zone can be included in the eastern limb of the synclinorium, the southwestern boundary is arbitrarily placed at the contact between the middle and upper Miette Groups on the northeast limb of the synclinorium. Thus the zone is underlain almost totally by Miette Group strata; the only exception is a small area of Gog Group at the east boundary north of Morkill River. The term Forgetmenot Zone is used solely

to aid in the description of the structural geology and is not meant to have significance in other respects.

The relationship of the zone to the synclinorium is shown in cross-sections D-D', E-E' and F-F' in which the form of minor folding is indicated diagrammatically; the nature and orientation of the faults at depth is unknown. A schematic representation of the profile of the zone (Figure 5) can be constructed to include strata now eroded because the stratigraphy above the lower Miette Group is reasonably well known. Thus the position of the Gog Group can be approximately represented. The profile thus constructed emphasizes that broad, gentle, open folds characterize the structure of the transition zone in spite of the apparent complexity introduced by local zones of intense small scale folding. The position of the base of the Gog Group in the profile may be in error to the extent that the middle Miette unit is thickened by this folding. The Cushing and Morkill Faults evidently end in the series of prominent folds north of the junction of Morkill River and Forgetmenot Creek. Therefore these faults are unlikely to have appreciable strike-slip displacement and the maximum stratigraphic separation is probably not in excess of about 7,500 feet. The faults cannot be traced to the south with certainty (Mountjoy, 1971). Though many faults, some of apparently large displacement, are known in the Paleozoic rocks in the structural depressions adjoining the culmination, none seem to extend far into the Miette Group strata. This may be due to lack of adequate stratigraphic markers. Thrust faults in the Mount Robson map-area appear to die out northwestward in the Forgetmenot Zone although one of the authors (E.W.M.) believes that major faults may exist there. In that map-area four major thrust faults occur between Holmes River (east flank of Mount Robson Synclinorium) and the trace of the Snake Indian Fault (Mountjoy, 1971). The more northeasterly Snaring and Monarch Faults join the Snake Indian Fault where it swings southwesterly near Mount Featherstonhaugh thus these faults presumably join the Snake Indian at depth. The more southwesterly Pauline and Resplendent Faults can be traced from the southeast as far as Jackpine River in Mount Robson map-area. These faults may join the Snake Indian Fault at depth and they may connect with the Morkill and Cushing Faults respectively but, because in the intervening region they lie entirely within middle Miette Group strata it has not been

possible to trace them with certainty. Judging from the southwesterly dips (45 degrees to 70 degrees) of the axial surfaces of folds associated with the Cushing and Morkill Faults (Section G-G') these structures probably dip southwesterly and bring older rocks on the southwest against younger on the northeast, hence evidently have reverse displacements.

Intense minor folding in the Forgetmenot Zone is restricted to certain localities and is found exclusively within the middle and lower Miette units. The upper Miette is not appreciably folded. The most intense folding is in the lower Miette adjacent to the Cushing Fault, and in the middle Miette between the Cushing and Morkill Faults (Pl. XIII), close to the Idol Fault, and southwest and northwest of Mount Wallop. Elsewhere small scale folding is insignificant or absent. The rocks involved in folds in the Forgetmenot Zone are cleaved (Pl. XIII). The cleavage is sub-parallel with the axial surfaces, varies from penetrative schistosity to discrete fractures, and is best developed in fine-grained rocks though quartzite and grit are commonly highly fractured. The folds, similar or composite in form, vary from fairly open structures to isoclines and may be upright, inclined, or overturned toward the northeast. The amplitude varies from a few feet to several hundred feet. In all cases, with the possible exception of those northwest of Mount Wallop, the folds appear to have developed in response to stresses related to faults. The folds southwest of Mount Wallop were apparently developed as compensation for movement beyond the termination of the Cushing and Morkill Faults. They seem to merge northwestward into larger folds and faults in the Gog Group within the Mount Robson Synclinorium northeast of Holy Cross Mountain. The folds northwest of Mount Wallop are not easily related to any known fault.

The folds in the middle Miette Group in the panel between the Cushing and Morkill Faults are inclined or overturned toward the northeast; some, particularly just east of the Cushing Fault, are isoclinal. To the southeast in Mount Robson map-area the folding in this panel becomes less and less intense as higher stratigraphic units away from the structural culmination are encountered (Mountjoy, 1971) and ultimately, in Lower Paleozoic strata, the folds are relatively open concentric structures and faults are numerous. The change across the Morkill Fault is one from

highly folded middle Miette rocks on the southwest to gently folded almost flat-lying upper middle Miette, upper Miette, and Gog Group strata. In the region between the Morkill and the Idol Faults folding is more intense (isoclinal) in the stratigraphically lowest rocks close to the latter fault and immediately northeast of the Idol Fault younger strata are relatively little folded.

The structural relationships ~~delayed~~ diminished in the Forgetmenot zone imply that the strain represented primarily by faults in the Paleozoic rocks, for example northeast of Mount Robson, is accommodated by folding and ~~simple~~ pervasive shear in the deeper stratigraphic levels of the Miette Group. Although faults in the overlying rocks cut the Miette Group, where they are difficult to map, some can be expected to die out within it (Fig~~ure~~ 5). Similar ideas have been expressed by Charlesworth (Campbell and Charlesworth, 1970) based on observations in the Yellowhead Pass region. The change from the strongly anisotropic layering of the Paleozoic sequence to the relatively isotropic and hotter (as shown by metamorphism) Miette Group may in part explain the structural changes. The effect is accentuated by the variation in thickness of the Proterozoic section between the crystalline basement and the Paleozoic beds from little or nothing under the Foothills to 15,000 feet or more at the Trench. This great thickness consists of 4,000 to 5,000 feet of dominantly shaly rocks overlying nearly 10,000 feet of mixed shale and impure sandstone, grit, and minor conglomerate above an unknown but apparently substantial thickness (minimum of 2,000 to 3,000 feet) of shale, limestone, siltstone and sandstone. The sandstone, grit, and conglomerate are characteristically composed of clasts of quartz and feldspar in a shaly and chloritic matrix. The matrix is a high proportion of the rock. This assemblage responded to relatively low intensity stress and thermal environments by folding and penetrative recrystallization. No units seem to have had the capacity of reacting as competent brittle members relative to any others although stratigraphic markers are lacking and faults may have been overlooked as one of the authors (E.W.M.) believes.

The Miette Group may have acted as a thick cohesive zone of décollement or of flowage, as opposed to a single or group of discrete detachment surfaces, between the crystalline basement and the overlying Paleozoic strata. Although the

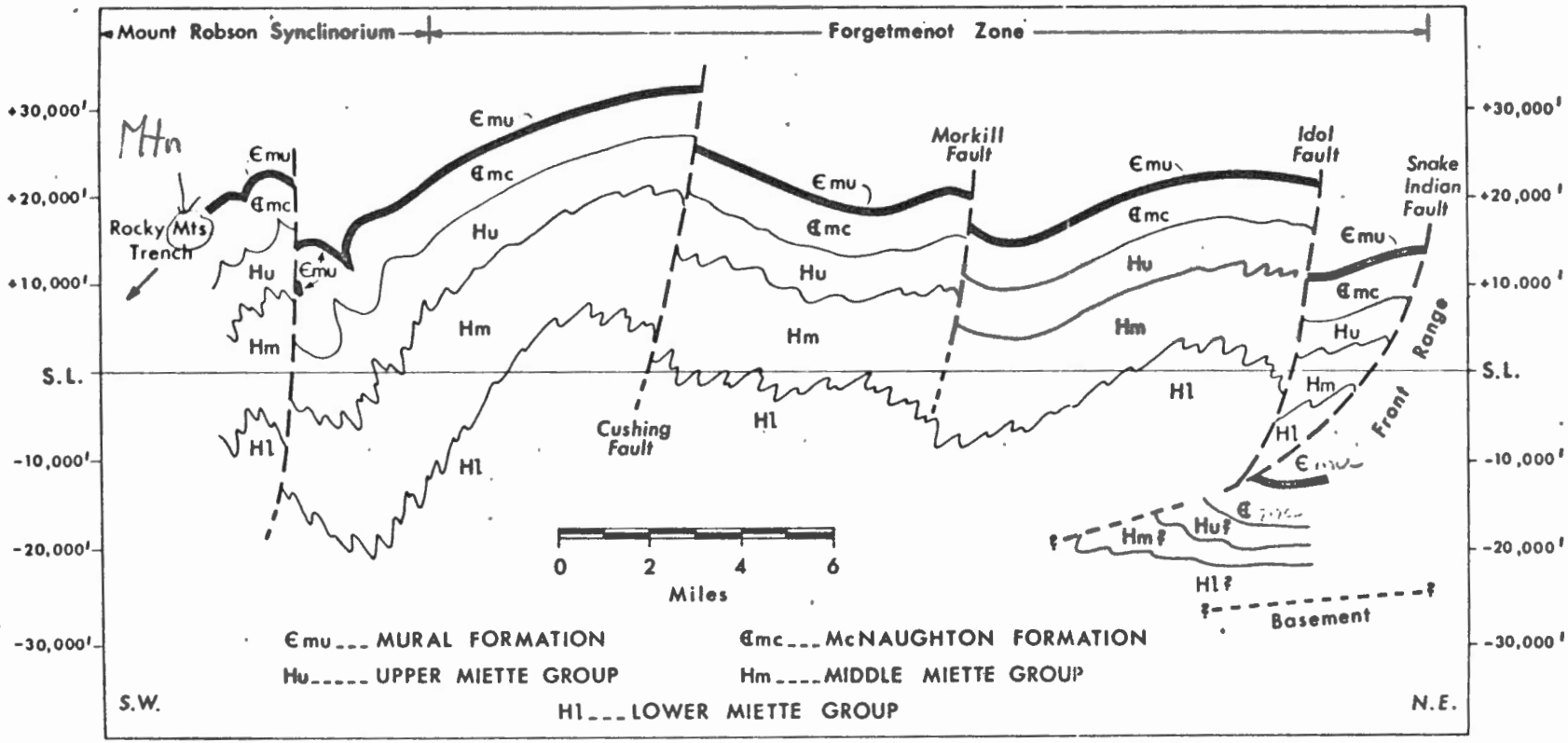

Fig. 57 Diagramatic cross-section through Mount Robson synclinorium and Forgetmenot Zone to Front Range of Rocky Mountains from north of East Twin Creek to west of Intersection Mountain

Enlarge

younger strata are cut by many faults that extend down into the Miette Group it does not follow that these faults are interconnected or that they merge into one or more detachment surfaces at the bottom of or within the older rocks. Evidence that thrust faults in the Foothills and Front Ranges flatten with depth and may overlie a décollement above the basement, (Price and Mountjoy, 1970) does not imply that the same happens to faults in the Main Ranges where the thick Miette Group section is involved. Existing data suggest that fault displacements in the younger strata may be all or partly compensated by folding in the Proterozoic rocks and crystalline basement involvement in the structures cannot be discounted. This paragraph reflects the opinions of one of the authors (R.B.C.) whereas another (E.W.M.) is in sharp disagreement (see Price and Mountjoy, 1970).

Mount Robson Synclinorium

The Mount Robson Synclinorium is clearly delineated by the outcrop of the McNaughton Formation of the Gog Group (Sections F-F' to H-H'). As a simple syncline, it can be traced southeastward from Mount Rider in McBride map-area for more than 100 miles to near Roche Noire southwest of Jasper and may continue for many miles farther to near Fortress Lake (Mountjoy, 1971; ~~and~~ Price and Mountjoy, 1970). Northwestward from Mount Rider the structure involves an increasing number of folds cut by faults and, because of the northwest regional plunge away from the culmination at McKale River, also involves strata younger than the Gog Group (Section A-A' to D-D'). Southeast from this culmination the plunge is very gentle for 50 miles where, at Mount Robson, it flattens in a structural depression then rises to the culmination at Yellowhead Pass (Price and Mountjoy, 1970) beyond which the plunge is southeasterly.

At Mount Robson the syncline exhibits a steep southwestern limb and a flat northeastern limb and appears to be a concentric or parallel fold. Toward the northwest it becomes a broad, upright fold but changes continuously until east of McBride it is inclined to the southwest with a steep northeastern and a moderately steep southwestern limb (Section G-G'). The form there varies from concentric folds in the more massive sandstone to similar folds with axial fracture ~~of~~ or cleavage in the more argillaceous rocks. Between East Twin and Walker Creeks the fold and subsidiary flexures are overturned toward the southwest and are nearly isoclinal (Sections D-D',

E-E' and F-F'). They are similar folds and have a well developed schistosity subparallel to the axial planes. Still farther northwest folds again become more open and are approximately upright (sections A-A', B-B' and C-C'). Here again the style and the development of cleavage depends on lithology.

From Mount Robson northeastward to the Snake Indian Fault (Mountjoy, 1971) the structure and stratigraphy is typical of the eastern Main Ranges. Concentrically folded thick Gog Group quartzite and a Middle and Upper Cambrian sequence dominated by carbonate rocks are exposed in a series of fault panels. Northwestward along the Mount Robson Synclinorium the structural changes described above are accompanied by the following stratigraphic changes. The upper two-thirds of the thick McNaughton Formation ranges from mainly quartzite to a shale-siltstone assemblage with thin quartzite layers. Though detailed stratigraphic evidence is lacking, the sections of Middle and Upper Cambrian rocks near Walker Creek suggest that the great carbonate sequences of Mount Robson and Mount Sir Alexander have given way to a shale and carbonate sequence (see section on stratigraphy). A transition to a dominantly shale sequence cannot be much farther west because carbonate is a minor part of the equivalent section across the Rocky Mountain Trench in Cariboo Mountains. The McNaughton Formation thins dramatically at Mount Rider (1,900 feet) from its more normal thickness east of McBride (6,800 feet) and at Walker Creek (7,500 feet). The part of the synclinorium between the eastern boundary of the map-area and Walker Creek was apparently hotter than elsewhere during deformation and mainly synchronous metamorphism. The heat was evidently greatest at Mount Rider and the peak to the south where chloritoid is present in pelitic schist near the top of the Gog Group. The stratigraphic and thermal changes northwestward from Mount Robson apparently had a significant influence on the style of deformation along the synclinorium, from dominant faulting with concentric folding typical of the eastern Main Ranges to similar folding with some faulting. The latter is unusual in the Rocky Mountains where folding involves the Gog Group. The entire synclinorium was probably formed during one episode of deformation hence this single large structure provides evidence in support of the concept that a fault-dominated structural regime in Rocky Mountains may change

progressively to a zone of folding in which faulting is of less importance. However, the structure at depth is unknown and thrust faults may underlie the entire region. This concept, also noted with respect to the Forgetmenot Zone, is thought by one of the authors (R.B.C.) to be of major significance in the deformational history of Rocky Mountains and the adjoining Cariboo Mountains. Factors described in this and preceding sections, particularly with respect to the influence of the Miette Group, suggest that the changes in structural style across the Rocky Mountains, at least in McBride map-area, precludes the validity of structural interpretations involving balanced cross-sections and the extension of typical Rocky Mountain thrust faults far to the west of the eastern Main Ranges. Another of the authors (E.W.M.) does not agree and supports the view that the entire western Main Ranges and probably also the eastern Cariboo Mountains must be underlain by important thrust faults (for example see cross-section in Price and Mountjoy, 1970).

ROCKY MOUNTAIN TRENCH

The Rocky Mountain Trench is a steep-walled flat-floored valley at McBride but northward it becomes wider and major breaches in the valley walls are prevalent. At the northern boundary of the map-area it merges with the Interior Plateau beyond Cariboo Mountans and loses its identity. Because exposures in the floor of the Trench are limited and widely scattered, little is known of the structures beneath it.

Near McBride the Trench is underlain partly and perhaps entirely by Gog Group quartzite that apparently lies in a graben within the folded Proterozoic succession exposed on the valley walls (Sections G-G' and L-L'). The fault forming the southwestern boundary of the graben may be the northern extremity of the Purcell Fault, a major structure that can be traced far to the south. The geomorphic forms of the Trench at McBride may be related to the graben though this is not proved. Northwest from the mouth of McKale River the Trench may contain a graben or a major fault or faults, but supporting data are lacking. Faults in the Trench are not necessarily more significant than those in the surrounding mountains; substantial displacement on one or more faults is a possibility. Stratigraphic differences between

the Cariboo and Gog Groups may indicate that the Trench is the locus of major faulting but data are too few to permit a conclusive assessment of this possibility. In the southern half of the map-area similarities and continuity in stratigraphy, structure, and metamorphism in Proterozoic rocks across the Trench suggest but do not prove that ~~no~~ major faults are not present between ~~separates~~ Cariboo ~~from~~ and Rocky Mountains.

CARIBOO MOUNTAINS AND INTERIOR PLATEAU

The southern part of McBride map-area southwest of the Trench can be divided into major northwesterly plunging fold structures. From the Trench southwestward these are the Premier Anticlinorium, Isaac Lake Synclinorium, Lanezi Arch or Anticlinorium, Black Stuart Synclinorium, and Lightning Creek Anticlinorium (Fig~~ure 6~~ 4 and Sections I-I' to M-M'). The last two continue far to the northwest beyond the limits of the map-area. The first three flatten to the north, merge, and lose their identities in a fault-dominated structural regime. Significantly the change from folding to faulting is coincident with a change from incompetent Proterozoic strata (Kaza Group and Isaac Formation; equivalent to the middle and part of the upper Miette Group~~s~~ respectively in Rocky Mountains) to relatively much more competent Proterozoic and Lower Cambrian rocks. This change is closely analogous to the structural transition between the Miette Group and younger rocks in Rocky Mountains as discussed in the previous sections.

Boundaries between the anticlinoria and synclinoria cannot be precisely determined from features observed in the field. Nevertheless, even though arbitrarily defined, they provide a useful frame of reference for description.

Premier Anticlinorium and Isaac Lake Synclinorium

The Premier Anticlinorium and Isaac Lake Synclinorium are most conveniently described together. These large structural elements which are most clearly delineated in Quesnel Lake (Campbell, 1963) and Canoe River (Campbell, 1968) map-areas to the south and southeast of McBride map-area were previously discussed with emphasis on the structural transitions displayed within them (Campbell, 1970).

Originally called the Milk River Anticlinorium by Sutherland Brown (1963),

the anticlinorium was renamed because of its clearly defineable form in Premier Range in Canoe River map-area as opposed to its rather vague form near the Milk River Valley in McBride map-area (Campbell, 1970). Sutherland Brown (1963) also named the Isaac Lake Synclinorium which he was the first to study east of Isaac Lake. These structures extend far to the southeast and apparently reach the Rocky Mountain Trench where they are cut by the Purcell Fault (Campbell, 1968; Price and Mountjoy, 1970).

The Premier Anticlinorium is the ~~succeeding~~ next major fold southwest of the Mount Robson Synclinorium. A precise boundary between the two is difficult or impossible to determine and is possibly complicated by faults in the Trench. If the graben of Gog Group rocks in the Trench near McBride is ignored then a reasonable continuity of deformed Proterozoic strata (middle Miette Group and equivalent Kaza Group) extends from the synclinorium into the anticlinorium. The Isaac Lake Synclinorium is largely fault bounded and hence the name may be misleading. However, the faults die out ~~laterally~~ on trend in older strata and may be presumed to die out at depth in a similar manner. If so, then a true synclinorium exists below the level of faulting and this can be observed in the structural culmination at the southern boundary of the map-area. The boundary between the two structures is arbitrarily placed along a line from near the head of Castle Creek through the northwest flowing upper part of Betty Wendle Creek. The boundary of the synclinorium with the Lanezi Arch lies along Isaac Lake where it is partly a faulted contact.

The intensity of deformation and metamorphism progressively decreases in each structure from southeast to northwest (Campbell, 1970); a relatively high intensity persists much farther northwestward in the anticlinorium than in the adjoining synclinorium. The anticlinorium plunges gently northwest throughout whereas the synclinorium, though generally plunging northwest, passes through a depression southeast of Mitchell Lake in Quesnel Lake map-area (Campbell, 1963 and 1970), rises northwestward to a culmination at the boundary with McBride map-area, and then resumes a northwest plunge. At the culmination of the synclinorium is not readily distinguishable from the anticlinorium to the east as the stratigraphic

level in each is about the same.

In Canoe River map-area (Campbell, 1968 ~~and~~ 1970) Kaza Group strata in the deepest levels of the Premier Anticlinorium are in the staurolite-kyanite grade of metamorphism and are deformed into isoclinal folds in which foliation and bedding are parallel. The folds are themselves arched across an antiformal axis. The antiform is isoclinal in the extreme southeast but northwestward becomes an open, gentle structure. The axial surfaces and hence the limbs of the isoclinal folds are parallel with the limbs of the antiform and are warped across its crest. Just South of McBride map-area the antiform plunges beneath and grades transitionally into a single anticline without apparent isoclines or other minor folds. Within the anticline foliation and bedding are parallel. The transition anticline, in turn, plunges northwest beneath, and merges southwestward into a zone of similar or composite folds in which foliation or cleavage and bedding are not parallel; the foliation may be parallel to the axial surfaces of the folds or it may form a fan. The axial surfaces of these folds are arranged roughly perpendicular to the surface of the transition anticline and hence to the deeper antiform and to the limbs and axial surfaces of the isoclines.

The zone of similar and composite folds involves Kaza Group and Isaac Formation rocks in a large area of the Premier Anticlinorium in the southeastern part of the map-area and in the structural culmination of the Isaac Lake Synclinorium south of Cariboo River. The largest folds have amplitudes from 5,000 to 10,000 feet or more and are best developed in the Kaza Group and the immediately overlying basal part of the Isaac Formation. Axial surfaces are arranged in a broad downward converging fan across the axis of the anticlinorium (Sections K-K' and L-L'). The thick, shaly Isaac Formation does not transmit the form of the folds so that higher in the section above the influence of the folded Kaza Group strata the large folds are replaced by many smaller flexures with strongly developed axial-plane cleavage. There the anticlinorium has little structural relief and is not clearly defined. Near the south boundary of the map-area in the Premier Anticlinorium the rocks are in or near the biotite grade of metamorphism. To the northwest the grade decreases progressively to the chloritic

phyllite, argillite, and shale of the Isaac Formation. The metamorphic transition takes place down plunge to the northwest and also laterally toward the Isaac Lake Synclinorium.

Above the Isaac Formation the relatively competent and essentially unmetamorphosed Cunningham Formation and other units of the Cariboo Group were dominant factors in the structural history. During deformation these rocks reacted primarily as brittle units overlying the deeper zone of folding. They yielded by faulting (Plates I and IX) and some concentric folding within individual fault blocks (Section H-H', I-I', and J-J'). Locally where faults are closely spaced, folding is intense in incompetent units, such as the Yankee Belle Formation. In such cases the overlying Yanks Peak Formation may be essentially unfolded. The faults that cut the Cunningham and younger formations do not extend far laterally into the older units; few if any recognizable faults cut the Kaza Group. From this it is inferred that the faults also die out at depth and merge into a zone of folding in Kaza and Isaac rocks.

Within the highly faulted zone the distinction between the Premier Anticlinorium and Isaac Lake Synclinorium is lost. The two structures merge in the highly fractured plate of Cunningham Formation and younger units and structural relief across the plate is relatively small. Southward along the synclinorium the faulted and relatively little folded character of the Cunningham Formation and younger rocks persists until, in the structural culmination, folding is prevalent in older strata. Beyond the culmination faulting again dominates the structure ~~in the structure~~ in the younger rocks in Quesnel Lake map-area (Campbell, 1963) but here the structures merge both laterally and along the trend (Campbell, 1968; Campbell and Campbell, 1970) into zones of more intense folding; a change accompanied by higher metamorphic grade.

The transition in structural style from the deeper levels in Premier Anticlinorium to shallower levels within the anticlinorium and in the Isaac Lake Synclinorium evidently reflect the varied response to stress of rocks of different character and in different thermal environments. The steep, mainly vertical faults that lie high in the structural progression in the anticlinorium suggest that the

transfer of material was essentially vertical and from this it may be inferred that the same applied to the deeper folded zones.

The structural transitions described above present an obvious analogy to the adjacent Rocky Mountains but display an equally obvious difference. In each case fold-dominated structures in metamorphosed Proterozoic rocks change transitionally into fault-dominated structures in unmetamorphosed younger rocks. In the Cariboo Mountains the fault movements were evidently primarily vertical though strike-slip movement may have occurred on the tectonically late northeasterly trending set. In the Rocky Mountains, on the other hand, the fault movements evidently varied from dip-slip on gently to moderately southwest-dipping faults in the Front Ranges and eastern Main Ranges to dip-slip on steeply dipping faults in the western Main Ranges.

The continuum in structural history from Cariboo to Rocky Mountains does not support the concept of two separate orogenic events separated at the Trench (Nevadan to the west and Laramide to the east) as previously discussed elsewhere (Campbell, 1968b; Price and Mountjoy, 1970). Thus a tectonic synthesis compatible with all observed structural phenomena in both mountain ranges is required. Because substantial horizontal displacements on reverse or thrust faults in the eastern Rocky Mountains can be demonstrated or inferred, it cannot be construed that the rocks for an indefinite distance to the west are equally displaced unless structural evidence substantiates such an hypothesis. This theme will be dealt with below.

Lanezi Arch

The Lanezi Arch or Anticlinorium was named by Sutherland Brown (1963) who provided a lucid description of many of the pertinent structural features. The arch is bounded on the east by a northwesterly line through Isaac Lake and on the west by an inferred fault that separates the Kaza Group within the arch from younger strata to the west. Northwest from the head of Isaac Lake in a region of poor exposures younger rocks occupy the down-plunge extension of the anticlinorium. The structure here is not well understood but the anticlinal form seems to persist to about Haggen Creek beyond which it cannot be recognized. The anticlinorium apparently

merges, together with the Isaac Lake Synclinorium and Premier Anticlinorium, into the faulted plate of Cariboo Group rocks. Southeastward the arch extends into Quesnel Lake map-area (Campbell, 1963) to near the head of the East Arm of Quesnel Lake where it becomes involved in a zone of intense deformation and sillimanite grade of metamorphism and where it can no longer be traced as a recognizable structural unit.

Little can be added to Sutherland Brown's description of the structures of the Lanezi Arch for the region he studied between Lanezi Lake and the head of Isaac Lake. He provided five structural cross-sections (Sutherland Brown, 1963, pp. 47-48 and 51-52, Fig.3) which show it to be a broad, gentle anticline from 8 to 12 miles wide. On the flanks the steepest dips vary from 35 to 60 degrees away from the broad gently folded central portion (Sections K-K' and L-L'). Minor folds are relatively rare and are most prevalent on the flanks of the structure where they are accompanied by the development of schistosity sub-parallel with axial surfaces. The latter dip steeply away from the axis of the arch on either flank. Along the main axis of the anticlinorium schistosity and bedding are parallel, a relationship that changes progressively to the axial-surface foliation on the flanks.

South from Lanezi Lake the zone of minor folding with axial surface schistosity on the southwest flank gradually widens whereas that on the northeast narrows. At Mitchell Lake about 9 miles south of the map-area (Campbell, 1963) flat-lying Kaza Group rocks of the anticlinorium lie adjacent to a similarly flat plate of Cariboo Group rocks in the Isaac Lake Synclinorium. There cleavage, if present, is steep throughout the structure. Southwest from the east end of Mitchell Lake deformation becomes more intense until the folds are isoclinal. This is accompanied by an increase in metamorphism from the low grade rocks of the arch to the sillimanite grade where polyphase folding is characteristic.

Near Lanezi Lake the plunge of the Lanezi Arch is flat or gently southeast but farther north it is gently northwestward. Because of poor exposures it is not possible to obtain a clear idea of the structure in the younger rocks above the Kaza Group north of the upper end of Isaac Lake. For some distance they are flat-lying but toward Haggen Creek dips are moderately steep. Folding and faulting may be

more important than realized.

The broad, gentle flexure of the Lanezi Arch in which Kaza Group rocks are almost flat lying over a wide area is unique in Cariboo Mountains; the transition anticline of the Premier Anticlinorium is a much smaller feature. The Arch represents the deepest known stratigraphic level in which the rocks are essentially flat-lying or are but mildly folded. This condition is otherwise restricted to the Cunningham Formation and younger units in the Isaac Lake Synclinorium and in the stratigraphically highest levels of the Premier Anticlinorium. Obviously the younger rocks that lay above the main part of the arch must have been relatively flat-lying. Similarly Kaza Group underlying the large, flat, unfaulted plate of younger rocks in the Isaac Lake Synclinorium southeast of Mitchell Lake in Quesnel Lake map-area, Campbell (1963), may be generally unfolded. It is that the flat lying parts of the two structures are adjacent. Apparently the Lanezi Arch lies at its present level partly because of its broad anticlinal structure and partly because it was raised by faulting on either side. The folding on the northeast flank may be due to fault movements, whereas that on the southwest, while perhaps partly due to faulting, is evidently transitional to the much more intensely folded Black Stuart Synclinorium in which Cariboo Group rocks are locally highly deformed.

Black Stuart Synclinorium

Sutherland Brown (1963) named the Black Stuart Synclinorium and discussed it separately from the Slide Mountain Trough. He indicated that the two features may be related but he believed that the major folding of the Kaza and Cariboo Groups pre-dated deposition of the Slide Mountain Group and that the coincidence of the two structures might be accidental. In contrast, the authors believe that the main folding is much later than deposition of the Slide Mountain Group (Columbian Orogeny culminating in the Laramide Orogeny; Douglas et al 1970) and that pre-Slide Mountain folding was not necessarily intense and may have been little more than regional tilting or warping. For this reason the Slide Mountain Trough is regarded as part of the Black Stuart Synclinorium which name is applied to the entire structure.

The Lower Devonian and (?) younger Black Stuart Formation unconformably overlies the Cariboo Group and in turn is apparently truncated by the Devonian (?), Mississippian and (?) younger Slide Mountain Group (sections J-J' and K-K'). All of the known Black Stuart Formation and Slide Mountain Group in McBride map-area lies within the Black Stuart Synclinorium. The eastern flank of the synclinorium is marked by outcrops of the Cariboo Group, particularly the Mural Formation. On the southwest flank south of Eight Mile Lake the Cariboo Group again ~~crops out~~ outcrops as it does completely around the hinge of the structure to the southeast in Quesnel Lake map-area (Campbell and Campbell, 1970). Much of the carbonate south of Eight Mile Lake is thought to be Mural Formation rather than Cunningham Formation though the distinction is difficult and doubts remain. The Mural Formation does, however, closely underlie rocks of the Black Stuart Formation completely around the hinge of the synclinorium (Mansy and Campbell, 1970) and can be traced with certainty along the northeastern limb for 40 miles to Haggen Creek and apparently continues for another 20 miles or more. Thus for a great distance the unconformity at the base of the Black Stuart Formation lies with little structural discordance above strata of the Cariboo Group. North from Eight Mile Lake bevelling apparently increases abruptly on the southwestern flank so that the base of the Slide Mountain Group rests directly on Kaza Group rocks. In this case, however, exposures are poor, and faults may play an important part in bringing the Slide Mountain and Kaza Groups together. In the hinge of the synclinorium to the southeast in Quesnel Lake map-area (Mansy and Campbell, 1970) the Black Stuart Formation may be more than 2,000 feet thick. On the southwestern flank of the synclinorium in McBride map-area, however, the formation, if present is very much thinner and is apparently truncated at the base of the Slide Mountain Group. Northwest from Antler Creek the base of the Slide Mountain Group evidently cuts down into the Cariboo Group and lies just above the Yanks Peak Formation at Summit Creek. Still farther northwest it apparently rests on the Kaza Group as it may do on the northeastern flank far to the north near Purden Lake. These relationships imply that the sub-Slide Mountain surface truncates the underlying strata at a substantially greater angle than does the unconformity at the base of the Black Stuart Formation.

East of the synclinorium the youngest rocks in Cariboo Mountains on Upper Cambrian and in the western Rocky Mountains are Siberian. Thus the unconformity at the base of the Black Stuart Formation must bevel successively older strata from east to west. Similarly the discordance at the base of the Slide Mountain Group cuts down section in a westerly direction.

The principal folding of the Cariboo Group obviously involved the Black Stuart Formation (Mansy and Campbell, 1970). A study of mesoscopic-scale structural fabric elements across McBride and parts of adjoining map-areas led Brown (1968, p.20) to comment: "The study suggests a continuity of deformation throughout the area and that all the rocks from Proterozoic to Late Triassic reflect the same deformational history." This conclusion is at variance with that of Sutherland Brown (1957 and 1963) and earlier workers (e.g. Johnston and Uglow, 1926) who studied the rocks in the Barkerville-Bowron Lake region. It conflicts particularly with the assertion by Sutherland Brown (1957) and Johnston and Uglow (1926) that the Guyet Formation conglomerate of the Slide Mountain Group contains randomly oriented foliated metamorphic rocks identical to lithologies in the older Cariboo Group and that the folding in the older rocks including the then unrecognized Black Stuart Formation, pre-dates the deposition of the younger.

Study of the conglomerate failed to corroborate the earlier observations. Matrix and clasts in the conglomerate were found to exhibit a pervasive cleavage not inconsistent with that in the older rocks. Random orientation of foliated clasts was not seen though commonly the foliation or cleavage is refracted when it passes through contrasting lithologies, for example, from a siliceous matrix to a pelitic clast. The difference in the intensity of folding between strata of the Slide Mountain Group and older rocks is believed to be real but is apparently the result of contrasting strain in rocks of vastly different relative competence (massive conglomerate or thick pillow lava as opposed to shale or limestone) rather than the result of separate episodes of deformation. In this respect it is interesting to note that the rise in metamorphic grade in the Kaza Group near Beaver Pass and northward to Willow River also affects a narrow strip of adjacent greenstone of the Slide Mountain Group which is converted to fine-grained amphibolite. It can be shown from the regional

pattern of metamorphic isograds that the metamorphic grade of the Slide Mountain Group (greenstone contains pumpellyite and prehnite, K.V. Campbell, pers. comm., 1970) is consistent with the metamorphism of the older rocks. The metamorphism is mainly syn-tectonic. Both the deformation and metamorphism is known to affect late Triassic rocks west of Wingdam and in Quesnel Lake map-area (Campbell and Campbell, 1970). The bulk of evidence supports the concept that the principal folding in Cariboo Mountains is younger than the Slide Mountain Group though some deformation may be older.

In the foregoing it is assumed that all or most of the Slide Mountain Group was deposited where it is now found. This assumption seems warranted for the older Black Stuart Formation which lies unconformably in apparent sedimentary contact above the Cariboo Group (Mansy and Campbell, 1970). It may or may not apply to the Guyet and Antler Formations, particularly the latter. Unfortunately the contacts of these formations are so poorly exposed that little is known about them. The huge mass of basaltic rocks of the Antler Formation, in which pillow lava is particularly prominent, is associated with argillite and ribbon chert. Chemical analyses show the basalt to be tholeiitic (K.V. Campbell, pers. comm., 1970). This assemblage has characteristics of ocean-floor deposits though it lies above a very thick sequence of marine sedimentary rocks derived from a continental source. No conduits that might have provided such a mass of basalt have been found in older rocks that outcrop around the Slide Mountain Group on the flanks of the Black Stuart Synclinorium. The Antler and perhaps the Guyet Formation may be a huge allochthonous slide or thrust sheet emplaced during the late Paleozoic (as suggested by Prof. Jean Dercourt, pers. comm., 1969), a result, perhaps, of the Missisippian Antler Orogeny well documented in Nevada (Roberts, 1964). Thus the Cariboo Orogeny (White, 1959) at its type locality may be manifest by major thrusting rather than by significant pre-Slide Mountain Group folding. It may correspond in time with the pre-Milford Group deformation in the Selkirk Mountains discussed by Wheeler (1968). In Nevada and in the Selkirk Mountains major west to east thrusting is an important feature of the deformation. Gabrielse (1967) presented data on the thick Devono-Mississippian clastic deposits of the northern Cordillera and

and related them to a possible late Paleozoic orogeny. The Guyet Formation, topped by pods of crinoidal limestone, might represent an orogenic sediment deposited in front of an advancing thrust sheet and subsequently overridden, or it may itself be allochthonous. Much careful work will be required to determine the validity of these speculations.

The Mural Formation along the northeast flank of the Black Stuart Synclinorium south of Sentinel Rock is gently folded and appears to be nearly flat-lying over fairly large areas (Section J-J'). Farther north folding is apparently more intense but the paucity of exposures makes satisfactory structural interpretation difficult. To the southeast of Quesnel Lake map-area folding involving the Mural Formation and the unconformably overlying Black Stuart Formation becomes nearly isoclinal near Mount Kimball in the hinge of the synclinorium (Mansy and Campbell, 1970; Sutherland Brown, 1963). The increase in the intensity of deformation is accompanied by rising metamorphic grade (Campbell and Campbell, 1970). Still farther southeast beyond Mount Kimball the rocks of the Cariboo Group are in the staurolite-kyanite grade of metamorphism and are highly deformed. The intensity of deformation is much greater than in the lower grade Kaza Group strata of the adjoining Lanezi Arch.

Northwest from Mount Kimball along the southwest flank of the synclinorium Cariboo Group and Black Stuart Formation strata are folded and faulted. Exposures are generally small and scattered in this region thus stratigraphic correlations and structural interpretations leave many uncertainties. However, new data on the stratigraphy of the Cariboo and Slide Mountain Groups (Young, 1968 and 1969; Mansy and Campbell, 1970; and this publication) have permitted the writers to suggest an interpretation that differs in some important respects from earlier efforts, principally by Holland (1954), Sutherland Brown (1957), and Johnston and Uglow (1926). Fundamental to the new interpretation is the belief that the Snowshoe Formation of Holland and Sutherland Brown is the stratigraphic equivalent of the Kaza Group (exposed in the Lightning Creek Anticlinorium) and that much of what was mapped by them as Midas Formation from near Roundtop Mountain in Quesnel Lake map-area to Eight Mile Lake in McBride map-area is in fact part of the Isaac

Formation. The principal point of departure from earlier interpretations is the inference of a strike-fault separating the band of Isaac Formation from the remainder of the Cariboo Group. Much of the limestone east of the inferred fault and below the Slide Mountain Group is thought to be Mural Formation and apparently little if any Cunningham Formation is present except just to the south of Eight Mile Lake. In McBride map-area there is evidently no complete section of the Cariboo Group between the inferred fault and the base of the Slide Mountain Group. This is manifest particularly by the absence in any one cross section of two distinct carbonate units (Cunningham and Mural Formations). If the suggested stratigraphic correlations are accurate then one or more strike-faults must be present.

Strata of the Cariboo Group along the southwest flank of the Black Stuart Synclinorium and east of the inferred strike-fault dip moderately to steeply northeastward and, though folded, they display no apparent major repetition as a result of folding. The axial surfaces and sub-parallel cleavage of the few exposed folds dip steeply northeastward. The folds are inclined and locally overturned. The apparent absence of major stratigraphic repetition and the form of the observed folds suggests that this section of Cariboo Group rocks lies entirely on the northeast limb of a large anticlinal structure and that it is not, within itself, folded into an overturned anticline as interpreted by Sutherland Brown (1957, Fig.9). A further indication of this is that the Isaac Formation and Kaza Group rocks west of the inferred strike fault (part of the Midas Formation and Snowshoe Formation of Sutherland Brown, 1957) are distinctly more highly deformed and metamorphosed and more intensely cleaved or schistose as compared to the rocks immediately to the east. These circumstances strongly support the stratigraphic and structural interpretations proposed herein.

Within the map-area the intensity of deformation or the grade of metamorphism, or both, diminish toward the stratigraphically highest parts of the Black Stuart Synclinorium from the adjoining anticlinoria and from the deeper levels of the synclinorium. The change in structural style is accentuated by the change in relative competence of the rocks from the Cariboo Group and the Black Stuart Formation on the one hand to the Guyet and Antler Formations on the other. Though the structure

of the latter is most imperfectly known the folds appear to be rather broad and open. Layers of bedded chert, on the contrary, are commonly intricately folded possibly as a result of slippage between more massive units. Cleavage is well developed in the Black Stuart Formation, is prominent in the Guyet Formation but is virtually absent from most of the Antler Formation. The Black Stuart Synclinorium exhibits some of the structural and metamorphic transitions noted in parts of Rocky Mountains and in the Premier Anticlinorium previously discussed. It cannot be demonstrated that the higher and relatively brittle rocks of the synclinorium are much faulted as are rocks in equivalent structural positions in the other regions because the lack of a distinctive succession in the Antler Formation makes recognition of faults difficult or impossible. Several late-stage northeasterly trending faults can be mapped or inferred. As in the northern part of Cariboo Mountains these faults cut the older folds and strike faults.

Lightning Creek Anticlinorium

The Lightning Creek Anticlinorium is exposed in the southwest corner of McBride map-area (Sections J-J' and K-K'). It extends for many miles northwesterly into Prince George map-area (Tipper, 1961) and southeasterly into Quesnel Lake map-area (Holland, 1954; Sutherland Brown, 1957; and Campbell, 1961) where its crest is mapped as the Lightning Creek Axis. The axis of the structure was first noted by Bowman (1889) and subsequently by Johnston and Uglow (1926) and by Holland (1948b). From a well-defined structure near Mount Burdett in Quesnel Lake map-area the axial zone becomes broad and ill defined toward the northwest. Near Beaver Pass foliation strikes northeasterly and dips gently to moderately northwestwards. These attitudes lie in the axial region and the dips approximate the plunge. On the flanks the strikes become northwesterly and the foliation dips moderately to steeply away from the axis.

The anticlinorium is perhaps an antiform rather than a true anticline. Its internal structure is not well understood and stratigraphic relationships are far from clear. An anticlinal character is supported by the distribution of younger rocks on the flanks; Slide Mountain and Cariboo Groups on the northeast and Triassic and younger strata on the southwest. The rocks within the anticlinorium are Kaza Group and

Isaac Formation according to the present interpretation. In Prince George map-area to the northwest the Mesozoic rocks envelop the Proterozoic strata in the core (Tipper, pers. comm.) though this is not obvious on the published map (Tipper, 1961).

The folding and foliation of the rocks within the anticlinorium are well described by Sutherland Brown (1957, p.46-51). He notes that the rocks he refers to as Snowshoe and Midas Formations (Kaza Group and Isaac Formation in this report) are intensely folded, that the complexity of folding varies with lithology, being particularly complicated in pelitic rocks and in thinly interlayered phyllite and quartzose schist, and that foliation may be sub-parallel with the axial surfaces of the folds or it may be parallel with bedding completely around fold hinges (the writers found the latter to be very common). Though some folds are isoclinal or nearly so, many are more open, and beds on one or both limbs may be thinned relative to the hinges. He mentions that evidence of two stages of folding such as folded folds or folded axial-plane cleavage is so sparse as to be insignificant. This seems to support the writers' view that pre-Slide Mountain Group folding was little more than regional tilting and did not involve metamorphism and severe deformation. This conclusion is strengthened by the overlap of metamorphism from the anticlinorium into the rocks of the Slide Mountain Group near Willow River as previously mentioned.

Foliation or schistosity is arched across the anticlinorium and hence the sub-parallel axial surfaces of the minor folds are arched in a similar manner (Section I-I'). Minor folds may be drag folds related to the major structure but evidence is inconclusive. The common parallelism of schistosity and bedding in the limbs and hinges of folds suggests that interstratal slip during the development of the major structure has in some way produced the bedded schistosity and the folds. In younger rocks on the flanks of the anticlinorium axial-plane cleavage or schistosity is developed. Cleavage-bedding relationships in the Lanezi Arch and Premier Anticlinorium also indicate that bedding and cleavage may be parallel in entire folds in some environments and have angular relationships in others of the same generation. The first of these relationships cannot always be accepted as clear evidence of two stages of folding.

Intermontane Zone

A small area slightly more than two miles wide in the southwest corner of the map-area, which is underlain by dark grey phyllite, of possible Upper Triassic age, is referred to as part of the Intermontane Zone. The pelitic unit can be traced far to the south through Quesnel Lake (Campbell, 1961 and 1963) and into Bonaparte Lake map-area (Campbell and Tipper, 1971). It also extends northward into Prince George map-area (Tipper, 1961) for many miles. The unit apparently lies unconformably above all older rocks with which it is in depositional contact. Near Crooked Lake in Quesnel Lake map-area (Campbell and Campbell, 1970) it lies above a layer of amphibolite, which may be equivalent to part of the Slide Mountain Group. In Bonaparte Lake map-area (Campbell and Tipper, 1971) the phyllite unit apparently lies above the Fennell Formation believed an equivalent of the Antler Formation. In Prince George map-area it lies directly on the meta-sedimentary rocks of the Lightning Creek Anticlinorium and also on the Antler Formation in the extension of the Black Stuart Synclinorium (Tipper, pers. comm. 1967). At Crooked Lake and locally in Prince George map-area the unit is apparently conformably beneath ~~underlies~~ Triassic-Jurassic volcanic clastic rocks that underlie a large area of the Intermontane Zone.

The volcanic clastic rocks are cut by many faults and folding is of minor importance (Campbell and Tipper, 1970, 1971). The phyllitic rocks, on the other hand, are highly folded and in that respect seem structurally more related to the older rocks to the east than to the younger ones to the west. From Quesnel Lake northwestward into Prince George map-area the phyllite unit may be in fault contact with the younger rocks though evidence is not completely conclusive. This possibility is strengthened by the structural unity between the phyllite and older rocks of the anticlinorium. The folds and penetrative foliation in the phyllite are consistent with its position on the flank of the anticlinorium. This, together with the fact that the younger volcanic clastic rocks are also involved in the deformation and metamorphism at Crooked Lake (Campbell and Campbell, 1970) is convincing evidence that the major folding and metamorphism in Cariboo Mountains is Lower Jurassic or later.

SUMMARY

The reconnaissance study by Brown of mesoscopic fabric elements from the Interior Plateau across the Cariboo Mountains and into Rocky Mountains in McBride and adjoining map-areas shows that "all the rocks from Proterozoic to Late Triassic reflect the same deformational history" (Brown, 1968, p.12). Hence a western Columbian (Nevadan) Orogeny is not distinct in space or time from an eastern Laramide Orogeny, a conclusion expressed elsewhere (Campbell, 1968; Price and Mountjoy, 1970). In support of this concept is the unity in structure and metamorphism between Cariboo and Rocky Mountains across the Rocky Mountain Trench. Brown's work and the present study also cast doubt on the nature of the late Paleozoic Cariboo Orogeny (White, 1959) based on evidence presented by Johnston and Uglow (1926) and Sutherland Brown (1957) who believed that the strata of the Cariboo Group were severely deformed and metamorphosed prior to deposition of the Slide Mountain Group. While the existence of a sub-Slide Mountain Group discordance or unconformity seems indisputable, the authors believe that the main folding and metamorphism of the region post-dates the Slide Mountain Group and is, in fact, post-Early Jurassic. The possibility of part of the Slide Mountain Group being an allochthonous mass or sheet thrust from the west during the Cariboo Orogeny is an interesting speculation. Whether or not such a relationship exists will only be determined by additional careful field work.

The impressive transitions in deformational style from one structural level to another are an important aspect of the geology of McBride map-area. In these transitions folds at the deepest levels give way upwards to fault-dominated structural regimes. The progressive change in the style of strain evidently reflects change in the physical character of the rocks from one level to another during deformation; the rocks from level to level have different relative competencies and become more brittle upwards. The change is thus partly controlled by stratigraphy but in addition the temperature of the rocks during deformation, now manifest by metamorphic grade, is a vital factor. Because isothermal surfaces were not rigidly parallel to the strata, metamorphosed Cariboo Group rocks may be highly folded, as in part of the Black Stuart Synclinorium, or may be faulted and little folded where unmetamorphosed as

in part of the Isaac Lake Synclinorium. Generally and predictably, however, metamorphic grade increases with stratigraphic depth and hence the Kaza Group in Cariboo Mountains and its equivalent and older rocks in Rocky Mountains are relatively the most highly metamorphosed over the entire region. Aside from metamorphism, the very thick Proterozoic succession (Isaac Formation, Kaza Group and Miette Group) consisting of impure, matrix-rich sandstone with thick shale sequences, inevitably display different strain characteristics than the thick carbonate and pure quartz sandstone strata of the overlying Cariboo and Gog Groups, and younger rocks. The inherent difference in competence accentuated by metamorphism (but locally obliterated by it) thus provided a situation where deformation by intense folding at deeper levels was accompanied by faulting at shallower levels.

Another factor in the structural development is the variation in thickness of the Miette Group in Rocky Mountains and its pre-Cunningham Formation equivalents in Cariboo Mountains. From little or nothing under the Foothills and Front Ranges these rocks thicken to 15,000 feet or more at the Trench and this thickness is probably maintained or increased to the west. This profound stratigraphic change coupled with the relatively high temperature of the rocks during deformation is of prime importance in any hypothesis proposed to explain the structure of the region. In the view of one of the writers (R.B.C.) at least some faults in the relatively brittle high-level, anisotropically-layered Paleozoic strata in the Main Ranges of Rocky Mountains can be expected to display progressively less displacement and ultimately to disappear as they penetrate the relatively plastic, deeper, hotter, more isotropic rocks of the Proterozoic sequence. Deep-level folding is believed to compensate for the high-level faulting as seems clearly to be the case in Cariboo Mountains. One of the authors (E.W.M.) emphatically disagrees with this concept.

~~Structures in the Cariboo and western Rocky Mountains do not~~ support the concept that ~~the rocks of the region have been transported en masse toward the north-east. On the contrary, they seem~~ to suggest vertical transport, ~~and, in the west particularly in~~ Quesnel ~~Lake map-area (Campbell and Campbell, 1970), transport~~ appears to be southwesterly ~~if the direction may be inferred from major~~ overturned or

Structures in Cariboo and Western Rocky Mountains, taken by themselves, provide no clear evidence in support of the concept that the cover rocks of the entire region have been transported en masse toward the northeast above a passive basement although they do not necessarily rule against such a possibility. These structures suggest vertical transport and in the west, particularly in Quesnel Lake map-area (Campbell and Campbell, 1970), transport is southwesterly if the direction may be inferred from major overturned or inclined folds. Thus the entire belt displays some elements of symmetry insofar as a central zone of apparent vertical movement, is flanked by zones with structures suggesting transport away from the central axis. The major apparent transport is northeastward hence the hypothesis of detachment from a passive crystalline basement requires that the entire belt has moved northeastward, relative to the basement, as suggested by Price and Mountjoy (1970). On the other hand, if the central zone is regarded as an autochthon flanked by zones of outward directed transport, then basement must have been involved in the deformation and the combination of the folding discussed above coupled with basement involvement in the structures must compensate for shortening apparent in the eastern Rocky Mountains. This concept, favoured by only one of the writers (R.B.C.), ~~requires~~ needs elaboration beyond the scope of this paper. Suffice to say it requires that the shortening accomplished by thrust faulting in the eastern Rocky Mountains was basically the result of southwesterly directed underthrusting, that the crystalline basement beneath the eastern Rocky Mountains moved southwesterly relative to the central zone of the orogenic belt, and that the basement is involved in structures of the central part of the orogenic belt southwest of the zone of detachment in the eastern Rocky Mountains.

New Page

CHAPTER IV

METAMORPHISM

Rocks of the Proterozoic Miette and Kaza Groups and Isaac Formation, with few exceptions, display the effects of low-grade regional metamorphism over the entire map-area. Equivalent metamorphism of younger rocks is restricted to the flanks of the Lightning Creek Anticlinorium, to the central part of the Mount Robson Synclinorium (see section on structural geology and Figure 4) and locally within the Rocky Mountain Trench. Otherwise younger rocks are essentially unmetamorphosed or they are affected to a minor degree.

Contrary to earlier opinions (Johnston and Uglow, 1926; Sutherland Brown, 1957 and 1963) the writers believe that the principal episode of metamorphism and of deformation post-dated deposition of all rocks in the map-area with the exception of the Upper Cretaceous or early Tertiary Bowron River coal-bearing beds and probably the Upper Jurassic rocks of the Rocky Mountain Foothills. Near Crooked Lake in Quesnel Lake map-area evidence seems clear that Upper Triassic and/or Lower Jurassic rocks were affected by the metamorphism (Campbell and Campbell, 1970) and thus the age of metamorphism is bracketed between Early Jurassic and Late Cretaceous. Within McBride map-area the probable Upper Triassic phyllite in the extreme southwest corner is involved in the metamorphism and deformation.

Regionally, McBride map-area occupied a broad depression in the isothermal surfaces, now manifest by isograds, that existed during the episode of metamorphism. To the southeast are higher grade rocks of the Shuswap Metamorphic Complex (Campbell and Campbell, 1970; Campbell, 1968a; and Wheeler, 1970b, etc.) and northwestward is the Wolverine Metamorphic Complex (Muller and Tipper, 1969). The thermal zone in which the metamorphism occurred was elongate and relatively narrow but its width varied substantially from place to place so that locally it extended into the Rocky Mountains and the Intermontane Zone from its main axis in Columbia Mountains and northwestward. The zone may have been steep sided at least insofar as the higher grades of metamorphism were concerned. The upper surface was apparently marked by a series of elongate thermal "anticlines" and "synclines" of various plunge along the trend. These were individually steep-sided

where the higher grades of metamorphic rocks were developed but the "thermal topography" was evidently more subdued at higher levels. Over substantial areas the grade of metamorphism and stratigraphic level are roughly coincident, but this does not apply locally, and regionally, isograds transect strata through great thicknesses. The plunges of thermal "folds" did not necessarily coincide with those of structures.

In McBride map-area the general concordance of low intensity metamorphism to stratigraphic level leads to the restriction of metamorphic rocks mainly to the anticlinoria southwest of the Trench and to the broad structural culmination in the Forgetmenot Zone to the northeast (see Figure 6). In these structural elements rocks of the Kaza and lower and middle Miette Groups are metamorphosed to the greenschist facies, mainly to the muscovite-chlorite subfacies and locally to the biotite-chlorite subjacies. Generally, though not everywhere, the Isaac Formation and Upper Miette Group are similarly metamorphosed.

In Lightning Creek Anticlinorium the grade increases from Beaver Pass northwestward where the rocks contain abundant large garnets. This higher grade of metamorphism overlaps from the rocks of the Kaza Group into the Slide Mountain Group where a narrow belt of basaltic rocks are converted to actinolitic amphibolite north of Pundata Creek. The grade of metamorphism decreases outward and stratigraphically upward from the flanks of the anticlinorium so that the Cariboo Group and the lower part of the Slide Mountain Group on the northeast and the Upper Triassic (?) rocks on the southwest are partly within or higher than the muscovite-chlorite subfacies. The grade decreases abruptly, however, and metamorphic effects are difficult to detect in the bulk of the Antler Formation within the Black Stuart Synclinorium where prehnite and pumpellyite have been found in basaltic rocks, and in the Mesozoic volcanic rocks to the southwest where zeolitic alteration was noted.

Metamorphic rocks of Lanezi Arch grade upward and outward from high greenschist facies (biotite and some small garnets) in the deepest levels near Lanezi Lake (see Sutherland Brown, 1963, p.18) to essentially unmetamorphosed rocks at higher levels down the plunge of the structure and into the adjoining Black Stuart and Isaac Lake Synclinoria. Significant metamorphic effects are only local above the top

of the Isaac Formation and the upper beds of the Isaac exhibit but the faintest mica sheen in much of the southern part of the Isaac Lake synclinorium.

All rocks of the Kaza Group and Isaac Formation in the Premier Anticlinorium are in the greenschist facies. Near the southeastern corner of the map-area a few small garnets were noted and, there and near the Trench, particularly near Doré River, are small amounts of fine biotite. Otherwise the rocks are mainly in the muscovite-chlorite subfacies as is the Isaac Formation in the highly faulted terrane northwest of Goat River and the small area of Kaza Group near Purden Lake.

South of Dome Creek rocks in the floor of the Trench, including parts of the Cariboo and Gog Groups, mostly display white mica flakes on cleavage surfaces.

In Rocky Mountains the Miette Group is metamorphosed though the effects are barely discernible in upper Miette strata on the ridge south of Forgetmenot Creek, and in the eastern Main Ranges. The grade is perhaps greatest near the Trench though biotite apparently did not develop. There metamorphism extended stratigraphically higher than elsewhere. In the Mount Robson Synclinorium near East Twin Creek Lower and Middle Cambrian pelitic rocks have been converted to muscovite-chlorite phyllite and schist with minor chloritoid. The upper stratigraphic limit of similar metamorphic effects becomes progressively lower along the synclinorium and reaches the base of the Gog Group near Walker Creek to the northwest and at about the eastern boundary to the southeast.

The middle and lower Miette Group is metamorphosed within the muscovite-chlorite subfacies. Biotite was not recognized but may have been overlooked. Within the Forgetmenot Zone the metamorphic grade increases with stratigraphic depth hence the most highly developed schistose rocks are at the deepest levels where the strata are also the most highly folded. Examples are found adjacent to the Cushing Fault, close to the Idol Fault, and can be expected in the drift covered valley of McGregor River near the Snake Indian Fault.

Over broad areas of McBride map-area the grade of metamorphism shows a relationship to stratigraphic level. The rocks of the Kaza and equivalent middle Miette Group are metamorphosed everywhere and hence a reasonable assumption suggests that they are also similarly metamorphosed where they are obscured by

younger rocks. Generally metamorphism affected the rocks of the Isaac Formation and upper Miette Group and locally it influenced rocks thousands of feet stratigraphically above the top of the Kaza-Middle Miette. Thus obvious depth control of the degree of metamorphism was very much modified by heat flow into higher levels in certain zones. This is consistent with observations of higher grade metamorphic rocks in the same metamorphic belt to the south in Quesnel Lake map-area (Campbell and Campbell, 1970).

The period of metamorphism was accompanied by the principal deformation of the rocks though overlaps one way or the other can be demonstrated. The close relationship of metamorphic intensity to the intensity of deformation expressed as folding and internal recrystallization in the rocks implies a close relationship between thermal energy and deformation. As this relationship holds for rocks at a variety of stratigraphic levels the possibility that isograds were originally flat and have subsequently been folded to produce their present pattern seems unlikely. More probably the development of the regional structure was related to and dependent upon localization of heat flow. Thus formation of the major structures would occur while the rocks within them were undergoing metamorphism. Disruption of isograds immediately below the zone of brittle deformation in unmetamorphosed rocks by faults and locally folds should be expected. This appears to be the case in the Forgetmenot Zone in Rocky Mountains.

New Page

CHAPTER V

ECONOMIC GEOLOGY

The only significant commercial mineral production from within McBride map-area has been from the placer and lode gold deposits of the Barkerville and Wells region. Much has been written about the placer and lode deposits to which the writers have nothing new to add.

The most recent comprehensive work on the placer deposits was reported by Johnston and Uglow (1926) who studied the region when placer mining was still an active industry. Present activity is sporadic and on a limited scale. Principal production was from the main streams and tributaries of Antler and Lightning Creeks, and Willow River; Williams Creek is tributary to the latter.

Sutherland Brown (1957) presented detailed information on many of the lode gold properties including the Cariboo Gold Quartz and Island Mountain mines at Wells where production was discontinued in 1967. His report includes an extensive bibliography. Annual reports of the British Columbia Department of Mines include many reports on the placer and lode deposits of the district.

Elsewhere in the map-area mineral deposits of potential commercial importance are rare. Copper mineralization in the Dome Creek drainage of Cariboo Mountains has long been known (e.g. Ann. Rept. B.C. Min. Mines, 1934, p.C 18) but none has warranted extensive development.

Lead-zinc mineralization is commonly associated with Lower Cambrian limestone both to the northwest and southeast of Cariboo Mountains but no important deposits have yet been discovered in McBride map-area. The carbonate rocks of the Mural and Cunningham Formations provide the most likely hosts for lead-zinc deposits and may warrant some exploration. Near Stony Lake the Slide Mountain Group contains sparse disseminated pyrite with very minor chalcopyrite in basaltic rocks (Campbell, 1967). This unit may have some potential for exploration.

The scarcity of known mineral deposits within McBride map-area, other than ~~for~~ placer and lode gold, may reflect the absence of granitic plutonic rocks, and in much of the area, the low intensity of deformation and metamorphism. The direct relationship of these factors to mineral deposits is problematical but one or

more of them is present where deposits do occur to the northwest and southeast along the trend. In this context Lay (Ann. Dept. B.C. Min. Mines, 1934, p.C 18) reported a 600-foot-thick acid still associated with copper mineralization in the Dome Creek drainage. Though the writers probably did not see the locality described by Lay, which is heavily overgrown, no sills were observed in well exposed rocks in the immediate vicinity.

The wet climate and heavy vegetation in much of the McBride map-area have combined to make surface travel slow and arduous in inaccessible parts of the region and until recently roads existed only in the southeast around McBride and in the southwest in the Wells-Barkerville district. Much of the area has probably never been subjected to the intensity of exploration (except for placer) received by many other parts of the Cordillera.

Silurian quartzite on Bearpaw Ridge could provide a source of high-purity silica close to transportation facilities. The phosphatic content of the Midas Formation in the northern Cariboo Mountains, where collophane grains constitute up to 25 percent of some of the sandstone, could be easily investigated to determine the commercial possibilities.

Coal in Cretaceous and/or Tertiary sedimentary rocks along Bowron River in the northwestern part of the area has been known for many years and exploration has been conducted by underground workings and surface drilling. Sutherland Brown (1967) has summarized available information on the deposit which apparently consists of three seams from 8 to 12 feet thick that extend from the surface to a depth of about 2,000 feet.

Gypsum in the Triassic Whitehorse Formation in Mount Robson map-area (Govett, 1961) suggests the possibility of similar deposits in McBride map-area.

Suitable structural or stratigraphic traps for petroleum may exist beneath the Cecilia and Snake Indian thrust sheets.

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