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BULLETIN No. 47

GEOLOGY
of the
Cariboo River Area, British Columbia

by
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Geology of the Cariboo River Area, British Columbia

SUMMARY

The Cariboo River area includes about 1,000 square miles of dissected plateau of the Quesnel Highlands and alpine peaks of the Cariboo Mountains in east central British Columbia.

The area is underlain by three groups of stratified rocks. The Kaza Group is a thick succession (12,000+ feet) of gritty feldspathic micaceous quartzites and silvery green schists of Late Proterozoic age. It is overlain conformably by the Cariboo Group of Cambrian, Ordovician (?), and later age. This group is composed of 7,000 to 9,000 feet of phyllites, micaceous quartzites, and limestones and is divided into six formations. Carbonate and fine clastic rocks are dominant in the lower part of the group, whereas coarser clastic rocks are dominant in the upper. The Slide Mountain Group is composed of at least 5,000 feet of basal conglomerate, pillow basalts, and bedded chert, and is probably of Mississippian age.

Tectonism rose to a peak toward the end of Kaza deposition, but stable shallow marine conditions persisted throughout early Cariboo deposition. Tectonism increased again erratically but progressively toward the close of Cariboo deposition. Folding and metamorphism preceded deposition of the Slide Mountain Group.

The structure of the region culminates in a broad northwest-trending anticline, the Lanezi arch, which exposes the Kaza Group. This fold is flanked on the northeast by the Isaac Lake synclinorium, a system of moderately tight folds and parallel normal and thrust faults. Individual folds are overturned to the southwest, and the intensity of overturning and compression increases toward the Lanezi arch (southwest). The synclinorium exposes chiefly Cariboo Group and some Kaza Group. The Lanezi arch is flanked on the southwest by a folded belt of Cariboo Group, and this is overlain in part by the trough of the Slide Mountain Group. Folds in the Cariboo Group are gentle on the flank of the Lanezi arch but increase in overturning and compression to the southwest, becoming isoclinal toward the Little River. All folds plunge gently northwestward.

A system of strike faults is related to folds of the Isaac Lake synclinorium. Northerly and northeasterly normal faults are widely distributed and compensate in part for the northwestward plunge of folds.

All clastic rocks except those of the Slide Mountain Group are schistose, but the degree varies widely with locality and rock type. Schistosity is generally related to fold axial planes. In the Lanezi arch it is related to the axial planes of some of the larger secondary folds of the flanks, but progressively changes to bedding schistosity toward the main axis.

In general, Kaza rocks are in the biotite-chlorite subfacies and Cariboo rocks in the muscovite-chlorite subfacies of the greenschist facies. Toward the southwest, Cariboo rocks have been raised locally to amphibolite facies in association with a belt of small plutons at the edge of the area.

CHAPTER I.—INTRODUCTION

The Cariboo River map-area includes just over 1,000 square miles of highlands and mountains on either side of the Cariboo River in east central British Columbia. The area is T-shaped, the outside limits being 52° 45′ to 53° 20′ north and 120° 45′ to 121° 30′ west. The map-area is east of the Antler Creek area (A. Sutherland Brown, 1957) and Yanks Peak-Roundtop Mountain areas (Stuart S. Holland, 1954) and overlaps these areas slightly (*see* index map, Fig. 1). The project that was started by Holland at Yanks Peak is completed with the publication of this bulletin. The two earlier bulletins form a necessary introduction to the understanding of this one.

Holland started mapping at Yanks Peak in 1948 at 400 feet to the inch and locally at 100 feet to the inch in order to solve the complex stratigraphic and structural problems of that part of the Cariboo district. How successful he was is shown by the fact that his rock units have subsequently been mapped throughout the whole area, and although changes occur in thickness and facies the units are essentially the same at the farthest east or south.

ACCESS

The area is not readily accessible. A road leads to the north end of Bowron Lake, 18 miles northeast of the town of Wells, which is 50 miles east of Quesnel. A road to the Cariboo Hudson mine traverses the extreme southwest of the Bowron Lake area. Otherwise there are no roads in the area. Canoe travel about the trapezoidal chain of lakes from Bowron Lake is relatively simple, with wooden rails on several of the small portages. The Cariboo River is navigable from the settlement of Keithley Creek on Cariboo Lake to the lower falls above Kimball Creek. Currently a road is under construction up the valley from Keithley Creek. Trails are few and mostly in poor condition. A trail leads from the Cariboo Hudson road on Cunningham Creek to the Cariboo River at the lower falls. Another trail leads to the north end of Isaac Lake from the Rocky Mountain Trench via Goat River. The areas east of Isaac Lake and southeast of the Cariboo River are particularly difficult to reach. In the course of the present work, travel between camp-sites was by boat where possible and where not by back-packing with air supply drop.

The area enclosed by the trapezoidal chain of lakes was a game reserve when the field work was in progress but, together with a peripheral strip, has recently (1961) been created a class "A" park, the Bowron Lake Park.

PREVIOUS WORK

The first systematic geological map of any part of the northeastern Cariboo district, that of Amos Bowman, published in 1889, is the only one that covers much of the present map-area. Bowman produced a map at 2 inches to the mile from Quesnel Lake to Indianpoint Lake. This map is coloured as far east as Isaac Lake, but it is apparent from the lack of plotted observations, the discussion, and the triangulation net that the area was not visited. Bowman's main concern had been the geology of the placer- and lode-gold-producing areas.

Johnston and Uglow (1926) mapped the Barkerville area, which slightly overlaps the present map-area in the west, north of 53 degrees. A. H. Lang (1938, 1940) mapped the Little River area, which has been largely remapped as a main part of the present map-area south of 53 degrees. The Cariboo River area overlaps slightly the Roundtop Mountain (Stuart S. Holland, Bull. No. 34, 1954) and the

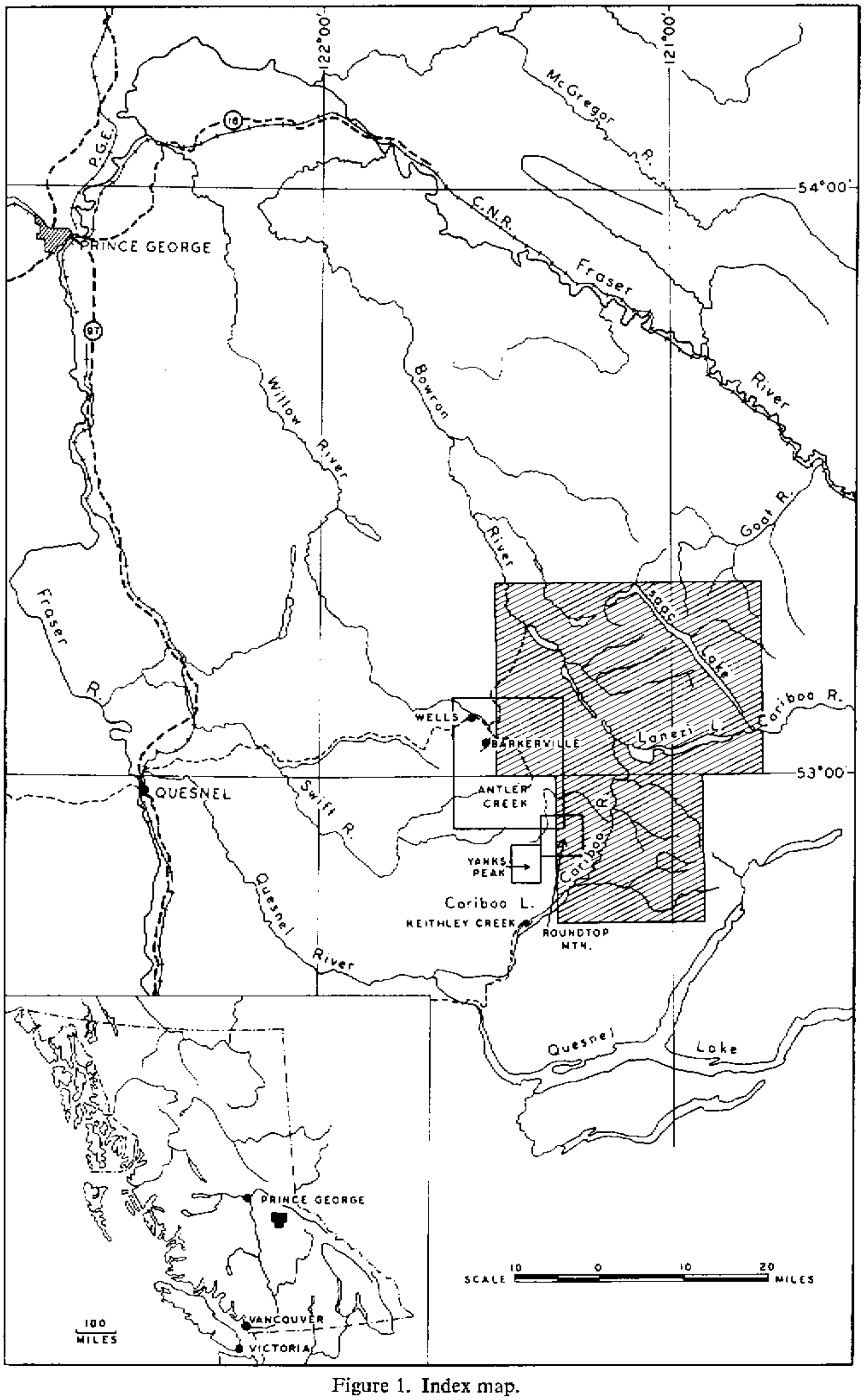

Figure 1. Index map.

Antler Creek (A. Sutherland Brown, Bull. No. 38, 1957) areas. These bulletins contain fuller statements on previous work in the district and a critical review.

FIELD WORK

This report is based on the following field work: One month in 1954 and one in 1955, four months in 1956, and two months in 1957. The mapping was of a much coarser scale than that of the previous bulletins and field-glass observations were used between widely spaced traverses. The geology was recorded on air photographs with an approximate scale in the centre of one-half mile to the inch, and plotted on preliminary forest base maps at the same scale. The geology was transferred to preliminary national topographic sheets at 1:40,000 when these were issued in 1958–59. The scale of the final geological map is 2 miles to the inch.

Very brief reconnaissance was done southeast of the Cariboo River in 1954 and along Spectacle Lakes and Lanezi Lake in 1955. Most of the work was done in 1956, when the geology of the Bowron Lake Park and the area fringing Isaac Lake on the east was mapped, and the geology of 1954–55 was checked and elaborated. Work in 1957 was primarily that of checking and filling in gaps, but ground north of Betty Wendle Creek was mapped and a single traverse was made across to the Rocky Mountain Trench south of the Goat River.

Capable assistance in the field was given by the following: E. Burton in 1954, W. S. Hopkins and Y. Kamachi in 1955, R. J. Cathro and R. Thompson in 1956, and R. O. Brammall in 1957.

Subsequent to completion of the field work but prior to its publication, R. B. Campbell, of the Geological Survey of Canada, began field work in the Quesnel Lake area. The area of this bulletin south of 53 degrees is common to both projects. Dr. Campbell and the writer have had the freest exchange of information, and some modification of the writer's maps has been made as a result of Campbell's work.

PHYSIOGRAPHY

The physiography of the Cariboo River area includes alpine terrain in the east and dissected plateau in the west. The alpine terrain is part of the Cariboo Mountains, and the dissected plateau is part of the Quesnel Highland* (*see* Stuart S. Holland, Landforms of British Columbia, Bull. No. 48, in preparation). The line separating the Cariboo Mountains from the highlands follows the valley of the lower Bowron River, Spectacle Lakes, and Matthew River (*see* A. Sutherland Brown, 1957, p. 13). The alpine nature of the mountains is shown in Plates II, V, and VII and the contrasting nature of the highlands in Plates III and IV. In the mountains, summit elevations range from 6,700 to 8,600 feet. The highest peaks are Kaza (8,350 feet), Ishpa (8,304 feet), Amos Bowman (8,550 feet), and an unnamed peak southeast of Bowman (8,650 feet). The major valley bottoms or lake levels are at 3,000 to 3,500 feet. The Quesnel Highland has recognizable but well-dissected upland surfaces with an average elevation of 6,000 feet. Highland peaks are small eminences on the old upland surface, with elevations lower than those of the mountain peaks. Summit heights range from 5,500 to 7,000 feet, with Mount Tinsdale (7,027 feet), Palmer Mountain (6,901 feet), and Kimball Mountain (6,894 feet) the only ones much above 6,500 feet. Except for the valley of the lower Cariboo River, elevations of valley bottoms in the highlands are greater than those in the mountains. The elevation of the valley bottom of the lower Cariboo River is about 2,800 feet, whereas that of the valleys in the main highland masses east and west of the river is about 4,000 feet.

* Holland uses the terms "highland" for a terrain transitional between mountains and plateau in which a considerable amount of upland surface is evident.

Denudation in the mountains is rapid, and much of it is accomplished by snow-slides. These occur yearly in many chutes, and the ones on the northeast side of Isaac Lake have built small deltas. Where slides are frequent the topography is characteristic. Individual chutes resemble a sherry glass in section, with the fan as the foot, the chute as the stem, and the gathering area as the cup.

The area is drained largely by the Bowron and Cariboo River systems, but the northeastern corner is drained by the Goat River system. The drainage pattern is complicated as a result of having been disturbed in the Pleistocene epoch and possibly shortly before. The unique trapezoidal chain of lakes does not belong to one drainage system; Isaac, Lanezi, Sandy, and Babcock Lakes belong to the Cariboo system, and Bowron, Indianpoint, and Spectacle Lakes belong to the Bowron system. Very small changes in elevation could divert major portions of the Cariboo River system into the Bowron, or vice versa. The Cariboo River was so diverted during deglaciation when the upper Cariboo flowed northward from Sandy Lake through the valley of Spectacle Lakes (*see* below). The present level of Sandy Lake is controlled by the upper falls on the Cariboo River—retreat of the falls will relatively soon drain this shallow lake. The outlet of Bowron Lake is currently being raised by bar-building, so that the delta of the upper Bowron River is being flooded. If this situation continues, the Cariboo River will relatively soon capture the Spectacle Lakes and the upper Bowron River. The origin and development of the valleys of Huckey Creek and the upper Bowron River and their relation to the valley of Isaac Lake and Betty Wendle Creek have been obscured by glacial overdeepening and erosion of an older drainage system.

GLACIAL GEOLOGY

The Cariboo River area contains small glaciers today, and during Pleistocene time was completely submerged by a mountain ice-sheet. At some time between the last glacial maximum and the present, the area contained extensive cirque and some valley glaciers. The direction of ice movement is not everywhere apparent, but in general the ice moved outward from the mountains to the southwest, the northwest, or both.

The upper surface of the ice indicated by topographic details of mountain and highland areas and by the distribution of erratic boulders appears to have been about 7,000 feet. All major valleys and all minor ones except post-glacial canyons such as on the Cariboo River at the lower falls have well-developed catenary shapes (*see* Plates II and V). The slopes of facetted spurs on the major valleys extend up to elevations of 6,000 to 7,000 feet; hence intense ice erosion occurred to these levels. This depth of ice is confirmed by the existence of numerous far-travelled erratic boulders at elevations from 6,500 to 6,900 feet, the highest levels at which erractics were found. The following table shows the known upper limit of distribution of erratics found in mountains and highland:—

Locality	Lithology		Elevation
	Erratic	Bedrock	
			Ft.
1. Peak south of Mount Amos Bowman	Kaza Quartzite	Cunningham Limestone	6,600
2. Ridge east of McLeary Lake	Kaza Quartzite	Isaac Phyllite	6,550
3. Ridge east of Milk River	Kaza Quartzite	Kaza Phyllite	6,900
4. Mount Tinsdale	Kaza Quartzite	Slide Mountain Greenstone	6,600
5. Mount Murray	Kaza Quartzite	Slide Mountain Greenstone	6,500
6. Little River Stock	Kaza Quartzite	Quartz Monzonite to Granodiorite	5,500
7. South to southeast of Little River Stock	Quartz Monzonite to Granodiorite	Cunningham Limestone	4,500–5,800

It is doubtful whether there were many nunataks in the mountain area during maximum glaciation. If the the average ice level was 7,000 feet, it would be above many peaks. Matterhorns are not well developed, and some that are slightly developed, such as the peak of Kaza Mountain (*see* Plate VII), probably formed mainly after the glacial maximum. Furthermore, the glaciers and icefields today occur to the highest levels of the peaks between Isaac Lake and Betty Wendle Creek.

The erosive effects of glaciation are different in the highlands from those in the mountains because the highlands were completely overridden by moving ice. Rounded forms are dominant, and the isolated ridges and hills in the Spectacle Lakes valley show these to a marked degree.

The area as a whole lacks glacial striæ and polished rock surfaces, except immediately adjacent to contemporary glaciers, which are retreating. Elsewhere the intense frost wedging and the unsuitability of most of the rocks to maintain a polish results in the quick destruction of these features.

Glacial till mantles the lower slopes and partly fills some of the valleys. In some areas it is mantled in turn by outwash sands. Good exposures of till are relatively rare because of the heavy forest-cover on the slopes to 6,000 feet or more, and the cover of outwash sands and recent alluvium. However, a considerable thickness of till is evident on lower Tinsdale Creek and lower Antler Creek, and erratic boulders are common on the lake-shores.

The movement of glacial ice was outward from the mountains, but in detail it was complex. Unconsolidated deposits along the western side of the valley of Spectacle Lakes and the lower Cariboo River have been fluted, but the direction of ice movement is not clearly shown. On the hill between Turks Nose Mountain and Mount Tinsdale, the indicated movement is almost due south. In contrast to this, the movement indicated near Bowron Lake appears to be northwestward. The valley contains a drainage divide, and it is likely that ice may either have been extruded from the valley in opposite directions or may have moved in opposite directions at different times. From regional considerations it appears likely that ice moved down the Cariboo River valley to the south and down the Bowron River valley to the northwest and that an ice divide is represented. Movement is proven to the south and slightly southeast by the boulder train from the Little River Stock; to the west along Lanezi Lake by Kaza boulders on Cunningham Limestone on the south shore of Sandy Lake; and to the northwest along Isaac Lake by Kaza boulders all along the east side of the lake on Isaac and Cunningham Formations. Movement to the south to southwest is indicated in the adjacent Antler Creek area (Bull. No. 38, p. 14) and by Kaza boulders on Mount Tinsdale. All these movements are essentially outward from the mountains.

Following the last glacial maximum there was a stage during which cirques were developed and minor valley glaciers formed. These cirques mostly have their floors at 5,000 to 5,700 feet elevation, although a few, such as those northeast of Ishpa Mountain, have floors at 4,000 to 4,500 feet. Most of the latter ones were the largest cirques, and many supplied small valley glaciers. In some valleys, such as that of Harold Creek and the one south of Indianpoint Mountain, a definite fringing line exists at about 5,500 feet (*see* Plate V). In the alpine area the cirques are not very distinct from the erosional forms of the mountain ice-sheet, but in the highland area they are fretted out of the rounded forms of the upland and are developed predominantly on the northeastern slopes.

Glaciers today cover only about 4 square miles of the map-area. Several small glaciers occur in the Mowdish Group within the chain of lakes, several south of Lanezi Lake, and the rest between Isaac Lake and Betty Wendle Creek. All except one in the southeastern corner of the area and one between Isaac Lake and Betty

Wendle Creek are inactive. The active ones have their snouts below 6,500 feet elevation, whereas the others are at 6,500 feet or above. A considerable icefield occurs to the southeast of the map-area at the headwaters of the Cariboo River. This river has the characteristic milky appearance of a glacial stream, but in contrast the Isaac River and Lake are extremely clear in spite of being glacier-fed, perhaps because most of the glaciers are on limestone and much of the rock flour dissolves.

It is apparent that the drainage was changed during the time of deglaciation. Drainage by way of the Cariboo River to the south was blocked either by till or ice, and the entire drainage of the Isaac Lake area was toward the north. A plug of till across what must have been the old channel of the river occurs east of the lower falls, and diversion into the present canyon occurred when drainage was re-established to the south. Between Sandy Lake and the outlet of Bowron Lake a kettled outwash plain is evident. The plain at the bend of the Cariboo River between Sandy Lake and the upper falls is at about 3,040 feet, whereas the remnant of the plain at the north end of Bowron Lake is just over 3,000 feet. Unna, Tenas, and many more small lakes and probably the larger ones are kettles. At some late stage before the re-establishment of southward drainage, the Cariboo River flowed across the plain from Sandy Lake to approximately the upper falls. Drainage of Isaac Lake, in addition to that from McCabe Creek and Indianpoint Lake, probably was to the north in the Indianpoint River Valley. The delta built into Indianpoint Lake probably dates from this period, but that of Dewitte Reed Creek into Sandy Lake is related to the present lake level and hence was formed after the time of northward drainage.

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CHAPTER II.—GENERAL GEOLOGY

The Cariboo River area is underlain principally by sedimentary and metasedimentary rocks with lesser volcanic rocks and minor plutonic rocks. The stratified succession is divided into three groups—the Kaza Group of Late Proterozoic age; the Cariboo Group of Cambrian, probable Ordovician and later age; and the Slide Mountain Group of probable Mississippian age. The Kaza Group is a thick succession of gritty feldspathic micaceous quartzites and silvery-green schists. The Cariboo Group, which overlies it conformably, is composed dominantly of phyllites, micaceous quartzites, and limestone. Carbonate and fine clastic rocks are dominant in the lower part of the Cariboo Group, whereas coarser clastic rocks are dominant in the upper part. The Kaza and Cariboo Groups were intensely folded and regionally metamorphosed prior to the deposition of the Slide Mountain Group of basal conglomerate, pillow basalts, and bedded chert.

The structure of the region culminates in a broad northwest trending anticline, the Lanezi arch, which exposes the oldest rocks, those of the Kaza Group. Most of Bowron Lake Park within the trapezoidal chain of lakes is involved in this structure. It is flanked on the northeast by an imbricated synclinorium, the Isaac Lake synclinorium, which is formed of Cariboo and some Kaza rocks. Southwest of the Lanezi arch, folds in the Cariboo Group increase in complexity to the southwest, and include, in that direction, the Kimball syncline, Black Stuart synclinorium, Cunningham anticlinorium, and Snowshoe synclinorium. The Slide Mountain Group occurs in a trough that mainly overlies the Black Stuart syncline northwest of the Cariboo River and is folded parallel to the earlier folds in the other two groups.

Many of the problems of the region which were investigated repeatedly in the Barkerville area and were solved with such difficulty in the Yanks Peak-Roundtop Mountain and Antler Creek areas are much simpler in the area under study. Both structure and stratigraphy are, in the main, readily observed and do not require the same laboured investigation, compilation, and synthesis. However, many problems remain that will only be solved by detailed work.

KAZA GROUP

The Kaza Group is named from Kaza Mountain in the southwestern corner of Bowron Lake Park, where a section about 6,000 feet thick is well exposed between Lanezi Lake and the peak. This section does not include the uppermost 3,000 feet or so of the group, which is less well exposed along Lanezi and Sandy Lakes to the west. The uppermost part of the group is better exposed on Indianpoint Mountain and the northeastern part of the park. The name Kaza Group was first used in Bulletin No. 38 (A. Sutherland Brown, 1957, p. 57) in a preliminary way, but it was not then adequately defined, and its usage included some rocks that now are placed in the Isaac Formation.

Distribution.—The Kaza Group outcrops primarily in the broad Lanezi arch that occupies much of the park and continues to northwest and southeast. The group also outcrops less extensively northeast of Betty Wendle Creek and at the south branch of North Star Creek.

Thickness.—The Kaza Group is at least 12,000 feet thick, judging by projection of the base of the Isaac Formation (*see* Fig. 3, section F-F'). Over 6,000 feet of it can be seen in continuous exposure, such as that on Kaza Mountain.

TABLE OF FORMATIONS

Era	Period or Epoch	Group	Unit and Thickness in Feet	Lithology
Cenozoic.	Pleistocene and Recent.			Till, glacio-fluvial sand, silt, and gravel; alluvium.
Unconformable contact.				
Mesozoic (?).	?		Little River Stock.	Porphyritic granodiorite to quartz monzonite.
Not in contact, intrusive into Cariboo Group.				
Palæozoic.	Mississippian (?).	Slide Mountain Group.	Antler Formation, 3,600+.	Pillow basalts, variously coloured chert and argillite, diabase and gabbro sills, etc.
			Conformable contact.	
			Guyet Formation, 1,125–1,500.	Grey to brown conglomerate, lithic greywacke, basic volcanic rocks, crinoidal limestone.
	Unconformable contact; Guyet Formation not in contact with Snowshoe Formation.			
			Proserpine dykes.	Ankeritic acidic dykes.
	Intrusive contact.			
	Ordovician (?).	Cariboo group.	Snowshoe Formation, 1,000+.	Grey to brown micaceous quartzite; grey, brown, and green phyllite; impure limestone.
			Conformable or slightly unconformable contact.	
			Midas Formation, 1,000+.	Black to dark grey phyllite, metasiltstone and some dark limestone.
			Conformable contact.	
			Yanks Peak Quartzite, 0–1,200+.	Grey to white, dense pure quartzite; rare limestone.
			Conformable with Yanks Peak or Midas Formations.	
			Yankee Belle Formation, 1,000–1,500.	Brown to green phyllite, metasiltstone; brown fine quartzite; minor limestone.
			Conformable contact.	
	Early and (?) Middle Cambrian.		Cunningham Limestone, 1,500–3,000.	Grey massive limestone; grey to buff pelletal limestone, dolomite, minor phyllite.
			Interfingering and conformable contact.	
			Isaac Formation, 1,000–2,500.	Grey phyllite and calcareous phyllite and limestone.
Conformable contact.				
Proterozoic.	Windermere.		Kaza Group, 12,000+.	Gritty feldspathic micaceous quartzites and green schists.

Lithology.—The Kaza Group in the type area consists entirely of schistose clastic sedimentary rocks that have been regionally metamorphosed to the greenschist facies. The group is characterized by alternating gritty micaceous quartzites and schists that both commonly weather some shade of brown but are normally silvery green on fresh surfaces. The micaceous quartzites or quartzofeldspathic schists are gritty rocks with prominent chalky white feldspars and variably developed schistosity and cleavage. Most have clastic particles of sand size, but ones with granules or fine pebbles are not rare. The mica schists may be planar or crinkly and may contain abundant knots of biotite or, more rarely, garnet.

At a distance or close at hand the Kaza Group has a characteristic appearance imparted by thick alternating beds of different lithology in relatively gentle attitudes and with intense but variably oriented schistosity. The appearance of the rocks is shown in Plates XIII to XVIII.

At a distance the bedding is most striking (*see* Plates V, VI, and VII), as it is in some instances close at hand (*see* Plates XIII, XIV, and XVII). Commonly the cleaved character of the micaceous quartzites or the schistose nature of the schists is most noticeable close (*see* Plates XV and XVIII). The variable relation between schistosity, cleavage, and bedding in different structural situations results in quite different appearance of similar rocks (*compare* Plates XV and XVII—both are of medium-grained micaceous quartzites, but one shows a widely spaced cleavage at a large angle to bedding and the other shows bedding and schistosity and cleavage parallel). Much of the micaceous quartzite has a lenticular blocky nature resulting from the intersection of sigmoidal cleavage with bedding planes (*see* Plate XV). The schistosity and cleavage are discussed on pages 17 and 51.

The coarser arenaceous rocks on weathered surfaces normal to schistosity have a rice-like texture with prominent chalky-white feldspar grains forming about 10 per cent of the rock. The feldspar characteristically does not show cleavage faces even on fractured fresh surfaces. In contrast the quartz is commonly glassy and never dark-eyed. Well-crystallized silvery-green to brown weathered mica forms a significant part of the rock, and on the main foliation surfaces wraps over the quartz and feldspar grains. Commonly these grains are noticeably elongated in the *b*-fabric axis and flattened in the *c*-axis. The finer arenaceous rocks are similar, but all these characteristic features are less apparent.

The schists are silvery green when fresh and may remain so on weathering. Nevertheless they normally have a rusty stained or gradationally mottled rust and silvery-green weathered surface. Many of the schists are crinkled by regular or irregular chevron folding of 5 millimetres amplitude or less. Others, particularly in the southwest of the park, are knotted with biotite (rarely garnet) porphyroblasts 1 to 4 millimetres in greatest dimension. A very small percentage of the argillaceous rocks are dark-grey lustreless phyllites, and these commonly occur only in thin interbeds. Similar rocks occur as "fish" in a small percentage of the coarser arenaceous rocks.

Microscopy.—The mineral composition of the micaceous quartzites is shown by Figure 4. The average of nineteen specimens examined is:—

	Per Cent
Quartz	72
Feldspar	10
Muscovite	6.5
Biotite	5.5
Chlorite	4
Other (iron ores, garnet)	2

The quartz varies from 63 to 90 per cent, all feldspar from 5 to 17 per cent, and

2

mica from 5 to 30 per cent. The feldspar is predominantly oligoclase, but potassic feldspar is common and some untwinned albite is present. In almost every specimen two or three micaceous minerals are included. Biotite quite commonly occurs as porphyroblasts, but also occurs in the matrix interleaved with muscovite and (or) chlorite. Almandine garnet is present in some specimens up to 10 per cent, but mostly less than 1 per cent. Iron ores, mostly ilmenite, form more than 1 per cent. Tourmaline is a common accessory, and a few rounded zircon grains are present in each section.

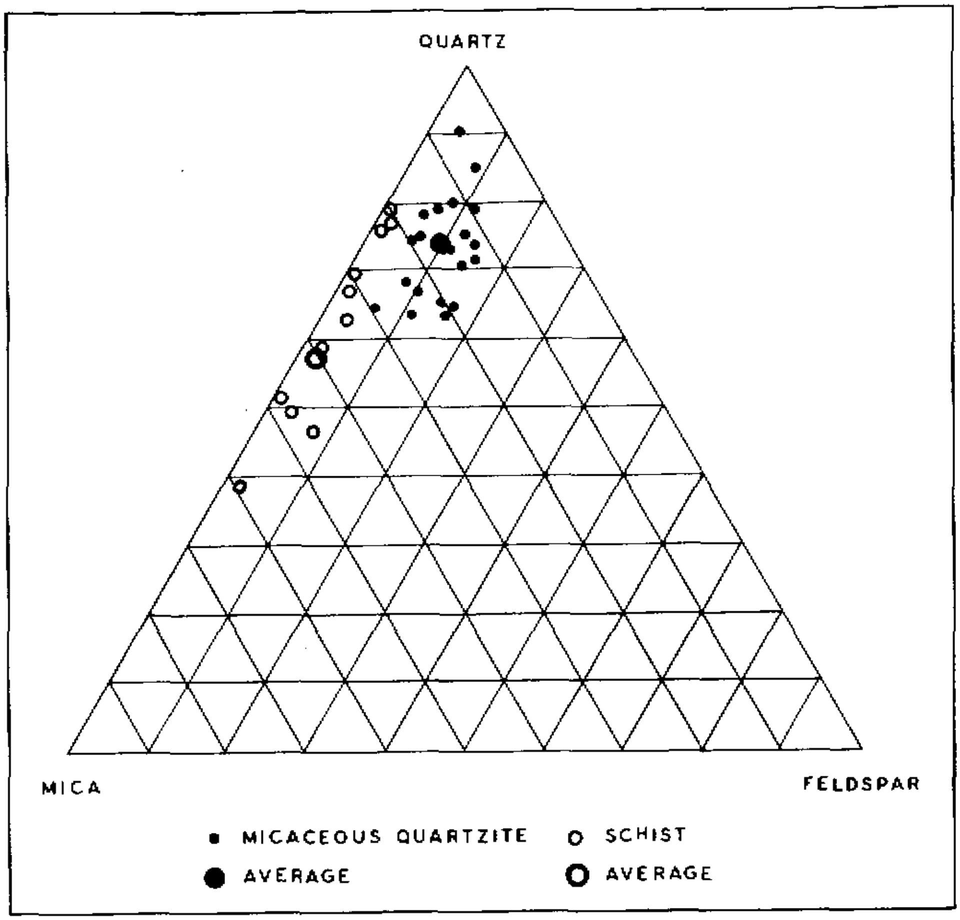

Figure 4. Mineral composition, Kaza Group.

The mineral composition of the schists is also shown by Figure 4. The average of eleven specimens examined is:—

	Per Cent
Quartz	40
Feldspar	0.5
Muscovite	29
Biotite	7
Chlorite	20.5
Other (garnet, ilmenite, tourmaline)	3

The quartz varies from 40 to 80 per cent, the micas from 20 to 60 per cent, and the feldspar is uniformly very low. Three micaceous minerals are present in most specimens. Biotite occurs predominantly as porphyroblasts that are commonly 1 to 5 millimetres in greatest dimension. Almandine garnet is present up to about 5 per cent in some specimens and replaces the biotite. As in the micaceous quartzites, the main accessory minerals are ilmenite and tourmaline, but the former is better crystallized than in the quartzites. Some tourmaline is detrital with overgrowths, but most is porphyroblastic with *c*-crystallographic axes growing parallel to the *b*-fabric axis.

Figure 4 illustrates an essentially continuous variation from micaceous quartzite to schist with increasing mica and decreasing quartz and feldspar. Very fine micaceous quartzites of original silt grade are seen along the mutual boundaries of the two fields.

Fabric.—The fabrics of both schists and micaceous quartzites are deformed. Typically, the micaceous quartzites have a flattened fabric formed of lenticular bundles of quartz or feldspar sheathed in a mesh of mica. The bundles or grains have their greatest dimension parallel to the *b*-fabric and the fold axes and least parallel to *c*. In large bundles a common proportion of a:b:c is 2:3:1. The bundles of quartz or feldspar are derived from originally detrital grains. Quartz shows a complete transition from strained whole grains to lenticular bundles composed of mosaic-like aggregates. In rare instances the transition is evident in a single section. Most grains of plagioclase have highly erratic twinning, and of those that do not, most have an obvious preferred lattice orientation in which the *b*-crystallographic axis tends to be parallel to the *a*-fabric axis. Sheaths of micas and chlorite with ilmenite outline the detrital grains. Normally two of the micaceous minerals are interleaved in the matrix and, in addition, biotite or, more rarely, chlorite may form porphyroblasts. The porphyroblasts are not as large or as common in the micaceous quartzites as in the schists. An evident sequence of development of the porphyroblastic minerals is discussed below.

The fabrics of some micaceous quarzites may be less deformed than the normal type just described, whereas others are more deformed. Some specimens which are less foliated and flattened are more nearly quartzites, with only about 5 per cent mica. Even though in these specimens the grains are not greatly deformed in shape, they are normally greatly strained, lamellar, and fractured. Still other specimens are more foliated and rolled out than the normal. A few specimens might be called phyllonites because the general grain size is greatly reduced and the identity of the bundles is obscured.

The fabric of the schists is formed primarily by the alignment of mica and chlorite in the main secondary foliation (S_2). Bedding (S_1) may or may not be recognizable microscopically and may or may not be parallel to S_2. The secondary foliation (S_2) is quite commonly crinkled into chevron folds some 5 millimetres or so in amplitude to form a third foliation (S_3) by the alignment of axes and limbs. Angular and unstrained quartz silt occurs embedded in the micaceous field. Some specimens without crenulations have mica and chlorite combined grains that are elongated in S_2 and are bounded by other grains with cleavage faces in S_2 but have their cleavage faces nearly normal to S_2. In some cases this tendency is marked enough to form a macroscopic second foliation (S_3).

Growth of the main porphyroblasts shows an interesting sequence of development. The least well-formed and most poikilitic porphyroblasts are chlorite, better formed ones are biotite, and the best are garnet. Chlorite porphyroblasts are recognizable in hand specimens as ill-defined greenish knots up to 3 to 4 millimetres across. They are formed of felted chlorite crystals and include up to 50 per cent of inclusions of quartz, muscovite, etc. The quartz is noticeably less deformed and strained than the quartz of the schistose part of the rock. The chloritic knots are rotated in some instances. The early growth of chlorite has apparently formed a knot around which schistosity has developed. Biotite porphyroblasts have developed first by replacing the chloritic knots and then by growth beyond them. The biotite porphyroblasts are freer of inclusions than the chlorite ones and in general form one crystal rather than many. The biotite is commonly oriented with the *c*-axis subparallel to the *c*-fabric axis, although there are many exceptions, some of which can be seen to have been rotated. Quartz shadows are particularly common on the lee side of such rotated crystals. Garnet forms the end of the sequence, replacing biotite porphyroblasts. For example, garnet crystals centred on biotite but growing out into matrix commonly show relict cleavage where they replace biotite and none beyond; they may have a small quantity of inclusions similar to that in the biotite, but a large quantity where they have grown beyond the biotite.

Metamorphism.—The Kaza Group has been regionally metamorphosed to the greenschist facies, mostly to the biotite-chlorite subfacies. The grade of metamorphism is slightly higher in the southwest of the park, where knotted biotite schists are dominant and garnetiferous ones are common. In other areas the biotite-chlorite subfacies may just have been reached, and rocks of the muscovite-chlorite subfacies are common. As all the rocks are non-calcareous, the assemblages are relatively uncomplicated and epidote and actinolite are virtually absent. The schists are commonly muscovite-chlorite-quartz-biotite rocks, but may be muscovite-biotite-quartz rocks. In the former case, biotite commonly occurs as large porphyroblasts. The assemblage of the arenaceous rocks is most commonly quartz-feldspar-muscovite-biotite (chlorite), less commonly biotite exceeds muscovite; chlorite is rarely the commonest micaceous mineral. The grade of metamorphism, as judged by the distribution of the occurrence of garnet, biotite, and chlorite porphyroblasts and by the distribution of biotite-chlorite subfacies in relation to the muscovite-chlorite subfacies, appears to increase toward lower topographic (and stratigraphic) levels and toward the southwestern part of the park.

Some of the dynamic effects of the regional metamorphism have previously been described in dealing with the fabric. The fabric has a moderate to intense secondary foliation, and a marked *b* lineation from intersection of foliations (bedding (S_1), S_2, and S_3) and from grain orientation. Foliation and cleavage are discussed further in Chapter III (pp. 51–52). One can infer that the rocks of the Kaza Group were subject to a pronounced flattening and rolling out at moderate temperatures.

Stratigraphy.—The reconnaissance nature of the work did not permit detailed study of the stratigraphy. There are no obvious marker beds, and it was not found possible to correlate sections by granule beds or groups of coarse-grained beds. It appears that individual beds and groups of beds do not have much continuity, and hence it is not possible to establish a composite section that adequately represents the group. The composite section following illustrates the type of section present in the Kaza Group.

The group as a whole is characterized by alternating beds of brown weathering micaceous quartzite and silver-green schists. Schistose granule conglomerate beds are relatively common within the micaceous quartzites. Beds of micaceous quartzite are commonly fairly massive, a thickness of 10 feet being common, and groups of coarse-grained beds without significant fine ones can aggregate several hundred feet. The schists occur in beds and groups of beds of the same order of thickness as the micaceous quartzites but in addition may be more finely bedded, with rocks of original silt grade separating rocks of finer original grade.

The great majority of coarse beds and almost all granule beds are contained within the upper 7,000 to 8,000 feet of the group, and are commonest in the upper 4,000 feet.

COMPOSITE SECTION OF KAZA GROUP, BOWRON LAKE PARK

Lithology	Thickness in Feet	Feet Below Isaac
Base of Isaac Formation.		
Coarse micaceous quartzite and some schistose granule conglomerate and green schist	100	100
Mixed micaceous quartzite and green schist with micaceous quartzite predominating	800	900
Coarse micaceous quartzite	100	1,000
Mixed micaceous quartzite and green schist with schist predominating	500	1,500
Mixed micaceous quartzite and green schist with micaceous quartzite predominating and some granule beds	1,500	3,000
Coarse micaceous quartzite and granule beds	500	3,500
Mixed micaceous quartzite and schist about equal	700	4,200
Green schist with about 30 per cent micaceous quartzite	600	4,800
Granule beds with micaceous quartzite	300	5,100
Mixed micaceous quartzite and green schist subequal	1,200	6,300
Micaceous quartzite with some green schist	500	6,800
Mixed micaceous quartzite and green schist subequal	1,200	8,000
Green schist and micaceous metasiltstone and some micaceous quartzite	4,000	12,000
Base not exposed.		

Age and Origin.—The Kaza Group is of Late Proterozoic, Windermere age. The correlations are considered in some detail on pages 41 to 43, and it is sufficient to say here that the Kaza corresponds roughly in age and lithology with the Horsethief Creek Group of the type area and possibly with some of the Hamill Formation of the Lardeau. It is the rough equivalent of the Hector Formation in the Jasper-Sunwapta Pass area and some of the Jonas Formation (Hughes, R. D., 1955, pp. 72–78).

The Kaza Group was laid down as a group of alternating muds and dirty feldspathic sands and fine gravels in a Late Proterozoic subsiding trough. The sediments in general became coarser upward and possibly toward the west. The source of the feldspar in the Horsethief Creek Group puzzled Reesor (1957, pp. 160–162), who reasoned that it was provided by a source, presumably of Shield rocks, not far to the east or north of the known area of outcrop of the Windermere. Hughes noted that the quartzites in the Jonas Formation are more argillaceous in the west than the east of his area, some 100 miles east of the Cariboo River area (Hughes, 1955, p. 76). The degree of sorting apparently increases to the east. The evidence observed in the Cariboo River area does not indicate whether the main source area lies to the east or the west.

The Kaza Group is in some ways similar to the Snowshoe Formation, and a comparison is instructive (*compare* Figs. 4 and 6). The two units may be distinguished readily in any considerable area of exposure, but a small outcrop could be difficult to identify positively as belonging to one unit or the other. In gross lithology the Kaza Group is formed entirely of clastic rocks, whereas the Snowshoe has a significant content of calcareous rocks (estimated at 6 to 7 per cent, Bull. No. 38, p. 29). The metamorphism of the Kaza in adjacent areas is higher, as evidenced by biotite-muscovite subfacies and schists compared with muscovite-chlorite subfacies and phyllites. The feldspar content of micaceous quartzites of the Kaza Group is about 10 per cent as compared with about 5 per cent in the Snowshoe (*see* Figs. 4 and 6). The appearance of the rocks is somewhat different. The Snowshoe micaceous quartzites are dominantly grey rocks whether weathered or fresh, whereas the Kaza are brown weathering and are silvery-green fresh. The Snowshoe phyllites are chiefly grey, whereas the Kaza phyllites are almost all silvery green. In conclusion, in spite of some general similarities the two units are quite distinctive.

CARIBOO GROUP

The Cariboo Group is a mixed assemblage of phyllites, micaceous quartzites, and limestone. The group is divided into six units that are, from oldest to youngest, the Isaac, Cunningham Limestone, Yankee Belle, Yanks Peak Quartzite, Midas, and Snowshoe Formations. The Isaac Formation is named and defined in this bulletin for the first time. The group is composed dominantly of clastic rocks, but the Cunningham is entirely limestone, the Isaac Formation is significantly calcareous, and the other units all contain some carbonate rocks. Originally the clastic rocks were chiefly impure sandstones (quartz greywacke) or variously coloured mud rocks and rarely fine pebble conglomerates. One unit is composed of well-sorted well-rounded quartz sands, the Yanks Peak Quartzite. Regional metamorphism has raised all rocks to at least the muscovite-chlorite subfacies of the greenschist facies. The intensity of deformation varies widely from one area to another, but everywhere the rocks are schistose.

The thickness of the Cariboo Group is not well known, partly because measurements are still of a reconnaissance nature and because the youngest unit, the Snowshoe Formation, is not seen in contact with younger rocks. However, the thickness measured from the base of the Isaac Formation to the top of the Yanks Peak Quartzite is believed to be moderately accurate, and the thickness of this part of the group is of the order of 6,500 feet. In addition, the Midas Formation is at least 1,000 feet thick, and the Snowshoe Formation, according to Campbell, is at least several thousands of feet thick, so that the total thickness must be 10,000 feet or more.

The age of the Cariboo Group is imperfectly known, but much or all of it is Early Palæozoic. Diagnostic fossils are found only in the Cunningham Limestone, in the gently folded portion along Spectacle Lakes valley and Kimball Ridge. The archæocyathids and trilobites found are mostly Early Cambrian, but some trilobites may be Middle Cambrian. In addition, very poorly preserved bryozoa were identified in Yanks Peak Quartzite from one locality in the same general area, so that this formation is presumably Ordovician or younger. No fossils except algæ have been found in the Isaac Formation, which might be Late Proterozoic, but it interfingers in part with the Cunningham Limestone, and both units present such a decided contrast with the Kaza Group that the Isaac Formation is regarded as Early Cambrian. Hence the Cariboo Group is regarded as Early Cambrian to Ordovician and younger.

The Cariboo Group was originally called the Cariboo Schists by Bowman (1889) and the Cariboo Series by Johnston and Uglow (1926). The rocks included in the Cariboo Schists by Bowman are only approximately the same as those of the Cariboo Group, as he did not include the massive limestone (Cunningham Limestone), which he thought was part of the Bear River beds (Slide Mountain Group). On the other hand, the rocks of the Cariboo Series and Group are substantially the same, except that the full group is not exposed in the classic Barkerville area. However, the subdivision of the former series and present group is entirely different. Holland (1954, pp. 14–15) showed the formations of Johnston and Uglow to be unreal, just as Benedict (1945) had previously shown the structure in one locality to be fallacious. For a complete discussion of the various interpretations of the geology of the Cariboo rocks, the reader should see Bulletin No. 38 (A. Sutherland Brown, 1957, pp. 16–20).

Isaac Formation

The Isaac Formation is the oldest unit of the Cariboo Group. It overlies the Kaza Group conformably and underlies and interfingers with the Cunningham Limestone. The Isaac Formation consists predominantly of grey phyllites, many of which are calcareous. The unit is described here for the first time.

Distribution.—The Isaac Formation is extensively exposed along the mountains northeast of the southern half of Isaac Lake. This is the type area, where it is best and most completely exposed, although it is cut by faults and duplicated by poorly defined folds. No simple complete section is known. The lowermost part of the formation is well exposed on Indianpoint Mountain and Mount Peever. Complete but structurally complicated sections occur southwest of North Star Mountain and near the northeastern boundary of the area. Lesser exposures occur just below the upper falls on the Cariboo River at the base of Turks Nose Mountain, just northwest of Sandy Lake and on Huckey Creek.

Thickness.—The Isaac Formation changes in thickness considerably from southwest to northeast, being thinnest in the southwest where the Cunningham Limestone is thickest. In the southwest at Huckey Creek the formation is apparently less than 1,000 feet and possibly only 700 to 800 feet thick. On Indianpoint Mountain and Mount Peever the formation is 1,500 to 2,000 feet thick; at the type locality and near North Star Mountain it is 2,000 to 2,500 feet thick.

Lithology.—The Isaac Formation is composed of a mixed assemblage of fine-grained rocks, dominantly middle grey in colour. The most characteristic rock is a middle grey, slightly lustrous calcareous phyllite. This is commonly interlaminated or interbedded with non-calcareous grey phyllite, or buff to grey argillaceous or silty limestone. These other types may be the dominant type locally. Beds of impure limestone may be 100 to rarely 200 feet thick. Rocks of minor importance include greenish-grey to grey metasiltstone, buff weathering calcareous quartzite to sandy limestone, mottled buff and grey calcareous graphitic schist, and dark-grey pelletal limestone. All of these minor types are most common at the base of the formation or in the western exposures.

Isaac rocks are commonly finely schistose and cleave along planes of schistosity rather than of bedding (*see* Plate XIX). In the normal fine-grained rocks bedding is generally inconspicuous, but where it is noticeable the rock is normally finely bedded to laminated. Plate XII shows calcareous phyllites coarsely bedded, but fine laminations are obscured by the schistosity. Interbedded impure limestone and phyllite are commonly conspicuously though finely bedded. Other rocks in which bedding is prominent are some of the basal metasiltstones and quartzites, which may be well and coarsely bedded.

The Isaac Formation does not outcrop boldly, and at a distance looks uniformly grey and unbedded. It forms low rounded mountains, or more commonly the basal parts of mountains capped by Cunningham Limestone.

Microscopy.—The mineral composition of twenty specimens is shown on Figure 5, in which specimens northeast and southwest of Isaac Lake are indicated separately. A fairly continuous variation from limestone to quartz-mica phyllite is apparent. The field of the main fine-grained Isaac rocks is shown, and this essentially is coincident with that of the rocks northeast of Isaac Lake. The average composition of all specimens is:—

	Per Cent
Quartz	41½
Feldspar	2½
Muscovite	16
Chlorite	6
Carbonate	31½
Other (iron ores, heavy minerals)	2½

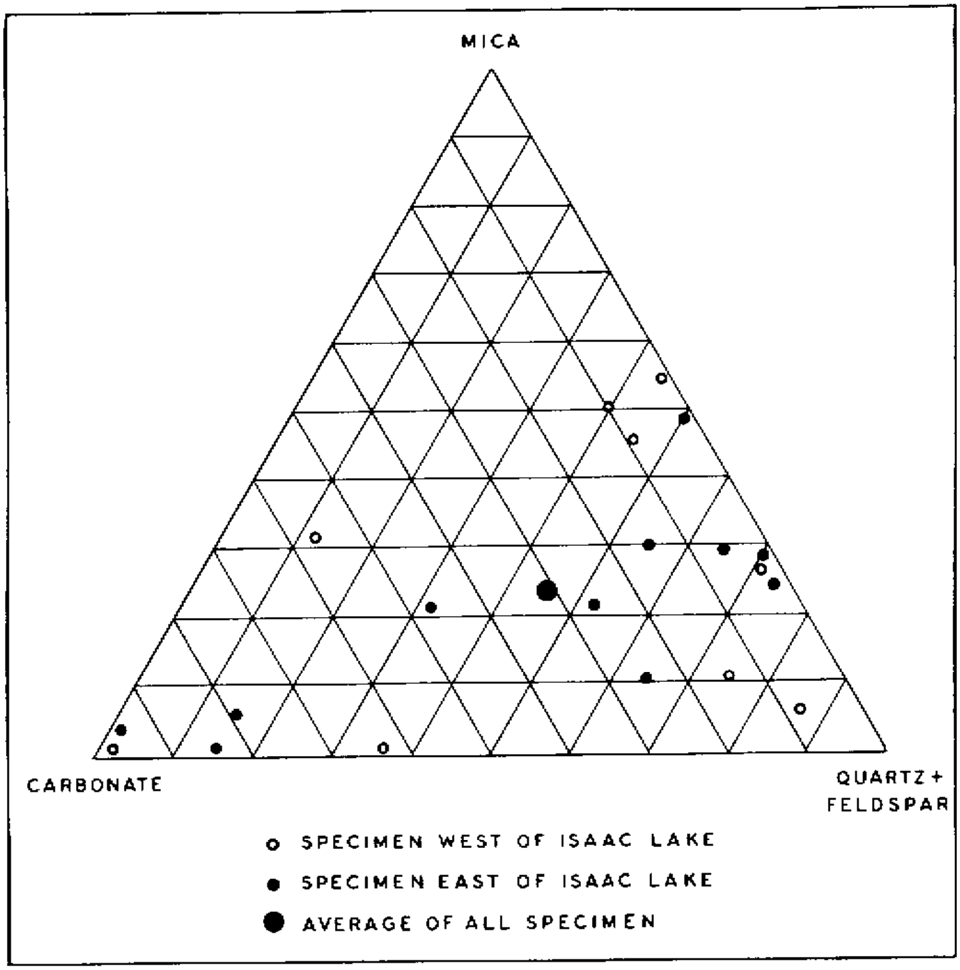

Figure 5. Mineral composition, Isaac Formation.

As there is a complete gradation from non-calcareous phyllite to limestone, the mineralogy of all rocks is treated together. Quartz varies from 2 to 77 per cent, but commonly from 30 to 60 per cent, and feldspar from trace to 15 per cent, but commonly less than 1 per cent. Both minerals are of silt size in all but two specimens examined, both of which are from near the base of the formation in the west. The mica is almost invariably muscovite-sericite, finely porphyroblastic, and accompanied by a lesser amount of new chlorite. In addition, there are in many phyllite specimens elliptical to barrel-shaped detrital grains of sand size composed of chlorite or rarely interleaved chlorite and muscovite. The carbonate is most commonly calcite, but may be dolomite, siderite, or ankerite. In a few specimens the carbonate is entirely secondary, occurring either as veins or replacement. Most commonly it is primary and is present as disseminated grains, as matrix, or as granular aggregate. The amount of carbonate varies from trace to 98 per cent. The limestones are characteristically quite impure. Most limestones are finely granular, with calcite grains of silt size which in some specimens look detrital. The opaque minerals most common in all rocks are pyrite or ilmenite, which are normally porphyroblasts about ten times bigger than the average grain size, and they may be poikilitic and in some cases rotated. In some sections very fine needles and aggregates, possibly rutile and goethite, are abundant. Heavy minerals are not rare; tourmaline and zircon are most common, and the former is normally porphyroblastic.

A characteristic but minor type of limestone is a mottled dark-grey to buff pelletal or algal silty limestone. This rock is formed of about 40 to 45 per cent pellets in a matrix which is composed of about 30 per cent quartz silt with 65 per cent calcite and some siderite and about 5 per cent iron oxides and other opaque minerals. The pellets are rounded but variably shaped bundles containing smaller, more spherical grains composed of calcite crystals that are randomly shaped in the centre of a grain but are like onion skins on its periphery. In the compound pellets the amount of quartz silt is negligible and opaque material is concentrated in the skin and "matrix." The mottled calcareous-graphitic schist may well be the deformed equivalent of this pelletal limestone.

Fabric.—The fabrics of most rocks are deformed, and a very good secondary foliation is developed in almost all rocks, including some limestones. In most instances the main secondary foliation (S_2) is at an angle to bedding (S_1). The dimensional orientation of quartz and calcite is very nearly as marked as that of mica and chlorite, and both the former minerals may commonly be five times as long as thick. The sericite-muscovite and chlorite may be oriented entirely in S_2 or may be oriented partially in two microfoliations, S_3 and S_4, that have a common axis with S_2 in the *b*-fabric or the fold axis but are at about 35 to 45 degrees to S_2 as seen on the *ac* plane. Some coarse mica or chlorite oriented parallel to the bedding is most certainly detrital. The latter includes the aforementioned barrel-shaped grains. The main secondary foliation may be folded in chevron folds of small to microscopic size, but this does not generally result in a "crenulation" cleavage.

Metamorphism.—The metamorphic grade of the Isaac Formation is not as high as that of the Kaza Group in the areas mapped. The phyllites of the Isaac Formation are in the muscovite-chlorite subfacies of the greenschist facies in contrast to the schists of the Kaza Formation which are normally in the biotite-chlorite subfacies.

Stratigraphy.—The Isaac Formation overlies the Kaza Group with seeming conformity. The base is drawn at the first limestone, calcareous quartzite, or calcareous phyllite, and this coincides with a general change in lithology from alternating coarse and fine clastic rocks to fine clastic and calcareous rocks. As stated previously, the unit thickens rapidly from southwest to northeast, coincident with a thinning of the overlying Cunningham Limestone, and the two units appear to interfinger. The top of the Isaac Formation is taken as the base of the massive Cunningham Limestone.

The sections of Isaac Formation in the map-area are all complicated by small-scale structures, masked by obscure bedding, and cut by faults of unknown movement. No certain marker beds of established continuity have been identified, and consequently the stratigraphy is not known with any precision. The following sections are representative of this variable formation. The section at the type locality is a composite of three sections at successive avalanche chutes south of Betty Wendle Creek. The mylonitic zones of the Isaac fault have been used to correlate from one section to the next, even though these may not be strictly parallel to the strike. The section on Mount Peever at the angle of Isaac Lake is complicated by intense minor folding and is incomplete.

Age and Origin.—The age of the Isaac Formation is assumed to be Early Cambrian because, although no fossils other than algal(?) remains have been found in it, it interfingers with the Cunningham Limestone of Early Cambrian age. For the purposes of reconnaissance mapping it has been assumed that the top of the Kaza Group represents the base of the Cambrian system. Correlations are considered later in some detail, and it is sufficient to state here that the Isaac in some measure is the equivalent of the upper Hamill Formation of the Kootenays.

The Isaac Formation indicates a fundamental change in conditions from that of the alternating coarse and fine clastic sedimentation in the Late Proterozoic to that of the fine clastic and carbonate sedimentation in the Early Cambrian. As the carbonate rocks thicken southwestward and the clastic rocks thicken northeastward, a northeastern source of the Isaac sediments seems likely.

COMPOSITE SECTION—SOUTHEAST ISAAC LAKE

Lithology	Thickness in Feet	Feet below Cunningham Limestone
Base of Cunningham Limestone.		
Grey phyllite	300	300
Grey to buff limestone, minor phyllite	100	400
Grey calcareous phyllite, minor thin limestone interbeds	100	500
Grey argillaceous limestone and interbedded phyllite	50	650
Grey to buff phyllite, some calcareous; minor 1- to 6-inch limestone beds	750	1,400
Mylonitic calcareous phyllite and thin-bedded limestone	300	....
Fawn to grey phyllite, minor limestone	50	....
Covered	100	....
Grey pyritic phyllite and fine micaceous quartzite	50	....
Light-grey thin-bedded limestone	30	....
Mylonitic calcareous phyllite and thin-bedded limestone	100	....
Grey phyllite	100	....
Fawn to grey phyllite, calcareous phyllite, and minor 6- to 1-inch-thick red weathering carbonate beds	400±	....
Kaza Group.		

SECTION ON MOUNT PEEVER

Lithology	Thickness in Feet	Feet above Kaza
Structure obscure and complicated but near top of exposure.		
Grey phyllite	130	1,480
Grey phyllite and siltstone with lesser interbedded grey micaceous quartzite	50	1,350
Grey phyllite, minor thin limestone interbeds	250	1,300
Poorly exposed silver to grey phyllite	450	1,050
Brown limestone and grey calcareous phyllite interbedded	100	600
Covered	100	500
Grey phyllite, some calcareous	200	400
Reddish-brown thin-bedded crystalline dolomite and buff to silvery calcareous phyllite	150	200
Reddish-brown calcareous quartzite	50	50
Kaza Group.		

Cunningham Limestone

The Cunningham Limestone is composed almost solely of limestone and carbonate rocks, is dominated by middle-grey thickly bedded limestone, and is characterized by pelletal-textured rocks. The formation was described first by Holland (1954, pp. 16–17) from a type area about Roundtop Mountain and was further described by the writer (1957, pp. 23–24). The limestone overlies and interfingers with the Isaac Formation and is overlain conformably by the Yankee Belle Formation. The Cunningham Limestone was the lowest formation of the Cariboo Group seen in the Roundtop Mountain and Antler Creek areas. The recognition of the Isaac Formation and its inclusion in the Cariboo Group lowers the base of the group. The Cunningham Limestone forms a massive and persistent unit of distinctive lithology that is of great value in outlining the gross structure of the area.

Distribution.—The Cunningham Limestone is distributed throughout the map-area and is well exposed in the Kimball Creek area, east of Isaac Lake, and about North Star Mountain. It is less well exposed in the valley of Spectacle Lakes. It has recently been mapped well beyond the present map-area by officers of the Geological Survey of Canada (north to the big bend of the Fraser River, southeast to Quesnel Lake, and west to Quesnel; Campbell, 1961; Tipper, 1960).

Thickness.—The Cunningham Limestone thins to the east and interfingers with the Isaac Formation in that direction—in fact the thickness seems to vary inversely with that of the latter formation. The Cunningham Limestone is thickest (2,000 to 3,000 feet) west of the Lanezi arch where the Isaac is thinnest and the converse is true east of the arch. This tendency continues eastward, and the section at North Star Mountain appears to be significantly thinner than at Isaac Lake (1,500 feet as compared to 1,800 feet).

Lithology.—The Cunningham Limestone is composed almost entirely of limestone; dolomite and shale or phyllite together probably total less than 5 per cent. The formation is normally thick to very thick bedded, but it may be thin bedded or even laminated (*see* Plate XI). The colour of the carbonate rocks is most commonly middle grey, but many rocks are finely mottled with darker or lighter grey and some with buff or orange. Still other rocks are dark-grey fetid limestones or recrystallized sugary marbles and dolomites commonly somewhat lighter than the normal. Many of the limestones have macroscopic textures, of which the most characteristic, common, and widely distributed is pelletal. The size of pellets ranges from those of *Girvanella,* about 2 centimetres in long dimension to ones 0.5 millimetre or less; most range from 1 to 3 millimetres. The smaller pellets are ubiquitous. *Girvanella* pellets are only found in the vicinity of Turks Nose Mountain and less certainly just south of Betty Wendle Creek. As much as a quarter or a third of many large exposures of the formation are composed of obviously pelletal limestone. In many instances pelletal limestones are slightly darker grey and may appear buff at a distance because not uncommonly they are partly dolomitic. Other textures in the limestone emphasize the bedding. Some of these appear to be algal mat structures, and some appear to be only the result of differential recrystallization, which is most commonly associated with the formation of dolomite. One other bedded texture results from difference in colour of locally derived discoidal pebbles from enclosing matrix. All these textures are much rarer than pelletal ones.

Interbedded fine detrital rocks are rare, although widely distributed. Some are biscuit-coloured silty shales with flatly conchoidal fracture; others are grey phyllitic rocks similar to those of the typical Isaac Formation; still others are green micaceous laminæ.

Microscopy.—The specimens of Cunningham Limestone that were examined microscopically are not representative because specimens showing macroscopic textures were gathered preferentially. Most of the unit is composed of finely crystalline calcite with a trace to 1 per cent of quartz silt and some iron ores or organic matter and has no obvious textures. The grain size of the calcite is about that of the silt, unless it is obviously recrystallized. Most of the collected specimens were pelletal, although probably only a quarter to possibly a third of the formation is obviously pelletal. Pellets are more readily visible macroscopically than they are microscopically because recrystallization has commonly obscured detail. Pellets are most commonly 0.5 to 3 millimetres long and form 50 to 70 per cent of a pelletal limestone. The shapes are varied—most are roughly bean-shaped but some are rod-like, some disk-like, and some fairly angular. Internal structure is commonly lacking, except that a peripheral zone contains the most finely crystalline calcite and a slight concentration of organic or iron oxide dust. A faint concentric structure is apparent in some and rarely an onion skin-like periphery. Pellets larger than about 2 to 3 millimetres may contain smaller pellets internally. Pellets form a fine-grained interstitial aggregate in *Girvanella* limestones and also occur internally in *Girvanella* pisolites. Indeed, large pellets with internal small pellets seem to form a link in a series extending from pellets to *Girvanella* pisolites. Recrystallization and dolomitic replacement are evident in many pelletal limestones. A sequence of recrystallization is evident. Matrix commonly recrystallized first with medium crystalline calcite or dolomite and then the pellets, starting centrally with a few large crystals and continuing until the whole pellet was one crystal. Quartz silt commonly forms one-half to rarely 2 per cent of pelletal limestones and is preferentially present in the matrix.

Laminar textures are most commonly observed in dolomites, as a result of differential recrystallization of laminæ. Some of these textures seem only to emphasize a simple laminar bedding, but others that have finely arcuate or cloud-like bounding surfaces may represent replaced algal mats.

Metamorphism.—Metamorphism of the Cunningham Limestone is evident only as recrystallization of variable intensity. Recrystallization is generally least in the valley of Spectacle Lakes and most south of Kimball Creek. In the former area, archæocyathids and *Girvanella* may retain their macroscopic character although microscopic detail has been lost. Preservation even in this general area is local. On a hill near Indianpoint Lake, beds containing archæocyathids can be traced until the fossils progressively become more obscure and cannot be recognized. Near Maeford Lake in the Kimball Creek area, original textures cannot be recognized in marbles, which have an average grain size of 1½ millimetres. East of Isaac Lake, recrystallization is greater than in the Spectacle Lakes valley, but there are no marbles. In a specimen of what is almost certainly *Girvanella* limestone from the very base of the unit south of Betty Wendle Creek, no detail remains, except lighter areas in the shape of the pisolites and a vague pelletal matrix.

Dolomitization may be of two types—slight, selective dolomitization preferentially replacing pelletal beds and complete and unselective dolomitization. The former type may be diagenetic, the latter in some situations is definitely spatially related to fault zones. Along faults near Babcock and southern Spectacle Lakes, not only breccia zones are replaced but adjacent strata over a considerable area.

Fabric.—The fabric is not as obviously deformed in most of the limestones as in adjacent detrital formations, probably because of the extensive recrystallization. However, much of the pelletal limestone seems to be slightly flattened and some greatly so. The original pellets were not spherical, and observation and measurement of the flattening are difficult except where deformation is extreme, but the deformation of fossils is more easily measured. A glabella of an Olenellid trilobite found in the canyon of the Cariboo River above the lower falls showed a length twice the width, representing about a 50-per-cent elongation.

Cleavage and secondary foliation are developed in the limestone in many localities of tight folding, both in the Kimball Creek area and east of Isaac Lake. In some instances these rocks have a microscopic dimensional orientation of calcite crystals parallel to the secondary foliation.

Stratigraphy.—The Cunningham Limestone is almost entirely composed of carbonate rocks, predominantly limestone. The following reconnaissance section at Turks Nose Mountain is representative of the unit southwest of Lanezi arch. However, the top of the formation is poorly exposed on the upland surface and appears to contain more dolomite than is typical.

Archæocyathids at Turks Nose Mountain were found at 450 to 500 feet above the base of the formation, but those at the hill near Indianpoint Lake are much higher in the formation and are in association with Olenellid trilobites (*see* p. 28).

TURKS NOSE MOUNTAIN SECTION

Lithology	Thickness in Feet	Feet above Isaac Formation
Base of Yankee Belle Formation.		
Poorly exposed limestone and dolomite	1,000+	2,300±
Grey to fawn silty shale with *Wanneria* sp.? and *Olenellus cf. gilberti*	50	1,300
Dolomite	100	1,250
Covered	100	1,150
Interbedded pelletal and grey limestone	200	1,050
Finely interbedded dark-grey limestone and red weathering argillaceous limestone	75	850
Buff calcareous shale	25	775
Girvanella limestone	50	750
Massive grey limestone, some pelletal	200	700
Grey limestone with archæocyathids	50	500
Thick-bedded grey limestone with some laminated algal-like texture	360	450
Laminated dark- and middle-grey limestone	90	90
Isaac Formation. Green and brown phyllite and cross-bedded brown to white quartzite	500 (poorly exposed)	

Sections east of Isaac Lake are characteristically thinner than those west. The poorly preserved *Girvanella* found south of Betty Wendle Creek are almost at the base of the formation, whereas those on Turks Nose Mountain are some 700 feet above the base. If the *Girvanella* beds are equivalent, then 700 feet of limestone at Turks Nose Mountain is represented by calcareous phyllite and minor limestone east of Lanezi Lake. Sections east of the lake are characterized by a higher proportion of pelletal limestones—up to a third of some sections—and by an absence of recognizable fossils except algæ.

Age.—The age determination of the Cariboo Group is dependent primarily on fossils found in the Cunningham Limestone as no other fossils have been found except in one locality in the Yanks Peak Quartzite. The Cunningham appears to be mostly of Early Cambrian age, although it may be partly Late Proterozoic and partly Middle Cambrian. Archæocyathids are found within 500 feet of the base of the formation and Olenellid trilobites at least 1,300 feet above the base at Turks Nose Mountain.

Fossils other than algæ seem to be preserved only in the relatively gently folded area on the southwestern flank of the Lanezi anticline. Collections were made by the writer on the hill between Bowron and Indianpoint Lakes, on Iltzul Ridge, Turks Nose Mountain, the canyon of the Cariboo River above the lower falls, and Kimball Ridge, and by Lang (1940, 1947) on Kimball Ridge. Professor V. J. Okulitch of the University of British Columbia examined the writer's collections.

I. At Turks Nose Mountain, collections were made at 450 to 500 feet, 700 to 750 feet, and 1,250 to 1,300 feet above the base of the limestone. At 450 to 500 feet, rare archæocyathids were found which were identified as:—

Coscinocyathus sp.

Pycnoidocyathus sp.

At 700 to 750 feet above the base and for several miles along the mountain, a member is composed largely of algal pisolites which were tentatively identified as:—

Girvanella

At 1,250 to 1,300 feet in grey to fawn silty shale, fragments and rare whole trilobites were found that were identified as:—

Wanneria sp.

Olenellus cf. gilberti.

II. On the top of the hill between Bowron and Indianpoint Lakes, abundant archæocyathids were found that were identified as:—

Ajacicyathus sp.
Coscinocyathus dentocanius.
Pycnoidocyathus sp.

Rare trilobites found in 12 feet of biscuit-coloured silty shale interbedded with the archæocyathid-bearing limestone were identified as:—

Olenellid trilobite possibly *Callavia.*
Genial spine of *Olenellus(?).*
Olenellus cf. thompsoni.
Olenellus (gilberti(?)).

Below the beds containing these fossils obscure archæocyathids could be recognized for 300 feet. The archæocyathid beds are at least 1,500 feet above the base of the formation if the interpretation of the structure is correct.

III. On Iltzul Ridge, one indistinct archæocythid was found and identified as possibly:—

Protopharetra.

IV. Lang's collection at localities on Kimball Ridge is more extensive than the writer's, but the distribution of fossils at three localities is not indicated. The fossils were examined by C. E. Resser, and his identifications are stated by Lang (1947, pp. 31–32) as follows:—

"*Pædeumias* sp.
"*Kootenia* sp.
"*Salterella* sp.
"*Bonnia* sp.
" New genus related to *Kootenia.*
" New genus of Olenellid trilobite.

" Dr. Resser reported that all the above were Lower Cambrian, with the possible exception of the genus related to *Kootenia,* which could be Lower or Middle Cambrian. He also stated that the same unnamed genus of Olenellid trilobite, and possibly the same species, occurs in the Eager Formation near Cranbrook, B.C."

At Lang's northwestern locality the writer found:—

1. *Bonnia* sp.

At the central locality the writer found small deformed trilobites identified by V. J. Okulitch as:—

2. *Ogygopsis klotzi* Rominger.

The stratigraphic position of these localities is uncertain but near the top of the formation.

V. In the canyon of the Cariboo River above the lower falls the writer collected three different fossils within a hundred stratigraphic feet in a black fetid limestone. This limestone is about 700 feet from the base of the formation as projected from Turks Nose Mountain. The fossils in apparent ascending stratigraphic order were identified as:—

1. *Obolus* sp.
2. *Glossopleura cf. stenorhacis* Rasetti.
3. *Pædumias (Olenellus) gilberti.*

Professor Okulitch said of the collections at localities I, II, III, and IV (1) that:—

" The fauna clearly indicates the upper Lower Cambrian. The trilobites are similar to the Eager fauna near Cranbrook; and the Archæocyatha resemble the ones from the Donald Formation."

The collection at IV (2) indicated a Middle Cambrian age.

The collection at V presented a problem. Professor Okulitch said the brachiopod *Obolus* is Middle to Late Cambrian but not diagnostic; *Glossopleura cf. stenorhacis* Rasetti is a good Middle Cambrian fossil and *Pædumias (Olenellus) gilberti* a definite Early Cambrian fossil. These fossils were on strike with Early Cambrian fossils at Turks Nose Mountain. After discussion with Professor Okulitch the collections were sent to Professor Rasetti, who confirmed the identifications, and it could only be concluded that there must have been structural complications, possibly thrust faulting. A paper given in Vancouver by C. A. Nelson (1960, pp. 2070–2071) reopened the question, and Professor Okulitch later stated:—

"At present, and in the view of what Dr. C. Nelson reported, I can only conclude that these rocks are Lower Cambrian—regardless of *Ogygopsis* and *Glossopleura*. . . . The presence of *Olenellids* is the most important factor."

Origin.—The origin of the Cunningham and Isaac Formations must be considered together as they apparently interfinger. The deposition of the coarse clastic sediments of the Kaza was followed by the deposition in a quieter basin of well-sorted fine clastic sediments. Some well-sorted sands were laid down, particularly in the west and possible as a result of the reworking of latest Kaza sediments. The basin probably subsided slowly as muds poured in from the east, and with the progression of time the muds were either flushed less distance into the basin from the east or were restricted by algal reefs. The entire carbonate sequence was probably deposited in fairly shallow water.

Yankee Belle Formation

The Yankee Belle Formation overlies the Cunningham Limestone conformably and in turn is overlain conformably or with minor interfingering by the Yanks Peak Quartzite. The Yankee Belle is composed predominantly of light-coloured phyllites, many of which are a light grey-green and on weathering have a range of colours from light green to rusty brown. The formation includes green to brown metasiltstones to fine quartzites and a small number of thin brown weathering white limestones. The type area is in the core of the Yanks Peak anticline on the Yankee Belle property (Bull. No. 34, pp. 17–18). The unit is exposed on the limbs of the Cunningham anticlinorium and has been described by the writer from occurrences in the Antler Creek area (Bull. No. 38, pp. 24–25).

Distribution.—In the map-area the Yankee Belle Formation outcrops extensively in the Kimball Creek area and in the deeper synclinal troughs in the Isaac Lake synclinorium from Mount Amos Bowman northwestward. Beyond the map-area it is recognized by Campbell (1961) in a large area north of Quesnel Lake.

Thickness.—The formation is 900 feet thick in the type locality where the base is not exposed. In the Antler Creek area a thickness of 300 feet was measured on a limb that had probably been extensively thinned during folding; the stratigraphic thickness at that locality is now believed to be at least 600 feet. In the Kimball Creek area the unit is apparently close to 2,000 feet thick, whereas east of Isaac Lake it is 1,300 to 1,500 feet thick.

Lithology.—The Yankee Belle Formation is an assemblage of alternating beds of phyllite, metasiltstone, fine quartzite, and minor limestone. Phyllite is the dominant rock. Arenaceous rocks vary widely in amount and distribution but rarely aggregate as much as 35 per cent of the unit; limestone forms up to 5 per cent of the unit. The rocks are characteristically light coloured, most being light grey-green through grey to fawn. They weather a yellowy green to rich purply brown. Bedding is commonly pronounced; the beds are 1 to 2 feet thick, except in some of the quartzites and limestones, in which beds 4 to 10 feet thick are common. Secondary foliation is variably developed but may be very intense and produce papery phyllites. In some localities of complex folding a crenulation cleavage crosses the main secondary foliation.

Rare variant rock types occur, most of which are calcareous. Both phyllites and fine quartzites are found with bedded pods and lenses of limestone 1 inch or less thick (*see* Plate XX). Another rare type is crossbedded sandy limestone. Rarely some of the limestones have a pelletal or oolitic texture. More commonly they are buff weathering fine white dolomite. In the vicinity of the Cariboo River and lower Kimball Creek a middle grey slate is found.

Microscopy.—Yankee Belle rocks show a fairly complete variation in mineral composition between the following extremes:—

	Phyllite	Arenaceous Rocks	Carbonate Rocks
	Per Cent	Per Cent	Per Cent
Quartz-feldspars	20	80	5
Muscovite-chlorite	75	15	5
Ferroan carbonate and oxide	5	5	90

The metasiltstones and quartzites generally contain about 65 per cent combined quartz and feldspar, of which the feldspar is commonly 5 to 10 per cent. The grain size is uniform in any specimen and commonly ranges between 0.05 and 0.1 millimetre. The proportion of chlorite to muscovite or sericite ranges from nearly all of one to nearly all of the other in phyllite or quartzite. In the phyllites the quartz commonly forms 20 to 35 per cent and occurs as angular plates oriented parallel to the secondary foliation. Much of the iron in quartzite or phyllite is present as siderite or ankerite, but oxide and leucoxene may be present.

The carbonate rocks range in composition from limestone to dolomite and from pure to very silty rocks. Pelletal rocks are very rare, and some pellets have a vague radial structure that may indicate that they are deformed oolites.

Fabric.—The fabric of Yankee Bells rocks is particularly varied; as varied as the degree and style of folding of the unit. Commonly the metasiltstones have slight to moderate secondary foliations, whereas adjacent phyllites have moderate to intense secondary foliation. Less commonly the phyllites have in addition an intense crenulation cleavage. Not rarely the microscopic fabric may be only slightly more intense than normal in phyllite and metasiltstone, but the deformation may have exceeded the limits of stratiform folding and the arenaceous beds may be dismembered in a plastic phyllitic matrix. Most localities where this has happened are southwest of the Lanezi arch, but one is on the peak just west of the head of the Goat River. The wide variation in fabric and structure is related to the great internal variation and to the relative incompetence of the unit as a whole which is sandwiched between two competent units.

Metamorphism.—The rocks of the unit are almost all metamorphosed to the muscovite-chlorite subfacies. In general, neither the size of the chlorite or muscovite crystals nor the intensity of the secondary foliation is as great in the Isaac Lake synclinorium as in the Kimball Creek area, where the limestones are almost marble.

Stratigraphy.—The following reconnaissance section is a composite of the sections observed east of Lanezi Lake and is primarily based on the section on the mountain southeast of Wolverine Mountain.

The section exposed in the Kimball Creek area appears similar, although it is thicker (about 2,000 feet) and possibly contains more quartzite and metasiltstone and less limestone. At about 300 feet above the base there is a 50- to 75-foot sequence of limestone beds.

COMPOSITE SECTION

Lithology	Thickness in Feet	Feet above Cunningham Limestone
Base of Yanks Peak quartzite.		
Interbedded phyllite (70 per cent), fine brown quartzite (25 per cent), thin-bedded limestone (5 per cent)	300	1,300
Interbedded brown to grey-green phyllite (75 per cent), metasiltstone (25 per cent), rare thin limestone beds	700	1,000
Dolomite, 10-foot beds	30	300
Interbedded brown to grey green phyllite (70 per cent), brown metasiltstone (15 per cent), including some with limestone pods, thin-bedded limestone (15 per cent)	220	270
Interbedded brown phyllite and limestone	50	50
Top of Cunningham Limestone.		

Origin.—The Yankee Belle Formation marks a radical change from the preceding conditions. The marine basin in which previously the thick Cunningham Limestone was deposited was invaded by clastic sediments which were well sorted into muds, silts, or fine sands. Calcareous deposition continued in some measure, and the possible oolites together with the other features indicate the basin was shallow and swept by currents or waves. The unit appears to thicken to the southeast.

Yanks Peak Quartzite

The Yanks Peak Quartzite overlies the Yankee Belle Formation and is in turn overlain by the Midas Formation. However, in the west the unit is not everywhere present. It is composed almost solely of pure quartzite, but there are everywhere thin interbeds of phyllite, and in the southeast the unit includes calcareous cemented quartzite and limestone. The type locality is at Yanks Peak (Bull. No. 34, pp. 18–19), and other localities occur on the Cunningham anticlinorium near Roundtop Mountain and at Summit Creek (Bull. No. 38, pp. 25–26).

Distribution.—The quartzite is well exposed in the Isaac Lake synclinorium northwest of Betty Wendle Creek as the youngest unit in the synclinal troughs. It is probably exposed in the unmapped portion of the synclinorium south and west of Betty Wendle Creek. The quartzite is well exposed on Kimball Ridge and outlines the Black Stuart syncline on Anderson Ridge.

Thickness.—The quartzite is 50 to 100 feet thick at the type locality, is 1 to 200 feet thick near Roundtop Mountain, and about 150 feet thick at Summit Creek. In the present map-area it is very much thicker: east of Lanezi Lake it is some 1,000 to 1,200 feet thick, in the Kimball syncline it may be 1,500 feet thick, and in the Black Stuart syncline about 500 feet thick. Rapid changes in thickness are characteristic of the quartzite at Yanks Peak and Roundtop Mountain, and in the present map-area the difference in thickness from one side of Kimball Creek to the other may indicate the same thing.

Lithology.—The Yanks Peak Quartzite is composed almost entirely of thick-bedded pure quartzite. Colour of the fresh quartzite is most commonly middle to light grey or bone white, but may be brownish grey or purplish grey. Weathered colours are commonly a darker grey to grey-brown. Beds are commonly 2 to 8 feet thick and are separated by thin phyllitic interbeds that weather preferentially. Rarely phyllitic beds resembling those of the Yankee Belle may aggregate a few feet or tens of feet. Crossbedding within the thick quartzite beds is common but not readily visible. Rare quartzose granule conglomerate occurs where the formation is thickest and forms parts of the thick beds. It has particles as big as 15 millimetres, with an average size of about 3 to 4 millimetres. Curiously, the sphericity of the granules is noticeably less than that of the quartz sand. The normal facies described above is exclusively present at all localities except those described below.

The Yanks Peak Quartzite, near the lower falls on the Cariboo River and about the north limb and trough of Black Stuart synclinorium, contains a facies different from the normal. At these localities, in addition to the normal quartzite, a variety is found that contains calcareous cement; similar rock contains fragments and blocks of limestone up to 2 feet in diameter and some smaller phyllite fragments. There are also medium crystalline limestones that originally may have been lime sands.

Microscopy.—The normal quartzite is simple and uniform, being almost wholly composed of well-rounded quartz grains of high sphericity. The composition of the quartzite varies only within the following limits:—

	Per Cent
Quartz	95–98
Feldspar	Trace– 1
Sericite	2– 5
Iron oxides, carbonate	Trace– 1
Heavy minerals (tourmaline, zircon, sphene)	Trace–½

The sorting is good. The average size of quartz grains ranges between 0.1 to 4 millimetres with about 0.3 millimetre the most common size. In rocks of sand grade the quartz grains almost all appear to have been of igneous origin, but in rocks of granule grade some are clearly vein quartz, and others less clearly are quartzitic fragments. The sericite occurs as thin sporadic films or sheaths on the quartz grains, or as detrital or squeezed grains. Some may represent altered feldspar. Iron oxides occur at random between quartz grains; some iron carbonate may partly replace detrital grains. Heavy minerals are common, well rounded, and about one-third to one-half the diameter of the quartz grains.

In undeformed specimens the quartz grains may be greatly compacted with scalloped impacted contacts, or they may have a considerable quartz overgrowth cement or an essential sericite matrix. Some combination of these features is common.

The calcareous quartzite is identical with the normal quartzite, except that it has a small amount of silica overgrowths and dominantly calcareous cement. Calcite sand grains and fossil fragments may occur and, in some specimens, large limestone and phyllite fragments. The extreme development in the carbonate facies is a fine calcite marble.

Metamorphism.—The quartzite is not readily subject to metamorphism. No chlorite is evident in specimens examined, and muscovite is the only mica. Recrystallization of the limestone has been enough to obscure its origin.

Fabric.—The Yanks Peak Quartzite of the map-area is considerably less tightly folded than at Yanks Peak and Roundtop Mountain, and consequently, although hand specimens from each area look identical, their microscopic fabrics are very different. In the present map-area the fabric is scarcely deformed. The original grain boundaries are commonly evident, and though the rock has been compacted there is no granulation and little recrystallization, although there is considerable evidence of strain. In the type locality the quartz grains were granulated, recrystallized, or greatly strained and had a sutured fabric with muscovite primarily oriented in a microscopic foliation with little regard for original grain boundaries. Rounded detrital grains were evident only in some of the less deformed specimens. The quartz grains also had a noticeable flattened dimensional orientation.

Origin.—The composition, thickness, and sorting of the formation suggest deposition in a shallow marine basin over a long period of time. The thickening to the east and spotty deposition in the west may indicate an eastern source or a greater subsidence in that direction. The rounding and sorting indicate that the rock is a second cycle quartzite.

Age.—In microscopic examination of specimens of the calcareous cemented quartzite from near the lower falls on the Cariboo River, the writer found fragmentary fossils which Professor Okulitch recognized as bryozoa but which were not well enough preserved to identify. As bryozoa first appeared in the Ordovician, the Yanks Peak Quartzite must be Ordovician or younger.

Midas Formation

The Midas Formation is composed primarily of dark-grey to black phyllite, slate, argillite, and metasiltstone, and some limestone that is commonly black. The formation overlies the Yanks Peak Quartzite, and the colour contrast combined with the change in rock type makes the contact a useful marker. The Midas Formation is overlain in turn by the Snowshoe Formation, conformably or somewhat unconformably. The type locality is at Yanks Peak (Bull. No. 34, pp. 19–22).

Distribution.—In the map-area the Midas Formation is found only in the Black Stuart syncline and in parts that overlap with the Antler Creek area. In the latter area the Midas Formation is exposed along the flanks of the Cunningham anticlinorium and the core of the Island Mountain anticline (*see* Bull. No. 38, pp. 26–29). The formation has also been mapped north of Hobson Lake by Campbell (1961), in the Prince George area by Tipper (1961), and in the McLeod Lake area by Muller and Tipper (1962).

Thickness.—At the type locality, an area of intense deformation, Holland measured some 570 feet of Midas Formation. In the Antler Creek area the writer judged there was more than 1,000 feet of Midas Formation at Island Mountain. In the Black Stuart syncline no stratigraphic section was measured, but the unit must be considerably greater than 1,000 feet thick and may be 2,000 feet. However, the formation is a monotonous, poorly bedded and closely folded assemblage so that estimates are subject to large error.

Lithology.—The Midas Formation is composed of black and dark-grey phyllite, slate, argillite, and metasiltstone with minor black limestone. These rocks are readily bleached, so that instead of the typical dark colour the rocks may locally be light grey, brown, or purplish, and the limestone may be mottled black and white or white. Much of the unit is composed of black phyllite in which bedding is rarely observable. Also common are blocky black argillites to metasiltstones, or more rarely fine quartzites, that commonly have recognizable bedding. Not uncommonly the bedding may be emphasized by recrystallization of occasional laminæ, so that the primarily black rock has random white laminæ. Both phyllite and metasiltstone quite commonly contain ankerite or pyrite porphyroblasts.

Probably more than 90 per cent of the formation is composed of the two general rock types, phyllite and metasiltstone. Other types occur in minor quantity, and except for dark, mottled, or white limestone they are only locally developed. Limestone locally forms as much as 5 per cent of the formation. The limestone beds are commonly silty and contain micaceous laminæ and may be ankeritic or dolomitic. In the Black Stuart synclinorium other minor types include (1) interbedded red weathering light-grey quartzite and black phyllite or slate, and (2) brown weathering chloritic rocks, of which some look vesicular and some resemble deformed agglomerates. The chloritic rocks are almost certainly of volcanic origin, but field relations and textures are so obscured by the general deformation that it has not been determined whether the rocks were intrusive, extrusive, or pyroclastic. Basic sills and dykes occur in the area, and for lack of other evidence have been considered to be correlatives of the Slide Mountain-Mount Murray volcanic rocks. The principal and minor rock types are described at greater length in Bulletin No. 34 (pp. 19–22) and Bulletin No. 38 (pp. 26–29) together with microscopic details (illustrated by

Plates IVA, VA, and VIB in the former bulletin and Plates IVA, VIIA, and IXA in the latter).

Snowshoe Formation

The Snowshoe Formation is composed of a mixed assemblage of coarse and fine clastic rocks with lesser carbonate rocks. The characteristic rock is a schistose, poorly sorted grey micaceous quartzite with dark or opalescent quartz eyes. The formation is the youngest of the Cariboo Group and overlies the Midas Formation conformably or possibly slightly unconformably. The Snowshoe Formation is not exposed in the map-area, except where it overlaps the Antler Creek area, so that only a brief review is given here. The type locality is the Snowshoe Plateau (Bull. No. 34, pp. 22–23).

Distribution.—The Snowshoe Formation in the type area and in the Antler Creek area is exposed principally in the Snowshoe synclinorium. The Snowshoe Formation has been mapped over a wide area northwest of Quesnel Lake by Campbell (1961), in the Prince George area by Tipper (1961), and in the McLeod Lake area by Muller and Tipper (1962).

Thickness.—The top of the formation has not been seen, and the thickness is unknown. Holland (Bull. No. 34, p. 22) thought the exposed unit about 500 feet thick. The writer thought it greater than 1,000 feet thick (Bull. No. 38, p. 29). Campbell (personal communication) has evidence it is much thicker.

Lithology.—The coarsest rocks are fine pebble conglomerates and are most common at the base of the formation. Much of the Snowshoe Formation is composed of grey micaceous quartzites which characteristically have a pronounced secondary foliation and dark or opalescent blue quartz eyes. The colour of the quartzites is typically middle grey but may be light or dark or greenish grey or brown. An original lack of sorting is evident—the rocks were deposited as subgreywackes. Were it not for their highly deformed fabric, these rocks would be called, according to Williams, Turner, and Gilbert, quartz greywackes. In Bulletin No. 38 they were called subgreywackes. Much of the remainder of the unit, and locally as much as half, is composed of variously coloured phyllites and phyllitic siltstones, the majority of which are dark grey. Arenaceous and argillaceous rocks may be interbedded in all proportions. Calcareous rocks range in colour from dark grey to white; many are buff weathering ferroan dolomites, and most are quite impure, with a fairly complete gradation through sandy or argillaceous limestone or dolomite to calcareous quartzite or phyllite. Many of the carbonate rocks are well and finely bedded with laminæ of phyllite.

The mineral composition of the arenaceous rocks of the Snowshoe Formation in the Antler Creek area is shown on Figure 6, which is repeated from Bulletin No. 38, for comparison with the somewhat similar rocks of the Kaza Group. The average composition of twenty Snowshoe arenaceous rocks was (p. 31):—

	Per Cent
Quartz	74
Muscovite	17
Ankerite	5
Feldspar	4

SLIDE MOUNTAIN GROUP

The Slide Mountain Group comprises two formations—the Guyet Formation, which is characterized by conglomerate, and the Antler Formation, which is characterized by ribbon chert and basic pillow lava. The group overlies the Cariboo Group with great unconformity. The Slide Mountain Group was renamed by John-

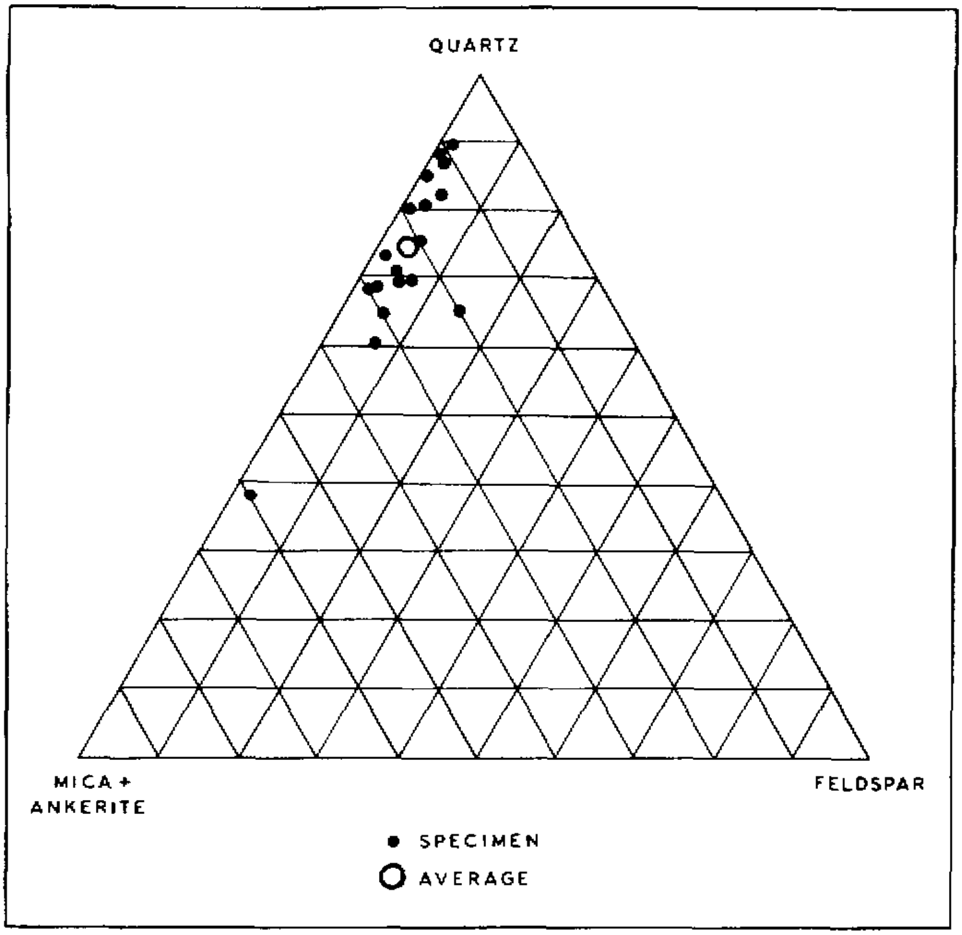

Figure 6. Mineral composition, Snowshoe Formation clastic rocks.

ston and Uglow (1926, p. 18), having been originally called by Bowman (1889, p. 206) the Bear River Series, which, however, included rocks not properly part of the group as it is known now. The stratigraphic nomenclature of Johnston and Uglow was revised in Bulletin No. 38 (p. 33). The Guyet and Antler Formations were retained, the Greenberry Limestone was reduced to a member of the Guyet Formation, and the Waverly Formation abandoned. In the map-area the group is exposed only within the Slide Mountain trough, which extends northwestward from the southern base of Mount Tinsdale. Tipper recognizes the group in the Prince George area near the mouth of the Willow River (Tipper, Map 49-1960) and Muller and Tipper (Map 2-1962) in the McLeod Lake area. The type locality of the Guyet and Antler Formations is not specifically named by Johnston and Uglow, but the writer assumes it to be on Slide Mountain or Mount Murray, both of which are in the Antler Creek area and also mostly within the present map-area. Both formations were described rather fully in Bulletin No. 38 (pp. 32-40 and 97-98), and the treatment here summarizes that description and emphasizes the new work.

Guyet Formation

The Guyet Formation is characterized by conglomerate but contains many other rocks, including lithic greywacke, argillite, crinoidal limestone, and basic volcanic flow and fragmental rocks. At the type locality and at Mount Guyet the unit is almost entirely conglomerate; elsewhere the amount of conglomerate is less and may be subsidiary. The Guyet Formation overlies the Cariboo Group with great unconformity. The unconformity can be seen on Cunningham North Mountain, although it is nowhere well displayed. The Guyet Formation is not in contact with the youngest rocks of the Cariboo Group, but it overlies Cunningham, Yankee Belle, Yanks Peak, and Midas Formations successively. Pebbles recognizable as Cariboo rocks are found in the conglomerate. There is a very great difference in structure and metamorphism between the two groups.

Distribution and Thickness.—The formation outcrops as a band at the base of the group along its southwestern and southern margins. It is seen on the northeast only at the islands at the north end of Spectacle Lakes, because this margin is mostly covered. The only new exposures examined were on the southern slopes of Mount Tinsdale and the islands in Spectacle Lakes. The formation is 1,125 feet thick at Mount Murray and may be thicker to the south, possibly 1,500 feet thick.

Lithology.—The Guyet conglomerate is a dense, silicified conglomerate that is generally a subdued mottling of grey and brown. Most of the conglomerate is pebble sized, but in some localities much is cobble and some boulder conglomerate. Bedding is very poorly evident, as beds are massive, and the change from one grade size to another is gradational. In some areas the composition of the conglomerate reflects the adjacent preconglomerate bedrock, and limestone, greenstone, and schist conglomerate facies occur. Most commonly the conglomerate is a mixture of rock types in which quartz, quartzite, and chert pebbles predominate with scattered phyllite, argillite, limestone, and basic and acidic volcanic pebbles. In weathered exposures a percentage of the less resistant pebbles weather out but the rock remains hard and dense. The conglomerate on the islands at the north end of Spectacle Lakes is probably more uniformly composed of quartz, chert, and quartzite than are exposures on the southwestern flank of the Slide Mountain trough. The arenaceous matrix of the conglomerate is generally similar to the lithic greywackes of the formation.

Included within the formation (Bull. No. 38, pp. 35–36) are basic volcanic flows and agglomerates that are essentially similar to those of the Antler Formation. They are described with the Antler Formation in the present bulletin.

The Greenberry limestone member occurs intermittently at the top of the formation, and where present usefully marks the top. Above the limestone member no conglomerates or coarse greywackes are found, but such rocks interfinger with the limestone. The member is a clastic crinoidal limestone which may have abundant chert nodules or may even be entirely replaced by white chert. At a very few localities the member is not obviously crinoidal but is argillaceous and finely crystalline. At some localities its place is taken by highly calcareous, basic flow rocks. The member occurs on the southern slopes of Mount Tinsdale, where it is highly crinoidal, and on the islands at the end of Spectacle Lakes, where some crinoid columns are present although the member is generally finely crystalline.

Microscopy.—The average composition of twelve specimens of fine conglomerate and greywacke was given in Bulletin No. 38 (p. 34) as:—

	Per Cent
Quartz	50
Feldspar	12
Rock fragments	25
Mica and chlorite	13

Specimens from the islands in Spectacle Lakes contain more chert rock fragments, slightly less feldspar, and less mica and chlorite. Many of the quartz sand grains are well rounded and of high sphericity, but the rock fragments may be angular and are of low sphericity. The same may be true of larger particles, and so possibly the round quartz sand is originally from the Yanks Peak Quartzite. Most of the rock fragments are chert, but some are siltstone, phyllite, and micaceous quartzite. The last resembles Snowshoe rather than Kaza quartzite. The rock is very well compacted, and phyllite, siltstone, and chert in some cases are squeezed into interstices. The whole rock is well bonded by a cherty silicification. Specimens from the southern slope of Mount Tinsdale are similar but have a very high percentage of angular chert granules together with some rounded quartz sand.

Metamorphism and Fabric.—The clastic rocks of the formation are unaffected by regional metamorphism and are essentially undeformed. They are, however, very well compacted and are affected by a cherty silicification. The rocks exposed on the islands at the north end of Spectacle Lakes, including the Greenberry Limestone, are finely sliced by subparallel fractures, on some of which there has been small movement. This fracturing is probably related to the adjacent large Antler Creek fault.

Stratigraphy.—No new sections were measured. Those given in Bulletin No. 38 (pp. 97–98) are representative.

Antler Formation

The Antler Formation is composed mostly of basic volcanic rocks and thinly bedded chert and overlies the Guyet Formation conformably. At the type locality on Slide Mountain-Mount Murray about half the section is chert and argillite and half volcanic flows and sills. The Mount Murray sills were thought by Johnston and Uglow to be considerably younger than the Slide Mountain Group, but the writer showed them to be related in age and origin to the effusive rocks of the group (Bull. No. 38, pp. 42–45). The term "Mount Murray" is dropped, and the sills are not separately distinguished in this bulletin as they are now believed to be volumetrically less important than they were. The type section is not entirely typical, and recent work shows that pillow lava is the dominant rock, followed by chert and argillite and then diabase dykes and sills.

Distribution and Thickness.—The Antler Formation is well exposed in the Palmer Range and on the upper part of Mount Tinsdale, the eastern ridge of Slide Mountain, lower Antler Creek, and the ridge south of Bowron Lake. The thickness of the formation, including the sills, at the type locality is about 3,600 feet. A somewhat greater thickness may be found in the Palmer Mountains.

Lithology.—The volcanic rocks of the Antler Formation are dominantly dark grey-green fine-grained basalt pillow lavas. The pillows are massive, with little matrix or variety in texture, and hence are not very obvious. Some of the areas shown as Mount Murray sills by Johnston and Uglow are pillow lavas; for example, the eastern ridge of Slide Mountain is entirely pillow basalt. Other areas mostly formed of pillow basalts include the ridge south of Bowron Lake, the top of Mount Tinsdale, and the eastern part of the Palmer Range. Ribbon cherts and interbedded chert and argillite are common in the formation, especially in the lower part, where several hundreds of feet or more of chert are common. Elsewhere the chert occurs intercalated in the lavas in thinner groups of beds, some of which are highly and irregularly folded and warped forms. The cherts are variously coloured grey, green, or, less commonly, red. Associated with the cherts in a few places are thin beds of black fine-grained lithic greywackes, similar in many ways to the finer rocks of the Guyet Formation. In addition to the pillow basalts, other volcanic rocks occur, some of which are obviously intrusive and are diabases. In many cases these are sills and formerly would have been called Mount Murray Intrusions. However, they are clearly related to the effusive basalts, and in many cases it is difficult to distinguish between basalt and diabase as every gradation in grain size occurs and the field relations are commonly obscure.

Microscopy.—Fresh holocrystalline specimens of the basalt are composed of subequal quantities of plagioclase and augite or augite and hornblende, with a few microphenocrysts of chloritized olivine, 2 or 3 per cent ilmenite or leucoxene skeletal crystals, and rarely a very minor amount of quartz. The texture may be finely subophitic to variolitic. Many of the specimens have a significant amount of semi-opaque indeterminate groundmass in which the above minerals occur, and most specimens are considerably chloritized. The diabases are similar but coarser, with a pronounced diabasic texture; the ones examined were all quite chloritized. The basalts and diabases were described at length in Bulletin No. 38 (pp. 39, 42–45) with chemical analyses, calculated norms, and modes. The rocks were shown to be slightly spilitic basalts because they were higher in soda and lower in lime than normal basalts.

The cherts also were described at length in Bulletin No. 38 (pp. 37–40). One feature of the ribbon cherts that appears to be less common in other regions is the relative abundance of evidently detrital fine quartz silt. The fine lithic greywacke that forms a rare rock within the formation is akin to arenaceous rocks of the Guyet Formation but has some differences. This rock is composed of approximately:—

	Per Cent
Quartz	50
Chert	20
Other rock fragments	10
Feldspar	5
Carbonaceous matrix	15

Much of the quartz is angular and of low sphericity, but some is rounded and highly spherical and probably was derived from the Yanks Peak Quartzite. Most of the other particles are angular. Chert is the most abundant rock fragment, but fine siltstone, phyllite, and turbid volcanic rocks also occur. Feldspar includes some microcline and is quite fresh. The matrix is black and non-reflecting and probably carbonaceous or bituminous.

Metamorphism.—Like those of the Guyet Formation, the sedimentary rocks of the Antler Formation are neither affected by regional metamorphism nor seriously deformed, hence they contrast strongly with those of the Cariboo Group.

Age.—Dating of the whole Slide Mountain Group is dependent on poorly preserved fossils found in the Greenberry limestone member at the top of the Guyet Formation. Crinoid stems are abundant in this unit in most localities, but other fossils are rare. Johnston and Uglow found a small number of other fossils on Two Sisters Mountain west of the present map-area and on Mount Greenberry within the map-area, but his localities were not recorded and the writer could find nothing but the crinoid columns. E. M. Kindle examined Johnston and Uglow's collection and is quoted by them (1920, pp. 20–21) as follows:—

" Specimens of limestone consisting chiefly of large crinoid column sections comprise the bulk of the material. Several specimens of a coral resembling, so far as can be judged from the poorly preserved material, a *Zaphrentis*, are present. Two brachiopods with obscure features which may represent *Spirifer keokuk* and fragments suggesting an *Orthoceras* complete the fauna as represented by this collection. Notwithstanding the limited number and extremely unsatisfactory state of preservation shown by these fossils, I have no doubt that they represent a Carboniferous fauna probably of Mississippian age. The material, however, is not good enough to demonstrate this correlation of the fauna."

The Slide Mountain Group seems to be equivalent in part to the thick Devono-Mississippian greenstone-chert-greywacke assemblage of northeastern British Columbia and the Yukon (Gabrielse and Wheeler, 1960, pp. 6–7), and resembles this more closely than the Rundle Group of the Rocky Mountains, with which it is correlative if the determination of *Spirifer keokuk* is correct.

INTRUSIVE ROCKS

Instrusive rocks underlie a very small part of the map-area, as there is only one small granitic stock and a minor array of dykes and sills. In the major part of the area, including the Lanezi arch and most of the Isaac Lake synclinorium, there are no igneous rocks exposed. A few continuous thin lamprophyre dykes are found on North Star Mountain. In the Slide Mountain Group the diabasic to fine gabbro sills and dykes of the " Mount Murray Instrusions " have been discussed together with the basalts of the Slide Mountain Group. Basic dykes in the Cariboo Group of the Antler Creek area were regarded as Mount Murray Intrusions and treated with them (Bull. No. 38, pp. 44–45). Ankeritic acidic dykes, the Proserpine dykes, are common in the Cariboo Group of the Antler Creek area and, although volumetrically insignificant, are important because cobbles of similar type occur in the Guyet conglomerate and thus indicate a pre-Mississipian age of igneous activity (*see* Johnston and Uglow, 1926, pp. 15–17, and Bull. No. 38, pp. 41–42). In the Kimball Creek area there are some fairly large altered basic dykes that may be related to the Slide Mountain volcanism as they are on strike with the Slide Mountain trough. There are a few biotite lamprophyre dykes on Kimball Ridge. The main intrusive body lies between the northerly branches of the Little River and is named the Little River Stock.

Little River Stock

The Little River Stock is a granitic pluton with an outcrop area of about 4 square miles. The stock has a lensoid plan oriented parallel to the local strike of about north 70 degrees west. The western end is covered by drift in the valley of the northern branch of the Little River, but must terminate abruptly compared to the ragged eastern end. Intense small-scale folding in the adjacent limestone appears to be evidence that the walls have been shouldered aside.

The stock is composed of porphyritic granitic rocks that look quite uniform and vary imperceptibly from granodiorite to quartz monzonite of a slightly pinkish middle-grey colour. In general the feldspars have a preferred orientation that gives a slight foliation to the rock, but this is not readily evident in the field. More noticeable is a common jointing that strikes north 10 degrees east and dips steeply east and hence is normal to the long axis of the stock.

Microscopy.—The main mass seems to vary within the following limits:—

	Per Cent
Quartz	15–20
Plagioclase (An_{30}–An_{40})	50–45
Microcline	10–25
Hornblende	12–Trace
Biotite	12–10
Sphene	1+

Commonly there are no opaque minerals but instead abundant sphene. The plagioclase is altered partially to clinozoisite and muscovite. A rare, more basic variant of the stock is found in a few localities near the walls or large pendant blocks; it is pyroxene porphyry that could be called a shonkinite. It is composed of:—

	Per Cent
Augite	50
Oligoclase	20
Microcline	15
Quartz	5
Clinozoisite	5
Sphene	5

The stock has produced very minor metamorphism of its wallrocks. Pyroxene skarns are present in some areas, particularly in pendants or inclusions, over a few tens of feet from the contact. More commonly there is a slight coarsening of grain of the limestone to a fine marble, but this is very restricted.

Very few dykes related to the stock are found more than a short distance beyond the periphery, unless a few lamprophyres are related. Some large, clean bulbous quartz veins and some silicification are related areally to the stock and so may have originated from it.

Age.—The age of intrusion of the Little River Stock is unknown, except that it is definitely post-Yankee Belle Formation and probably post-Midas Formation. It is possible that it is a correlative of the Proserpine dykes, but much more likely it is related to Mesozoic plutons of the Quesnel Lake area (Campbell, 1961).

REGIONAL DISCUSSION

Origins and Sources

The Kaza, Cariboo, and Slide Mountain Groups have considerable contrasts in lithology and in origin. The Kaza Group was laid down as a great thickness of muds, impure feldspathic sands, and fine gravels in alternating sets of beds without interruption. An increase in percentage and size of coarse clastic particles toward the end of Kaza deposition indicates tectonism rose to a climax and then decreased sharply to stable conditions during early Cariboo deposition. Evidence of the source of the Kaza sediment is slight, although Reesor (1957, pp. 160–162) has reasoned that in the equivalent Horsethief Creek Group the feldspars originated in Shield rocks not far east of the present outcrop of that group.

The Cariboo Group, in contrast to the Kaza Group, is characterized by calcareous rocks for, although clastic rocks predominate, carbonates are present in every unit. The Isaac Formation and Cunningham Limestone at the base of the group are the most important carbonate units, but succeeding formations generally contain 5 to 10 per cent limestone. Transition between Kaza and Cariboo conditions is apparent in the Isaac Formation, composed chiefly of muds, calcareous muds, and thin limestone members but containing some siltstones and sandstones and quartzites, some of which are calcareous. The Isaac Formation interfingers with the Cunningham Limestone in such a way as to suggest that muds were flushed successively less and less distances to the west from an eastern source. The retreat of muds to the east may be the result of a number of causes, of which a progressive submergence of source area might be one and growth of algal reefs possibly another. Much of the thick Cunningham Limestone is pelletal, and probable algal structures are common, so that a quiet, slowly subsiding, shallow marine basin is the likely setting of its deposition.

The stable period of calcareous deposition was brought to an end by the reintroduction into the basin of muds and silts of the Yankee Belle Formation. It is possible that the main source area was in the west after the stable period, for the writer believes that the Midas and Snowshoe Formations had a western source (Bull. No. 38, pp. 29, 32, and 63), and it is possible that the Yankee Belle and Yanks Peak Formations also had a western source. The Yanks Peak Quartzite which followed the Yankee Belle Formation is a pure quartzite composed of very well-rounded and well-sorted quartz sand. It is thus unique among the arenaceous rocks of the region and indicates unique conditions of slow subsidence of a shallow marine basin with vigorous currents and probably the reworking of older sands. The unit is thickest in the east and thin to intermittent in the west. In all probability this indicates merely greater subsidence in the east in a period of general tectonic stability. Following the deposition of the Yanks Peak Quartzite, instability increased in an erratic but progressive manner. The basin apparently subsided more quickly and was filled first by the black muds and silts of the Midas Formation and later by the poorly sorted, coarse, impure sands and intercalated muds of the Snowshoe Formation. Both units show minor indications of distant volcanism, both contain minor carbonate beds, and, as just stated, both may have had a western source. The Midas rocks are carbonaceous and sulphurous, such as may have been deposited in a basin of restricted circulation. The Snowshoe rocks indicate rapid, unselective deposition, and complete a cycle that started with stability and ended with increasing instability. The Cariboo Group may have been folded very soon after its deposition, and the start of a new cycle of deposition (Slide Mountain) may not have been long delayed thereafter.

The Slide Mountain Group is eugeosynclinal, being made up of pillow lavas, cherts, greywacke, argillite, and conglomerate. Deposition started with the Guyet conglomerate in local piles, between which finer detrital rocks and basic flows accumulated. Guyet deposition concluded with an intermittent clastic crinoidal limestone. The distribution of conglomerate piles probably indicates the mouths of torrential streams and the crinoidal limestone a marine environment of deposition (*see* Bull. No. 38, p. 36). The finer detrital rocks are essentially microbreccias and indicate rapid, unselective deposition. Kaza rocks are absent, and Proserpine dyke rocks and Cariboo rocks are abundant in the coarse pebbles of the western outcrop belt, so that a western source is evident at least for this part of the Guyet Formation. It is tempting to speculate that the western margin of outcrop approximates the western shoreline of the trough, and that it may have been essentially a fault line at present covered or undetected. The concluding event was the Antler deposition which followed. Pillow lavas, cherts, and argillites accumulated to some depth in a narrow marine trough, the borders of which may no longer have had marked relief.

Correlation

Correlation of the rocks of the area is not known with any precision because of the dearth of fossils. Certain general relations are evident from the fossils that have been collected and from consideration of lithologies and sequences of lithologies. Correspondence of lithologies is much greater along the regional strike than across it. Lithologic similarity between the Cariboo sections and those of the Ferguson area (Fyles and Eastwood, 1962, pp. 13–34), over 200 miles distant, is marked, whereas similarities between the Cariboo sections and those at Sunwapta Pass (Hughes, 1955, pp. 73–86) or Mount Robson (Burling, 1955, pp. 15–51), less than 100 miles distant, are slight.

The only definite correlation is between the lower part of the Cunningham Formation and the Donald Formation of the Dogtooth Mountains (C. S. Evans, 1923) and part or all of the Mount Whyte of Sunwapta Pass (Hughes, 1955, pp. 80–86) and other Early Cambrian formations of the Columbia and Rocky Moun-

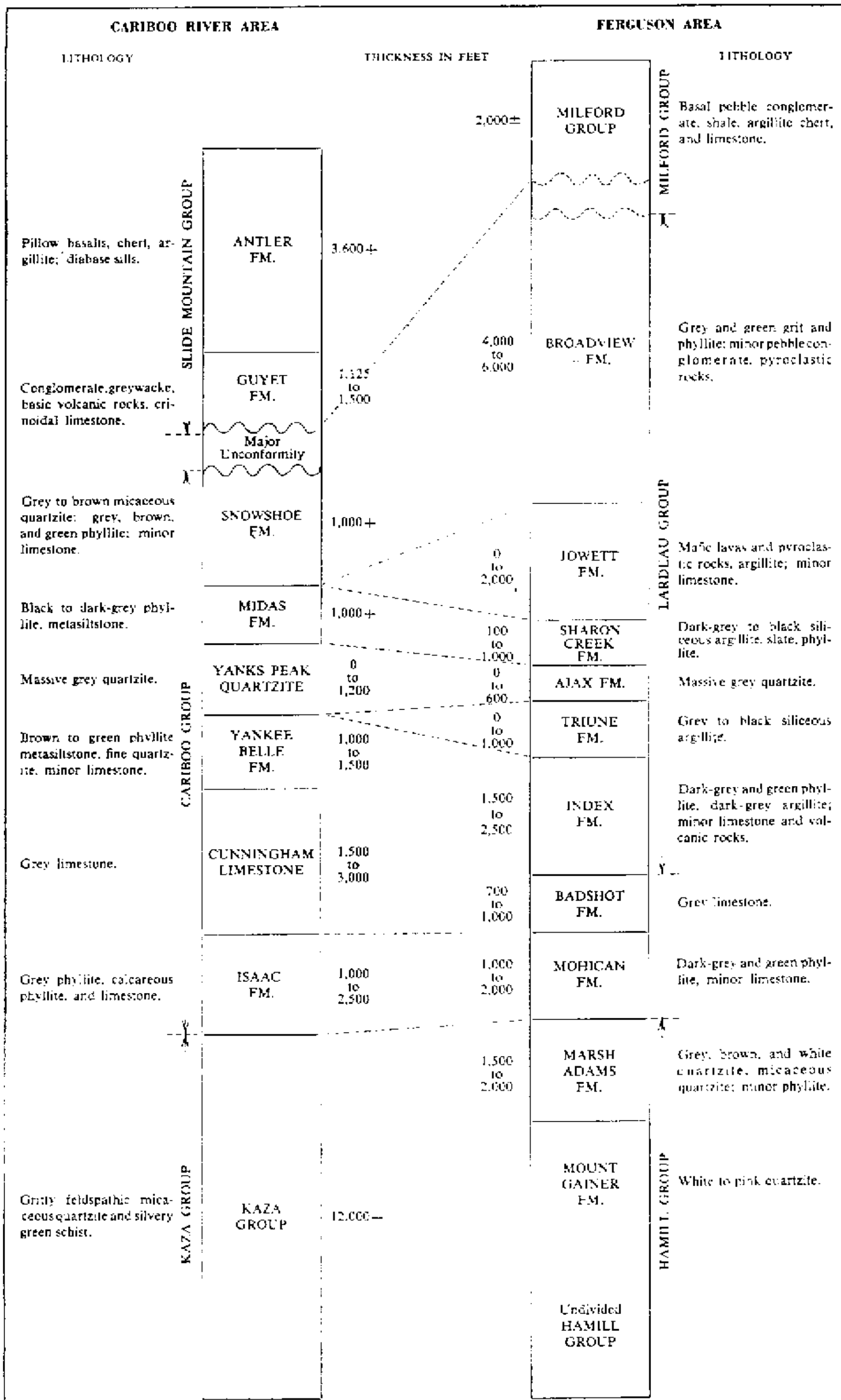

Figure 7. Geological column of Cariboo River area compared to that of Ferguson area.

tains. Also, if the identification of *Spirifer keokuk* is correct, then the Guyet Formation is presumably of Osagean age and the Slide Mountain Group is the approximate equivalent of the Rundle Group of the Rocky Mountains. Lithologically, however, the Slide Mountain is more nearly like the Sylvester Group of McDame area (Gabrielse, 1954), some 500 miles northwest.

Lithological similarities and stratigraphic position enable crude correlations to be made between the Kaza Group and the Hector of Sunwapta Pass and the Horsethief Creek of the Dogtooth Mountains. The Isaac Formation and possibly the upper part of the Kaza Group are equivalent to the Jonas Formation; and to the Fort Mountain, Lake Louise, and St. Piran; and to the Hamill of these respective areas. The upper part of the Cunningham Formation may well be younger than Early Cambrian (*see* pp. 27–29). Poorly preserved bryozoa found in the Yanks Peak Quartzite indicate a post-Cambrian and probable Ordovician age, and it is interesting to speculate on a possible correlation with the Wonah Quartzite of the Rocky Mountains.

A most striking lithological similarity exists between the sections in the Cariboo River and Ferguson areas, considering the distance between them and the facies changes within each area. Figure 7 compares the two sections. For some time the Badshot Formation has been believed to be the correlative of part of the Laib Formation of the Salmo area and so of Early Cambrian age, but no fossils were found in it until 1961, when Earle Dodson, of Falconbridge Nickel Mines Limited, and J. O. Wheeler, of the Geological Survey, found archæocyathids at separate localities in the Rogers Pass area. Hence the Badshot Formation is correlative with part of the Cunningham Limestone. Using this correlation as a datum, the sections are found to be very similar. Most striking similarities are between the Ajax and the Yanks Peak Quartzites, and the Broadview and the Snowshoe Formations. The top of the Hamill Group is shown on Figure 7 as the top of the Marsh Adams Formation, to agree with a recent article by Fyles (Two Phases of Deformation in the Kootenay Arc, 1962, Western Miner, Vol. 35, No. 7, pp. 20–26).

CHAPTER III.—STRUCTURE

GENERAL STATEMENT

The Cariboo River map-area is divided into four major structural units that coincide in part with the two major physiographic units. The Cariboo Mountains are formed of rocks that are structurally up-arched relative to rocks of the Quesnel Highlands. In the mountains there are two major structural units—the Lanezi arch and the Isaac Lake synclinorium. The chain of lakes contains the Lanezi arch, and the mountains east of Isaac Lake form the synclinorium. The Quesnel Highlands southwest of the mountains are formed also of two units—the isoclinal fold belt underlain by the Cariboo Group and the Slide Mountain trough. Northeast of the map-area, between it and the Rocky Mountain Trench, is another major anticlinorium.

The structures west of the lower Cariboo River in the tightly folded Cariboo Group have been treated at length in the Yanks Peak-Roundtop Mountain (No. 34) and Antler Creek (No. 38) bulletins. Although part of the area west of the river is shown on the maps of the present bulletin, the discussion of structures within it is cursory. A very brief account of structures east of the lower Cariboo River and in the Lanezi arch was given in Bulletin No. 38.

The structures in the Cariboo River area are much better exposed to direct observation than those in the Antler Creek and Yanks Peak-Roundtop areas, in which the ideas of structure and stratigraphy were the result of compilation of study of many individual outcrops. Field work in the Cariboo River area was rapid because far less observation was required than previously, but many structural complexities and problems remain to be solved by more detailed work.

FOLDS

The following discussions are concerned primarily with folding, but some discussion of faulting is included to aid understanding. The patterns of folds and of some faults are related, and the processes have been partly synchronous. Strike faults in particular seem to be related to the folds in distribution as well as in orientation.

Folds in the different structural units are discussed separately, starting with the isoclinally folded rocks in the Kimball Creek area, and successively with the Slide Mountain trough, the Lanezi arch, and finally the Isaac Lake synclinorium.

Kimball Creek Area

The Kimball Creek area, in the Quesnel Highlands on the southwest flank of the Lanezi arch, is underlain principally by isoclinally folded rocks of the Cariboo Group. Compression and overturning of folds increases toward the southwest from the gently folded flanks or the arch.

The main part of the Kimball Creek area was mapped by Lang (1940, Map 561A), but differently from the writer. The differences are more stratigraphic than structural, but the structural interpretation is greatly affected by them. In Bulletin No. 38 (pp. 57–58) the differences were explained as follows:—

"Lang's map showed a syncline which is occupied unconformably by the Slide Mountain and Cariboo groups (that is the same as the Black Stuart synclinorium of Figure 14). A major strike fault on the northeastern flank of the syncline cuts off the Slide Mountain group, and the Cariboo group rocks cannot be correlated across the fault. A small area of Cambrian strata occurs between the fault and the trough of the syncline, which strata are conformable with the Cariboo group but are not named or included with them. A thick limestone, named the Jackpot, occurs on the northeast limb of the syncline as part of the Slide Mountain group. This limestone pinches out rapidly to the southeast and does not appear on the southwest limb. Lang (1938, pp. 14–15; 1947, pp. 31–32) reported that Carboniferous or Permian 'poorly preserved corals' were collected from the Jackpot formation but listed none in either publication."

In contrast to Lang, the writer found the Slide Mountain Group no farther southeast than the mouth of Tinsdale Creek, where a normal section from basal Guyet conglomerate upward is found dipping gently northwestward. The Black Stuart syncline involves only the Cariboo Group, from the Cunningham Limestone to the Midas Formation. The Cunningham Limestone is continuous in outcrop from Turks Nose Mountain to Kimball Ridge and around the syncline to the Roundtop Mountain area. Cambrian fossils have been found at a number of localities in the limestone from Turks Nose Mountain to Kimball Ridge, including areas previously assigned to the Jackpot Limestone of supposed Carboniferous or Permian age.

The fundamental structure of the Kimball Creek area is a series of folds descending to the southwest from the culmination in the mountains, the Lanezi arch. The structure of the area is illustrated by sections G-G′, H-H′, I-I′, J-J′ of Figure 3. Of these folds, the most important are the Cunningham anticlinorium, the Black Stuart synclinorium, and the Kimball syncline. The latter may be a duplication by faulting of the Black Stuart synclinorium. All folds are deflected from the regional strike to a more easterly orientation. In general the folds are gentle adjacent to the southwest flank of the Lanezi arch and along Spectacle Lakes. The folds become progressively more compressed and more overturned toward the south. Metamorphism also increases toward the south, so that the limestone and phyllites of the north become respectively sugary marble and amphibolite, garnet, and microcline gneisses.

The most readily observed fold in the area is the Black Stuart synclinorium, which is outlined by a thin quartzite and limestone (Yanks Peak) that outcrops boldly between the Yankee Belle and Midas Formations. The shape of the plunging keel is shown also by the top of the Cunningham Limestone. The synclinorium is slightly overturned to the south, with the north limbs near vertical or slightly overturned and the south limbs dipping 45 to 60 degrees to the north. Axial plane schistosity is well developed, but not so prominently that it obscures bedding. The fold is not as compressed as the Cunningham anticlinorium to the south or most folds in the Antler Creek area. The syncline plunges northwestward at 30 to 40 degrees, from the Cunningham contact at the keel to about Anderson Creek, but beyond plunges at 10 degrees. East of the Cunningham-Yankee Belle contact the plunge becomes gentle. The axis is deflected from the normal northwesterly trend to east-west at the eastern limit of mapping. This deflection is somewhat more marked than it is in the other major folds and, taken with the steep local plunge, may indicate that the rocks were shouldered aside by the Little River Stock.

South of the main synclinorium and west of the stock, an anticline, one of a number that form part of the Cunningham anticlinorium, is warped and truncated by the stock (*compare* sections I-I′ and J-J′). The fold plunges westward at 15 to 25 degrees, and the south limb is overturned to dip 75 degrees north.

The Cunningham anticlinorium becomes more widely exposed to the southeast than it is northwest of the Cariboo River, as successively more anticlinal folds are revealed. In the south these folds become more overturned, the anticlines having long, moderately dipping north limbs, sharp crests, and steep short overturned southern limbs. This pattern is most readily seen in the minor folds (*see* Plate XXI), but it is true also for the major ones, such as those just north of the Little River and its main tributary. Cleavage and schistosity are developed, even in the limestones, and bedding is commonly difficult to distinguish. The plunge is more moderate than that of the Black Stuart synclinorium or the folds south of the Cunningham anticlinorium, and ranges from 10 to 25 degrees westward.

The relationship of the low-grade rocks with the medium-grade metamorphic rocks south of Maeford Lake is not simple. Superficially, the sugary limestones south of Maeford Lake appear to overlie the schists and gneisses with a dip of about 40 degrees to the north. Bedding was not recognized with certainty, and cleavage in the fine-grained marbles was not very pronounced. The evidence seen did not indicate positively that the contact structure is an attenuated overturned anticline, as shown in the section, or whether it is a thrust fault. The stratigraphy and structure of the metamorphic rocks to the south do not rule out either possibility. The serial change in style of folding to the south is completely in harmony with either concept because the fold, if it exists, would be entirely similar in nature to a thrust. Recent mapping by Campbell (Maps 3 and 42, 1961) shows major faults in the valley of Maeford Lake, and also that the limestone south of the fault is part of the metamorphosed equivalent of the Snowshoe Formation.

The folds in the metamorphic rocks were examined very briefly. The main fold recognized is a very steeply plunging syncline with attendant dragfolds. The axial plane trends northwestward and dips about 75 degrees northeast. The plunge is about 45 degrees northwest near the central peak of Three Ladies Mountain but lessens both east and west. The rocks adjacent to the Cunningham limestones are poorly exposed and the structure is uncertain.

North of the Black Stuart synclinorium the main fold is the Kimball syncline. This fold is outlined at its plunging keel by the trace of the Cunningham Limestone-Yankee Belle contact. The structure is also clearly shown along the transverse ridge at Kimball Mountain west of Comet Creek. The Kimball fault truncates the south limb, and west of Kimball Mountain cuts across the axial plane. The syncline plunges westward at 45 degrees at the limestone contact in the east and at 20 degrees at Kimball Mountain. The fold is moderately compressed and slightly overturned to the south. Schistosity is only slightly developed. The north limb east of Comet Creek is complicated by a number of minor folds. The movement on the Kimball fault is not known, but it may be such that the Kimball syncline is a duplication of the Black Stuart syncline.

Folds northeast of the Kimball syncline are poorly exposed but are rather simple in outline, being mostly open and upright.

Slide Mountain Trough

The Slide Mountain Group is folded parallel to the Cariboo and Kaza Groups. The folds are generally open and upright and plunge gently northwestward, bedding commonly dips less than 55 degrees, and the rocks have no axial plane schistosity. Individual folds are not well defined, partly because much of the group consists of massive volcanic rocks and partly because of lack of outcrop in the Spectacle Lakes valley.

The trough appears to be formed of two synclines which merge southeast of Antler Creek. The southwestern syncline is well defined from Slide Mountain to Antler Creek, but the northeastern one is not well defined. The sequence of outcrops on the islands at the north end of Spectacle Lakes indicates that at the eastern side of the trough the basal conglomerate and crinoidal limestone dip to the west. The remainder of the eastern side is covered at the southeast end of the trough.

South of Mount Tinsdale the rocks dip gently northwestward. Sections A-A′, B-B′, C-C′, and E-E′ show parts of the Slide Mountain trough.

Within the lavas there are contorted layers of banded chert. The structure outlined by the pillow lava shows that the contortions are probably the result of penecontemporaneous deformation.

The alignment of the Slide Mountain trough with the Black Stuart syncline may or may not indicate a relationship between them. There is no apparent reason why the trough should be localized on the earlier fold, and although the sedimentary characteristics of the Guyet Formation favours the idea of localization of the trough by bounding faults, no such faults were detected. Regardless of its origin, the folding of the trough would certainly have accentuated pre-existing structures in the Black Stuart syncline.

Lanezi Arch

The Lanezi arch is the largest structural unit of the area. It exposes rocks of the Kaza Group in a broad whale-backed anticline 12 miles wide in the south and 8 miles wide in the north. The arch plunges northwest. Secondary folds, although fairly large, are minor in comparison. The anticlinal core of Kaza Group is flanked on the southwest by a series of gentle folds in the Cunningham Limestone and Isaac Formation. These are transitional to the isoclinal folds in the Cariboo Group to the southwest. On the northeast the arch is flanked by the Isaac Lake synclinorium, which is separated from it by a fault zone.

The over-all anticline is somewhat whale-backed, as is shown in the sections B-B′ to F-F′ of Figure 3. Dips are steepest adjacent to both flanks and range from 35 to 60 degrees. In general the flanks are not well exposed, and large secondary folds may be more numerous than is shown. The anticline plunges gently northwestward, as shown by the plunges of individual folds, and by the constriction of outcrop of the Kaza Group in the northwest. The only significant outcrops of Isaac Formation within the mountains of the park are near the northwestern end, and this tendency to hood over the Kaza Group continues to the northwest. Beyond the map-area, between Indianpoint and Haggen Creeks, Cunningham Limestone and Isaac Formation seem to completely cover the Kaza Group.

Comparison of section B-B′ with F-F′ shows the decrease in height of the crest of the fold. The amount of plunge, judged by comparing the sections, is 5 or 6 degrees. Plunges of many of the minor folds are 10 to as much as 20 degrees, with relatively few plunges to the southeast, except near Lanezi Lake. The difference between the indicated plunges and the average plunge may be the result of east- or south-dipping normal faults, as is the case in the adjacent Antler Creek area (Bull. No. 38, pp. 54–55) and the Isaac Lake synclinorium. Small normal faults in such a large group of similar rocks are not readily detected, nor are they easily distinguished from the numerous large joints.

The axis of the Lanezi arch is shown by a continuous line on the map (Fig. 2), but in reality it seems to have small offsets from one group of peaks to the next. The axis may follow a series of slightly in echelon minor folds, or it may be offset by transverse faults in the transverse valleys.

Minor folds range in size from the anticline on Kaza Mountain, which is some 3,000 feet from limb to limb, to microscopic crenulations. The larger individual folds do not have much continuity and cannot be traced positively more than a mile or two. An exception is the anticline on Kaza Mountain (*see* Plate VII), which may be traced from Lanezi Lake for about 6 miles. Most of the secondary folds are fairly gentle, but some near the flanks are quite sharp. The relationship between bedding, axial planes of folds, and schistosity are quite varied and are discussed later under schistosity.

The general structure of the arch is illustrated in the sections, Figure 3, and also in Plates V, VI, and VII, which show the central part of the arch and the Kaza anticline.

The generally simple picture is complicated by consideration of the schistosity, the metamorphism, the boundary of the northeast limb, and the minor folds in the northeastern corner of the park. The last named are folds in calcareous phyllites and limestones of the Isaac Formation and the micaceous quartzites and schists of the Kaza Group. Although the over-all relations appear normal, the details are not. In general the rocks northeast of the axis dip to the northeast and plunge northwestward, but the minor folds in the Isaac Formation trend 30 to 40 degrees more westerly than the main structure and are sharply overturned toward the north. Some dragfolds in the upper part of the Kaza Group show interbed movement opposite to that resulting from normal stratiform folding. These dragfolds are recumbent. The largest seen, on Mount Peever, is at least 200 feet in wave length. Both the overturned folds in the Isaac Formation and the recumbent reverse dragfolds indicate a movement of uppermost beds to the north or northeast, contrary to that involved in formation of the arch. The matter is considered again in regard to the Isaac Lake fault zone and imbricated synclinorium (pp. 56–57).

The folding on the southwestern limb of the arch is generally gentle, with dips commonly 10 to 30 degrees. The isolated outcrops in the wide valley of Spectacle Lakes do not permit a detailed appraisal of the structure. In general there appears to be a broad syncline with some gentle warps, flanked on the southwest by an anticline that toward the south becomes quite sharp. The structure appears to become more disturbed toward the south, and near Sandy Lake it appears likely that faulting is important, although little is known about it. The Kimball fault probably strikes along the foot of Turks Nose Mountain. Bedding attitudes suggest either an east-west fold or fault at Sandy Lake.

Isaac Lake Synclinorium

The Isaac Lake synclinorium flanks the Lanezi arch on the northwest. It is a complicated system of moderately tight folds and parallel normal and thrust faults that, considered as a whole, is compressive and synclinal. Its synclinal nature is apparent from structural and stratigraphic evidence. It is formed predominantly of lower Cariboo Group rocks in contrast to the Lanezi arch to the southwest and another anticlinorium to the northeast. As in all other parts of the map-area, individual folds plunge to the northwest. The southwestern boundary of the unit may be taken as Isaac Lake. The northeastern boundary is not as well defined, but lies roughly along the line of limestone peaks that extend southeast from North Star Mountain.

There is a close relationship between folds and strike faults in the synclinorium. Fold axes and fault lines are very nearly parallel, and most faults transect folds at points of major flexure. Furthermore, northerly or northeasterly normal faults cut both folds and strike faults. Hence, if the folds and strike faults are not synchronous, the one must have been influenced by the other, and both were completed before the cross-range normal faulting occurred.

The structures of the synclinorium are shown on the map, Figure 2, and by the sections (Fig. 3), especially C-C′, which shows the full width. Figures 8, 9, and 10 and Plates I, VIII, IX, and X show some details.

The southwestern " edge " of the synclorium is bordered by the Isaac Lake fault zone, which is a complicated zone not entirely understood. It will be considered in somewhat more detail (pp. 53–54). It is sufficient here to point out that the fault zone truncates units at the north end of Isaac Lake, and at the

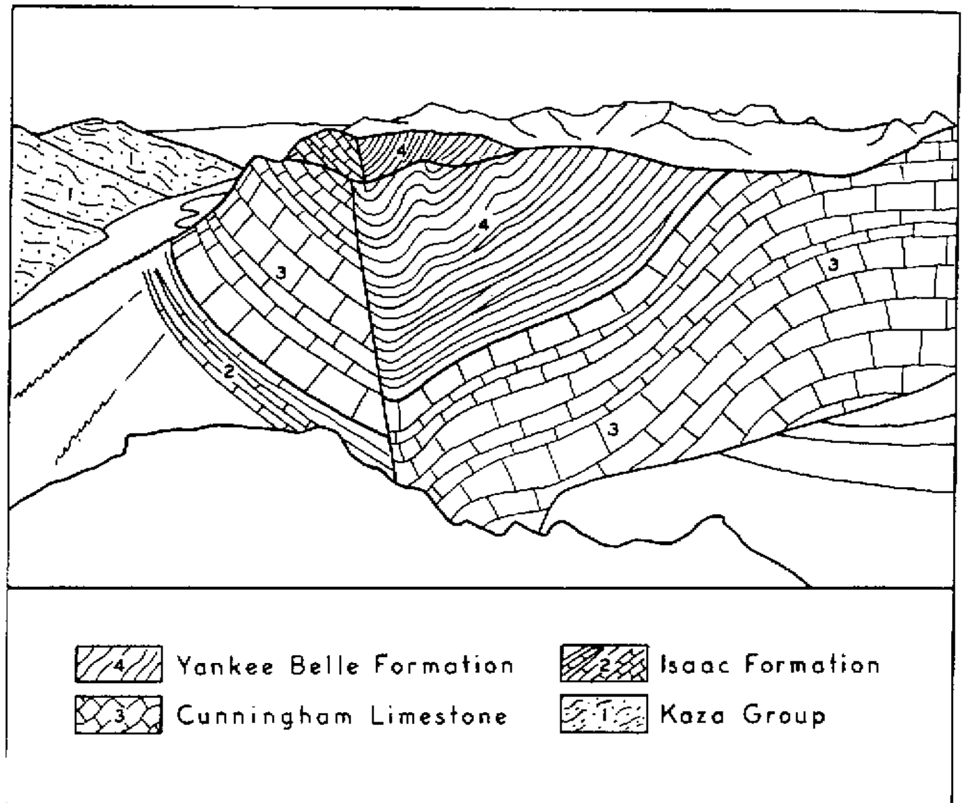

Figure 8. Geological diagram of Amos Bowman fault and syncline, from Plate X.

south end consists of two main strands. In appearance and in relation to the fold structure in the Isaac Formation, the faults resemble thrusts dipping about 60 degrees to the northeast, but as they appear to drop the units on the northeast there may be involved a complicated type of movement that will be considered later. Whatever the nature of the Isaac Lake fault zone, it is related to a group of secondary folds that are overturned to the southwest and rise to the northeast in a step-like manner. South of Betty Wendle Creek these folds are in Isaac Formation, and north of the creek are less sharply developed in Cunningham Limestone. Lower Betty Wendle Creek appears to mark the trace of an east-west fault because structures do not match across it.

South of Betty Wendle Creek the first major fold is a syncline which is overturned to the southwest and is broken near the axis by a normal fault that dips 75 to 82 degrees northeast and is very nearly coincident with the axial plane. As do other folds of the synclinorium, this syncline strikes north 40 to 50 degrees west and plunges 8 to 10 degrees northwestward. Cunningham Limestone on the west limb is faulted against Yankee Belle Formation on the other. The amount of both formations increases northwestward because of the plunge. Plate X shows the fault and fold viewed northward from Mount Amos Bowman, and Figure 8 shows a geological diagram of the same view. Plate I shows a distant view of the syncline.

The strata rise northeastward from this syncline to a gentle anticline and syncline, about which less is known. Cunningham Limestone forms the upper parts of the mountains carved from these folds. The limestone is cut off sharply on the northeast by a nearly vertical normal fault.

All these structures have their approximate equivalents north of lower Betty Wendle Creek. The rising series of minor folds occurs in Cunningham Limestone at the base of the mountains. Next on the northeast is the overturned syncline, but if this is the continuation of the one to the southeast, it is more complex and the fault at the axial plane is not everywhere evident. The continuing northwest plunge is evident in the younger rocks involved in the folds, the core being filled with Yanks Peak Quartzite. At section C-C′ the syncline is complicated by two flanking synclines and by intense dragfolding, especially in the Yankee Belle Formation. The axial fault has reverse movement, the opposite to that of the fault to the south. The east limb of the combined syncline dips southwestward at 80 degrees and the west limb at 30 degrees northeast. Plunges of dragfolds vary from 5 to 15 degrees to the northwest. The syncline is broken by northerly and northeasterly faults which clearly lift the western block. The width of the Yankee Belle-filled portion of the syncline is progressively reduced in each successive block to the north, and on Wolverine Mountain the projected keel of Yankee Belle Formation just misses the surface of the slope.

The next anticline to the northeast is considerably sharper than its equivalent south of Betty Wendle Creek, as can be seen by comparing section C-C′ with D-D′. The west limb dips southwestward at 75 degrees and the east at 20 to 55 degrees northeast. The axis is torn by a small fault near the crest and is cut off sharply by a steep normal fault which is probably the same as the fault that cuts off the limestone south of Betty Wendle Creek. The fault is coincident with a syncline. Plate VIII shows an oblique view of these structures from the northwest, and Figure 9 shows a geological diagram of the same view.

From this fault and syncline northeastward to the Betty Wendle Creek thrust there is a monoclinal succession of Yanks Peak Quartzite, Yankee Belle Formation, and Cunningham Limestone, all dipping 40 to 65 degrees southwestward.

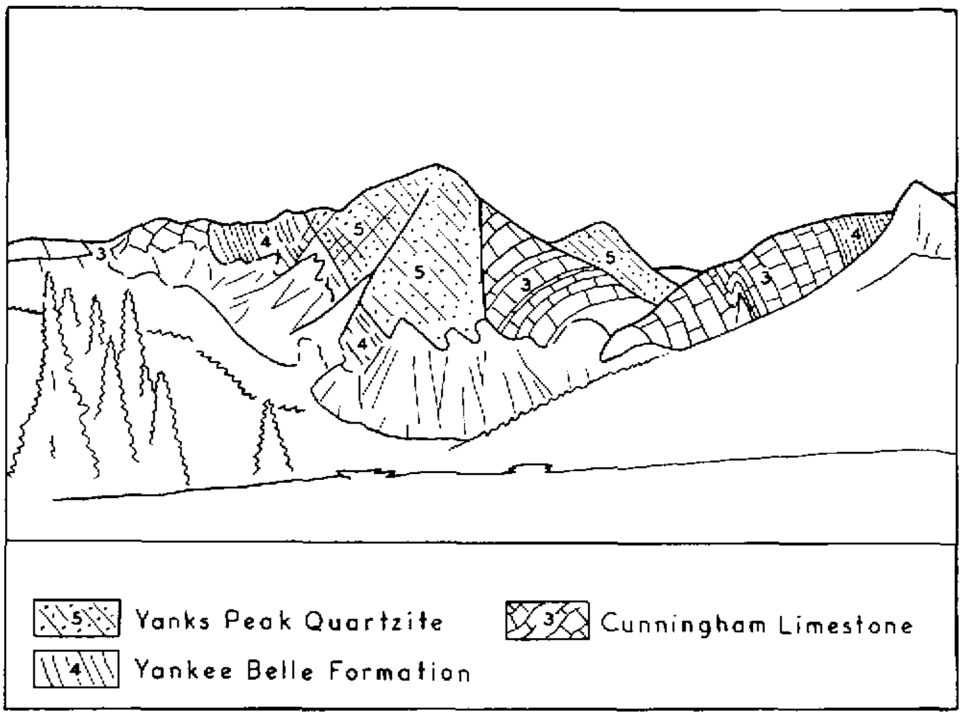

Figure 9. Geological diagram of structures at the head of the Goat River, from Plate VIII.

The Betty Wendle thrust dips northeastward at 48 degrees. The east block brings up a nose of Kaza rocks and a succession of secondary folds descending to the northeast and outlined by the limestones in the Isaac Formation and the Isaac-Kaza contact. The axial planes of these secondary folds dip from 60 to 75 degrees northeast.

The easternmost fold of the Isaac Lake synclinorium is a faulted syncline similar to the first one in many respects. It trends southeast from North Star Mountain and the tops of the next three peaks to the southeast. The syncline appears abnormal, inasmuch as the schistosity indicates an axial plane dipping about 65 to 70 degrees northeast, but the southwest limb dips 60 degrees northeast and the northeast limb dips 20 to 25 degrees southwest. The fault dips northeast at 75 degrees and is normal. Plate IX shows an aerial view of these structures from the south, and Figure 10 shows a geological diagram of the same view.

Beyond the Isaac Lake synclinorium to the northeast a series of folds rises to a culmination east of the Milk River. These folds are formed in Isaac Formation and Kaza Group rocks east of the map-area, but north of the Goat River are formed in the overlying Cunningham Limestone.

SCHISTOSITY

The development of schistosity is variable from one locality to another or one rock type to another. The localities with the most intense schistosity are the isoclinally folded belt of the Cariboo Group, the Lanezi arch, and the southwestern part of the Isaac Lake synclinorium. The areas of least schistosity are the Slide Mountain trough, where there is essentially none, and the gentle folds flanking the Lanezi arch to the southwest, where limestone is the chief rock exposed and schistosity is slight. In several areas there is a progressive development of schistosity. For example, from the Matthew River valley toward the southeast there is a progressive increase in axial plane schistosity coincident with increased compression of the folds in that direction. There is a similar increase in the Isaac Lake synclinorium toward the southwest and the area of tighter folding. Characteristically, the fine-grained clastic rocks have the highest development of schistosity in any one locality. In the coarser clastic rocks the greater the quantity of matrix or the less the sorting, the more intense the schistosity. Pure carbonate rocks are not readily rendered schistose, but they do become remarkably schistose at numerous localities, as for example the tight folds in the southwestern part of the Isaac Lake synclinorium or in the Cunningham anticlinorium.

Schistosity in the Kaza rocks of the Lanezi arch is intense and shows a sequential change in its relationship to bedding. In all other parts of the map-area, schistosity is subparallel to the fold axes. In the Lanezi arch, schistosity is parallel to axial planes in some of the larger secondary folds, and on the flanks of the arch is steep and hence subparallel to the main axial plane. However, there is a progressive change toward bedding schistosity toward the main axis, where both the bedding and the intense schistosity are essentially flat. On the flanks the schistosity dips 65 degrees or more away from the axis; secondary folds are either upright or slightly overturned toward the axis, and the schistosity is commonly parallel to their axial planes. However, on approaching the axis, especially from the southwest, the schistosity dips progressively less, and more nearly parallels bedding until, near the axis, the two are parallel and essentially flat. This sequence of change is first apparent in the finer-grained rocks, and bedding schistosity is reached in these farther away from the axis than in the coarser rocks. Schistosity surfaces may be fairly planar on the flanks and in the axial region, but between they are commonly warped; coarse beds have sigmoidal shapes in section, and finer beds have crenulated shapes. Both types of warped planes indicate continued movement on bedding planes with tectonic transport toward the axis greatest in the upper beds. The development of all these features is asymmetric, being much greater southwest of the axis. The recumbent reverse dragfolds near Mount Peever may be related to the greater development of interbed slip southwest of the axis. Plates XV to XVIII illustrate various phases of the schistosity discussed above.

FAULT SYSTEMS

Faults in the Cariboo River area are important, and some involve large displacements. Many form part of extensive fault systems. The main systems are strike faults in the Isaac Lake imbricated synclinorium, northerly and northeasterly transverse normal faults, and minor faults about the Little River Stock. The Antler Creek fault belongs to the northerly system and the Isaac Lake fault zone to the strike fault systems, although each has characteristics not common to other faults in the system. Major faults that are not part of a known system include the Kimball fault, the possible Little River fault zone, and a possible fault in the lower Cariboo River valley.

STRIKE FAULTS

The oldest system is that of the strike faults of the Isaac Lake synclinorium. These faults have been treated briefly in the discussion of the folding of the synclinorium (pp. 48–49) because they appear to have been formed at a late stage during the folding. They strike parallel to fold axes, and most of them occur at points of major flexure. They are older than the northerly and northeasterly striking faults. The strike faults include steep reverse and normal faults, a thrust fault of moderate dip, and the complicated Isaac Lake fault zone. The latter zone bounds the system on the southwest, and the easternmost large fault of the system as mapped is on the southwest side of North Star Mountain. The faults will be described from northeast to southwest.

The North Star fault is a normal fault that strikes about north 50 degrees west and dips about 75 degrees northeast on the average. It cuts the top of the south peak of North Star Mountain, where it is very evident. This is shown on Plate IX, which is taken from the air looking north. Figure 10 is a geological diagram of the same view. Vertical movement is not easily assessed, possibly because of some lateral separation, but the east block appears to have been dropped about 1,000 to 1,500 feet. This fault has not been continuously traced to the southeast. It does not show well in the Isaac Formation phyllites and is probably cut by a northeasterly fault at the head of the central branch of North Star Creek.

The next fault to the southwest is the Betty Wendle thrust, which is concealed by alluvium to the south, but from Betty Wendle Creek can be traced to the Goat River and on to Wolverine Creek. It strikes uniformly about north 55 degrees west and dips 48 degrees northeastward. It raises a rolled nose of Kaza and Isaac Formations over Cunningham Limestone and has a thrust separation of 2,000 feet or somewhat more. The thrust is shown in sections B-B′ and C-C′. The steep northwest slope of the mountains of the southwest block north of Betty Wendle Creek represents the actual fault plane from which the upper plate has been eroded.

The next fault to the southwest has no convenient geographic name. It is a nearly vertical fault striking about north 45 degrees west and dipping 80 degrees or more to the northeast. The northeast block appears to be dropped about 3,500 feet. The fault can be traced from near Wolverine Mountain southeast to Betty Wendle Creek, where it seems to be offset to the east. The fault is shown on sections B-B′, C-C′, and D-D′. Plate VIII and Figure 9 both show an oblique view toward the

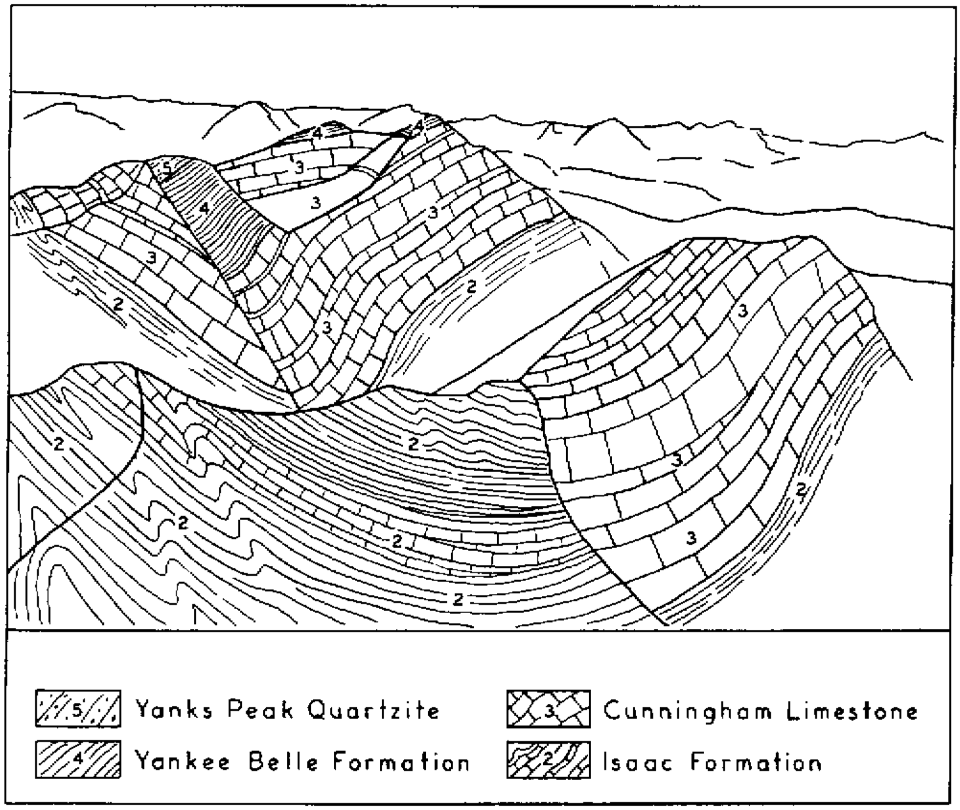

Figure 10. Geological diagram of North Star Mountain, from Plate IX.

east; the fault can be seen to have no expression on the upper slope of the mountain even though there is a major difference in rock character and attitude across the fault plane.

The next major fault to the southwest is the Amos Bowman fault, which strikes about north 45 degrees west on the average and dips 75 to 82 degrees northeast. It is a normal fault that appears to drop the eastern block as much as 2,000 feet. The fault can be traced from the delta of Betty Wendle Creek southward to a high valley in the southeast that is parallel in trend. This fault is shown in sections D-D′, E-E′, and F-F′ and in Plate X and Figure 8. The latter is a geological diagram of the plate. The Amos Bowman fault has not been identified north of Betty Wendle Creek. A lesser fault near the axis of the syncline north of the creek is a reverse fault and is too far to the east to be its equivalent.

The westernmost of the series is the Isaac Lake fault zone, which is a complicated zone not fully understood. The fault has two strands south of Betty Wendle Creek. The zone is entirely under the lake or covered by alluvium north of the creek. There is structural and stratigraphic evidence of a fault at the mouth of Wolverine River, but the fault is not exposed. The fault zone is well exposed along the avalanche chutes on the slopes of Isaac Lake south of Betty Wendle Creek, although it is difficult to recognize in ordinary calcareous phyllites of the Isaac Formation. Where the rocks of the zone are water-washed, they are seen to be very heterogeneous, ranging from mylonitic or more coarsely comminuted rock to rock containing attenuated, torn, and isolated isoclinal folds. In much of the zone, bedding is not recognized, except in fragments, but there is a marked secondary foliation and sometimes a lineation. Plate XXII illustrates comminuted calcareous phyllite and limestone of the fault. The complete zone is about one-half mile wide, within which there are two strands of greatest intensity. These strands appear to dip about 60 degrees northeast, and the over-all strike is between north 40 to 45 degrees west. The fault strands are related to overturned folds which commonly have overturned limbs on the western side and relatively flat upright limbs on the eastern side. Above and to the northeast of the two main faults, a similar pattern of folding affects the Isaac Formation. The fold-fault pattern suggests a high angle thrust, but the net separation appears to let the eastern block down.

The present information is insufficient to determine the nature or movement of the Isaac Lake faults or the relation of the faults to the flanking block of Kaza rocks in the arch. The wide zone adjacent to the faults covered by lake, drift, or alluvium seriously limits observation in the critical area. Several explanations for the presently known facts are possible. There may have been two or more periods of faulting with different types of movement, a single complex movement, or normal faulting on an undetected fault perhaps under the lake. However, it seems possible that some small thrusts subparallel with bedding in the flank of the arch might form to compensate for downwarping of the eastern flank, of which possibility there is some evidence.

North and Northeasterly Fault Systems

A large number of faults striking northward and northeastward were believed in the adjoining Antler Creek area to be related members of a single stress system. They appear to dip steeply to the east or southeast and drop the eastern or southeastern side (*see* Bull. No. 38, pp. 53–55). Most of them are relatively small. The Antler Creek fault is the only very large one, and is the only one that has appreciable wrench (strike-slip) separation. In the Cariboo River area less evidence is available concerning the faults with the same two orientations.

Few of these faults are recognized in the Kaza Group because the separation is not evident in such uniform stratigraphy. Doubtless they are present and may account for the discrepancy between the plunge calculated from projecting the base of the Isaac Formation and that indicated by the plunge of minor folds. There are indications that the valleys of Huckey Creek (and lower Betty Wendle Creek), Harold Creek, and possibly the upper Bowron River are eroded in valleys guided by northeasterly faults. The main parts of these valleys are covered with alluvium, but in the lower part of Harold Creek and east of the bend of Betty Wendle Creek there are definite faults. Separations on the latter fault indicate the southeast block has been dropped and probably moved left.

In the Isaac Lake synclinorium north of Betty Wendle Creek there are several northeasterly faults and one northerly fault. Little is known about these, except their approximate position and that they all seem to drop the southeastern block. One other small northerly fault with similar separation occurs north of McLeary Lake.

A marked breccia zone in the Cunningham Limestone has a northerly trend on Iltzul Ridge, and its southerly projection is aligned with a prominent lineal feature that is believed to be a large northerly fault.

Northerly and northeasterly faults in the Slide Mountain-Mount Murray Range were considered briefly in the Antler Creek bulletin. A group of faults of similar orientation and slight movement occur on Mount Tinsdale.

In the Quesnel Highlands the northerly faults northwest of the Cariboo River were described by Holland (Bull. No. 34, pp. 33–34). Southeast of the river they are neither numerous nor large. One was observed on Green Cone and south of it. Others probably escaped notice.

The Antler Creek fault is the only large northerly fault (Bull. No. 38, pp. 55–56). It can be traced for about 25 miles, and in the Antler Creek area has a right-hand offset of 9,000 feet. A similar amount of offset is indicated by the juxtaposition of Cunningham Limestone and pillow lavas of the Slide Mountain Group south of Bowron Lake. Minor faulting and shearing related to this fault are well displayed on the islands at the north end of Spectacle Lakes. Elsewhere the course of the fault is covered by wide areas of alluvium. A fault of similar orientation to the Antler Creek fault probably exists in the valley of the lower Cariboo River, but little is known about it.

A group of small faults or large joints occurs in the southern part of the axial zone of the Lanezi arch. These are traceable up to 3 miles individually, but appear to produce only slight offset. They strike parallel to the axial plane, about north 35 degrees west, and dip nearly vertically.

Faults near the Little River Stock

A group of small faults exists near the stock on upper Little River. Two of these are shown on the map. Other smaller ones were seen on Anderson Ridge, many of them with uncommon orientations. This group of small faults may be related to the emplacement of the stock.

Unclassified Faults

This group includes faults that do not fit into any general class. Included are a number of small faults oriented in the northwest quadrant and two large ones, the Kimball fault and the Little River fault.

The Kimball fault was first mapped by Lang (1940). It is well exposed on Kimball Ridge, but to the northwest and southeast its course is conjectural. Its strike varies from north 45 degrees west in the northwest to north 75 degrees west in the southeast. The deflection of strike from southeast to east is similar to that of the enclosing rocks and may reflect a similar cause, possibly related to the intrusion of the Little River Stock. The dip is about 80 degrees northeastward and the separation is normal, the northeast block having apparently moved down some 2,000 to 3,000 feet. A possibility exists of large right-hand strike-slip movement. The northern trace of the fault is not known, but it seems likely that it passes northeast of Turks Nose Mountain. To the east it may pass into the valley of Connection Creek.

The Little River fault, if it exists, is a thrust that carries Cunningham Limestone and Yankee Belle Formation over more metamorphosed upper Cariboo Group rocks near Three Ladies Mountain. The trace of the fault would be similar to that of the main branch of the Little River from Macford Lake west, hence about north 70 to 80 degrees west. The dip would be about 40 degrees northward. The discussion on page 46 regarding the folding of this area mentions briefly that the contact between the fine marbles of the Cunningham Limestone and the gneisses and schist of Three Ladies Mountain may be either an attenuated overturned fold or a thrust. The character of the folding associated with it would support either view. Since the present mapping was done, R. B. Campbell in mapping the Quesnel Lake sheet has concluded that the contact is a fault (Map 3-1961).

METAMORPHISM

Metamorphism has substantially affected only the Kaza and Cariboo Groups. The Slide Mountain rocks are well lithified and compacted, but only adjacent to some intrusive bodies do they show any sign of metamorphism. Low-grade regional metamorphism has affected all of the Kaza and Cariboo Groups, and locally higher-grade metamorphism has affected the Cariboo Group. Most of the Kaza rocks have been raised to the biotite-chlorite subfacies of the greenschist facies, whereas most of the Cariboo rocks only to the muscovite-chlorite subfacies. The Kaza rocks have coarser mica than the Cariboo rocks; the former are schists and the latter phyllites. Knotted schists are characteristic of the Kaza Group but are distributed mainly in the lower part, except near the western end of Lanezi Lake, where they extend well up in the group. Knots of chlorite are most widely distributed, but knots of biotite are most abundant. Almandine garnet is relatively rare. Microscopically it can be seen that the sequence of development of knots progressed from chlorite to almandine (*see* p. 17). The Cariboo rocks, except in the Kimball Creek area, are in the muscovite-chlorite subfacies. A few of the uppermost Kaza rocks are in the same subfacies. There appears to be a general relation between depth of burial and degree of metamorphism.

Higher-grade dynamo-thermal metamorphism is locally impressed on the Cariboo rocks in the Kimball Creek area. The grade increases from Lanezi Lake southward. The increase is marked south of Maeford Lake, where the rocks are gneisses and schists of the amphibolite facies with assemblages such as quartz-muscovite-microcline-clinozoisite-plagioclase or hornblende-quartz-biotite-oligoclase-almandine. Metamorphism has obscured the original stratigraphy in the vicinity of Three Ladies Mountain, but the rocks were originally a mixture of coarse and fine clastic rocks in which thin beds of marble or calc-silicate rocks are now found. Campbell (Map 3-1961) has mapped these as Snowshoe Formation and comments that the higher-grade metamorphic belt extends southward from Little River to Quesnel Lake, and that it contains many small plutons, dykes, and sills of muscovite granite and pegmatite. About the Little River Stock the rocks are in addition hornfelsic for at most a few tens of feet from the stock.

The age of the regional metamorphism is unknown, but it is probably the same as that of the period of intense folding which White has named the Cariboo orogeny (White, 1959) and is post-Ordovician and pre-Mississippian in age. However, the time of the extrusion of the pillow lavas and folding of the Slide Mountain Group may also have been times of recrystallization in the older rocks. The metamorphism of the belt south of Little River is clearly associated with the emplacement of the granitic rocks, and may be much younger than part or all of the regional metamorphism.

COMMENTARY

In the over-all view the structure of the Lanezi arch and Isaac Lake synclinorium seems relatively simple, but there are still some perplexing problems. Some of these are related to the varied development of schistosity, but others are concerned with the fundamental structure and how it developed.

If the folding and strike faulting occurred at separate times, the structure at the termination of the folding would have been a monoclinal series of folds descending toward the southwest. The arch, if it existed, would have been just a broad terrace in the monoclinal series of folds descending from a culmination east of the Milk River and continuing to the southwest to the limit of mapping by Holland and the writer. However, the pattern was never that simple because the evidence for the synchronous or nearly synchronous development of folds and strike faults is strong. No monoclinal series of folds was developed, but rather two culminating anticlinoria with the Isaac Lake synclinorium between.

Any concept of the deformation must account for the following facts: (1) The northeasterly overturned folds in the Isaac Formation in the northeast part of the park, (2) the recumbent " reverse " dragfolds in the same vicinity, (3) the initial development of the Isaac Lake fault zone, (4) the series of rising overturned folds from this fault zone, (5) the decrease in overturning to the southwest within the synclinorium.

After initial development of the Lanezi arch, the Milk River anticlinorium, and the Isaac Lake synclinorium, continued compression brought about some changes in the character of the folding. The compression must have resulted in preferential movement in the upper part of the Kaza Group and Isaac Formation in the Lanezi arch with movement on the bedded schistosity. This was combined with a squeezing of the synclinorium and a resulting tendency to upward wedging. As these movements continued, possibly dragfolds that had developed southwest of the axis were pushed beyond the axis and other reverse recumbent drags were formed. A downwarping on the east side of the axis and a wedging in the synclinorium would produce structures that resembled overthrusting from the east, but the net effect might be the deepening of the syncline. The Isaac Lake fault zone then developed, but the mylonitic development on some of the fault planes may have resulted from later movement.

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1963

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Plate I. Isaac Lake from the southeast. Faulted syncline of Cunningham Limestone on Mount Amos Bowman to the right. Interbedded limestone and phyllite of Isaac Formation in foreground.

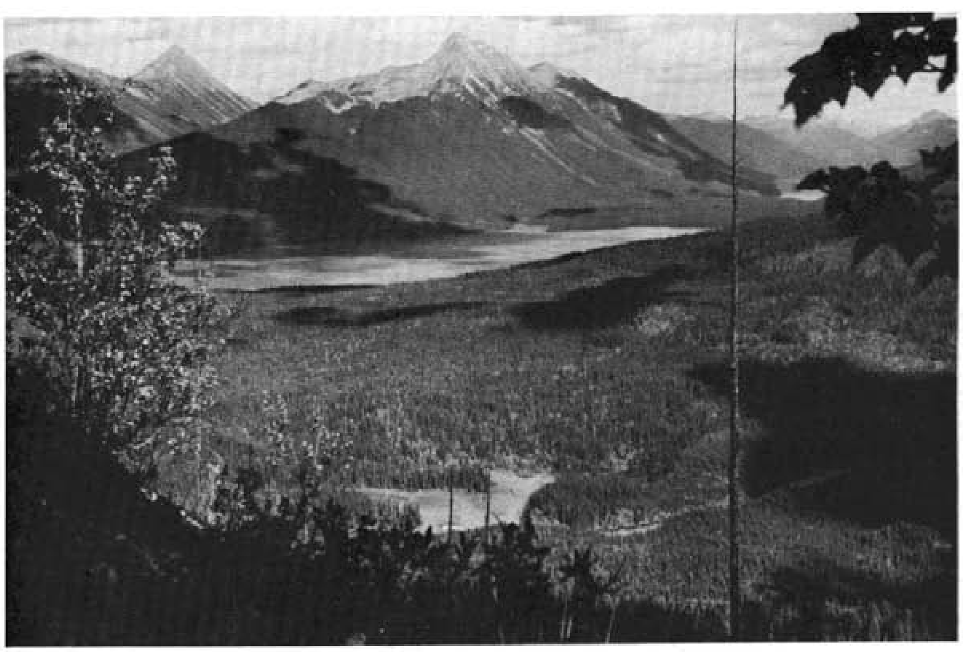


Plate II. Kaza Mountain and Sandy Lake from the southwest.

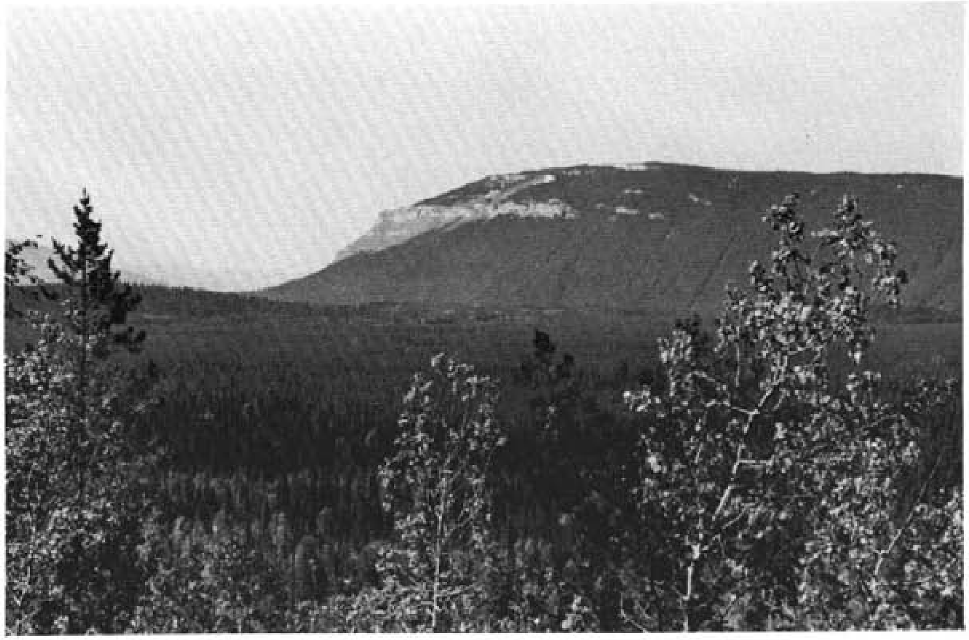


Plate III. Cunningham Limestone on Turks Nose Mountain from the northeast. *Girvanella* limestone forms most prominent member. Outwash plain west of Sandy Lake in foreground.

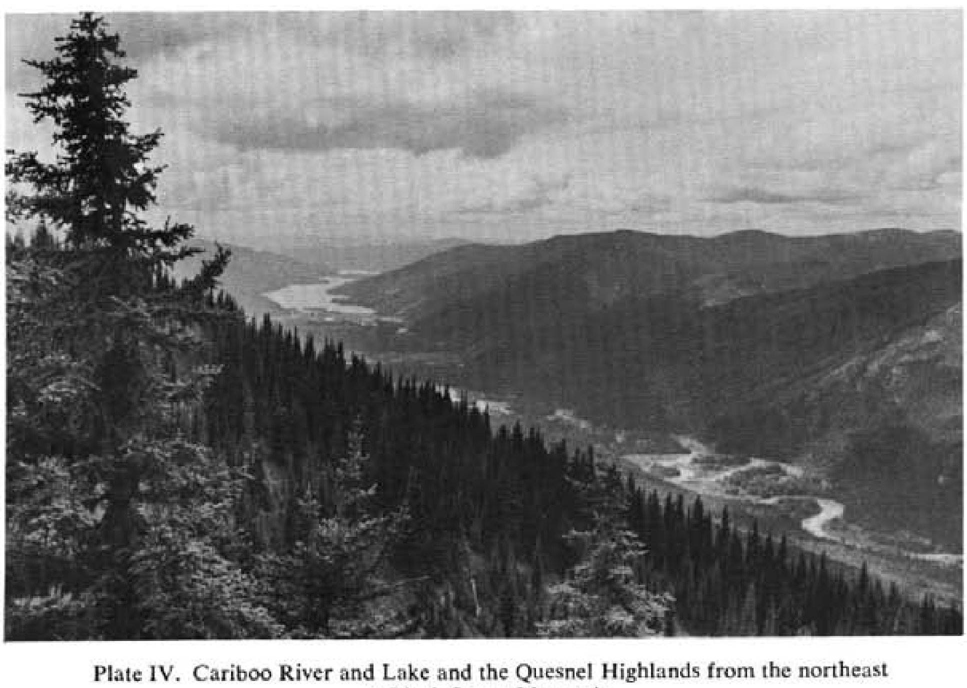


Plate IV. Cariboo River and Lake and the Quesnel Highlands from the northeast at Black Stuart Mountain.

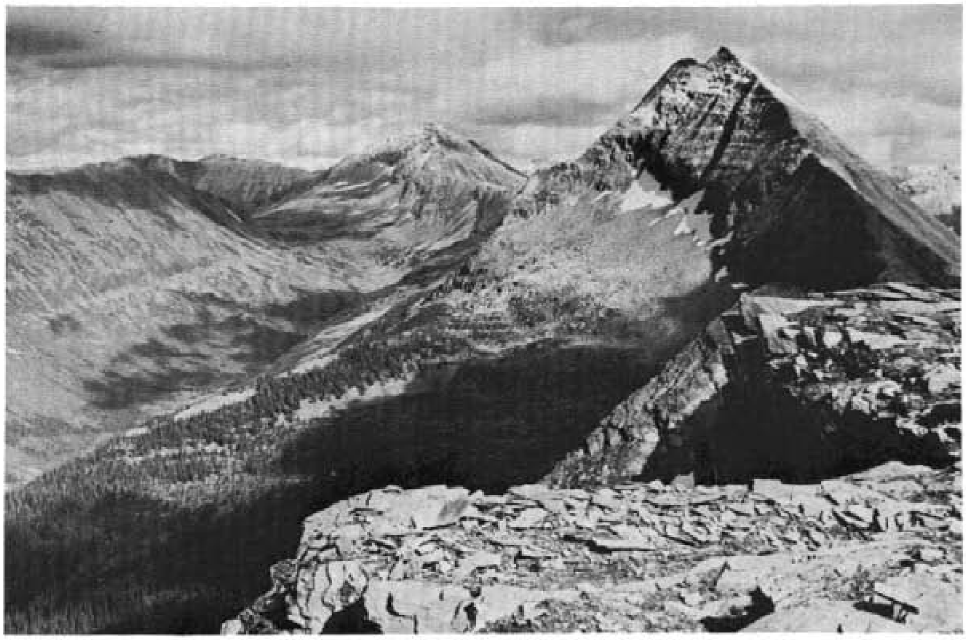


Plate V. Unnamed peaks of the Mowdish Group in Bowron Lake Park underlain by Kaza Group, showing its well-bedded character on the right peak and its well-cleaved character in the foreground. Note fringing line in valley.

Plate VI. View north from Kaza Mountain, showing 3,000 feet of Kaza Group in gentle folds in the central part of the Lanezi arch.

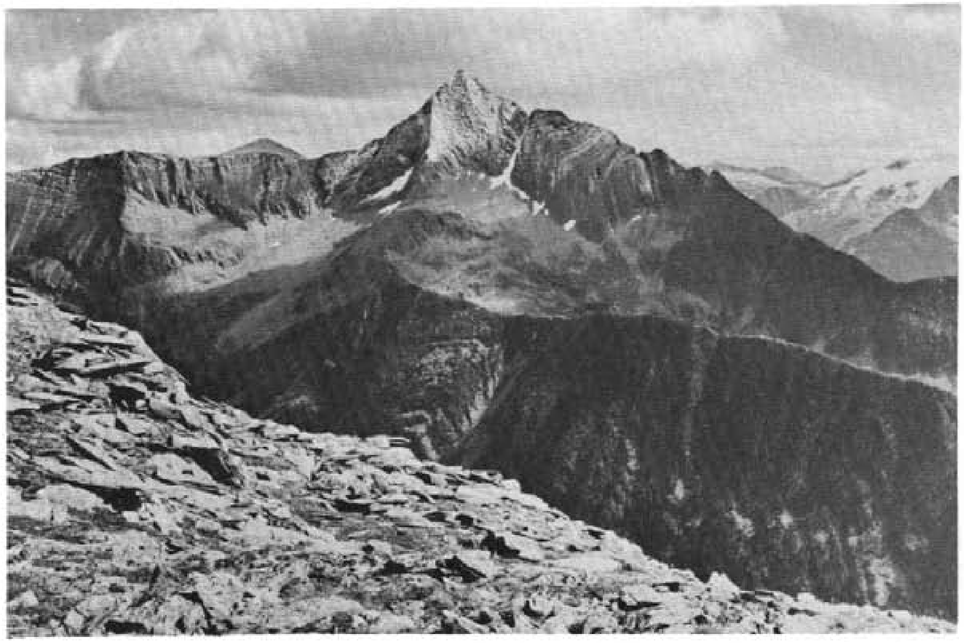


Plate VII. Kaza Mountain from the west, showing a subsidiary anticline of Lanezi arch.

Plate VIII. Unnamed peak at the head of the Goat River, from the west. An anticline of Cunningham Limestone on the right is faulted against west-dipping Yanks Peak quartzite. *See* geological diagram on page 50.

Plate IX. North Star Mountain from the south, showing the fault crossing its southern peak and the saddle in the foreground. *See* geological diagram on page 53.

Plate X. Amos Bowman faulted syncline viewed northwest from Mount Amos Bowman. *See* geological diagram on page 49.

Plate XI.

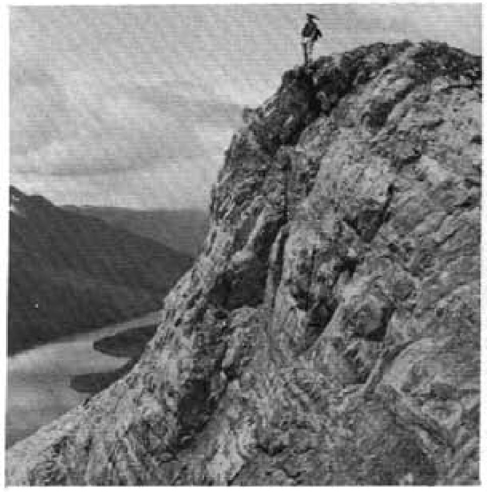


Plate XII.

Plate XIII.

Plate XIV.

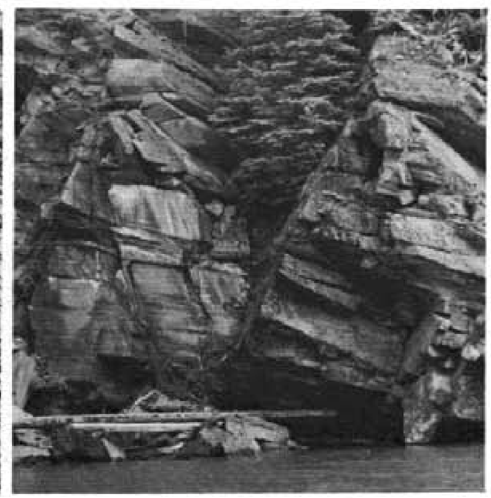


Plate XI. Cunningham Limestone on ridge northeast of Isaac Lake.

Plate XII. Calcareous phyllites of the Isaac Formation in avalanche chute on Mount Amos Bowman. Bedding nearly flat; schistosity dips right (northeast) at 45 degrees.

Plate XIII. Interbedded Kaza micaceous quartzite and schist on Kaza Mountain. Photograph taken normal to the schistosity.

Plate XIV. Fine micaceous quartzite of the lower part of the Kaza Group near the mouth of the Turner River on Lanezi Lake in the central part of the arch.

Plate XV.

Plate XVI.

Plate XVII.

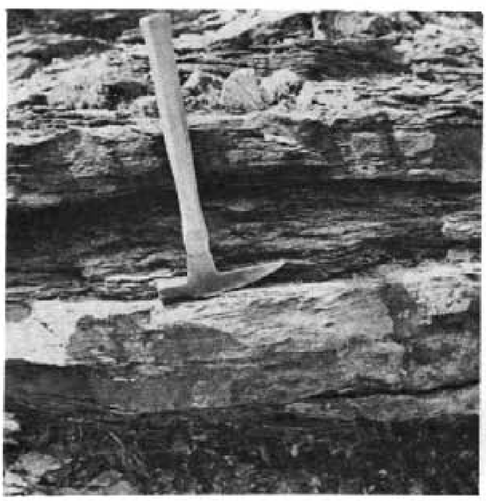


Plate XVIII.

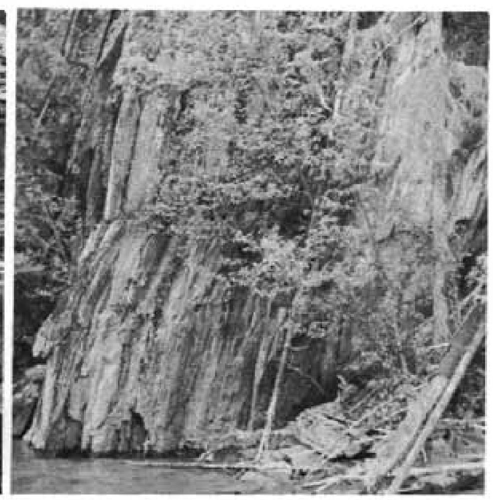


Plate XV. Kaza micaceous quartzite in the western Mowdish Peaks. Bedding dips gently southwest (left); slightly sigmoidal cleavage nearly vertical.

Plate XVI. Cleavage and schistosity at a small angle to bedding in Kaza micaceous quartzites on the Tediko Peaks west of the Lanezi axis. Finer beds above have bedding schistosity.

Plate XVII. Cleavage and schistosity parallel to flat bedding in Kaza micaceous quartzites of the axial zone of the Lanezi arch, Tediko Peaks.

Plate XVIII. Thickly bedded Kaza micaceous quartzites at the western end of Lanezi Lake. Bedding dips gently west (left); schistosity and cleavage nearly vertical.

Plate XIX.

Plate XX.

Plate XXI.

Plate XXII.

Plate XIX. Isaac Formation phyllites northeast of Isaac Lake, showing bedding and gently northeast-dipping steeper cleavage and schistosity.

Plate XX. Calcareous lenses in fine Yankee Belle quartzites on Mount Amos Bowman.

Plate XXI. Minor folds in thinly bedded limestone near Maeford Lake, showing gentle north limbs and steep overturned south limbs.

Plate XXII. Mylonitic calcareous phyllites of Isaac Formation in the Isaac Lake fault zone. Details partly obscured by loose rubble.

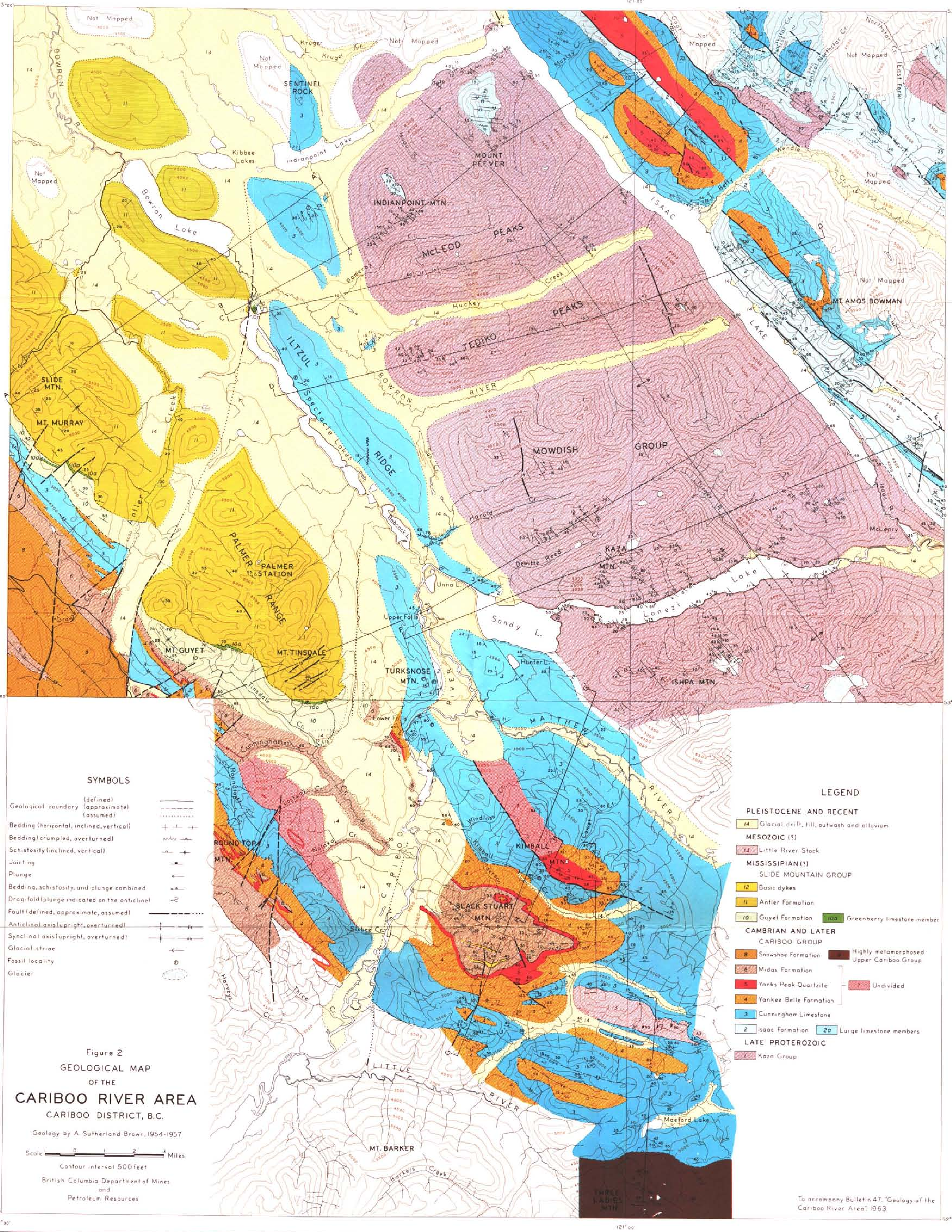
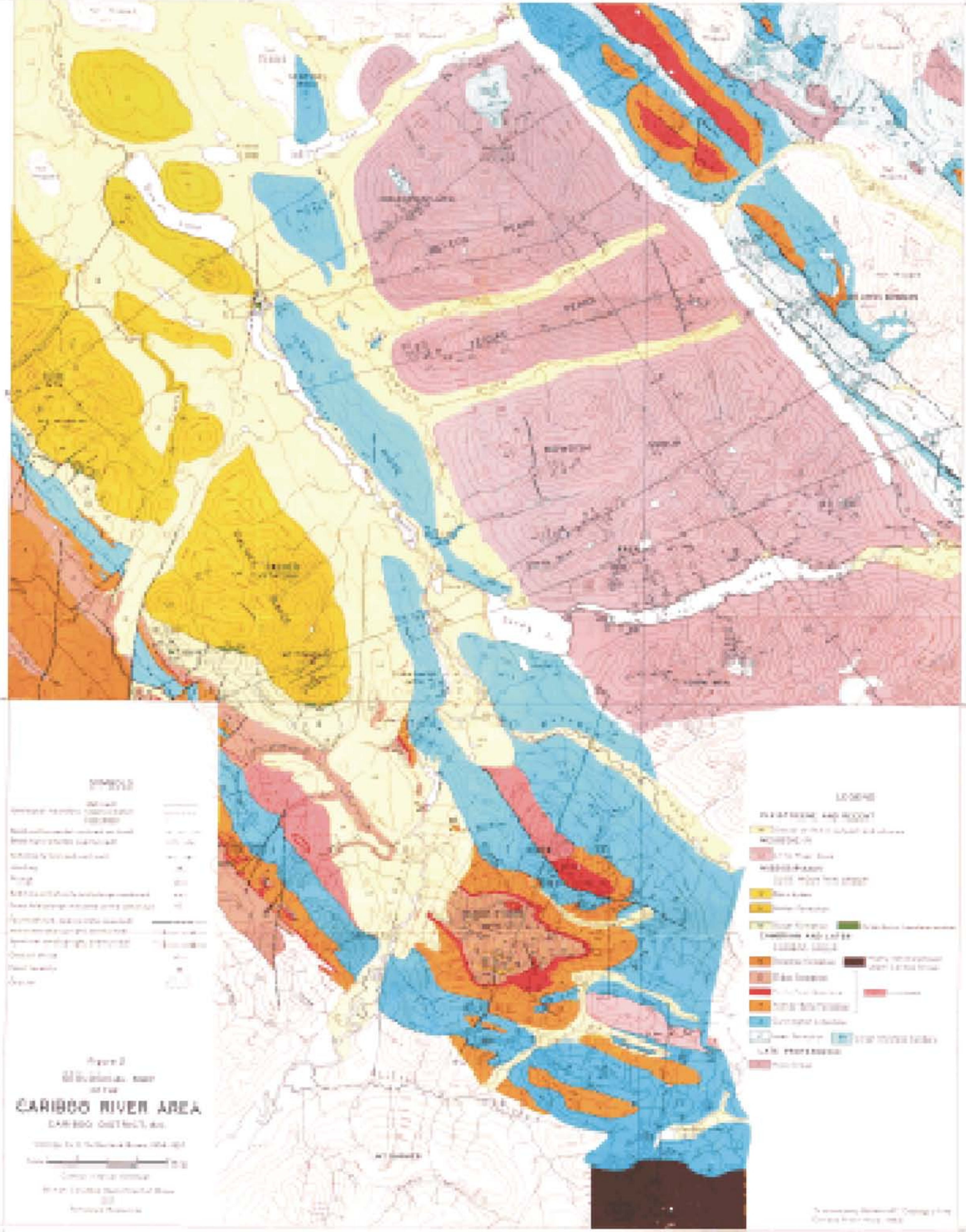


Figure 2
GEOLOGICAL MAP
OF THE
CARIBOO RIVER AREA
CARIBOO DISTRICT, B.C.
Geology by A. Sutherland Brown, 1954-1957
Scale 1 0 1 2 3 Miles
Contour interval 500 feet
British Columbia Department of Mines and Petroleum Resources
SYMBOLS
Geological boundary (defined) (approximate) (assumed)
Bedding (horizontal, inclined, vertical)
Bedding (crumpled, overturned)
Schistosity (inclined, vertical)
Jointing
Plunge
Bedding, schistosity, and plunge combined
Drag-fold (plunge indicated on the anticline)
Fault (defined, approximate, assumed)
Anticlinal axis (upright, overturned)
Synclinal axis (upright, overturned)
Glacial striae
Fossil locality
Glacier
LEGEND
PLEISTOCENE AND RECENT
14 Glacial drift, till, outwash and alluvium
MESOZOIC (?)
13 Little River Stock
MISSISSIPIAN (?)
SLIDE MOUNTAIN GROUP
12 Basic dykes
11 Antler Formation
10 Guyet Formation
10a Greenberry limestone member
CAMBRIAN AND LATER
CARIBOO GROUP
8 Snowshoe Formation
9 Highly metamorphosed Upper Cariboo Group
6 Midas Formation
5 Yanks Peak Quartzite
7 Undivided
4 Yankee Belle Formation
3 Cunningham Limestone
2 Isaac Formation
2a Large limestone members
LATE PROTEROZOIC
1 Kaza Group
To accompany Bulletin 47, "Geology of the Cariboo River Area," 1963
MOUNT PEEVER
INDIANPOINT MTN.
MCLEOD PEAKS
TEDIKO PEAKS
MOWDISH GROUP
ILTZUL RIDGE
SLIDE MTN.
MT. MURRAY
PALMER RANGE
PALMER STATION
MT. GUYET
MT. TINSDALE
TURKSNOSE MTN.
KAZA MTN.
ISHPA MTN.
MT. AMOS BOWMAN
KIMBALL MTN.
BLACK STUART MTN.
ROUND TOP MTN.
MT. BARKER
THREE LADIES MTN.
SENTINEL ROCK
Bowron Lake
Isaac Lake
Lanezi Lake
Sandy L.
Spectacle Lakes
Indianpoint Lake
Kibbee Lakes
Unna L.
Hunter L.
McCleary L.
Maeford Lake
BOWRON RIVER
CARIBOO RIVER
MATTHEW RIVER
LITTLE RIVER
Not Mapped


SYMBOLS
LEGEND
CARIBOO RIVER AREA

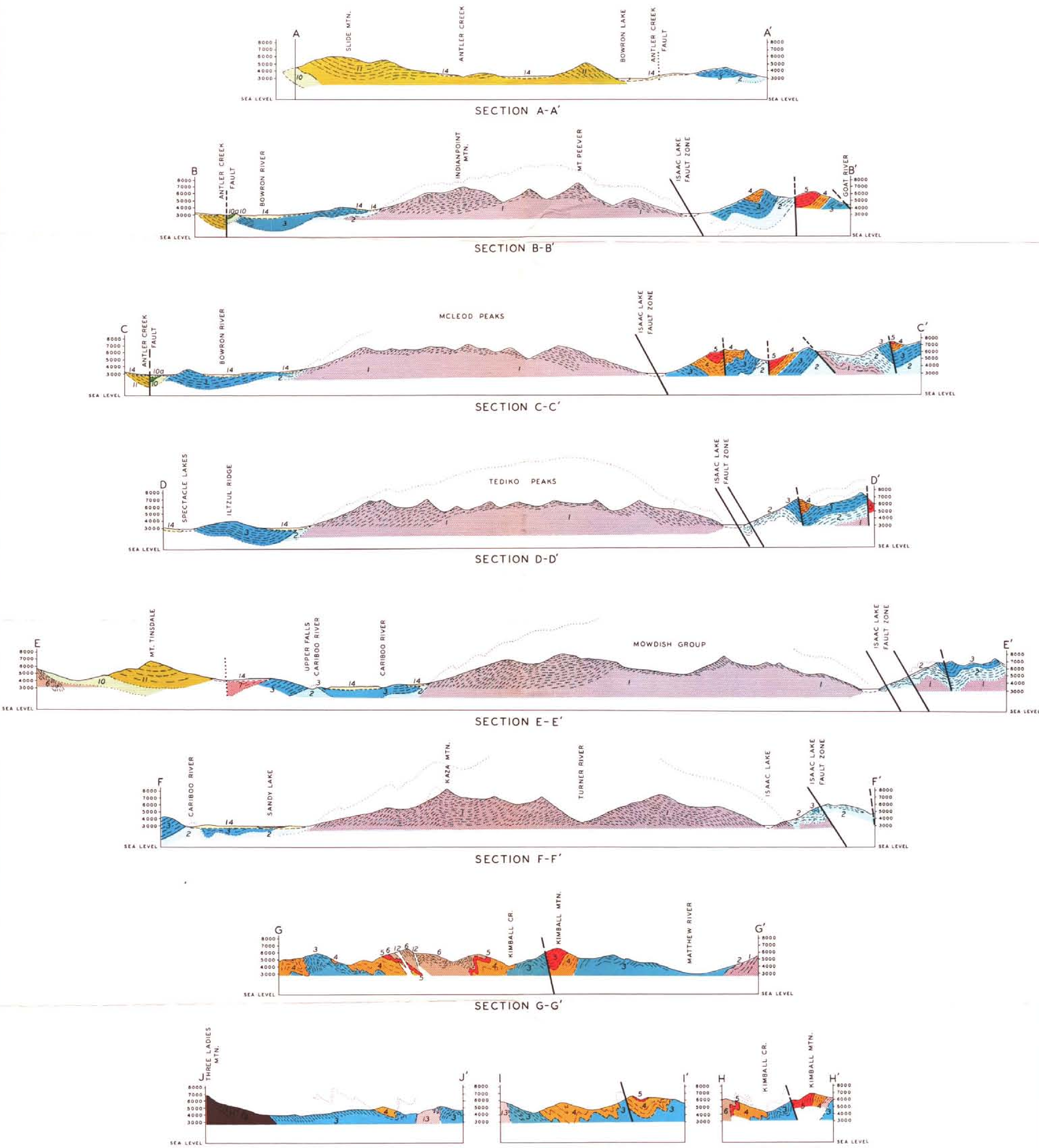


Figure 3

STRUCTURAL SECTIONS OF THE CARIBOO RIVER AREA

Scale 1 0 1 2 3 Miles
Horizontal

For legend see Figure 2

To accompany Bulletin 47, "Geology of the Cariboo River Area." 1963.