CANADA
DEPARTMENT OF MINES AND RESOURCES

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GEOLOGICAL SURVEY OF CANADA

MEMOIR 251

McCONNELL CREEK MAP-AREA, CASSIAR DISTRICT, BRITISH COLUMBIA

BY
C. S. Lord

OTTAWA
EDMOND CLOUTIER, C.M.G., B.A., L.Ph.,
KING'S PRINTER AND CONTROLLER OF STATIONERY
1948

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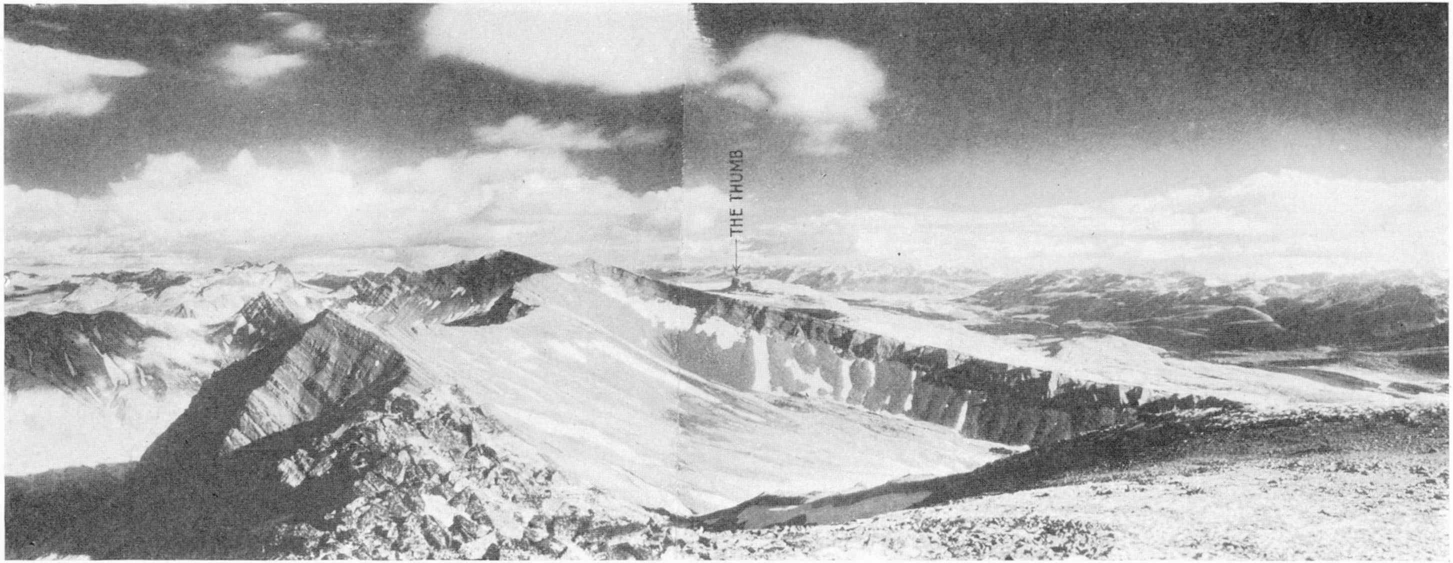
PLATE I



Looking southeasterly from the northwest end of Connelly Range. The gently inclined, well-stratified rocks are typical members of the Sustut group. In the centre distance is The Thumb, a projecting plug of Tertiary basalt. The outlet of Bear Lake lies in the right middle distance.

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PREFACE

McConnell Creek map-area lies in a mountainous, relatively inaccessible region near the centre of the northern half of British Columbia. Little was known about it until 1907-08 when placer gold was discovered on McConnell Creek. This activity, and that of a later rush of placer miners in 1932, quickly waned, without disclosing commercial mineral deposits or material geological information. Subsequent investigations by the Geological Survey in areas to the south succeeded, however, in drawing attention to the McConnell Creek area as a possible source of lode deposits. Accordingly, field work was commenced there by Dr. Lord in 1941, and, although interrupted by more urgent wartime duties, was completed by him in 1945.

The present report is descriptive of the geology, structure, and economic features of the area. Granitic intrusions, both of Mesozoic and Tertiary age, are described, and the presence, in this part of the province, of a large area of Upper Cretaceous and Paleocene strata is noted for the first time. A belt of strong, post-Paleocene faults, in part continuous with the Pinchi fault zone, traverses the area from southeast to northwest, and probably extends far beyond. Many occurrences of gold, silver, copper, coal, and other minerals, found in the course of geological mapping and resultant active prospecting, are described. Although none of these is yet known to be commercially valuable many are of sufficient interest to warrant further search. As an aid to the prospector, Dr. Lord has listed the more favourable host rocks, and has defined the areas within which mineral occurrences are most concentrated.

GEORGE HANSON,
Chief Geologist, Geological Survey of Canada

OTTAWA, March 25, 1948

McConnell Creek Map-Area, Cassiar District, British Columbia

CHAPTER I

INTRODUCTION

GENERAL STATEMENT

McConnell Creek map-area lies in the mountainous central part of northern British Columbia between latitudes 56 and 57 degrees, and longitudes 126 and 127 degrees. It includes about 2,600 square miles. Geological mapping was begun by the writer in 1941 and continued by him during 1944 and 1945.

No previous geological mapping had been done in the area by the Geological Survey, although Malloch (1914)[1] briefly visited Sustut Valley in 1912 and correlated certain coal-bearing strata found there with his Skeena series of the Groundhog coalfield. The placer gold deposits of McConnell Creek, in the northern part of the area, have been described by W. F. Robertson (1908) and D. Lay (1932) of the British Columbia Department of Mines.

Permanent residents are several white men and a score or so Indians. The only settlement is the Indian village of Bear Lake, where C. Hanawald maintains a small trading store. The McConnell Creek placer camp was deserted when visited in the autumn of 1945 except for two men who planned to winter there.

The writer was ably assisted in 1941 by E. J. Kermode, G. B. Leech, and G. Mason; in 1944 by A. C. Knight, J. H. Parliament, and H. W. Tipper; and in 1945 by L. Adie, J. G. Fyles, and H. W. Tipper. The many courtesies and services rendered by prospectors, local residents, and others interested in this part of the province are all gratefully acknowledged, and special thanks are due the late A. J. F. Rae of Vanderhoof, D. Hoy and L. Dickinson of Fort St. James, and C. Hanawald of Bear Lake.

ACCESSIBILITY

The nearest railway station is at Vanderhoof, on the Canadian National Railway about midway between Prince Rupert, British Columbia, and Jasper, Alberta. Vanderhoof connects with Fort St. James, 41 miles to the north, by regular bus and truck service operating over a good gravelled road. The latter point provides the nearest satisfactory outfitting point and communication centre.

The centre of the area is about 165 miles north-northwest of Fort St. James. Aircraft available at the latter point employ either floats or

[1] Dates, in parentheses, are those listed with author's name in bibliography at end of this chapter.

skiis, and provide the most ready means of access. Those operating in 1945 carried a maximum pay load of about 1,200 pounds, and were chartered at 65 cents a mile. The following lakes afford good landings for aircraft equipped with floats: Thutade, Thorne, Fredrikson, McConnell, Sustut, Johanson, Bear, Nanitsch, and Aiken (on Mesalinka River 9 miles east of longitude 126 degrees). Should future freight requirements warrant it, aircraft on wheels, carrying pay loads of several tons, might be used. These could operate from Prince George, on the Canadian National Railway, 230 miles to the southeast, or from other points. They could probably land on Bear, Thutade, or Sustut Lakes during the winter; or a suitable airstrip could be built at nominal cost on one of the many broad, sparsely timbered gravel flats found in most of the larger valleys.

During the summer season Hoy's Water Transport maintains freight and passenger service from Fort St. James to Bulkley House at the head of Takla Lake, a distance of 125 miles. Scows capable of carrying up to about 20 tons are used, but the loads are usually limited by rapids and shallow water in Tachie and Middle Rivers, and much freight is portaged or transhipped on Tachie River. Pack-horses are best taken by this route to Bulkley House, and thence north by pack-trail. In 1945 the following rates prevailed between Fort St. James and Bulkley House: horses, $20 a head; passengers, $8 a person plus 15 per cent excise tax; camp equipment and provisions, 2 cents a pound. The navigation season lasts from about June 1 to early October.

Pack-horses provide the most suitable means of transportation within the area. Bulkley House and McConnell Creek placer camp, near the north edge of the area, are connected by about 105 miles of fair packhorse trail that maintains a general northerly direction throughout its length. At no point does this trail reach an elevation of more than 5,000 feet, and it is usable from early June until well into October when lack of horse feed renders travel impracticable. A trail built many years ago by the Royal Northwest Mounted Police to connect Fort St. John with the fourth cabin on the Telegraph trail traverses the area in a westerly direction by way of Omineca River, Bear Lake village, and Bear River, and is still in fair condition in this section. A good pack-trail from Aiken Lake, 8 miles east of the area, extends northwesterly via Miller Creek, Moose Valley, and Attichika Creek to Thutade Lake.

In the spring of 1945 the Geological Survey pack-train, going from Fort St. James to Bulkley House by boat and thence north by trail, reached the mouth of Dortatelle Creek, near the centre of the map-area, in about 11 days travelling time. The same route was covered in late September, southbound, in 9 days travelling time.

HISTORY

The early history of the area concerns the fur trade and centres on Bear Lake in the southwest corner. The lake was referred to by Simon Fraser (Morice, 1904, p. 56) of the North-West Company in 1806 who, however, knew of it only by Indian accounts. In 1826 (Morice, 1904, p. 129) the Hudson's Bay Company established Fort Connelly on the small island at the entrance of Tsaytut Bay in Bear Lake. The fort was later moved to the site now occupied by Bear Lake village at the outlet of the lake, and subsequently abandoned.

Later noteworthy events have to do with mining. Placer gold was discovered at the mouth of McConnell Creek in 1899 by P. Jensen (Lay, 1932, p. 1). Returning there in 1906 he located more productive ground 3½ miles above the mouth of the creek. News of this discovery quickly spread and resulted in a rush to the creek in 1907 and 1908. The deposits, however, proved disappointing, and the camp was shortly deserted except for the discoverer, and remained so until the spring of 1932, when false statements of the discovery of coarse gold on bedrock instituted a second brief period of activity.

Gold-bearing quartz veins were found east of Goldway Peak by the Geological Survey in June 1945, and, independently, during the same summer by the late R. M. Godfrey. Limited prospecting of this area during the summer of 1946, following the publication of a Geological Survey report (Lord, 1946), disclosed numerous gold occurrences, and the rich samples afforded by some of these resulted in an influx of mining men to the area in the spring of 1947.

PHYSICAL FEATURES

About half of the map-area drains into the Pacific Ocean, mainly by way of Sustut River, which flows westerly into Skeena River, but partly by way of Driftwood River and Lion and Kastberg Creeks, the waters of which eventually enter Fraser River. The northern and eastern parts of the area are drained easterly by the Finlay and its tributaries, Ingenika, Mesalinka, and Omineca Rivers, into Peace River and thence to Mackenzie River and the Arctic Ocean.

The area is mountainous. Elevations range between about 2,600 and 8,100 feet, but the local relief rarely exceeds 4,000 feet. The general elevations of both valley bottoms and peaks rise from a minimum near the southwest corner to a maximum near and northeast of a line joining Carruthers Creek to Thutade Lake. The only valleys with important areas lying below 3,000 feet are those of Bear Lake and lower Sustut River, in the southwest, and only small parts of the ridges in this vicinity exceed an elevation of 7,000 feet. Farther north and northeast, as in the Moose Valley-Sustut Lake depression and at the head of Ingenika River, are extensive valleys lying above 4,000 feet: nearby peaks commonly reach or exceed elevations of 7,000 feet, and culminate in Sustut Peak, with an elevation of 8,100 feet. Several of the higher tracts in the southwest half of the area, such as Tsaytut Spur, Connelly Range, Sikanni Range, and Axelgold Range, form northwesterly trending ridges or mountain masses, whereas to the northeast the mountain masses are, in general, rectilinear, rounded, or quite irregular in outline. The complex drainage pattern forms an interlocking network of deep, and commonly broadly U-shaped, valleys with the result that the numerous mountain masses and ridges projecting above an elevation of 5,000 feet rarely exceed 12 miles in length.

The topography shows a marked relation to the underlying rocks. Some of the most rugged mountains are those underlain by volcanic rocks of the Takla group, particularly those of the lower division. Such mountains are characterized by ragged, knife-edged ridges, spires, abrupt crumbling slopes, and nearly vertical cliffs. They form the particularly rugged terrain of Sikanni Range and much of that extending northwest from

Asitka River to Niven River, including Sustut Peak. The region with the greatest proportion of surface rising above 6,000 feet, and including many of the higher peaks, extends along the east border of the area from near the mouth of Carruthers Creek north to Fleet Peak just south of Ingenika River. It is underlain by granite and by granite and greenstone. The most distinctive topography is that underlain by rocks of the Sustut group. It is marked by great, stratified, mainly grey cliffs, such as form the east slope of Bear Lake Valley and the hills surrounding Thutade Lake. Where the strata are inclined, as on Connelly Range and its extension northwestward beyond Sustut River, the ridges are asymmetrical in section; thus the surface forming one side of a ridge approximately parallels the gentle dip of the strata, whereas that of the opposite side is characterized in the upper part by abrupt cliffs and steep talus slopes. Where the strata are nearly flat, as northwest of Thutade Lake, the mountains rise abruptly, through alternating cliffs and steep slopes, to nearly flat tops.

The generally rugged character of the mountains is interrupted here and there by extensive, undulating or gently inclined, plateau-like surfaces lying 5,000 to 6,500 feet or more above sea-level. Some of them truncate underlying formations of various types, flank major, steep-walled valleys, and slope gently upwards away from the valleys to abut against abruptly rising slopes or to become so thoroughly dissected as to lose their identity; others form the flat tops of mountains underlain by essentially horizontal strata. The most obvious surface of the first type lies east of and about parallel with the trail from McConnell Creek, and extends southerly from between Fredrikson Lake and Jensen Peak to the northwest end of Ingenika Range, a distance of about 30 miles. Its maximum identifiable width is about 4 miles, and it slopes upwards and easterly from an elevation of about 5,500 feet at the edge of Ingenika River Valley to Fleet Peak, at an elevation of 7,630 feet. A similar, and well-developed tract lying at elevations ranging from 5,500 to 6,000 feet, extends northwesterly from the mountain 2 miles southwest of the mouth of Dortatelle Creek to a point about 2 miles south of Sustut Peak; and smaller plateaux were noted at about the same elevation 2 miles northwest and 2 miles southwest of the mouth of Quenada Creek. Surfaces of the second type include the mountain tops northwest of Thutade Lake, lying between 6,000 and 6,500 feet above sea-level, and the top of a spur of Omineca Mountains extending south-southeast from The Thumb, with elevations ranging from 5,000 to a little more than 5,500 feet. These scattered, high-level, comparatively little-dissected tracts may be the remnants of an undulating surface formed in about mid-Tertiary time and subsequently involved in uplift and widespread erosion.

GLACIATION

Glacial striæ and erratics were noted at a maximum elevation of 7,250 feet, and are abundant at many places above 7,000 feet. These observations were made on mountain crests, and the near parallel alinement of striæ on successive crests and the presence of foreign erratics indicate that these places were overridden by an ice-sheet. No evidence of an ice-sheet was noted at elevations in excess of 7,250 feet, but only a few such peaks were climbed and these are so rugged that records of a former ice cover would almost surely have been destroyed. Good evidence for the direction of movement of the ice-sheet was found only in the northeast half of the map-area. Here, striæ and stoss and lee slopes on the mountain crests, and the distribution of erratic boulders, indicate that the ice moved from the vicinity of Thutade Lake easterly and southeasterly across Forrest Mountain, McConnell Range, and the mountains lying between Johanson Lake and the outlet of Fredrikson Lake. In following this course the ice transported boulders of Sustut sandstone, with a maximum diameter of about a foot, for distances up to about 10 miles; and moved smaller erratics of the same rock as much as 15 miles from the nearest possible source. It crossed the deep transverse valleys now occupied by Thorne Lake and by McConnell Creek and upper Ingenika River, thus acting as a sheet so thick that flowage of its upper parts was not influenced appreciably by the topography. Presumably, then, the upper surface of the ice lay considerably above the many 7,000-foot, erratic-strewn surfaces of McConnell Range, and must have nearly, if not completely, covered the map-area.

With few possible exceptions, all valleys have been strongly eroded by glaciers flowing along them, as evidenced by their U-shaped profiles, truncated spurs, and hanging, tributary valleys. Some of this erosion, particularly in the very large, southeasterly trending valleys, may have been caused by the ice-sheet: examples of such valleys are those of Bear River and Bear Lake, Moose Valley and Moosevale Creek, and Omineca River east of Axelgold Range. Nevertheless, other strongly glaciated valleys, such as those of Sustut and Asitka Rivers, lie nearly transverse to the flow of the ice-sheet and most probably owe much of their glacial carving to a valley-glacier stage that followed the gradual wasting of the ice-sheet.

Alpine glaciers are far more numerous than those mapped, and innumerable cirques, mainly on the northern and eastern slopes, attest the former presence of many others. Photographs taken in 1937 by the Topographic Survey show that some of the glaciers were at that time noticeably larger than at present.

CLIMATE

Vegetation, distribution of snow- and ice-fields, and observed rainfall and snowfall indicate that the area lies near the eastern edge of a district of abundant precipitation. Driftwood and Bear Lake Valleys and most of the Sustut drainage basin south and west of Sustut Lake lie within this relatively wet belt. Probably the maximum rainfall occurs in the Sustut basin between the mouth of Asitka River and Sustut Peak: only five rainless days were recorded here during August 1944, and rains lasting a day or more were common. The remainder of the map-area receives much less rain and snow and, particularly northeast of a line through Dortatelle and Niven Peaks, long periods of fair weather are the rule during the summer months. Snow attains a depth of 6 to 20 feet (Stanwell-Fletcher, 1943, pp. 9-10) in the valleys of the wet belt during the winter, whereas depths of from 2 to 8 feet are more common elsewhere.

Annual temperatures range from a maximum of about 95 degrees Fahrenheit to a minimum of about -60 degrees Fahrenheit (Stanwell-Fletcher, 1943, pp. 7-8). The maximum temperature recorded by the Geological Survey was 88 degrees on July 16, 1941, but periods of such warm weather appear to be exceptional and of short duration. Not a fortnight passed without frost during the 1945 field season, but this season was spent in the relatively high northeast half of the area.

The season for efficient prospecting, much of which must be done near or above timber-line, is from about June 7 to September 21.

FLORA AND FAUNA[1]

The abundant trees are alpine fir, white spruce, black spruce, and lodgepole pine: less common varieties include aspen, balsam poplar, and white birch. Willows and ground birch are widespread and mountain ash, alder, juniper, and devil's club were also noted. Dense stands of timber are found nearly everywhere below elevations of 3,500 or 4,000 feet, and are particularly common in the southern and southwestern parts of the area, as in Sustut and Bear River Valleys, where growth is encouraged by relatively abundant precipitation. Between elevations of 4,000 and 5,000 feet, which includes many of the valleys north and east of Moose Valley, sparser stands, including much lodgepole pine, are the rule, and are interspersed with quite extensive grassy meadows, as those of Moose Valley and Niven River. Timber-line is about 5,000 feet above sea-level.

Mountain goat, moose, caribou, black and grizzly bears, and sheep were observed, the first three being common enough in places to provide prospecting parties with an intermittent source of fresh meat. Grizzly bears are rare, and sheep were seen only on the mountains immediately north of Wrede Creek. Smaller mammals present in important numbers include marten, fisher, weasel, mink, wolverine, otter, fox, wolf, lynx, beaver, muskrat, marmot, porcupine, and lemming.

The abundant game birds are Franklin's grouse (Stanwell-Fletcher, 1943) and white-tailed ptarmigan. Blue grouse and willow ptarmigan are common locally near timber-line, and ruffed grouse are found in Bear Lake and lower Sustut River Valleys. Canada geese are not uncommon in the late summers on the larger rivers and lakes.

Great numbers of sockeye salmon ascend Bear and Sustut Rivers to Bear, Sustut, and Johanson Lakes in August and September. Spring and cohoe salmon are reported by the Indians to follow the same route. Grayling are common in Omineca River. Other varieties of fish include steelhead, rainbow, and lake trout, Dolly Varden char, whitefish, sucker, and ling.

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[1] *See* also Stanwell-Fletcher (1943).

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CHAPTER II

GENERAL GEOLOGY

SUMMARY STATEMENT

The consolidated rocks examined in McConnell Creek map-area range in age from late Palæozoic to Recent; somewhat older strata probably cross the unexplored northeast corner. The most widespread sedimentary and volcanic formations are of Permian, Triassic, Jurassic, Cretaceous, and Paleocene ages; and the principal intrusive rocks are those of the Omineca batholith, emplaced in Upper Jurassic or Lower Cretaceous time. A more complete list of formations will be found in the following table.

TABLE OF FORMATIONS

Era	Period or epoch	Formation and thickness in feet	Character
Cenozoic	Recent		Stream alluvium and delta deposits, talus, soil, calcareous tufa.
	Pleistocene		Glacio-fluvial and glacio-lacustrine deposits; erratic boulders, morainal deposits; other glacial drift.
	Tertiary to Recent		Basalt necks, dykes, lavas; minor cone-like (Recent) pyroclastic deposits.
	Intrusive contact		
	Tertiary (early Tertiary (?))	Kastberg intrusions	Feldspar and feldspar-quartz porphyries, with dense, chalky weathering groundmass; medium-grained, porphyritic granodiorite and quartz diorite. Dykes, sills, and a stock.
Intrusive contact			
Mesozoic and Cenozoic	Upper Cretaceous and Paleocene	Sustut group 3,000+	Buff to grey impure sandstones, conglomerates (with granitic pebbles), red, green, and grey shales; minor dacitic tuff (Paleocene) and coal. Well-bedded continental deposits characterized by crossbedding and fossil plant remains.
Unconformity			
	Upper Jurassic or Lower Cretaceous	Omineca intrusions	Chiefly grey to pink, equigranular to porphyritic, massive granodiorite and quartz diorite. Omineca batholith and related stocks and dykes.

TABLE OF FORMATIONS—*Conc.*

Era	Period or epoch	Formation and thickness in feet	Character
Mesozoic	Intrusive contact		
	Jurassic (?)		Olivine gabbro, mainly well banded; peridotite, pyroxenite, dunite, and serpentine.
	Relations to upper Takla rocks uncertain; probable intrusive contact with lower Takla rocks.		
	Jurassic	**Takla group** (**Upper** division) **23,000 +**	Greywackes, conglomerates (with chert pebbles), shales, and argillites; minor limestone and coal. Marine fossils numerous.
			Andesitic, basaltic, and dacitic, commonly red, purple, or grey, tuffs, agglomerates, and lavas; in part interbedded with Jurassic sedimentary rocks. Contains deposits of copper, silver, and other metals.
	Mainly conformable, locally disconformable		
	Upper Triassic and (?) Jurassic	**Takla group** (**Lower** division) **10,000 ±**	Dark green, andestic and basaltic tuffs, agglomerates, and lavas with prominent black, blocky grains and phenocrysts; minor tuffaceous argillite; probably equivalent meta-andesite and meta-basalt, greenstone, basalt, and hornblende schist and gneiss, with a little intercalated limestone, tuff, and argillite. May include some undifferentiated older rocks. Contains deposits of gold, copper, and other metals.
Disconformable contact with Asitka group; contact with Cache Creek group not observed			
Palæozoic	MiddlePermian(?)	Cache Creek group	Slate, argillite, phyllite, argillaceous quartzite, and ribbon chert; schist and gneiss derived from andesitic lavas and tuffs; minor limestone.
	Contact not observed		
	Lower Permian and (?) earlier	Asitka group 8,500 + (base not exposed)	Massive, streaked, and spherulitic rhyolitic lavas; andesitic lavas and interlayered tuffs and breccias (also, derived greenstones, slaty tuffs, phyllites, and schists); argillite, slate, and phyllite; bedded, grey, green, and red chert; massive to bedded limestone, minor dolomite. Foraminifera numerous.

ASITKA GROUP

Distribution

The rocks of the Asitka group extend northwesterly from the north side of Carruthers Creek, along the south side of Sustut Lake and Moose Valley, to Niven River near Niven Peak. Isolated areas outcrop 2 miles northwest of the mouth of Quenada Creek and on the southwest slope of the Sikanni Range.

Lithology

The strata comprise rhyolitic and andesitic lavas and associated pyroclastic rocks, various argillaceous rocks, chert, and minor limestone and dolomite. Northwest of Sustut Lake volcanic material predominates, but to the southeast the assemblage is probably mainly of sedimentary origin.

Rhyolitic Lavas. These are the most characteristic volcanic members of the Asitka group. They constitute the most abundant rock type between Sustut Lake and Niven River, but were not recognized southeast of Sustut Lake. They are hard, dense, red, green, or buff lavas and range from massive, mottled, cherty textured rocks, with rare $\frac{1}{16}$ inch feldspar phenocrysts, to others that over wide areas exhibit excellent, although commonly contorted, flow lines. A little of this material shows well-developed columnar jointing perpendicular to the flowage planes. The lavas include occasional, very conspicuous layers of spherulitic rhyolite, and are accompanied by minor rhyolitic tuffs and breccias. The spherulitic rock contains numerous, red and white, concentrically banded, spherical, ellipsoidal, or kidney-shaped bodies, commonly $\frac{1}{16}$ to $\frac{1}{4}$ inch across, set in dense, bright green-streaked rhyolite. It probably resulted from the devitrification of a glassy lava.

Andesitic Lavas and Associated Pyroclastic Rocks. The andesitic lavas are dark green, brown, or red, commonly amygdaloidal and locally porphyritic. Many of the amygdules are $\frac{1}{8}$ to $\frac{1}{4}$ inch across and a few are as large as 1 inch: they consist of grey to bright red chalcedony, ankerite, quartz, and chlorite, and where most abundant comprise about 40 per cent of the rock. Many of the flows are about 50 feet thick. The lavas are interlayered with about an equal amount of pyroclastic material, mainly red and grey banded tuffs and red, green, or rarely grey breccias, composed of fragments of fine-grained, non-porphyritic, volcanic rock. Much of the andesitic material between Sustut Lake and Niven River is massive or only slightly foliated, whereas between Sustut Lake and Carruthers Creek the lavas have been sheared and altered to foliated greenstones, the banded tuffs to streaked, red and grey, slaty tuffs and phyllites, and the breccias to flaky, red and green mottled rocks that still retain traces of their original fragmental texture.

Argillaceous Rocks. These range from black argillite and slate to glistening light grey phyllite, and are abundant between Sustut Lake and Carruthers Creek. The slate and argillite are characteristically rather soft, jet-black, and carbonaceous.

Chert. Grey, green, and red cherts make up the most characteristic sedimentary bands, although they comprise only a small part of the assemblage. They occur in beds ranging from less than 1 inch to about 1½ feet thick, and are commonly crumpled or shattered. Many of the beds have soft, slaty tops, or are separated by thin layers of slaty material that weathers more rapidly than the chert and gives rise to ribbed outcrops.

Limestone and Dolomite. Massive to bedded, crystalline limestone occurs as scattered bands, apparently mainly in the upper part of the exposed section of this group. Some bands are as much as 200 feet thick, but most of them are relatively thin. In part the rock is light grey, pure limestone, but much of it contains argillaceous, tuffaceous, or carbonaceous impurities and is dark grey, green, pink, or black. Bands of finely crystalline dark grey dolomite, commonly less than 10 feet thick and weathering buff to chocolate-brown, were noted 2 miles northwest of the mouth of Quenada Creek.

Structure

Northwest from Sustut Lake the strata of the Asitka group dip consistently southwest at angles ranging from 30 to 70 degrees and averaging 50 degrees. Southeast from Sustut Lake nearly to the mouth of Carruthers Creek, both strike and dip vary widely, and drag-folds and abrupt reversals of dip are common locally. The general trend of the beds is, however, northwesterly, and east of Mount Carruthers drag-folds and traces of bedding on cleavage planes suggest that the major folds there plunge northwesterly at angles of between 15 and 40 degrees. About 2½ miles northwest of the mouth of Quenada Creek these rocks form an anticline that plunges northwest at about 20 degrees.

The top of the Asitka group is exposed on a spur extending north from Sustut Peak, but the base was not recognized at any place. The available data from the Sustut Peak spur do not eliminate the possibility of some repetition, but, assuming no repetition, about 8,500 feet of mainly volcanic rocks are exposed there and represent a minimum thickness for the group.

Fossil Collections

Foraminifera and other fossils are numerous, particularly in the calcareous strata. The most useful collections are listed below, with ages assigned to them by the authorities acknowledged.

F1.[1, 2] Locality: 1·5 miles northeast of Niven Peak.

Forms identified: *Schubertella* n.sp. 1[3]
Rugofusulina n.sp. 1
Schwagerina n.sp. 1

Age: Lower Permian

F2. Locality: 1 mile northeast of Niven Peak.

Lot A[4]

Forms identified: *Productus* sp. 1

Age: Permian (?)

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[1] This symbol appears on the accompanying geological map at the locality specified.

[2] Forms identified and age assigned by C. O. Dunbar, Peabody Museum of Natural History, Yale University, New Haven, Conn., U.S.A.

[3] This number indicates that this new species of *Schubertella* is the same as that identified in collection F2, Lot B.

[4] Forms identified and age assigned by Alice E. Wilson, Palæontological Section, Geological Survey of Canada.

Lot B[1]
Forms identified: *Schubertella* n.sp. 1
Schwagerina n.sp. 2
Age: Lower Permian

F3. Locality: 2·7 miles east of Niven Peak.
Forms identified: *Rugofusulina* n.sp. 1
Schwagerina n.sp. 1
Age: Lower Permian

F4. Locality: 4·4 miles west-northwest of the outlet of Sustut Lake.
Lot A[2]
Forms identified: cf. *Polythecalis* n.sp.
Age: Pennsylvanian or Permian
Lot B[1]
Forms identified: *Parafusulina* n.sp.
Pseudoschwagerina n.sp.
Age: lower half of the Permian

F5. Locality: 3·7 miles west-northwest of the outlet of Sustut Lake.
Lot A[1]
Forms identified: *Rugofusulina* n.sp. 1
Schwagerina n.sp. 3
" n.sp. 4
" n.sp. 5
Age: Lower Permian
Lot B[2]
Forms identified: coral, cf. *Corwenia chihsiaensis* Yoh.
Age: Lower Permian (?)

F6.[2] Locality: 2·4 miles west-northwest of outlet of Sustut Lake.
Forms identified: *Triplophyllum* (?)
Lithostrotian sp.
Dictyoclostus n.sp. 1
Age: Pennsylvanian or Permian (?)

F7. Locality: 2·2 miles west of outlet of Sustut Lake.
Forms identified (Fritz, 1946):
Tabulipora sustutensis Fritz n.sp.
Fistulipora sp.
Age: Permian (?)

F8.[2] Locality: 1·4 miles southwest of mouth of Dortatelle Creek.
Forms identified: cup coral sp. 1
crinoid stems
Productus sp. 1
Spiriferina sp. cf. *S. cristata octiplicata* (Sowerby)
Age: Permian (?)

F9.[2] Locality: 2·6 miles northwest of the mouth of Quenada Creek.
Forms identified: cup coral sp. 1
Crinoid stems, two types
Echinoconchus sp. near *E. waageni* Roth.
Productus sp. 1
Avonia (?) n.sp.
Dielasma sp.
cf. *Meekella* sp.
gastropod, two types
Age: Permian (?)

F10.[2] Locality: 2·5 miles west-northwest of the mouth of Quenada Creek.
Forms identified: *Productus* sp. 1
Age: Permian (?)

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[1] *See* footnote No. 2, p. 11.
[2] *See* footnote No. 4, p. 11.

F11.[1] Locality: 8 miles east of the outlet of Saiya Lake.
Forms identified: cup coral
crinoid stems
Dictyoclostus n.sp. 1
Age: Pennsylvanian or Permian (?)

F12. Locality: 6·2 miles east-northeast of Mount Carruthers.
Lot A[2]
Forms identified: parts of poorly preserved foraminifera that belong to the fusulinoids
Age: Pennsylvanian or Permian
Lot B[1]
Forms identified: coral, upper surface is *Lithostrotion*-like
Age: Pennsylvanian or Permian (?)

Age and Correlation

The fossils identified with assurance (collections F1, F2, F3, and F5) are of Lower Permian age. These came from the upper part of the group and provide evidence for correlating[3] the enclosing strata with the Wolfcamp series (Dunbar, 1940) of Texas. Other collections, some of them from stratigraphically lower horizons, are less diagnostic, but point to ages ranging from Pennsylvania to Permian. Thus, the available palæontological evidence indicates that the Asitka group is, in part at least, of Lower Permian age, but does not preclude the possibility that some of it is of Pennsylvanian age. However, in other parts of northern British Columbia Permian strata comprise the upper part of an assemblage representing much of Palæozoic time (Hanson and McNaughton, 1946, p. 5); and in McConnell Creek area wide areas of the Asitka group are presumably drift covered or, as southeast from Sustut Lake, have yielded only scattered collections of useful fossils. It is, therefore, thought best to designate the age of the Asitka group as Lower Permian and (?) earlier, rather than Lower Permian and (?) Pennsylvanian as suggested by available palæontological evidence.

The palæontological data provide evidence for correlating at least part of the Asitka group with the Cache Creek group but, for reasons cited above, pre-Cache Creek (pre-Pennsylvanian) strata may also be present.

CACHE CREEK GROUP

Distribution

The members of the Cache Creek group outcrop on the low hills on the southwest side of lower Carruthers Creek and on parts of Axelgold Range.

Lithology

The rocks are dominantly of sedimentary origin and comprise mainly slate, argillite, phyllite, argillaceous quartzite, chert, limestone, and chlorite and amphibole schist and gneiss.

Sedimentary Rocks. The most characteristic strata are dark grey to black, platy, argillaceous rocks and grey cherts with minor interlayered

[1] *See* footnote No. 4, p. 11.
[2] Forms identified and age assigned by R. T. D. Wickenden, Geological Survey of Canada.
[3] C. O. Dunbar, Peabody Museum of Natural History, Yale University, New Haven, Conn., U.S.A., personal communication.

limestone. They are most widely exposed on the west side of lower Carruthers Creek, on the northeast slope of Axelgold Range southeast of Axelgold Peak, and on the eastern part of two spurs 3 and 5 miles, respectively, south of Axelgold Peak. They include what are commonly known as ribbon cherts, composed of platy or crumpled layers of grey chert separated by thin partings of lustrous black, partly graphitic argillite or slate in places altered to mica schist. The chert layers are normally less than 3 inches thick; a great many are less than $\frac{1}{4}$ inch thick and form a rock that separates readily into thin, hard leaves with black, argillaceous or silky, silvery schistose faces. In places the argillite or slate is interlayered in like manner with fine-grained, dark grey, argillaceous quartzite as beds ranging from less than $\frac{1}{4}$ inch to about 6 inches thick. Less commonly, buff or grey, minutely fractured, relatively pure chert may form bands as much as 10 feet or more thick. Most of the associated limestone is massive or indistinctly bedded, crystalline, and light grey or white, and forms persistent bands rarely more than 100 feet thick, but some of it is fine grained.

Volcanic Rocks. Axelgold Range northwest of Axelgold Peak is underlain by much schist and gneiss derived, presumably, from andesitic lavas and tuffs. The schist is a fine-grained, dark green aggregate of fibrous amphibole and untwinned plagioclase, and commonly retains traces of fine bedding as though derived from tuffs. The gneiss is a medium-grained, streaked aggregate of the same minerals, but does not cleave readily. The streaks are lenticular or quite irregular, and are composed of various proportions of blocky amphibole and aggregates of interlocking or rounded andesine or labradorite grains. The amphibole grains attain a length of $\frac{1}{8}$ inch or more.

The formations in a belt adjacent to Ominicetla Creek and extending 4 miles north from the south boundary of the map-area were formerly andesitic volcanic rocks, but are now mainly fine-grained, green, well-foliated, chloritic schists or greenstones.

Structure

Adjacent bedding and foliation are parallel, or essentially so. They dip consistently between northeast and east at angles ranging from 40 to 70 degrees and averaging 55 degrees.

The rocks of the Cache Creek group were not found in contact with those of the Asitka group. In Carruthers Creek Valley, where they are most nearly in contact, they are separated by a belt, about a mile wide, of younger strata intersected by the Omineca and Quenada faults.

Age

No very satisfactory evidence is available as to the age of the members of the Cache Creek group in this map-area: no fossils were found in them, nor were they seen in unfaulted contact with other rocks of known age. They do, however, differ lithologically from those of the Asitka group in that only the latter contain the red and green cherts, abundant rhyolite lavas, and a unique variety of relatively fresh andesitic lavas and tuffs. Accordingly, the two groups probably differ, at least in part, in age. The strata assigned to the Cache Creek group may be traced southeasterly along their strike to similar strata designated as Cache Creek in the adjacent Takla map-area (Armstrong, 1946). The latter contain fossils of Middle Permian age. It is, therefore, probable that the rocks of the Cache Creek group within McConnell Creek area are likewise, at least in part, of Middle Permian age and thus slightly younger than those of the Asitka group. Nevertheless, this evidence provides no assurance that the formations of the two groups, as mapped, may not overlap slightly in age.

TAKLA GROUP

Summary Statement

The Takla group comprises an essentially conformable assemblage of more than 33,000 feet of volcanic and sedimentary strata. In most instances the strata have been readily assigned either to a lower (Upper Triassic and (?) Jurassic) division or an upper (Jurassic) division. The lower division embraces about 10,000 feet of mainly greenish pyroclastic rocks and lavas characterized by numerous blocky, black pyroxene grains and phenocrysts, or their pseudomorphs. Relatively fresh and complete exposures of these formations lie southwest of a line extending from the southeast corner of the map-area northwesterly through Sustut and Thutade Lakes; probable altered equivalents of these formations lie northeast of this line near the Omineca batholith, and enclose a few bands of tuff, limestone, and argillite. No diagnostic fossils were found within the strata of the lower division.

The upper division comprises more than 23,000 feet of volcanic and sedimentary rocks. The oldest part includes more than 18,000 feet of mainly reddish lavas and pyroclastic rocks characterized by numerous white feldspar phenocrysts and grains. These are overlain by more than 5,000 feet of shallow water, marine, fossiliferous sediments interlayered with minor volcanic rocks, carbonaceous strata, and coal. Fossils collected from volcanic and sedimentary beds indicate a range in age of from early Lower Jurassic to middle Upper Jurassic.

Lower Division

ANDESITIC AND BASALTIC TUFFS, AGGLOMERATES, FLOWS, AND TUFFACEOUS ARGILLITES

Distribution

Dark green, andesitic and basaltic, pyroclastic rocks and lavas, with minor tuffaceous argillite, occupy several northwesterly trending belts within the particularly rugged terrain between lower Carruthers Creek and upper Niven River. One belt underlies much of Sikanni Range, and another, 30 miles long, extends northwesterly through Sustut and Niven Peaks.

Lithology

The only complete section recognized is that found in the general vicinity of Sustut Lake, Sustut Peak, and Sustut River, about 5 miles below the mouth of Moosevale Creek. There the assemblage comprises about 10,000 feet of well-layered, fresh, mainly greenish, volcanic rocks of which tuffs and agglomerates are by far the most abundant constituents. The basal strata are thinly bedded, interlayered, tuffaceous argillites and fine-grained tuffs. These pass upwards into progressively more thickly bedded tuffs, which, in turn, are overlain by massively bedded coarse agglomerates and pillow lavas, each of these two parts of the assemblage containing minor interbeds of the immediately underlying part.

Tuffaceous Argillites. These are compact, dark grey to black rocks with sub-conchoidal fracture. They are generally interlayered with very fine-grained, greenish grey tuffs, and some tuffaceous beds grade from fine-grained tuff at the bottom to black tuffaceous argillite at the top. In general these intercalated rocks are characterized by excellent bedding, individual layers ranging from less than $\frac{1}{16}$ inch to as much as 6 inches thick. Rather commonly, however, they are crossbedded, or either individual layers or groups of layers pinch and swell, and are irregularly contorted in such a way as to suggest that they were deformed prior to their consolidation.

Tuffs. These are dark green, compact, and tough, and weather greenish grey, buff, or light brown. They range from fine-grained, sandy-textured rocks to others composed of subangular fragments up to about $\frac{1}{4}$ inch long, and these coarse phases are distinguishable from succeeding agglomerates only by the size of the fragments. The beds vary in thickness from less than 1 inch to more than 20 feet, the thicker beds generally containing the coarser material. Grains within many of the thinner strata are sorted, with the coarser material at the bottom. Much of the fine or medium-grained, sandy-textured tuff contains scattered angular fragments of black argillite. Under the microscope the common constituents are seen to be fragments of augite, hornblende, plagioclase, and various fine-grained, felted, feldspathic volcanic rocks, many of which contain phenocrysts of augite or, less commonly, plagioclase or plagioclase and augite. Augite and hornblende together comprise as much as 30 per cent of the rock, the former being by far the most abundant and occurring in grains up to $\frac{1}{4}$ inch long or longer. The plagioclase is in part andesine, but most of it is too altered to permit ready identification. Accordingly, part, and perhaps most, of the tuff has about the composition of andesite, but some, with abundant pyroxene fragments, may approximate that of a basalt.

Agglomerates. These are still coarser pyroclastic rocks with about the same general composition and colour as the tuffs. They are thickly bedded, massive rocks composed mainly of rudely sorted subangular fragments of porphyritic andesite or basalt. Most fragments range from less than an inch to about a foot in diameter, but a few are as much as 4 feet across. As a rule they are scarcely distinguishable on fresh surfaces from the tuffaceous matrix, but are readily visible on weathered surfaces. The abundant fragments are of dark green andesite with 10 to 30 per cent stubby black augite phenocrysts up to $\frac{1}{4}$ inch long and, less commonly, with white amygdules or a few laths of plagioclase. Widely scattered fragments are of dark grey, brown, or green basalt carrying numerous white laths of labradorite, an inch or more in length, set in a fine-grained groundmass with or without amygdules. Locally, and probably mainly in the upper parts of the agglomerates, are small, purplish red andesite fragments that form as much as 10 per cent of the rock; they contain numerous, tiny, white plagioclase laths, a few phenocrysts of black augite, and white amygdules.

Lavas. These are black to dark green, porphyritic, basic andesites or basalts that, together with the coarse agglomerates, comprise the high, rugged central core of the range extending northwesterly from near Sustut Lake, through Sustut Peak, to upper Niven River. They are particularly well exposed on the east slope of Sustut River Valley, where they are probably several thousand feet thick, and in Niven River Valley within 3 miles of the west boundary of the map-area. They generally weather grey, brown, or black. The phenocrysts are mainly $\frac{1}{8}$- to $\frac{1}{4}$-inch, black augite crystals, and these form 20 to 50 per cent of the rock. Less common phenocrysts are $\frac{1}{8}$- to $\frac{3}{8}$-inch plagioclase laths and an unidentified, grass-green, cleaved mineral. The lava is in part massive; and about $3\frac{1}{2}$ miles south of Dewar Peak massive lava contains seams and irregular lenses, up to several feet in length, of dense, red and green, massive to finely banded limestone. Much lava exhibits well-formed pillows up to 5 feet in diameter, and commonly these weather so as to form bulbous outcrops. Amygdules occur in massive and pillowed lava, but are most common in the latter type, especially near the chilled rims of the pillows. They are generally between $\frac{1}{16}$ and $\frac{1}{4}$ inch in diameter, and, rarely, as much as 1 inch or more. The common filling is calcite and chlorite, but some is a hard, milky white or pink material, possibly representing one or more zeolites. The groundmass of the lava, where examined with a microscope, is a finely crystalline aggregate of basic andesine or labradorite, augite, chlorite, and black metallic iron minerals.

META-ANDESITE AND META-BASALT, GREENSTONE, BASALT, HORNBLENDE SCHIST, AND GNEISS

Distribution

A group of rocks comprising meta-andesite and meta-basalt, greenstones, porphyritic basalt, and hornblende schist and gneiss underlies much of an area extending from upper Dortatelle Creek to Fredrikson Peak and including parts of Ingenika, Wrede, and McConnell Ranges.

Lithology

Meta-andesite and Meta-basalt. These rocks predominate. They are light green to greenish grey and almost everywhere contain numerous, black, stubby grains and phenocrysts, up to $\frac{1}{2}$ inch or more in length, of hornblende or, less commonly, of augite partly replaced by hornblende. These grains and phenocrysts comprise from 10 to 50 per cent of the rock. Epidote occurs as grains, seams, or knots up to a foot or so in diameter. Here and there the weathered surfaces display bedding, fragmental textures, amygdules, and other internal structural features that establish the original volcanic origin of the rocks. A little of the altered agglomerate and coarse tuff, particularly between the head of Dortatelle Creek and the west end of Wrede Range, contains calcite, and at the surface weathers to a mass of projecting fragments cemented by the more deeply weathered calcareous matrix. At the west end of Wrede Range and southeast of

Johanson Lake small areas of altered tuff and agglomerate contain a few rounded to angular bodies of fine-grained grey limestone from 1 inch to 18 inches long. Microscopic examination shows that, in addition to the grains and phenocrysts of hornblende and augite, these formations contain various proportions of plagioclase, fine-grained, fibrous hornblende, chlorite, calcite, ankerite, clinozoisite, quartz, black metallic iron minerals, and epidote. The plagioclase forms ragged, twinned, saussuritized crystals, some of labradorite but many probably of andesine.

Greenstones. The greenstones are fine- to medium-grained, altered volcanic rocks containing highly altered feldspar, chlorite, epidote, and other minerals. Although doubtless derived from the same rocks as the meta-andesites and meta-basalts, alteration has been more complete, and has obliterated most of the original internal structures and textures.

Basalt. An unusual type of coarsely porphyritic basalt outcrops on the southern end of McConnell Range. It contains numerous laths of altered labradorite, from $\frac{1}{4}$ inch to $1\frac{1}{2}$ inches long, set in a dense, purplish red, brown, or green groundmass. Here and there it is interlayered with a little finely bedded, red-brown tuff. In places it is a lava, as evidenced by epidote amygdules, but elsewhere these features were not observed and it may be that the rock is in part intrusive. Very similar rock forms a few of the fragments in the associated meta-andesite and meta-basalt agglomerates, and in the less altered andesitic and basaltic agglomerates between Sustut and Niven Peaks. Certain varieties on the southern part of McConnell Range contain $\frac{1}{4}$-inch labradorite laths and $\frac{1}{8}$-inch phenocrysts of pyroxene or hornblende, and may represent a phase of basaltic lava intermediate between the porphyritic basalt and the more common meta-andesite, which normally contains no conspicuous feldspar phenocrysts. The coarsely porphyritic basalt is provisionally assigned to the upper part of this group of altered volcanic rocks because it appears to be in part interlayered with meta-andesite and, nearby, immediately underlies volcanic formations thought to be of Jurassic age.

Hornblende Schist and Gneiss. These are fine to medium-grained, dark green to nearly black, foliated or banded rocks that, although derived mainly or entirely from the same volcanic group as the meta-andesites and associated rocks, into which they grade, have been markedly sheared and more or less completely recrystallized. They were found mainly near the larger granitic intrusions, as along and east of McConnell Creek, on Wrede Range, on either side of Dortatelle Creek, and thence southerly towards the north fork of Carruthers Creek. The most highly altered, gneissic phases generally lie within a few thousand feet of the borders of these intrusions, but not all rocks at such localities have been altered to this degree. The schists derived from tuffs show occasional traces of bedding, whereas some of those formed from agglomerates contain vague streaks and lenses resulting from the mashing and recrystallization of the agglomerate fragments. The microscope shows the schists to be composed mainly of fibrous, strongly pleochroic hornblende and andesine, and a little epidote. The gneisses are recrystallized rocks made up of lenticles, and bands as much as several feet wide, composed of amphibole and andesine in various proportions. Where they have been completely recrystallized, as within a few hundred feet of the larger granitic intrusions, the andesine, as revealed by the microscope, is free of alteration products, and occurs as interlocking grains, many of which are untwinned.

LIMESTONE, TUFF, AND ARGILLITE

A few rusty, well-layered bands of mainly interbedded limestone, tuff, and argillite are intercalated with the meta-andesites and related altered rocks, and with them are believed to comprise a conformable assemblage. They outcrop near upper Miller Creek, southeast of Johanson Lake, and between this lake and the head of Wrede Creek. Those south and southeast of Johanson Lake range from about 100 to 600 feet thick, but some of the bands north of the lake may be much thicker. The limestone is a thin-bedded, dark grey, finely crystalline rock forming layers up to 15 feet thick, which in many instances pinch and swell or end abruptly, due probably to flowage under stresses set up during the deformation of the enclosing strata. No fossils were found in this limestone although it was carefully examined. The tuffs are buff-surfaced, light grey, hard, sandy-textured rocks in beds ranging from a few inches to about 5 feet in thickness. Many are calcareous or contain calcareous layers, the latter type weathering to a ribbed surface as a result of the relatively rapid decomposition of the limy layers. The argillite is hard, black, and thinly bedded, and generally weathers rusty, due to finely disseminated pyrite. Some of it is gritty and tuffaceous, whereas other phases are soft and calcareous and not readily distinguishable from impure phases of the limestone.

Upper Division

Distribution

The volcanic and sedimentary formations that comprise the upper, Jurassic division of the Takla group occupy large parts of a belt, as much as 15 miles wide, that extends northwesterly from Ominicetla Creek to upper Niven River. They also underlie most of the area southwest of Bear Lake Valley.

Lithology

The principal rocks of this division are pyroclastic types, lavas, greywackes, conglomerates, shales, and argillites. The precise sequence is not known. Available evidence indicates that volcanic members greatly predominate among the lower strata and sedimentary members in the upper parts of the division, where, however, they are interlayered with volcanic rocks.

Approximately 18,000 feet of volcanic rocks outcrop between Bear Lake village and Driftwood River, where neither their upper nor their lower limits were recognized. Because of relatively complex structure few data are available on the aggregate thickness of the Jurassic sedimentary rocks. About 5,000 feet of strata are exposed in one section alone about 5 miles west-southwest of Mount Carruthers, but the aggregate thickness is obviously much greater. Thus the complete assemblage assigned to the upper division is probably considerably more than 23,000 feet thick.

Tuffs. The pyroclastic rocks include a wide variety of dominantly red, but in part brown, light green, and grey strata ranging from fine-grained tuffs to coarse agglomerates. The tuffs are thoroughly indurated, and vary from extremely fine-grained rocks to others consisting of subangular fragments up to about ¼-inch long, and which differ from the agglomerates only in the size of the constituent fragments. The tuffs generally form distinct beds from ¼-inch to 5 feet thick, the thicker layers commonly containing the coarser fragments. The grains and fragments within many of the layers range from coarse at the bottom to fine at the top. Occasional strata are crossbedded. Rare beds of very fine-grained red tuff, which were exposed to the atmosphere shortly after deposition, dried and broke into numerous saucer-like flakes that were later buried by other tuffs. Although most of the tuffs were deposited in water, others that formed thick unsorted layers or unbedded deposits may have accumulated on land. The fine-grained tuffs are homogeneous, reddish rocks that break with a conchoidal fracture: their texture on a freshly broken surface suggests that of an ordinary red building brick. A few tiny fragments of white feldspar may be visible. The typical medium- and coarse-grained tuffs display abundant rounded to angular fragments of white or grey feldspar and of fine-grained or porphyritic volcanic rocks in a fine-grained groundmass of similar material. The relative proportions of these three constituents vary widely from place to place. Microscopic examinations showed that the feldspar grains are generally altered, but those identified are albite or oligoclase. Most of the rock fragments are aggregates of minute feldspar laths: in some fragments the laths are oriented at random; in others they are sub-parallel. Other common constituents of the tuffs include carbonate, chlorite, specularite, and amorphous yellowish iron oxide. Much of the groundmass is indeterminate. These tuffs may have the approximate composition of acidic andesites. Rare varieties contain quartz and orthoclase fragments in an indeterminate reddish groundmass and are rhyolitic tuffs. Occasional grey or black layers of calcareous tuff weather rusty brown or grey, and contain up to 50 per cent ferruginous carbonate or calcite.

Agglomerates. These are bedded or massive rocks of about the same colour and composition as the tuffs; but they contain fragments ranging from ¼ inch to 2 feet or more in diameter. They are commonly interlayered with tuffs. The beds range from about 2 to 20 feet in thickness. Some beds show no evidence of sorting; others contain streaks resulting from the partial sorting of fragments of different sizes into different layers; and in a few beds the large pieces predominate at the base and the smaller ones at the top. Fragments are rounded, subangular, or angular. They are usually readily distinguishable from the groundmass on weathered outcrops, but are often very difficult to identify on fresh surfaces. In some exposures they comprise most of the rock, but elsewhere they are scattered more or less widely through a tuffaceous groundmass. The fragments are pieces of feldspar porphyry and massive or banded tuffs; the groundmass consists of smaller pieces of the same rocks. White feldspar grains, from $\frac{1}{10}$ to ¼ inch long, are generally abundant as phenocrysts in the porphyritic fragments and in places as grains in the groundmass. They stand out conspicuously on the red, green, and grey mottled, weathered surfaces.

A somewhat unique agglomerate was noted at several places throughout the length of the volcanic belt extends along the northeast side of the

Saiya fault and thence northwesterly beyond the mouth of Asitka River. It is best exposed on northeasterly facing cliffs 2 miles south-southwest of the source of Red Creek. It is there at least 180 feet thick, including two layers, 10 and 30 feet thick, of carbonaceous shale and coal. The agglomerate is dull grey to nearly black, and weathers grey or brown. It is rather friable, and appears to have been deeply weathered. It comprises an unsorted aggregate of rounded to subangular boulders and other fragments ranging from less than $\frac{1}{8}$ inch to more than 10 feet in diameter. These include feldspar porphyry, pyroxene porphyry, fine-grained calcareous rock, a variety of fine-grained, dull green or grey, volcanic rocks, and numerous black, carbonaceous fragments. Many of the calcareous boulders weather buff or rusty brown. The matrix is fine-grained tuffaceous material. A particularly characteristic feature is the widespread occurrence of silicified and carbonized fossil wood, the largest piece seen being a log $2\frac{1}{2}$ feet in diameter exposed for a length of 3 feet.

Lavas. These are mainly purplish red, red, or brownish red, porphyritic rocks; other varieties are green or grey. They are probably slightly less abundant than the tuffs and agglomerates with which they are interlayered. Typical lava displays numerous white or buff, lath-shaped plagioclase phenocrysts, $\frac{1}{16}$ to $\frac{1}{4}$ inch long, in a reddish, microcrystalline groundmass. These feldspar grains comprise 5 to 30 per cent of the rock, and in a few instances are accompanied by scattered quartz phenocrysts. Most of the lava is massive, but some contains amygdules, $\frac{1}{8}$ to $\frac{1}{2}$ inch or more in diameter, of chlorite, calcite, quartz, or other minerals. The amygdules are scattered more or less uniformly throughout the lava, or are concentrated in the basal and top parts of flows where they constitute as much as 30 per cent of the rock. Fragmental facies contain scattered angular fragments of porphyritic lava that so closely resemble the groundmass in colour, composition, and texture that they are commonly indistinguishable except on weathered surfaces. A distinctive variety occurring on Scallop Mountain and east of Yuen Creek contains abundant greenish white labradorite laths, up to $1\frac{1}{2}$ inches long, in a dense purplish groundmass; in places it displays pillows as much as $2\frac{1}{2}$ feet in diameter, and scattered amygdules. Individual flows range from about 25 feet to, in one instance, apparently more than 300 feet in thickness. Specimens examined under the microscope showed that the feldspar phenocrysts, largely altered to epidote, zoisite, calcite, white mica, and other minerals, range from albite to labradorite. Quartz, amphibole, and pyroxene form rare phenocrysts. The groundmass is a felt of feldspar laths associated with chlorite, epidote, and calcite and hematite. The lavas, accordingly, range from acid andesites to basalts and include rare dacites.

Greywackes. These are fine- to medium-grained, dark green to grey, sandy-textured rocks that weather green, grey-brown, or yellowish brown. They are well bedded, and are interlayered with conglomerates, slates, and argillites. The beds range from a few inches to several feet in thickness; a few layers are indistinctly crossbedded, and others contain rounded, rusty-weathered concretions of greywacke cemented by ferruginous carbonate or other material. Occasional well-sorted beds grade from coarse at the bottom to fine at the top. The greywackes comprise mainly subangular to partly rounded grains of chert and microcrystalline volcanic rocks: the latter are felted or subparallel aggregates of feldspar laths, or contain a few minute feldspar phenocrysts in an indeterminate groundmass. Occasional grains of plagioclase feldspars and of quartz were also noted, the latter comprising less than 10 per cent of the rock. Chlorite is abundant in the groundmass of the dark green greywackes.

Conglomerates. Most of the conglomerates have about the same composition as the greywackes and differ from them mainly in grain size. These are thoroughly consolidated grey, greenish grey, or limonite-stained rocks, and fresh fractures commonly pass through rather than around the pebbles. The conglomerates form layers ranging from a foot or so to many feet in thickness, but the thicker layers commonly contain lenses and beds of greywacke. The pebbles are subangular to rounded, and are generally less than 2 inches in diameter. Most of them are black, grey, and green, cherty rocks lithologically similar to cherty strata of the Asitka group. Pebbles of white quartz and red and green volcanic rocks, with $\frac{1}{16}$- to $\frac{1}{8}$-inch feldspar phenocrysts, are locally abundant. The matrix is apparently identical with the greywackes previously described. These conglomerates were probably derived from the same source as the greywackes, and are not known to mark significant breaks in deposition.

A unique volcanic conglomerate several thousand feet thick marks the base of the upper division 4 miles south of the southeast end of Sustut Lake. It is a well-bedded rock containing a few thin tuffaceous members. The conglomerate beds are commonly about 5 feet thick, and contain well-rounded pebbles and boulders loosely set in a red, sandy-textured, friable, tuffaceous matrix. The pebbles and boulders make up more than half the rock. Most of them are between 1 inch and 3 inches in diameter, but a few are as much as 2 feet across. They comprise mainly dark green porphyritic and amygdaloidal andesite or basalt indistinguishable from that of the lower division. The interlayered tuffaceous members are red, sandy-textured rocks, very similar to the conglomerate matrix. They form well-bedded layers ranging from a few inches to about 5 feet thick. Crossbedding was noted here and there.

Shales and Argillites. These commonly occur in sharply defined grey and black beds from less than 1 inch to about 2 feet thick. Some are soft and slightly calcareous; others are hard and siliceous; and probably many contain considerable fine, tuffaceous material. Argillites predominate, and are compact, banded rocks that break without particular reference to the banding into small, sharply angular blocks. Shaly beds, on the other hand, break along the bedding to form thin plates and slabs.

Other Rocks. Other minor strata found here and there include: grey, brown, or black limestone layers as much as 2 feet thick intercalated with the argillites; thin bands of light brown or grey impure limestone; and coal seams associated with carbonaceous shale or argillite.

Fossil Collections

Fossil remains of marine invertebrates are abundant in rocks of the upper division of the Takla group. They were found in greywacke, shale, argillite, limestone, impure limestone, calcareous tuff, and tuff. Fossil occurrences are far more numerous than indicated on the accompanying map (in pocket). The pointed, cigar-shaped skeletons of *Belemnites,* or their casts, are particularly common, and it is doubtful if any traverse in Jurassic sedimentary rocks failed to reveal a few of them.

The following collections proved to be most diagnostic[1]:

F13. Locality: 2 miles south of Dewar Peak.
Forms identified: *Platypleuroceras* sp. (group of *P. natrix* (Zietan))
Pecten sp.
Age: Early Lower Jurassic (Lower Lias)

F14. Locality: on Asitka River, 1 mile from mouth.
Forms identified: *Trigonia* (*Vaugonia*) sp.
Remarks: *Trigonia* with this style of ornament is almost or entirely confined to the Middle Jurassic.

F15. Locality: on top of ridge, 7 miles east of mouth of Saiya Creek.
Forms identified: *Cardioceras* (*Scarburgiceras*) aff. *scarburgense* (Young and Bird)
Phylloceras sp.
Age: middle Upper Jurassic (Oxfordian)

F16. Locality: on top of ridge, 8½ miles east of mouth of Saiya Creek.
Forms identified: "*Belemnites*" sp.
Trigonia sp.
Entolium sp.
Pecten sp.
Pleuromya sp.
"*Rhynchonella*" sp.
Age: Jurassic (Lower Jurassic?)

F17. Locality: 2½ miles west-southwest of mouth of Quenada Creek.
Forms identified: poor ammonite
Pecten sp.
large coral
Age: Lower Jurassic?

F18. Locality: 7½ miles east-southeast of mouth of Saiya Creek.
Forms identified: *Pseudocadoceras* (or *Longaeviceras*) sp. ind.
Age: probably middle Upper Jurassic (Oxfordian)

F19. Locality: 8 miles east-southeast of mouth of Saiya Creek.
Forms identified: *Trigonia*
Astarte sp.
Pecten sp.
Turritella sp.
other gastropods
Age: Jurassic

F20. Locality: 9½ miles east-southeast of the mouth of Saiya Creek.
Forms identified: "*Rhynchonella*" n.sp.?
"*Terebratula*" n.sp.?
Trigonia sp.
Age: Jurassic

F21: Locality: on creek, 6½ miles east of Saiya Lake.
Forms identified: *Trigonia* (*Vaugonia*) sp.
Remarks: *Trigonia* with this style of ornament is almost or entirely confined to the Middle Jurassic.

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[1]All identifications of ammonoids and correlations based on them are to be credited to Dr. L. F. Spath, British Museum of Natural History. Many of these identifications are tentative, owing to the poor preservation of the specimens.

The pelecypods were identified by F. H. McLearn, Palæontological Section, Geological Survey of Canada, who submitted the following remarks: "Many of the pelecypods belong to new and undescribed species. As the succession of Jurassic pelecypods has not yet been established by field studies, pelecypods at present have little value in correlation of Jurassic faunas in British Columbia".

F22. Locality: on top of ridge, 5 miles east-southeast of Saiya Lake.
Forms identified: Perisphinctid ind. (?*Binatisphinctes*)
Oxytoma sp.
Goniomya sp.
Entolium sp.
Age: Upper Jurassic, possibly middle Upper Jurassic (Oxfordian)

F23. Locality: on creek 5½ miles south-southwest of Mount Carruthers.
Forms identified: *Trigonia* sp.
Turritella sp.
Age: Jurassic

F24. Locality: 2¼ miles southwest of Mount Carruthers.
Forms identified: Perisphinctid sp. (?*Poculisphinctes*)
"*Belemnites*" sp.
Pinna sp.
Age: probably middle Upper Jurassic (Oxfordian)

F25. Locality: 2½ miles southwest of Mount Carruthers.
Forms identified: *Trigonia* (*Vaugonia*) sp.
Pleuromya cf. *laevigata* Whiteaves
Tracia sp.
Gervillia sp.
Remarks: *Trigonia* with this style of ornament is almost or entirely confined to the Middle Jurassic.

F26. Locality: 2 miles north of mouth of Yuen Creek.
Forms identified: Perisphinctid sp. ind. (?*Binatisphinctes*)
Age: middle Upper Jurassic?

F27. Locality: on Yuen Creek, 1½ miles from mouth.
Forms identified: *Witchellia* (s.l.) sp. ind.
Age: probably early Middle Jurassic.

F28. Locality: on west shore of Bear Lake, 4½ miles south of outlet.
Forms identified: *Pseudogrammoceras* sp. (group of *P. saemanni*)
?*Pseudogrammoceras* (or *Grammoceras*) sp.
Reynesoceras sp. nov.? (group of *R. ragazzonii* Hauer)
Trigonia (*Frenquelliella*) n.sp.?
Pecten, probably new species
Age: late Lower Jurassic (Upper Lias)

F29. Locality: on trail, ¼ mile south of south end of Bear Lake.
Forms identified: *Pecten* sp.
Trigonia sp.
Age: Jurassic

F30. Locality: on trail, ½ mile south of south end of Bear Lake.
Forms identified: *Haugia* sp. aff. *grandis* S. Buckman (periphery not preserved)
Trigonia sp.
Pecten sp.
Entolium sp.
Pleuromya sp.
"*Rhynchonella*" sp.
"*Terebratula*" sp.
Age: probably late Lower Jurassic (Upper Lias)

F31. Locality: 1 mile north of Scallop Mountain.
Forms identified: *Cardioceras* (*Scarburgiceras*) aff. *praecordatum* R. Douville
"*Belemnites*" sp.
Astarte sp.
Pleuromya sp.
Trigonia sp.
Age: middle Upper Jurassic (Oxfordian)

F32. Locality: ¼ mile southeast of Scallop Mountain.
Forms identified: *Stephanoceras* sp. (but periphery not preserved)
Age: probably Middle Jurassic

F33. Locality: on Ominicetla Creek, 3 miles north of latitude 56 degrees.
Forms identified: *Pecten* sp.
Trigonia sp.
Age: probably Jurassic

Structure of the Takla Group

INTERNAL STRUCTURAL RELATIONS

Relation of the Upper Division to the Lower Division

The formations of the upper division overlie those of the lower division without recognized angular discordance and without known evidence of widespread intervening erosion. Thus, about 3 miles northwest of Mount Carruthers, well-bedded, red and green, andesitic Jurassic tuffs are separated by about 100 feet of drift from the underlying, dull green, andesitic or basaltic tuffs and agglomerates of the lower division. The strata of the two divisions appear to have identical attitudes. No gradational facies, however, were seen, nor were strata typical of either division interlayered with the other. This contact is probably marked only by an abrupt change in the composition of the pyroclastic rocks. Similar abrupt changes in stratigraphy appear to mark this contact 1 mile north and 1½ miles east of Mount Carruthers. As already mentioned, the basal member of the upper division 4 miles south of the southeast end of Sustut Lake is well-bedded volcanic conglomerate several thousand feet thick. This rests without recognized angular discordance on basaltic lava and agglomerate of the lower division. The conglomerate consists of rounded boulders and pebbles of these or very similar volcanic rocks set in a friable, red, tuffaceous matrix. It is interpreted as evidence that, locally, a period of erosion preceded the deposition of the Jurassic formations. Whereas the base of the upper division is thus generally well defined and readily recognized, nevertheless 6½ miles west-northwest of the mouth of Quenada Creek no such sharp contact was found. There, the coarse, grey and red, andesitic agglomerates and tuffs tentatively assigned to the upper division grade downwards into the green andesitic and basaltic agglomerates and tuffs of the lower division. Accordingly, in this vicinity, vulcanism must have been an essentially continuous process, the composition of the ejected fragments becoming progressively more acid as the strata of the upper division began to accumulate.

Folds and Faults

The Takla strata occupy a broad, northwesterly trending synclinorium greatly complicated by faults and subsidiary folds. The approximate axial part of this structure, as indicated by the occurrence of the youngest fossiliferous Takla beds, extends northerly from Scallop Mountain to the mouth of Yuen Creek, and thence northwesterly towards the mouth of Asitka River and probably beyond along the southwest side of Red Creek Valley. This axial part of the synclinorium lies, throughout most of its length, close to the southwest edge of a parallel belt, some 12 miles wide, within which lie most of the known major faults of the map-area. As in the underlying Asitka strata, a few scattered observations suggest that the folds generally plunge northwesterly.

The oldest Takla rocks are found only on the northeast limb of the synclinorium. On this limb strata of the lower division occupy a belt as much as 14 miles wide extending northwesterly through Ingenika and McConnell Ranges. Between Johanson Lake and the east border of the map-area these rocks dip consistently west and southwest, but elsewhere, except for a synclinal fold that crosses upper Dortatelle Creek, little is known of their structure. However, as these formations display a true thickness of about 10,000 feet near Sustut Peak, the great width of the belt suggests much repetition by folding. Southwest from Asitka and Sustut Lakes and along Sustut River for 10 miles below its junction with Moosevale Creek, dark green volcanic rocks of the lower division and red volcanic rocks of the upper division dip consistently southwest, away from the underlying Asitka rocks. Between Mount Carruthers and Carruthers Creek, however, the same succession of Takla rocks displays consistent northeasterly dips for a distance of 3½ miles. Northwest from a point between these regions of opposing dips is a wedge-shaped area of mainly Takla rocks lying between the Omineca and Red Creek faults. Here, near the junction of the faults, the oldest Takla rocks occupy a northwesterly plunging anticline and rest on a similar structure in Asitka rocks; scattered attitude observations in younger Takla rocks to the northwest beyond Sustut River suggest that this structure extends northwesterly to the west border of the map-area.

The strata along the axial zone of the synclinorium exhibit greater and more abrupt variations in attitude than elsewhere, possibly due to the greater proportion of sedimentary Takla rocks involved.

Most of the strata of the southwest limb are buried beneath younger formations, but between Bear Lake Valley and Driftwood River Lower Jurassic reddish volcanic rocks dip consistently northeast.

EXTERNAL STRUCTURAL RELATIONS

Relation of the Takla Group to the Asitka Group

The basal members of the Takla group, although differing markedly in lithology from the members of the Asitka group rest on them without apparent angular discordance. The structural relations were best seen on the northern spur of Sustut Peak where the strata of the two groups succeed each other without marked change in attitude except that the basal tuffaceous argillite of the younger group is slightly sheared and crumpled for about 50 feet adjacent to the Asitka rocks. This disturbed zone does not appear to represent much displacement, because similar tuffaceous argillite was found at the base of the younger group at widely separate localities. However, exposures here, as elsewhere, are such that an angular discordance of perhaps as much as 10 degrees would not have been recognized. The Asitka rocks commonly include abundant schistose types, and are characterized by local crumpling, features extremely rare in the Takla group. Evidence, too, afforded by the conglomerates of the upper division of the Takla group indicates the Asitka supplied detritus to these conglomerates. Furthermore, the basal Takla strata rest on Lower Permian rocks near Sustut Peak and on Middle Permian beds to the southeast in the Takla map-area (Armstrong, 1946). Such cumulative evidence seems to imply at least a period of non-deposition and erosion preceding the deposition of the basal Takla strata.

Relation of the Takla Group to the Cache Creek Group

The rocks of the Takla group are separated from those of the Cache Creek group by the Ominicetla and Omineca faults, described in Chapter III.

AGE

Age of the Lower Division

Data pertaining to the age of the lower division of the Takla group apply only to the andesitic and basaltic volcanic rocks and tuffaceous argillites. However, the lithology of the meta-andesites, meta-basalts, and associated rocks suggest that they are the metamorphosed equivalents of this andesitic and basaltic assemblage and accordingly of the same age. Nevertheless, as these two essentially unfossiliferous assemblages are generally separated by wide, drift-filled valleys, and as they display various degrees of metamorphism from place to place, this correlation must be considered as provisional. The limestones, tuffs, and argillites are interlayered with, and, therefore, of about the same age as, the meta-andesites, meta-basalts, and associated formations, and hence tentatively of the same age as the andesitic and basaltic group.

No diagnostic fossils were found within the andesitic and basaltic assemblage, but on the northern spur of Sustut Peak its basal members rest on Asitka strata containing foraminifera (F5) of Lower Permian age. Other members are overlain, as on the south side of Asitka River about 2½ miles south-southwest of the mouth of Quenada Creek, by strata of the upper division of the Takla group, which contain in other places (F13, F28, F30) fossils of Lower Jurassic age. Accordingly, fossils provide no evidence for dating this assemblage, and likewise the rest of the lower division, more accurately than post-Lower Permian and pre-Lower Jurassic. The following features, however, suggest that it is more closely related to the overlying Jurassic rocks than to the underlying Permian strata, and is most probably of Upper Triassic age.

(1) It bears no lithological resemblance to the strata herein assigned to the Asitka and Cache Creek groups and probably differs from them in degree of metamorphism.

(2) It resembles the overlying Jurassic volcanic formations in internal structure and degree of metamorphism, but differs from them in composition and colour.

(3) Agglomerates and breccias, particularly in its upper part, contain a few fragments characteristic of the Jurassic volcanic members.

(4) It is believed to be overlain conformably, in most places, by the strata of the upper, Jurassic division of the Takla group.

(5) It is probably separated by a disconformity from the underlying Permian formations.

(6) No fossils of Middle or Lower Triassic age have been identified in any of the sedimentary formations of this part of British Columbia, although Upper Triassic and Jurassic collections have been obtained from many localities.

Age of the Upper Division

Palæontological evidence previously cited shows that the strata of the upper division of the Takla group range in age from early Lower Jurassic (Lower Lias), through Middle Jurassic, to middle Upper Jurassic (Oxfordian). The rocks providing Lower Jurassic fossils are parts of an essentially volcanic assemblage and lie near the southwest (F28, F30) or northeast (F13, F16) flanks of the broad northwesterly trending belt that embraces all known occurrences of upper division strata. On the other hand, the rocks holding Upper Jurassic fossils (F15, F18, F22, F24, F26, and F31) are of sedimentary origin, occupy parts of a medial area in this belt, and extend northerly and northwesterly from Scallop Mountain through the mouth of Yuen Creek towards the mouth of Asitka River. The prolongation of this area of Upper Jurassic strata extends northwesterly through Red Creek Valley and contains lithologically similar Jurassic sedimentary formations that may likewise be, at least in part, of Upper Jurassic age.

GABBRO, PERIDOTITE, PYROXENITE, DUNITE, AND SERPENTINE

Distribution

Dykes, sills, and other bodies of peridotite, pyroxenite, and dunite, or their serpentinized equivalents, were found at widely scattered localities throughout the length of the map-area and east of a line extending from Ominicetla Creek, at the south boundary of the area, northerly through the mouth of Dortatelle Creek to a point on the north boundary of the map-area about 4 miles west of Fredrikson Lake. Gabbro underlies much of Axelgold Range southeast of Axelgold Peak, and a smaller body outcrops at the north end of the range. None of these rocks were found more than 6 miles from exposures of the Omineca intrusions, and all occur within areas underlain by the Cache Creek group, by the lower division of the Takla group, or by the Omineca intrusions.

Lithology

Peridotite, Pyroxenite, Dunite, and Serpentine. The rocks of this assemblage generally weather to a soft, buff or reddish brown, slippery surface. Some outcrops are massive and well rounded; others are thoroughly broken and shattered and strewn with the resulting angular blocks ranging from a few inches to many feet in diameter. Fresh surfaces of these rocks are black, brownish black, or dark greenish grey, and very fine grained to coarsely crystalline. Many outcrops are traversed by seams of bluish green, flaky, serpentinous material; by pearly grey, pink weathering, talcose material; or by buff to rusty weathering talc-carbonate seams and knots. Green, flaky, or semi-fibrous serpentinous material commonly covers the fracture faces of talus blocks. Isolated grains and granular aggregates of magnetite and, rarely, chromite project from the weathered surface. Most ultrabasic bodies are sufficiently magnetic to interfere with compass readings. Some of the pyroxenites are so slightly serpentinized as to be readily identifiable in the field. Rocks classed as peridotites commonly show, on their otherwise smoothly weathered surfaces, scattered projecting nodules interpreted as altered crystals of pyroxene. Still other types are very fine-grained, homogeneous, highly serpentinized rocks lacking the nodular surface and scattered cleavage faces of former pyroxene grains, and are doubtless, in part at least, serpentinized dunites.

Specimens examined under the microscope contain various proportions of orthorhombic or monoclinic pyroxene, olivine, serpentine, talc, carbonate, chromite, and magnetite. Serpentine in various forms is the most abundant alteration product, but talc is an important constituent locally. The ultrabasic bodies of Axelgold Range and the southeastern tip of Sikanni Range have been almost entirely converted to these minerals, but retain remnants of unreplaced olivine, and were probably originally dunites and peridotites. A coarsely crystalline pyroxenite from the north end of the intrusion near the source of Dortatelle Creek contained about 85 per cent pale brownish augite, 10 per cent magnetite, and 5 per cent serpentine. Another specimen of fine-grained, soft black rock with a smooth buff surface was collected near the south end of this mass. It proved to be an altered dunite comprising about 60 per cent olivine, 30 per cent serpentine, and 10 per cent magnetite, the last occurring both as enhedral to subhedral grains and as minute specks scattered through the olivine or concentrated along the many serpentinized seams that traverse the olivine. A fresh, medium-grained, brownish black pyroxenite, probably a common phase of the stock-like body north-northeast of Johanson Lake, consisted mainly of a non-pleochroic, orthorhombic pyroxene with prominent schiller striations.

Although the body near the source of Dortatelle Creek contains variously serpentinized peridotites, pyroxenites, and dunites, and other masses were found to include more than one type, no sharp boundaries were found between any of these rocks. Most probably all are genetically related types of about the same age.

Olivine Gabbro. Much of this rock southeast of Axelgold Peak is well banded, and from a distance layers, which range from about 1 inch to 5 feet in thickness, may be so conspicuous as to suggest sedimentary strata. No banding was noted in the smaller body at the north end of Axelgold Range. Fresh gabbro surfaces are light to dark grey, but the weathered rock is generally light or rusty brown, and the degree of oxidation varies from layer to layer. In places the surface has disintegrated to a brown sand composed of the principal mineral constituents, feldspar and pyroxene. The layers differ from each other in grain size or in the proportions of minerals, or both, and each layer grades abruptly into the next. None was seen to thicken or thin appreciably. The proportion of dark minerals varies widely from layer to layer, but is nearly constant for each individual layer. Grain size generally ranges from $\frac{1}{16}$ to $\frac{1}{4}$ inch, but exceptional facies contain crystals $1\frac{1}{2}$ inches or more in length.

Under the microscope the constituent minerals are seen to be grey, white, or pale mauve labradorite, brown augite, and olivine, with minor amounts of biotite, brown pleochroic amphibole, magnetite, pyrrhotite, and pyrite. All minerals are remarkably fresh. Labradorite composes 40 to 90 per cent of the rock, the remainder consisting mainly of augite. Some of the more highly feldspathic layers probably do not contain olivine, but others with less feldspar include as much as 15 per cent. The metallic minerals are more plentiful in some layers than in others, but nowhere were estimated to exceed 5 per cent of the rock. The labradorite forms interlocking grains or imperfectly formed laths. The augite occurs as irregular interstitial grains or, less commonly, as larger, optically continuous grains enclosing several laths of labradorite and partly surrounding others.

Structure

The ultrabasic rocks form sills, dykes, and stock-like bodies. The sills and dykes are particularly common on Axelgold Range where they vary in width from about 30 to 500 feet and probably exceed 3 miles in length. The largest stock-like body, 3½ miles south of Wrede Creek, is about 3 miles long and 2 miles wide.

The sills and dykes intruded the Cache Creek strata of Axelgold Range. Where the contacts were observed the intrusive rock was sheared and altered to smooth, green, flaky serpentine, and the nearby enclosing strata were not noticeably more altered than elsewhere.

Near the source of Dortatelle Creek pyroxenite is in contact with gneissic, probably mainly pyroclastic, rocks of the lower division of the Takla group. In part the rocks are separated by as much as 3 feet of sheared, rusty rock possibly derived from pyroxenite, but at one place the contact is sharp, sinuous, and not sheared, and approximately parallels the foliation of the Takla formations. Neither rock is noticeably changed in composition or grain size at the contact. The pyroxenite probably intruded the Takla group rocks because: (1) it has the texture and composition generally ascribed to an intrusion; (2) it is in sharp lithological contrast with the Takla strata; (3) no evidence was found to suggest that the Takla strata are younger than the pyroxenite; and (4) the form of the pyroxenite body suggests that of a small intrusion in the Takla rocks.

The ultrabasic body 3½ miles south of Wrede Creek was not found in contact with the adjacent Takla rocks, but its stock-like form and the probability that its contacts cross the trend of the enclosing strata suggest that it, too, was injected into the formations of the lower division of the Takla group.

Partly serpentinized peridotite, near the source of Dortatelle Creek, is cut by dykes of granodiorite up to at least 15 feet in width. At the one contact observed, 1 foot to 5 feet of the peridotite adjacent to the granodiorite has been altered to a pink weathering talc schist.

The banded body of gabbro southeast of Axelgold Peak is about 7½ miles long and 3 miles wide. The bands are inclined at angles ranging from nearly horizontal to vertical. Most observations were made in the northwest part of the body, where they are horizontal or dip southwesterly at angles up to about 30 degrees; that is, in a direction opposite to that of the enclosing, older, Cache Creek beds.

Contacts between the gabbro and the enclosing strata of the Cache Creek group are sharp where observed, and gabbro dyklets cut these strata.

On the northeast face of Axelgold Peak the intrusion encloses, or nearly encloses, several tabular bodies of white crystalline limestone, presumably of the Cache Creek group, but the contacts with these bodies were not seen.

Age

The ultrabasic rocks, as indicated above, are cut by and, therefore, older than, the Omineca intrusions. As these intrusions supplied detritus to Sustut conglomerates of early Upper Cretaceous age, the ultrabasic rocks can scarcely be younger than very early Cretaceous and most probably are not younger than Jurassic. Further, if, as seems probable, they cut the lower Takla rocks they can hardly be pre-Jurassic because: (1) the lower Takla rocks are generally overlain conformably by strata that in places contain early Lower Jurassic fossils; and (2) the oldest rocks mapped with the Takla group are probably not older than Upper Triassic, and the Triassic was a relatively short period. Available evidence within the map-area, therefore, suggests that the ultrabasic rocks are of Jurassic age.[1]

Although the age of the gabbro relative to the ultrabasic rocks of the Axelgold Range was not determined, its proximity and basic character suggest a genetic relation and common, that is, probable Jurassic, age.

OMINECA INTRUSIONS

Distribution

The Omineca batholith, of which the granitic intrusions of McConnell Creek map-area form a small part, is a major geological feature of northern British Columbia. It has been traced 65 miles southeast of the map-area (Armstrong, 1946) and at intervals for more than 250 miles northwest into Yukon. In the map-area it has been deeply eroded over two main areas of about 100 square miles each, one lying south-southeast from upper Dortatelle Creek and the other north-northwest from upper Wrede Creek. In the intervening territory, on McConnell Range, and immediately northeast of Sustut Lake, granitic intrusions outcrop as scattered irregular bodies ranging from less than a mile to about 12 miles in length. Small outcrops of quartz porphyry were noted on McConnell Range and between upper Moosevale Creek and upper Niven River.

Lithology

The Omineca intrusions, except for pegmatitic dykes, light grey dioritic bodies, and quartz porphyry described below, are mainly grey to pink granodiorite and quartz diorite. They range from medium-grained, equigranular rocks to coarse-grained, porphyritic types carrying pink orthoclase phenocrysts about an inch long, and, in general, are remarkably free from inclusions of older sedimentary or volcanic strata. Rocks classified as granodiorite average 20 per cent quartz, 45 per cent oligoclase or andesine, 20 per cent microcline or orthoclase, and 15 per cent amphibole

[1]Similar ultrabasic rocks, known as the Trembleur intrusions, occur about 90 miles southeast of McConnell Creek map-area in the vicinity of Trembleur Lake. J. E. Armstrong, Geological Survey of Canada, states in a personal communication that at least some of these have supplied detritus to Upper Triassic sedimentary rocks and are, therefore, of pre-Upper Triassic age.

or biotite, or both, with accessory apatite, sphene, and metallic iron minerals. Those classified as quartz diorite average 20 per cent quartz, 65 per cent andesine, and 15 per cent amphibole or biotite, or both, with minor pyroxene, apatite, sphene, and metallic iron minerals. Both types, in places, contain up to 40 per cent quartz.

Pink pegmatite dykes are scattered throughout the granitic masses, but are nowhere very abundant. They also occur in the adjacent intruded rocks as far as 1½ miles from the nearest exposed granite contact. They are perhaps most common in the granitic bodies near their borders and in the immediately adjoining, older schistose and gneissic volcanic rocks, particularly in the general vicinity of upper Dortatelle Creek. Coarse-grained pink feldspar predominates and is accompanied by white feldspar, quartz, mica, and rare grains of red-brown garnet, beryl, and pyrite. Fine-grained aplitic facies comprise parts of many of the dykes.

Fine- to medium-grained, light grey, dioritic intrusions outcrop as three main bodies on the mountain immediately northeast of Sustut Lake, the largest of which has an outcrop length of about 2½ miles. Sills and dykes of similar rock are scattered throughout the general region extending easterly from Sustut Lake to the east boundary of the area and in McConnell Range. The visible constituents in the most common type of rock are blocky $\frac{1}{16}$- to $\frac{1}{8}$-inch grains of white plagioclase and $\frac{1}{8}$- to $\frac{1}{4}$-inch grains and laths of pyroxene or amphibole, or both, the dark minerals comprising about 15 per cent of the mass. Here and there a few tiny grains of quartz are visible, and north of Asitka Peak rounded quartz grains up to $\frac{1}{4}$ inch in diameter made up 5 to 10 per cent of the rock. In a few of the narrower dykes, 5 feet or less in width, the above minerals are set in a finely crystalline groundmass that comprises as much as 30 per cent of the rock. Thin sections show about 75 per cent of strongly zoned saussuritized plagioclase and about 10 per cent quartz as scattered, smaller, rounded grains. The plagioclase is probably basic andesine and labradorite, and the rock is probably mainly quartz diorite, but in part is quartz gabbro. These dioritic bodies are tentatively grouped with the Omineca intrusions, but carry less quartz than the normal granodiorite and quartz diorite of the batholith, and have a peculiar porphyritic texture due to the contained, predominately blocky, plagioclase crystals.

Scattered dykes of fresh, brownish pink quartz porphyry occur along the southwest side of McConnell Range and on a ridge 3 miles south-southeast of Dewar Peak. Small outcrops of similar rock were found along the Niven River trail about 2½ miles west-southwest of Niven Peak, but it is not known whether these are parts of dykes or of a larger stock-like mass. The conspicuous feature of the rock is the rounded, clear to cloudy quartz grains, from $\frac{1}{4}$ to $\frac{1}{2}$ inch in diameter, that make up about 15 per cent of the outcrop. These lie in a microcrystalline, pink or brown groundmass containing varying amounts of pink or brown, commonly striated, $\frac{1}{16}$- to $\frac{1}{8}$-inch grains of feldspar.

Structure

The Omineca intrusions are mainly massive rocks, but the two largest bodies, essentially granodiorite and quartz diorite, display local, slightly gneissic phases and vary a little in texture and composition from place to place. Nevertheless, the various facies commonly appear to grade into one another, though in places quite abruptly, and no sharp chilled contacts, such as might be expected between masses of widely different age, were observed. The intrusions, accordingly, are not known to represent more than one general period of emplacement.

The contact between the volcanic rocks and the large granitic body south of Dortatelle Creek is generally well defined, although the intruded rocks are cut by numerous granitic and pegmatitic dykes for as much as ¼ mile from the main body of the intrusion. However, at the northern tip of the mass, at the head of Dortatelle Creek, gneissic granodiorite grades, for about 1,000 feet, through a dark green injection gneiss, and layered hornblende-feldspar gneiss traversed by a swarm of pegmatite dykes and sills, into the normal schistose and gneissic phases of the meta-andesite rocks of the lower division of the Takla group.

The borders of the large intrusion extending north-northwest from Wrede Creek are similar, so far as examined, to those of the southern intrusion except on the east side of McConnell Creek Valley and on Ingenika River below the mouth of McConnell Creek. At the latter place, and on the tributary that enters McConnell Creek from the east about 6 miles from its mouth, what appear to be border phases of the batholith are medium-grained, equigranular, dark green rocks comprising about equal proportions of pink and dull greenish feldspar and chloritized amphibole and biotite. No sharp boundary was found between this material and either the normal granitic rocks on the one hand or the schistose and gneissic altered volcanic rocks of McConnell Creek on the other.

The two main bodies of the Omineca intrusions provide continuous exposures of granitic rock from the southeast corner of the map-area to Dortatelle Creek and again from Wrede Creek to the north boundary of the map-area. The many smaller intrusions found in the intervening region suggest that these two bodies are the surface expression of a batholith underlying the full length of the map-area; and that a depressed saddle-like part of its roof lies beneath the surface in the Johanson Lake region.

The scattered irregular intrusions between Dortatelle and Wrede Creeks and on McConnell Range, and the tongue-like body that projects south from the batholith to occupy the northeastern part of McConnell Range, are generally in sharp contact with the intruded rocks. The granitic rock is chilled for distances ranging from 1 inch to 5 feet from the contact. Thus, 5 miles west-northwest of the mouth of McConnell Creek, medium-grained pink biotite granodiorite with about 35 per cent quartz grades outward through a zone about 4 feet wide of progressively finer grained feldspar-quartz porphyry to a contact phase about a foot wide of dense, pink, porcelaneous to cherty rock with scattered, $\frac{1}{16}$-inch feldspar phenocrysts and rare quartz grains. Where these sharp, chilled contacts were found, the adjacent rocks of the meta-andesite assemblage have, as a rule, escaped the extreme metamorphism that in places adjacent to the batholith has altered them to gneisses and schists. These features are those that might be expected to attend steep-sided, plug-like intrusions.

The dioritic intrusions northeast of Sustut Lake are in sharp contact with the host rocks, and in places the border phase of the intrusion has been chilled, for widths of as much as 4 inches, to a dense, light grey, cherty-textured rock.

Age

The Omineca granodiorites and quartz diorites cut the meta-andesites and associated rocks of the lower division of the Takla group at many places in the map-area, but were not observed to cut Jurassic strata. However, they do cut the latter rocks, containing Lower Jurassic fossils, in the adjacent Takla map-area (Armstrong, 1946), and, therefore, can scarcely be older than late Lower Jurassic. Nevertheless, as no important unconformity has been recognized within the Jurassic assemblage of the Takla and McConnell Creek map-areas, and as strata of middle Upper Jurassic age occur in the latter area, it is quite possible that the Omineca intrusions are not older than very late Upper Jurassic. They contributed abundant cobbles and pebbles to the early Upper Cretaceous strata of the Sustut group of McConnell Creek map-area, and to upper Lower Cretaceous formations[1] of the adjacent Aiken Lake map-area, and, accordingly, were probably not emplaced later than early in the Lower Cretaceous epoch.

SUSTUT GROUP

Distribution

The Sustut group comprises a thick assemblage of conspicuously bedded and banded continental strata of relatively simple structure. Within the map-area they occupy a belt 10 to 15 miles wide, extending northwesterly from Kastberg Creek at latitude 56 degrees to cross longitude 127 degrees between Bear River and Red Creek Valleys; and they underlie the entire corner northwest of upper Niven River and Thorne Creek. Similar strata have recently been noted as far southeast as Takla Lake (Armstrong, 1946), and an examination of air photographs indicates that they extend northwesterly into unmapped terrain beyond McConnell Creek map-area at least to the headwaters of Stikine River and probably beyond. The Sustut strata of the map-area are thus part of a probably continuous, northwesterly trending basin of similar strata 160 miles or more in length.

Lithology

On the west side of Thutade Lake the Sustut group can be separated readily into a lower and upper division. Members of the lower division are mainly interbedded conglomerate and pebbly sandstone, but include many layers of sandstone without pebbles. Those of the upper division include mainly intercalated sandstone and shale, the basal members being interlayered with several thin bands of white weathering dacitic tuff. The change, however, appears to be a progressive one except that heavy conglomerates are confined to the lower division, and the boundary has been placed arbitrarily at the lowest exposed band of dacitic tuff. Elsewhere in the map-area it was not found practicable to subdivide the Sustut group in this manner, although, as shown on the accompanying map, the dacitic tuffs were found at widely separate localities. No evidence of any significant interval of non-deposition was found within the group. The base of the lower division was not found at Thutade Lake, but in one

[1] Armstrong, J. E.: personal communication.

measured section opposite Niven River about 590 feet of strata assigned to this division are exposed above the lowest outcrops, which lie 400 feet above the lake; and if, as appears probable, these strata extend to lake level the lower division is at least about 1,000 feet thick. The same section exposes about 1,550 feet of strata of the upper division, giving the group, at this locality, a probable minimum thickness of about 2,500 feet. The upper surface here, as in all exposures except those capped by Tertiary basalt, is the Recent erosion surface. Cliffs rising abruptly from the northeast side of Bear Lake at Tsaytut Bay display about 3,000 feet of strata, with the base unexposed; and appreciably greater accumulations are found on the northeast slopes of Connelly Range.

Conglomerates. The typical conglomerates of the Sustut group are grey, buff, or brown-surfaced rocks containing abundant rounded pebbles and cobbles that separate readily from a sandy-textured matrix that commonly comprises less than half the rock. Most pebbles are 1 inch or 2 inches in diameter, and the largest cobbles about 10 inches. Pebbles are more abundant than cobbles, but no great difference was noted in the composition or relative proportions of the various types of each. Both are smooth and ellipsoidal or sub-spherical, except that those an inch or less in diameter are in part subangular. The pebbles are of grey to pink, mainly equigranular granitic rocks; white vein quartz; grey, black, green, and bright red cherty rocks; purple, red, and green feldspar porphyries with aphanitic groundmass; green lavas and pyroclastic rocks with abundant black pyroxene crystals and grains; brown lava with ½-inch plagioclase laths in a microcrystalline groundmass; various fine-grained, hard, green to reddish, tuffaceous or argillaceous rocks; and rare pieces of coaly shales. The percentage of the various types varies widely from place to place, and not all types were found at any one locality. Perhaps pebbles of vein quartz are the most abundant: locally they comprise about 85 per cent of all pebbles present. Porphyritic volcanic rocks, many of them identical with those of the Takla group, are almost equally common. Granitic pebbles are most numerous between lower Sustut River and the northwest corner of the area, and in several places exceed in number all other types. They comprise nearly half the pebbles found in some exposures of the basal conglomerates. The sandy matrix is composed mainly of grains of rocks similar to those of the pebbles. The conglomerate forms thin lenses, or beds ranging up to 20 feet in thickness. Some beds are interlayered with sandstone; others occur in groups and form conglomerate bands up to 100 feet or more in thickness. These bands outcrop as ridges or vertical cliffs. One such band, on the northeast side of Connelly Range, was traced northwesterly for about 26 miles; yet no equivalent conglomerate was found on the Bear Lake side of this range, and it may thin out and end in that direction. Conglomerates are interspersed throughout that part of the group lying stratigraphically below the dacitic tuffs, and occasional thin beds are found higher up; in many, but not all, places they are the basal rocks of the group. No consistent relation was noted between the stratigraphic position of the conglomerates and the size of their pebbles and cobbles.

A brown or reddish conglomerate, recognized only on the southwest wall of Moose Valley, 5 to 7 miles southeast of the mouth of Pilot Creek, has been included provisionally with the Sustut group, but may be older. It is a vaguely bedded, poorly sorted rock with angular boulders up to 2½ feet in diameter, smaller rounded to subangular pebbles and cobbles, and occasional thin sandy layers. The boulders are mainly of grey, green, and red cherty rocks and grey, dense to crystalline limestone containing corals, crinoid stems, and fusilinids, and were probably derived from the Asitka group. Many of the pebbles and cobbles are of the same materials, but others are well-rounded pieces of grey to red amygdaloidal lava or brownish pink quartz porphyry: very similar quartz porphyry elsewhere occurs as dykes cutting rocks of the lower division of the Takla group. The matrix is sandy-textured material of about the same composition as the coarser detritus.

Sandstones. Buff, greenish brown, or light grey, fine- to coarse-grained sandstones are the dominant rocks of the Sustut group. Most of them are composed mainly of minute rock fragments, but local facies contain, in addition, prominent feldspar grains. Although these are well indurated rocks that, in places, provide huge talus blocks, they fracture around individual grains rather than through them. Beds range from a fraction of an inch to more than 20 feet in thickness, and commonly contain bands of various grain size that grade into one another. Crossbedding and ripple-marks are common features. The beds also contain scattered pebbles, seams and lenses of pebbles, concretions of brown calcareous sandstone up to about a foot in diameter, black carbonaceous grains, tiny lenses of coal, and fragments of well-preserved fossil wood. In many places they are intercalated with shale. Leaf imprints are common, particularly in thin, silty, micaceous layers in the lower part of the group.

Microscopic examination indicates that these rocks are composed of various proportions of angular to subangular grains of vari-coloured chert, a variety of fine-grained feldspathic volcanic rocks, quartz, plagioclase, microcline, and minor untwinned feldspar. Quartz grains comprise 5 per cent to, rarely, 35 per cent of the mass.

Shale. This is a red, green, or dark grey, soft rock that on drying breaks into small fragments, so that specimens of any size are almost impossible to obtain. It contains scattered rock grains and small pebbles, and a few calcareous concretions ranging from sub-spherical bodies an inch or so in diameter to elongate masses 2 feet in length. The shale is probably most plentiful in the upper part of the Sustut group, but occurs also interbedded with the lower strata.

Tuff. White weathering dacitic tuff occurs as bands, ranging from 2 to 50 feet or more in thickness, interlayered with other Sustut strata on Connelly Range, northwest of that range beyond Sustut River, and on the upper slopes of Thutade Lake and lower Niven River Valley. It is a dense, cherty-textured to medium-grained, light yellowish green, greenish grey, or dark brownish green rock. Most weathered surfaces show distinct beds that range in thickness from a fraction of an inch to 6 inches or more, and in a few places finely crossbedded layers were noted. Bedding planes are not well defined on fresh surfaces, except where emphasized by black carbonaceous films, and the rock commonly breaks with a sub-conchoidal fracture that crosses the bedding. Many of the carbonaceous films are a mat of fossil leaves, a few of which are well preserved. Occasional layers intercalated with the tuffs on Connelly Range and Sustut River contain scattered, rounded forms suggestive of amygdules, and may be lavas.

Microscopic study showed the tuffs to contain abundant brownish volcanic glass and microcrystalline material formed by the devitrification of glass; excellent shards appear to be a characteristic feature. The sharply angular crystal fragments scattered throughout the rock are mainly plagioclase, at least some of which is andesine; others include quartz and sericitized orthoclase.

It seems probable that the tuff bands, wherever they occur, are confined to a stratigraphic interval of perhaps 500 feet closely overlying the uppermost heavy conglomerate beds; but they are more numerous in some sections than in others, and in some places, as near the northwest end of Connelly Range, it is possible that no tuff was laid down in Sustut time. Thus, about 2 miles northwest of Peggy Peak numerous tuff bands, distributed throughout an estimated stratigraphic interval of 500 feet, overlie a prominent conglomerate member and decrease in number to the northwest so that on Sustut River and beyond only one or two bands were located; but again these lie just within and above the same conglomerate. Also, on either slope of Thutade Lake Valley, three or four tuff bands, the lowest lying just above the topmost prominent conglomerate, are separated by a maximum stratigraphic interval of about 475 feet.

Metamorphism

The Sustut strata have been intruded by large bodies of Kastberg quartz diorite near Peggy and Nep Peaks, where the shales, for as much as 10 feet from the borders of the intrusions, have been changed to hard, black, white weathering, slaty rocks. The sandstones throughout this area are harder and less weathered than elsewhere, and break through rather than around individual grains and pebbles. They contain a little calcite and fine-grained, pale brown mica, and are rust stained in places.

Internal Structural Relations

The Sustut strata northeast of Bear Lake and Bear River Valley form two great, open, northwesterly trending folds, a synclinal axis lying about 2 miles northeast of Bear Lake village, and an anticlinal axis about 6 miles farther northeast along the southwest side of Saiya Creek Valley. No minor folds were noted on these major structures northeast from Bear Lake nearly to the Saiya fault, nor along Sustut River for about 5½ miles upstream from the mouth of Bear River. However, strata exposed in the succeeding 3½ miles up Sustut River to a point a little upstream from the mouth of Saiya Creek, although also striking northwesterly, display several reversals of dip and faults of unknown magnitude. These strata mark a zone of comparatively complex structure that probably extends some 10 miles northwesterly to the west boundary of the map-area and may extend southeasterly along the partly drift-covered southwest side of Saiya Creek Valley. Fold axes in parts of this zone are less than a mile apart. The remaining formations of the Sustut River section, as exposed for about 2 miles downstream from the mouth of Asitka River, display consistent and fairly uniform southwesterly dips. Throughout the above described region dips are commonly less than 55 degrees, but in a few localities are steeper.

The structure of these formations is notably affected by the previously mentioned northwesterly trending belt of faults, about 12 miles wide, that includes most of the known major faults of the map-area. Thus, in general, dips steeper than 55 degrees are most common within these strata adjacent to the southwest edge of the faulted belt, that is, near the Saiya fault and the Red Creek and associated faults. For example, an isolated area of Sustut rocks, about 7 miles long, lying on the southwest side of and parallel with Red Creek, displays four consecutive fold axes within a space of about 1⅓ miles. These folds are overturned towards the northeast, and the axial planes trend about northwest and dip about 60 degrees southwest. The formations on the southwest flanks of the synclines are about vertical or, as indicated by crossbedding, grain gradation, and fracture cleavage, are overturned towards the northeast as much as 30 degrees, whereas strata on the northeast flanks commonly dip about 45 degrees southwest.

The progressively tighter folds and steeper dips exhibited by these strata as they approach the faulted belt, and the overturned axial planes in that vicinity, suggest that the Sustut formations were folded by a thrust from the southwest.

The strata near Thutade and Thorne Lakes and Niven River, which lie northeast of the faulted belt, are much more gently inclined than those within and southwest of the belt. Thus, northwest of Thutade Lake they are horizontal or inclined as much as 10 degrees. Between Thutade and Thorne Lakes they commonly trend about north and dip westerly at angles up to 25 degrees, although dips of about 10 degrees are probably more general. West of Niven River, and nearer the faulted belt, dips of as much as 20 degrees are common and the distances between fold axes are probably several miles.

The boundary between the gently inclined strata northeast of the faulted belt and their much more steeply inclined counterparts to the southwest crosses the west boundary of the map-area near Niven River and, as shown by air photographs, extends northwesterly from this point for many miles.

Local plunges of as much as 10 degrees were noted, some towards the northwest and others towards the southeast. In general, the folds involving the Sustut group probably plunge gently towards the northwest, because the formations of this group appear to become more widespread in that direction.

External Structural Relations

The Sustut formations rest on strata of the upper, Jurassic division of the Takla group, and almost surely on those of the lower division of the Takla group and the Asitka group. They are not known to occur in areas underlain by the Omineca intrusions or by rocks of the Cache Creek group.

The youngest Takla rocks are of Jurassic age, and the oldest Sustut, Upper Cretaceous. Thus, a long interval of erosion must have intervened between the deposition of the upper division of the Takla group and the

Sustut group. The Omineca intrusions cut Jurassic, Takla rocks in the adjacent Takla map-area, and supplied pebbles to Sustut conglomerates in McConnell Creek map-area. However, no marked angular unconformity was noted where members of the Sustut group and upper, Jurassic division of the Takla group were found in contact; the strata were essentially parallel in strike, and dips did not vary more than 5 or 10 degrees. This apparent slight discordance in dip is not necessarily significant, because the available exposures did not lend themselves to precise observation. Nevertheless, some angular discordance is inferred because of the emplacement of the Omineca batholith during the intervening erosion period, for it is improbable that this could have taken place without some folding. Furthermore, the widespread, extremely gentle dips of the Sustut formations in the vicinity of Thutade Lake are not, so far as known, duplicated anywhere within the Takla group, and it seems highly probable that a marked angular unconformity exists in places.

The Sustut formations were not found in contact with strata assigned to the lower division of the Takla group or to the Asitka group. However, they were found nearly in contact at several places in the general vicinity of upper Niven River, and there the discordance in attitudes leaves little doubt that the Sustut strata rest with marked angular discordance on these older rocks.

Fossil Collections

Fossil plant remains were seen in nearly all areas of Sustut rocks, but the most diagnostic collections[1] came from the vicinity of Thutade Lake and Niven River.

The following collections came from the lower division of the Sustut group:

F34. Geol. Surv. Cat. No. 3485
Locality: 1½ miles north-northeast of the mouth of Pilot Creek.
Angiosperms
Platanus latiloba Newberry
Ficus sp.
Viburnum ? integrifolium Newberry
Age: *See* remarks below

F35. Geol. Surv. Cat. No. 3484
Locality: 1¼ miles north-northeast of the mouth of Pilot Creek, and about 450 feet stratigraphically below F34.
Ferns
Cladophlebis striata ? (Presl.)
Cladophlebis frigida (Heer)
Angiosperms
Laurophyllum sp.
Ficus cf. *protogaea* Heer
Age: *See* remarks below

F36. Geol. Surv. Cat. No. 3486
Locality: 9 miles south of Thutade Lake at longitude 127 degrees.
Conifers
Elatocladus (Sequoia?) rigida (Heer)
Angiosperms
Dewalquea smithi Berry
Ficus cf. *stephensoni* Berry
Dicotylphyllum grandifolio-cretacea (Lesquereux)
Age: *See* remarks below

[1] All identifications, age determinations, and comments are by W. A. Bell, Chief, Palæontological Section, Geological Survey of Canada.

F37. Geol. Surv. Cat. No. 3492

Locality: on north face of mountain 2¼ miles south-southeast of Niven River at longitude 127 degrees.

Ferns

Tapeinidium ? undulatum (Hall) Knowlton
Sphenopteris (Aneimia ?) stricta Newberry

Conifers

Elatocladus (Sequoia ?) subulata (Heer) Seward

Angiosperms

Menispermites reniformis Dawson
Pseudoprotophyllum dentatum Hollick
Laurophyllum plutonium (Heer) Seward

Age: *See* remarks below

The fossil plants from collections F34, F35, F36, and F37 are considered to indicate an Upper Cretaceous age. *Cladophlebis frigida, Sphenopteris (Aneimia) stricta, Tapeinidium? undulatum, Pseudocycas unjiga, Ficus* cf. *stephensoni, Elatocladus (Sequoia?) subulata, Menispermites reniformis, Pseudoprotophyllum dentatum,* and *Laurophyllum plutonium* also occur in the Dunvegan formation of Alberta, which is considered to be of Cenomanian age; and it is inferred that the age of the above collections is probably Cenomanian (earliest Upper Cretaceous) or at most not later than Turonian (early Upper Cretaceous).

F38.

Locality: east bank of Sustut River about ½ mile downstream from mouth of Asitka River.

Remarks: this collection comprises a much broken specimen somewhat doubtfully identified as an *Artocarpus* comparable to *Artocarpus cretacea* Berry from the Ripley formation. Berry correlates the Ripley with some part of the Upper Cretaceous, Montana group.

Age: Tentatively Upper Cretaceous

F39. Geol. Surv. Cat. No. 3483

Locality: 4 miles west of Mount Carruthers.

Conifers

Pseudocycas unjiga (Dawson)

Angiosperms

Trochodendroides rhomboides? (Lesquereux) Berry

Classification uncertain

Krannera marginata (Heer) Seward

Age: not older than Albian nor younger than Cenomanian, i.e., late Lower Cretaceous or early Upper Cretaceous

The following were collected from the dacitic tuffs of the upper division:

F40. Geol. Surv. Cat. No. 3489

Locality: 1¼ miles northwest of the mouth of Niven River.

Conifers

Sequoia langsdorfii (Brongniart) Heer

Angiosperms

Laurophyllum, perhaps *Oreodaphne mississippiense* Berry

Age: probably Paleocene

F41. Geol. Surv. Cat. No. 3487

Locality: northeast side of peak 2¾ miles southeast of mouth of Attichika Creek.

Conifers

Sequoia langsdorfii (Brongniart) Heer

Angiosperms

Platanus reynoldsii Newberry var. *integrifolia* Lesquereux
Trochodendroides arctica Heer
Populus carneosa (Newberry)
Corylites hybridica? Seward and Holltum
Celastrinites insignis (Heer)
cf. *Oreodaphne coushatta* Berry
Myrsinophyllum groenlandicum (Heer)
Rhamnites sp.
Pterospermites sp.

Age: Paleocene

F42. Geol. Surv. Cat. No. 3488

Locality: 3 miles east-northeast of mouth of Niven River.

Ferns

Sphenopteris (*Asplenium?*) cf. *S. miertschingi* Heer
Aneimia sp. (fertile)

Conifers

Sequoia langsdorfii (Brongniart) Heer
Sequoia sp. (with foliage like many American specimens referred to *Glyptostrobus europaeus*, and cones smaller and more oval than those of *Sequoia couttsiae* (Heer)
Elatocladus (*Taxodites?*) *tinajora* (Heer)

Angiosperms

Viburnum contortum Lesquereux

Age: probably Paleocene, not later than lower Eocene

Age

The palæontological evidence indicates that the formations of the lower division belong, in places, to the lower part of the Upper Cretaceous epoch, and those of the upper division to the Paleocene. As no stratigraphic break has been recognized within the Sustut assemblage, the entire Upper Cretaceous series may be represented.

KASTBERG INTRUSIONS

Distribution

The Kastberg porphyritic intrusions are confined, with possible minor exceptions, to that part of the map-area lying south and southwest of Mount Carruthers. They are particularly well displayed in the vicinity of upper Kastberg Creek between Scallop Mountain and Comb Peak, and on the east slope of Bear Lake Valley.

Lithology

The rocks of the Kastberg intrusions are grey, buff, or rarely pale pink, generally distinctly porphyritic rocks, commonly thoroughly weathered to a depth of half an inch or more. This deep weathering has resulted in a characteristic soft chalky appearance as well displayed by the numerous erratic boulders and slabs seen along the trail a few miles southwest of Yuen Lake. Although these intrusions vary widely in grain size the most common facies exhibits numerous, blocky, white, ⅛-inch plagioclase phenocrysts in a finer grained, light grey groundmass, with readily visible biotite flakes. Other facies of about the same grain size contain a few quartz eyes, which, locally, are as abundant as the feldspar phenocrysts. Black amphibole needles are occasionally seen. Finer grained facies are commonly so thoroughly weathered that only scattered tiny quartz grains or biotite needles are discernible in the chalk-like kaolinized groundmass. The most coarsely crystalline rock, such as is found in the Nep Peak-Comb Peak stock, contains scattered ½-inch to 2-inch orthoclase crystals in a groundmass of blocky ¼-inch plagioclase grains interspersed with a few cloudy quartz grains and biotite flakes. In rare instances rounded quartz eyes are as much as ½ inch in diameter and weather out like pebbles from the kaolinized groundmass.

Specimens examined under the microscope varied in composition from granodiorite to quartz diorite. About 80 per cent of the phenocrysts are of strongly zoned plagioclase ranging from oligoclase to andesine; others include rounded quartz grains, minor orthoclase, biotite, and rarely amphibole. The groundmass is an equigranular interlocking aggregate of quartz (as much as 20 per cent), twinned and clear feldspar, and minor biotite, chlorite, sphene, apatite, and carbonate.

Structure

The Kastberg intrusions form one principal stock from which has been carved the isolated mountain mass extending more than 4 miles from Nep Peak to Comb Peak. Elsewhere they form tabular bodies ranging to more than 300 feet in thickness: a great many of these are gently dipping sills essentially parallel with the layering of the enclosing strata, but others are steeply dipping dykes cutting abruptly across the enclosing formations. One westerly dipping sill outcrops over much of the western slope of Scallop Mountain. A few sills display rude columnar jointing. The very fine-grained, indistinctly porphyritic intrusions are generally closely fractured and form talus slopes of small, sharply angular or platy fragments.

Sills or sill-like exposures of Kastberg porphyritic intrusions are abundant within parts of a U-shaped zone extending southeasterly from the Comb Peak-Nep Peak stock to Scallop Mountain and thence curving from southwest to northwest along the northeast side of Bear Lake Valley. They dip southwesterly on Scallop Mountain, are nearly horizontal on Kastberg Creek near latitude 56 degrees, and dip northeasterly near Bear Lake. It is probable that many of them emanate from the stock and comprise a synclinal zone that conforms approximately with the enclosing upper formations of the Takla group and the lower strata of the Sustut group, this zone being essentially continuous beneath the northwesterly trending mountain range that lies between Bear Lake and Comb Peak. The parent stock occupies the crest and flanks of the contiguous anticline involving Sustut formations.

Contacts between the sills and Sustut formations are generally sharp and unsheared, suggesting that the Kastberg rocks were injected when folding had nearly or entirely ceased. It is indeed not improbable that their emplacement was a late phase of an early Tertiary period of mountain building that deformed the Sustut formations.

Most borders of the porphyries are chilled for a few inches at their contacts with the enclosing Takla and Sustut strata. Near the contacts, too, the porphyries and adjacent strata may contain a little disseminated pyrite. The bordering strata have not been greatly altered, but locally they have been hardened and weather white.

Age

Although the Kastberg porphyries intrude the Sustut strata they have not been recognized in the upper, Paleocene division of that group. However, as no significant break in deposition is known between the lower and upper divisions, the Kastberg rocks are probably of post-Paleocene age. A feldspar-quartz porphyry body 3½ miles west-northwest of Mount Carruthers, lithologically similar to exposures of known Kastberg porphyry, is cut by dykes of Tertiary or later basalt, and the Kastberg rocks, therefore, are not younger than Tertiary. Furthermore, the time probably necessary for ensuing Tertiary events suggests that the porphyries were most probably emplaced in early Tertiary time.

BASALT NECKS, DYKES, LAVAS, AND PYROCLASTIC ROCKS

Distribution

The youngest known consolidated rocks comprise a distinctive group of intrusive and extrusive basalts and associated pyroclastic rocks, and occur as scattered bodies within the south-central part of the map-area. They are about co-extensive with the Kastberg intrusions. Volcanic necks were found about 5 miles east-southeast of the Indian village of Bear Lake, and thence at intervals about east-northeast for nearly 16 miles. Basalt dykes are numerous but generally small, and are not shown on the accompanying map (in pocket). Basalt lavas are well exposed 3½ miles east of Bear Lake village, 3½ miles east of Saiya Lake, 5 miles east-northeast of Saiya Lake, and 5½ miles south of Sustut Lake: the largest body is about 3 miles long. Two cone-like pyroclastic deposits lie 1¾ miles north-east and 6½ miles southeast of The Thumb.

Lithology

Necks, Dykes, and Lavas. So far as known, all rocks of the group may be corrrelated with the one, more or less continuous, though somewhat extended, period of volcanic activity, and all are believed to be lithologically similar. Necks, dykes, and lavas are the common forms, and are composed of hard, fresh, fine-grained, dark grey to nearly black rocks. Most of these are massive and are weathered light to dark grey, but in places are reddish and purplish. Parts of the lavas, however, are vesicular, ropy, or frothy, and most of these have been altered to various shades of brown, red, or purple. Blobs of black volcanic glass as much as 2 inches in diameter were noted in many places. Other prominent grains and phenocrysts, ranging from $\frac{1}{16}$ inch to about an inch, occur here and there and include[1]: honey-coloured, well-cleaved, translucent albite; black, well-cleaved hypersthene; olive-green, sugary olivine; and black, lustrous magnetite.

[1] Identifications by E. Poitevin, Chief, Mineralogical Section, Geological Survey of Canada.

Basalt specimens examined under the miscroscope contained about 25 per cent colourless to pale brown pyroxene, 60 per cent labradorite, and 15 per cent magnetite. All minerals are remarkably fresh. The lath-shaped crystals of labradorite generally form a random felt, but in a few places were observed to lie more or less parallel with each other as if oriented in a flowing magma.

Pyroclastic Rocks. These form cone-like deposits and comprise mainly pumice, ash, cinders, and other volcanic ejectamenta, but contain a little frothy and fragmental lava. The largest deposit, 6½ miles southeast of The Thumb, is about a mile long and ½ mile wide. In most places these deposits have weathered to shades of brown, red, or purple. In part they are well-stratified, loosely consolidated deposits, containing a few rounded, striated cobbles and boulders of Sustut sandstone and pebbly sandstone. Elsewhere they are unconsolidated and apparently unsorted.

Structure

The necks are approximately cylindrical, lava-filled conduits or cores of old volcanoes, and now project as much as several hundred feet above the more deeply eroded rocks as dark grey or black domes or flat-topped plugs. The largest, known as The Thumb, is about 1,000 feet in diameter and forms a conspicuous black knob about 5 miles east-southeast of Bear Lake village. It consists mainly of well-jointed, massive, black basalt, but in places near its border contains numerous vesicles and angular fragments of bleached Sustut sandstone. The surrounding Sustut strata dip very gently southwest and do not appear to have been disturbed by the intrusion of the basalt body. A smaller neck or plug of similar basalt lies in a fault zone about 3 miles northwest of Mount Carruthers and is thought to post-date the faulting. Although it lies in a small abandoned cirque it has clearly been shaped by the ice that cut the cirque and is, therefore, older than the last phases of alpine glaciation in this vicinity.

Most of the dykes are nearly vertical and less than 10 feet wide: the largest noted was about 200 feet wide. Many exhibit excellent columnar jointing, with the joint planes about perpendicular to the dyke walls. The borders are sharp and distinctly chilled, but the adjacent rock is not appreciably altered. Some of the dykes contain vesicles and fragments of wall-rock. They cut Sustut strata, which are inclined at angles of as much as 45 degrees, and project from deeply eroded valley sides, such as the northeast face of Connelly Range. Evidently the dykes were injected after the tilting of the Sustut beds but before the period of erosion that carved the deep valleys such as that now flanking Connelly Range on the northeast. As previously mentioned, they cut probable Kastberg porphyry 3½ miles west-southwest of Mount Carruthers. On the north side of Asitka River Valley, about 8 miles from the river mouth, a northerly trending fresh basalt dyke, about 3 feet wide, passes directly through a rusty crumpled zone believed to mark the Asitka fault, and is thus younger than both the faulting and the related alteration.

The lavas are horizontal or gently inclined. A cliff 3½ miles east of Bear Lake village displays about 185 feet of basalt, which, together with an unknown thickness removed by erosion from the upper surface, seems to comprise a single flow. Another body, 3½ miles east of Saiya Lake, is about

500 feet thick, and is composed of a succession of flows. Excellent columnar jointing is common. The lower parts of some flows are massive or streaky, whereas the tops, for as much as 10 feet, are vesicular and in part ropy. Vesicular pillows up to 5 feet in diameter were noted in a small unmapped occurrence 3 miles west-northwest of Mount Carruthers. Two of the four principal lava bodies are more than 5,000 feet above sea-level, and form horizontal caps bordered by cliffs and abrupt slopes leading to the valley bottoms more than 1,000 feet below. The lava field nearest Bear Lake village, although resting on the gentle western slope of the Connelly Range, is cut off on its southern side by a precipitous gorge more than 1,400 feet deep. None of these high-level lavas appears to have flowed down the sides of the present valleys, and they are probably remnants of formerly more extensive lava-fields that have since been largely removed by erosion. The largest lava-field, 5 miles east-northeast of Saiya Lake, lies astride a broad valley and may have been formed later than the high level occurrences, after erosion had carved the valleys to more nearly their present form. The lavas are separated from the Jurassic rocks of the Takla group by an angular unconformity. They were found resting without noticeable angular discordance on nearly horizontal Sustut strata 3½ miles east of Bear Lake village, but are evidently of much later age as they carry rounded boulders of Sustut rocks in the basal flow breccia. None of the lavas is known to have been folded or faulted, but in places they incline with the surface on which they were extruded.

The pyroclastic rocks rest with marked angular discordance on Sustut formations. Most of the pyroclastic strata retain various initial dips, but some at the northeast edge of the largest deposit are nearly horizontal.

Age

Basalts cut Paleocene, Sustut strata in many places on Connelly Range. They were also intruded into rocks tentatively correlated with the Kastberg intrusions, which, in turn, were emplaced in the Paleocene strata after their consolidation. The volcanic group must, therefore, be younger, probably much younger, than Paleocene. On the other hand, the high-level lavas, which are among the oldest phases preserved, now cap mountain tops standing 1,000 feet or more above the adjacent valleys, and must have been in existence throughout a long period of erosion. It is thus doubtful if these oldest phases can be younger than late Middle Tertiary: their outflow may have accompanied or closely followed the uplift and deformation of a once extensive Middle Tertiary erosion surface. The youngest phases of the vulcanism are represented by the cone-like pyroclastic deposits. These contain striated boulders that are probably glacial erratics, and occur in places where they would surely have been destroyed by the Pleistocene ice-sheet had they been in existence at that time. They are, therefore, considered to have been formed in Recent time. Accordingly, this group of volcanic rocks probably records a period of vulcanism that extended, with or without significant interruptions, from about Middle Tertiary to Recent time.

PLEISTOCENE AND RECENT

Considerably more than half the surface of the map-area is covered by unconsolidated Pleistocene and Recent deposits. In general these are thinnest above timber-line (5,000 feet) and become progressively thicker and more widespread toward the lower valley surfaces. The Pleistocene deposits are conveniently classified as: (1) mainly non-stratified deposits, herein represented by scattered erratics and ground moraine; and (2) mainly stratified deposits represented by glacio-fluvial and glacio-lacustrine accumulations laid down beyond the ice fronts and by kame terraces, kames, and eskers deposited in contact with the ice. Recent accumulations include stream deposits, deltas, alluvial fans, talus, soil, and spring deposits.

The non-stratified Pleistocene deposits found well above timber-line are mainly scattered ice-transported boulders, cobbles, and pebbles. These lie on nearly all surfaces except those too steep to retain them. Near timber-line the erratics are accompanied by unsorted sandy and gravelly detritus and form a thin till mantling large areas of bedrock. Presumably, a similar but thicker till underlies most of the timber-covered lower slopes, although it is there mainly obscured by younger deposits of soil or other material. These tills are interpreted as ground moraine, material generally considered to have accumulated largely beneath ice. No clay-rich till (boulder clay) was noted.

The observed stratified Pleistocene deposits were formed during the gradual melting and thinning of the ice. Great torrents of waters were released into partly ice-filled valleys. Some of this water, flowing along the margins of thick valley glaciers, formed gravel and sand deposits that now appear as discontinuous or short benches (kame terraces) at many places high up on the valley walls. Tributary streams, dammed by glaciers occupying the trunk valleys, formed occasional marginal lakes well above the valley floors; and in these lakes were deposited sands, silts, and finely bedded silty clays. As the fronts of the valley glaciers receded, turbulent streams issuing from them continually deposited great quantities of coarse detritus on the valley floors beyond the ice front. Thus, with the final disappearance of the ice, except for alpine glaciers, the bottoms of all the major valleys were deeply buried by outwashed sand and bouldery gravel varied here and there by eskers, kames, and kettles. During this process the present McConnell Creek Valley was occupied for a time by a lake, perhaps ice-dammed, within which were deposited the silts that now underlie the gold-bearing gravels.

In Recent time, the major streams, lacking the former abundant supply of glacial water, shrank to more nearly their present volumes, and have been engaged mainly in terracing and trenching the Pleistocene outwash deposits. Some of the resultant load has been deposited in conspicuous accumulations such as the delta of Niven River, but much has been widely dispersed or carried beyond the map-area. Other clearly Recent deposits are the numerous alluvial fans laid down where tributary streams debouch onto the wide floors of trunk valleys.

Talus clothes the lower slopes of many of the peaks and ridges, but is particularly characteristic of areas underlain by the Omineca intrusions or by the meta-andesites and associated rocks of the Takla group. The latter may commonly be identified by the particularly numerous, long talus slides that commence as thin points high above timber-line and widen downwards to coalesce near the valley bottoms.

Deposits of Recent calcareous tufa were noted on Fumar Creek near its junction with Omineca River, about a mile north of the mouth of Yuen Creek, and on the west side of Ominicetla Creek about west-southwest of Axelgold Peak. The tufa is mostly soft and porous, and grey, creamy, buff, or rusty brown, and is composed of layers commonly less than ¼ inch thick, some in pale brown, compact, paper-thin layers. It consists of calcium carbonate, mixed with a little iron oxide, and has been deposited at the present surface by cold springs or seepages, with the simultaneous release of carbon dioxide gas. On Fumar Creek tufa forms a cone about 8 feet high, in the top of which is a dry kettle-like depression, 5 feet in diameter and 5 feet deep, that marks the outlet of a former spring. Carbon dioxide still emanates from the bottom of this kettle, and issues as tiny bubbles from cold, odourless springs that partly surround the base of the cone. This deposit is locally and erroneously known as the Big Kettle fumarole.

CHAPTER III

STRUCTURE

FAULTS

GENERAL DESCRIPTION

Faults are outstanding structural features of the map-area, and as already stated most of those recognized lie within a belt some 12 miles wide, the northeast edge of which extends northwesterly from Omineca River at longitude 126 degrees to Niven River near longitude 127 degrees. The abrupt change in the attitude of Sustut strata northwest from Niven River near longitude 127 degrees, as observed on air photographs, suggests that the faulted belt extends well northwest of the map-area; whereas its southeastern counterpart is to be found in the adjacent Takla map-area (Armstrong, 1946). Faults are exposed in a few places, mainly in creeks and above timber-line, and their extensions are commonly indicated by the courses of valleys and shallow depressions. A few faults, whose existence has been inferred by abrupt structural discordances or by apparent gaps in the stratigraphic sequence, are, so far as known, not exposed. Most of the faults strike northwesterly, about parallel with the folds in the enclosing strata; others strike west, west-northwest, north, or northeast. In most places the inclinations of the fault planes are not known, but where observed they are steep, and the topographic expression of all faults is such as to suggest that all are steep. Where examined, the mapped faults are marked by altered and disturbed zones ranging from about 25 feet to possibly 1,000 feet or more in width. These zones are characterized by various combinations of schistose, fractured, crumpled, or carbonatized and otherwise altered rock. Replacement by buff or rusty weathering ferruginous carbonate characterizes many parts of the fault zones, particularly southeast of Asitka River; but not all carbonatized zones mark significant faults. Directions and magnitudes of the lateral displacements are not known. The apparent vertical displacements may be greatest in the northeast half of the faulted belt, along the Omineca, Carruthers, and Ominicetla faults where, in places, as much as 10,000 feet of lower Takla strata appear to be missing. The Omineca fault marks the northeast edge of the faulted belt, and available evidence suggests that the strata on the southwest side of this fault have moved upwards relative to those on the northeast side. A similar displacement has been described along its southeasterly extension, the Pinchi fault zone, which has been interpreted (Armstrong, 1946) as the site of major thrust faulting from the west. The apparent relative movement on other northwesterly trending faults in McConnell Creek map-area is in the opposite direction, as if the northeast sides had moved relatively upwards.

DETAILED DESCRIPTION

Saiya Fault

The Saiya fault, with a mapped length of 15 miles, extends southeasterly from near Saiya Lake across Omineca River, and probably across Yuen Creek 2 miles from Omineca River. Its extension in either direction is obscured by drift, and the dip of the fault is not known. Throughout most of its mapped length the fault separates northeasterly dipping Sustut strata to the southwest from older, in part northeasterly dipping, Takla formations to the northeast. The rocks on the northeast side of the structure thus appear to have moved upwards relative to those on the southwest side. Brecciated, rusty Takla rocks, cut by a network of white veinlets, mark the fault about 5 miles southeast of Saiya Lake, and nearby Sustut beds display many narrow fractures, some of which are polished as though by differential movement. At Omineca River, about 3½ miles upstream from the mouth of Yuen Creek, Sustut strata are exposed within 200 feet of Takla volcanic rocks, and the intervening drift-covered area is thought to mantle the fault zone. As the fault is approached from southwest to northeast the dips of the Sustut beds change from northeast, through gentle southwest, to about vertical at the edge of the drift mantle, as if dragged by the northeast side of the fault moving relatively upwards or towards the northwest.

Carruthers Fault

The Carruthers fault trends about northwest along the southwest side of the Sikanni Range for a mapped length of about 13 miles and passes about a mile southwest of Mount Carruthers. It involves northeasterly dipping strata of the Takla and Asitka groups, the older strata lying northeast of the fault. Here, again, the northeast block appears to have moved relatively upwards. Southeast for 6 miles from the ridge 1 mile west of Mount Carruthers the fault is marked by a band of buff weathering, flaky, carbonate-sericite-chlorite schist, 200 to 500 feet or more wide, in which the foliæ strike northwesterly and dip about 60 degrees northeast. Seven miles west-northwest of Mount Carruthers the fault zone outcrops as several hundred feet of thoroughly fractured and slickensided pale green rock cut by numerous quartz stringers. The displacement in this vicinity must have been considerable, as testified by the contiguity of upper Takla and Asitka formations, with the omission of at least the lower division of the Takla group. The fault was not observed farther northwest, but it may be concealed by the drift- and lava-filled depression extending towards the mouth of Asitka River. Although traversing a terrain of considerable relief, the trace of the fault at the surface appears to be nearly straight, and presumably the fault plane has a steep dip.

Ominicetla Fault

The Ominicetla fault, so far as known, is entirely concealed by drift. It is believed to trend northwesterly along the northeast side of Ominicetla Creek and thence to extend northerly across Omineca River to terminate at the Omineca fault. Its possible southeasterly extension or extensions have been mapped in the adjacent Takla area (Armstrong, 1946). The fault involves formations of mainly the Takla and Cache Creek groups, both of which strike northwesterly and dip northeasterly, and its presence is inferred by the fact that the Takla strata dip towards those of the older Cache Creek beds. The apparent displacement is that of an uplifted northeast block, and the dip of the fault is unknown.

Omineca Fault

The Omineca fault extends northwesterly from Omineca River at the east border of the map-area to Niven River at the west border. It enters the map-area from the southeast as the single northwesterly counterpart of the Pinchi fault zone of the Takla area (Armstrong, 1946), but has several branches in McConnell Creek map-area, as shown on the accompanying map. It marks the approximate northeastern limit of recognized major faulting.

The most southeasterly exposures of the fault were found at, and 1 mile northwest of, its intersection with Genlyd Creek. The isolated exposures of brecciated, buff weathering, carbonated rock noted there display many well-developed slickensided surfaces and a little bright green mineral, possibly mariposite, and are interpreted as altered rock of the fault zone. The wall-rocks were not seen.

On the east side of Carruthers Creek, about 5 miles from its mouth, purplish red, andesitic, pyroclastic rocks of the Takla group have been involved in the fault zone and now occur as a heterogeneous assemblage of comparatively unaltered material and buff to rusty weathered, carbonatized rock, the whole traversed by a network of carbonate veinlets and steeply inclined fractures displaying highly polished surfaces. Within this assemblage were seen several outcrops of, probably, a tabular body of light grey feldspar porphyry closely resembling a phase of the Kastberg intrusions. Although somewhat fractured, it is probably less disturbed and altered than the enclosing rock, and perhaps later than at least some of the movement and alteration along the Omineca fault zone. Thin-bedded carbonaceous Cache Creek strata on the west side of the creek are crumpled, sliced, and at one place cut by a seam, about 2 feet thick, of soft, sticky, light grey gouge with a steep southwesterly dip. The width of the fault zone here is probably several hundred feet.

Small scattered exposures of thoroughly carbonatized rock mark the postulated course of the fault between the above described point on Carruthers Creek and Asitka River.

About 3 miles northwest of Asitka River the fault separates Asitka and Takla strata on the southwest from younger volcanic members of the Takla group on the northeast. It is exposed at a point 3½ miles northwest of the river and, although viewed only from a distance, appears to dip steeply southwest and to comprise a crumpled, rusty, and reddened zone, 1,000 feet or more in width.

It was again located in the bed of a northerly flowing creek that enters Niven River about a mile east of longitude 127 degrees. Here, Sustut sandstones lie southwest of the fault and are gently inclined except within about 50 feet of the fault where they have been dragged to a nearly vertical position, sheared, fractured, and intersected by many white carbonate seams. The red and green Takla andesitic rocks that adjoin them and lie on the northeast side of the fault are similarly fractured and veined across a width of 100 feet or more, and display scattered irregular patches wherein they have been notably carbonatized and weather rusty brown.

Except at the last mentioned locality displacements are such that the oldest rocks appear southwest of the fault, suggesting that that side has moved relatively upwards. The displacement at two places has been sufficient to bring into juxtaposition Asitka and upper Takla (Jurassic) formations, and by the omission of at least the lower division of the Takla group, implies major displacement.

Quenada Fault

The Quenada fault, possibly a branch of the Omineca fault, lies along the northeast side of upper Carruthers Creek Valley, and probably extends northwesterly into lower Quenada Creek Valley. About 3 miles southeast of the cabin on Quenada Creek it is marked by 5 to 10 feet of crushed rock traversed by a few yellowish gouge seams an inch or so thick, and is bordered by 50 to 100 feet of greatly fractured but otherwise unaltered rock cut by a network of carbonate and quartz veinlets. Minor slips a few feet from the crushed zone, and probably about parallel with it, strike north 40 degrees west and dip 70 degrees southwest. The sinuous course of the fault trace across the hillside is also that of a southwesterly dipping structure. Jurassic volcanic rocks southwest of the fault dip northeast towards the older Takla strata northeast of the fault.

Genlyd Fault

Genlyd fault, interpreted as a northerly branch of the Omineca fault, closely follows the west border of the Omineca batholith. Where exposed 6 miles north of the mouth of Genlyd Creek the fault zone is rusty and about 300 feet wide. The western part of the zone, adjacent to a gneissic phase of the lower division of the Takla group, is so thoroughly carbonatized, veined by quartz and carbonate seams, and impregnated with fine-grained pyrite that its original characters have been obliterated. The eastern half of the zone is mainly schistose, friable, rusty granodiorite, which grades into coarse-grained, grey, slightly gneissic biotite granodiorite to the east and contains several northerly trending, vertical, brecciated bands as much as 5 feet wide. Associated with the schistose granodiorite is a little soft, white, fine-grained feldspar porphyry very suggestive of a phase of the Kastberg intrusions. At its most northerly mapped exposure, about 15 miles north of the mouth of Genlyd Creek, the fault zone lies within the Omineca batholith and comprises grey, rusty-surfaced quartz-carbonate rock, and a little fine-grained, light grey, feldspar porphyry tentatively correlated with the Kastberg intrusions. The intervening course of the fault is marked by scattered exposures of carbonatized rock. The dip of the fault is probably steep, but the magnitude and direction of displacement are not known.

Red Creek Fault

The Red Creek fault extends west-northwest from the Omineca fault, near the mouth of Quenada Creek, to the head of Red Creek Valley. Near its southeast end it forms the contact between Takla volcanic rocks and Asitka formations, and comprises a thoroughly sheared zone, 100 feet or more in width, in which the thin leaves of the resultant red and pale green schists strike about north 70 degrees west and dip about 70 degrees north. A little farther west, another part of the fault, as viewed from a distance, probably has a nearly vertical dip and is bordered by crumpled, thin-bedded members of the lower division of the Takla group. What is probably the same fault was again encountered on the west bank of Sustut River about half a mile upstream from Red Creek, where it is delineated by sheared and crumpled, glistening, black, concretionary argillaceous rocks exposed across a width of 50 feet. Its course for about 3 miles west-northwest from this exposure is inferred from the marked discordance in attitudes on opposite sides of the presumed course of the fault and from various, probably subsidiary, disturbed zones along Red Creek. Several branch faults may occur southwest of Red Creek near the west border of the map-area, but the main Red Creek fault probably lies about a mile southwest of the head of the creek. There Jurassic strata are involved in a crumpled zone 500 feet or more wide marked at one place on its northeast side by sloughed, crumpled, rusty, thoroughly fractured rock and at another place by a seam of gouge with a steep northeasterly dip.

Asitka Fault

The Asitka fault zone strikes about west, and outcrops as a rusty or yellowish band along the north side of Asitka River Valley west of its junction with the Omineca fault. About 5½ miles west of this junction the fault zone outcrops as a band of bleached, rusty weathered, pyritized rock, 50 feet or more in width, intersected by numerous interlacing white veinlets. The upper Takla red and green tuffs and fossiliferous grey argillite south of the fault strike about west, except within about 150 feet of the fault where they are crumpled and cut by nearly vertical fractures marking minor parallel displacements. The formations of the lower division of the Takla group north of the fault, where recorded, strike northerly. The fault zone and adjacent rocks are traversed by a vertical basalt dyke that strikes northerly without recorded evidence of significant alteration or displacement. About 2½ miles farther east, 20 feet of green chloritic rock in the fault zone separates fossiliferous Permian strata on the north from rocks provisionally assigned to the Jurassic, upper division of the Takla group, suggesting sufficient displacement to result in the omission of the members of the lower division of that group. The apparent displacement thus becomes greater as the junction of the Asitka and Omineca faults is approached.

Driftwood Valley

The possible occurrence of an unmapped northwesterly fault along Driftwood Valley is suggested by the abrupt variations in attitudes and abnormally steep inclinations displayed there by the Sustut sandstones and shales.

AGE OF FAULTS

The faults of McConnell Creek map-area may have formed at different times in its geological history, but, as evidenced by the Sustut strata, major, although not necessarily the greatest, displacements took place in post-Paleocene time. So far as known all significant faults are older than the Tertiary and Recent basaltic rocks. The probable occurrence of Kastberg intrusions in the Omineca and Genlyd fault zones, but not in the adjacent rocks, suggests that these structures existed prior to the emplacement of the intrusions, but does not preclude the possibility of some fault movement after intrusion. The post-Paleocene displacements may be in part a phase of an early Tertiary period of orogeny that resulted in the folding of the Sustut formations and presumably culminated with the emplacement of the Kastberg porphyritic rocks.

FOLDS

As previously described, most strata have been folded along northwesterly trending axes, and many of the resultant structures plunge northwest. These folds were formed mainly during two intervals. Although it is possible that some folding occurred prior to the deposition of the Takla strata, the first clearly defined interval of major folding was probably related to the emplacement of the Omineca intrusions: it followed the deposition of the Takla formations and preceded the accumulation of the Sustut rocks. As a result, Takla, Cache Creek, and Asitka rocks are folded to about the same degree. In general they are tightly folded. So far as known, the folding stresses of this interval were about equally effective throughout the map-area on assemblages of equivalent competency.

The second interval of major folding followed the deposition of the Paleocene, Sustut strata. During this interval the Sustut rocks southwest of the faulted belt were subjected, as previously explained, to a thrust from the southwest and warped into a series of open folds. However, to the north, near Thutade Lake, they remain only gently inclined or horizontal. Thus the thrust appears to have achieved nearly complete relief within at least the northwest part of the faulted belt. Furthermore, it seems reasonable to expect that, despite the lack of direct evidence of Sustut strata, similar relief was attained elsewhere along the belt. If so, it is probable that much or all of the map-area northeast of the belt (that is northeast of the Omineca fault) remained almost unaffected by the post-Paleocene folding, stabilized in part, no doubt, by the Omineca intrusions.

CHAPTER IV

HISTORICAL GEOLOGY

The following statement of the geological history of McConnell Creek map-area is based on data recorded in foregoing sections of this report, and is provisional to the extent that many of the basic data are admittedly incomplete or inconclusive.

In Lower and Middle Permian time sediments, lavas, and pyroclastic rocks were laid down in a marine basin. This basin extended many miles southeast of the map-area and may have originated in pre-Permian time. Vulcanism probably prevailed during the Lower Permain epoch, but sedimentation was the principal process during Middle Permian time.

The strata provide no recognized record of conditions in Upper Permian or Lower and Middle Triassic time. Probably uplift at the close of the Permian period initiated a Triassic interval of erosion that removed some of the Permian formations. Upper Triassic time opened with the relatively slow, quiet, sub-aqueous deposition of argillaceous sediments mixed with a little volcanic dust or ash. Vulcanism prevailed thereafter, and pyroclastic material accumulated at an ever increasing rate in thicker and thicker beds of progressively coarser material to culminate in the chaotic deposition of extremely coarse agglomerates accompanied by the outpouring of great thicknesses of lavas.

In places a temporary pause in vulcanism allowed erosion to act on the youngest members of the Upper Triassic assemblage, but elsewhere they were followed by Jurassic volcanic rocks without recognized intervening erosion. The Jurassic was a period of accumulation over at least the southwestern half of the map-area, and probably most of the strata were laid down in water. Vulcanism prevailed during Lower Jurassic time, when great thicknesses of pyroclastic rocks were deposited, partly at least in marine water. By Middle and Upper Jurassic time the sea occupied a basin of unknown width that extended northwesterly from Scallop Mountain probably to upper Niven River. Although volcanic materials were still extruded at intervals, most of the materials then laid down were derived from the attrition of sedimentary and volcanic rocks and consolidated to form greywackes and related sedimentary types. The occurrence of coal seams, in places close to strata carrying marine fossils, suggests that probably in late Jurassic time greywackes and argillaceous sediments were deposited in shallow marine water that receded from time to time to permit the accumulation of vegetable matter in shoreline swamps.

During late Upper Jurassic or Lower Cretaceous time the Omineca batholith was emplaced, the area uplifted, folded, and probably faulted, and marine waters completely and finally withdrawn. Active erosion commenced, and by the close of Lower Cretaceous time had exposed Permian, Upper Triassic, and Jurassic strata and parts of the batholith. Inasmuch as no Lower Cretaceous strata were recognized, it must be assumed that the products of erosion were swept beyond the map-area, probably westerly away from an upwarped area bordering and overlying the batholith.

More than 3,000 feet of sedimentary strata were accumulated in a shallow, sinking, continental basin during the Upper Cretaceous and Paleocene epochs. Initial deposition, from a bordering mountainous area that probably included the Omineca batholith, was everywhere rapid, as attested by the widespread deposits of coarse sandstones, and at times very rapid as evidenced by recurrent conglomerate sheets. Sedimentation continued without recognized interruption into Paleocene time, but by then the bordering mountains had been greatly reduced in height and the pace of erosion had slowed accordingly: this allowed time for considerable rock weathering, and resulted in the deposition of much shale in addition to fine- and medium-grained sandstones. Volcanoes at some unknown locality erupted briefly during the Paleocene, as testified by the occurrence of several thin bands of dacitic tuffs.

An early Tertiary period of orogeny resulted in the disappearance for all time of large bodies of water from the area. It resulted, too, in the uplift, folding, and faulting of the Sustut formations, and in the intrusion of the Kastberg porphyritic rocks.

Ensuing erosion produced an undulating surface, which, perhaps in Middle Tertiary time, was uplifted more or less contemporaneously with outpourings of basaltic lavas and related volcanic materials.

Pliocene erosion cut deep valleys in the upland surface and left upon it a few cap-like remnants of nearly horizontal basaltic lavas.

A great mass of ice nearly or completely covered the area during Pleistocene time, and moved towards the east and southeast. At this stage, and in its initial and final alpine and valley stages, it modified pre-existing topography both directly by erosive action and indirectly through subsequent accumulation of glacial and fluvioglacial deposits.

Vulcanism initiated in Middle Tertiary time persisted with interruptions of unknown duration into Recent time, the latest, but prehistoric phases being represented by a few cone-like deposits of basaltic pumice, ash, cinders, and other volcanic ejectamenta.

With the melting of the Pleistocene ice the rivers shrank to about their present volume and commenced to terrace and channel the fluvioglacial deposits that covered the bottoms of all major valleys. As a result, these deposits have been incised to depths of 100 feet or more. For short distances along some of the river channels, and for 13 miles along Sustut River above the mouth of Bear River, they have been almost completely removed from the underlying rock. In such places the rivers are now carving rock canyons.

CHAPTER V

ECONOMIC GEOLOGY

GENERAL STATEMENT

Although McConnell Creek map-area attracted the attention of prospectors as early as 1899 it has since aroused only very casual, intermittent interest, and the most promising mineral occurrences have been found since geological mapping was started there by the Geological Survey in 1941. Except for a little placer gold no minerals have been derived from the area and, with a minor exception on McConnell Creek, development to the end of 1946 was limited to inconsequential surface work. Ample evidence of the almost complete lack of a previous efficient search for metalliferous deposits is afforded by the number of interesting gold occurrences located by a few prospectors in 1946, during their first season in the area.

The following metals have been recognized in the known mineral deposits: gold (placer and lode), platinum (with placer gold), mercury (with placer gold), vanadium (with placer gold), copper, silver, lead, zinc, beryllium, molybdenum, and chromium.

Coal seams have been discovered in beds of the upper division of the Takla group and in the Sustut group.

METALLIFEROUS DEPOSITS

PLACER GOLD DEPOSITS

McConnell Creek

References: Robertson (1908); Lay (1932).

Gold-bearing gravels on McConnell Creek have been known since 1899, but despite a brief influx of gold seekers in 1907 and 1908 and again in 1932, have in general provided only intermittent employment for a few persons. However, the discoverer, P. Jensen of Takla, appears to have staked a singularly productive gravel deposit, which he has worked annually from 1906 until forced to abandon it recently because of failing health. About thirty men are reported (Lay, 1932) to have been employed on the creek in 1932. During 1945 only H. and J. Hundry, C. Fredrikson, and J. Olson were engaged in placer mining operations, and, partly because of an inadequate water supply, operated for only part of the summer. Essentially all gold has been recovered in sluice-boxes into which gravel was shovelled by hand. The amount of gold recovered from the creek is not known, but P. Jensen, from all accounts the most successful operator, is reported[1] to have recovered as much as 220 ounces of gold during a single season, with the assistance of several labourers. It is doubtful if current operations afford reasonable wages after transportation and other operating expenses are deducted.

[1] Fredrikson C.: McConnell Creek; personal communication.

McConnell Creek is about 6 miles long and flows south-southeast into Ingenika River. It has carved its present channel in the bottom of an older valley, the sides of which slope very gently upwards to the mountain ranges that parallel the creek at a distance of several miles. Thus, for about 2½ miles from its mouth it flows through a narrow rock canyon; and for the remainder of its course meanders over the terraced gravel floor of a rock-walled trench some 2,000 feet wide and 200 or 300 feet deep. Throughout most of its course it flows near the contact between granodiorite on the west and schistose and gneissic phases of volcanic rocks on the east.

Most placer mining has been done on the gravel benches bordering the creek for about 2 miles above the canyon. The gravel is reported (Lay, 1932) to rest on compact concretionary silt or, according to others[1], on a few feet of boulder clay, which in turn rests on the silt, but neither of these contacts was observed by the writer. The silt is probably a deposit formed in a former lake, and a shaft sunk by P. Jensen about 2 miles above the canyon is reported (Lay, 1932) to have encountered about 138 feet of this material without reaching bedrock. Judging by the shaft dump, the base of the gravel there approximates creek level. The gravel may not be more than about 25 feet thick, because it does not as a rule extend to more than that height above the creek. It was deposited in rapidly flowing water in channels that continually shifted from side to side. It is a poorly sorted, commonly crossbedded mixture of well-rounded boulders, cobbles, pebbles, and sand interspersed with layers and lenses of sand. The boulders range up to several feet or more in diameter. The gold is erratically but widely distributed in various layers from the surface down to the silt or boulder clay but, so far as can be ascertained, does not occur in the silt. Mining operations did not encounter bedrock anywhere along the creek, and it is not known whether gold was concentrated there. A little gold has been found in nearly all the tributary creeks.

The gold occurs as small, rounded grains, or as larger, generally flattened nuggets, the largest recovered by C. Fredrikson during many years of operation weighing less than $\frac{1}{10}$ ounce. It is accompanied by abundant black sand and occasional flakes of platinum as much as $\frac{1}{16}$ inch in diameter. A nugget, about ¼ inch in diameter, of a soft silvery mineral recovered from the gravel by J. Olson was an alloy[2] of silver and mercury with a specific gravity of 11·40, or somewhat less than that of arquerite. A sample of black sand concentrate recovered from sluice-boxes on Olson's claim in 1945 assayed[3]: gold, 7·36 ounces a ton; silver, 0·74 ounce a ton; tin, none; tungsten, none; platinum (by spectroscope), trace; palladium (by spectroscope), trace. A spectroscopic examination[4] of a similar sample confirmed the absence of tin and tungsten, but indicated the presence of a little vanadium. No systematic attempt has ever been made to determine the quantity or average gold content of the gravel, but the average of seventeen pan samples (Lay, 1932, p. 6) taken at widely separated points was: gold, $1.52 a cubic yard (presumably calculated at $20.67 an ounce); platinum $0.12 a cubic yard (calculated at $40 an ounce).

[1] Fredrikson, C., and Olson, J.: personal communication.
[2] Identified by E. Poitevin, Mineralogical Section, Geological Survey of Canada.
[3] Assay by Bureau of Mines, Department of Mines and Resources, Ottawa.
[4] By F. J. Fraser, Geological Survey of Canada.

Unfavourable operating features include the apparent erratic distribution of the gold, the numerous large boulders in the gravel, and the very low gradient of the creek.

The gold was formerly widely dispersed through great quantities of glacial debris that doubtless formerly lay in McConnell Creek Valley. Post-glacial streams have gradually cleared the valley of much of this debris, leaving behind most of the relatively heavy gold, which, during the process, continually worked its way downward towards the silt base, much as if the valley were a gigantic sluice-box.

The Pleistocene ice-sheet moved about east-southeast across McConnell Creek Valley, and appears to have been incapable of transporting significant quantities of rock debris more than 15 miles. Thus a possible ultimate source of the gold now found in the creek lay in the north end of McConnell Range, or its counterpart north of Thorne Creek, or in the adjacent drift-covered areas. These source deposits, however, did not necessarily contain commercial concentrations of gold.

LODE DEPOSITS

Gold

Most known gold occurrences have been found since geological mapping of the area was completed in 1945; and these, consequently, have not been examined by the writer. However, although 1946 was a season of many discoveries, limited surface development in 1947 has not, so far as known, proved any to be of commercial size and grade. Nevertheless, the widespread occurrence of gold in encouraging amounts seems to have been well established. Most of the deposits are in greenstones, tuffs, and other pyroclastic facies of the lower division of the Takla group, especially where these formations have been cut by the Omineca intrusive rocks. The gold occurs in quartz veins sparsely mineralized with sulphide minerals, or in veins of nearly solid sulphide minerals accompanied by a little quartz. Copper is the principal associated valuable metal. The common sulphide minerals are pyrite and chalcopyrite; other metallic minerals include galena, pyrrhotite, and magnetite.

King George Group (1)[1]

A mineralized area was noted on a creek that flows east into McConnell Creek 1 mile south of the south end of McConnell Lakes. It is on the precipitous south bank of the creek, about 1,000 feet upstream from the west wall of McConnell Creek Valley, and has been previously described (Lay, 1932, p. 10) as the King George group owned by P. Jensen and associates. The creek occupies a canyon, about 160 feet deep, in medium- to coarse-grained, pink biotite granodiorite of the Omineca batholith. A rusty area, shaped like an inverted triangle, lies with its apex 80 feet above the creek and extends about 80 feet up the slope so that its base, about 30 feet wide, lies close to the drift-covered lip of the canyon. Fractured granodiorite within this area is cut by a network of white quartz veinlets. The quartz contains many open cavities lined with quartz crystals

[1]Numbers in parentheses are those appearing on accompanying geological map (in pocket).

as much as 2 inches long, fragments of bleached granodiorite containing a little fine-grained pyrite, and scattered pockets of coarse-grained pale pyrite up to 3 inches or more in diameter. A selected sample of quartz, coarse-grained pyrite, and bleached pyritized granodiorite contained[1]: gold, trace; silver, 0·09 ounce a ton. A selected sample of granodiorite with a little chalcopyrite, from the talus below the mineralized area, contained: gold, 0·0025 ounce a ton; silver, 0·05 ounce a ton. Other rusty areas, mainly inaccessible, were seen on the canyon walls in the same vicinity.

Wrede Creek

On the north side of Wrede Creek Valley, 3½ miles south of Fleet Peak, a quartz vein cuts rusty, pyritic greenstone of the lower division of the Takla group. The vein is about 1½ feet wide, strikes about north, and contains pyrite. A selected sample assayed: gold, 0·075 ounce a ton; silver, 0·215 ounce a ton.

Quyzvhx Group (2)

The Quyzvhx group of eight claims, staked by A. B. Gooderidge in July 1946, is 9½ miles slightly east of north from Goldway Peak. The underlying rocks are probably sedimentary and volcanic members of the Takla group. The principal discovery is reported to be a quartz vein, 1 foot to 5 feet wide, exposed at intervals for a length of about 75 feet. It is said to have provided a rich gold sample from its widest section.

Solo Group (3)[2]

The six claims comprising the Solo group lie a mile east of Goldway Peak. They were staked by C. A. Bennett on August 6, 1946, and are owned by Springer Sturgeon Gold Mines, Limited. Several northwesterly trending quartz veins occur in what are probably greenstones of the Takla group. Most of these veins dip northeast, and contain very little gold. One vein dips southwest, and contains galena, pyrite, chalcopyrite, and considerable gold. Its width ranges up to 6 feet, but its length is not known.

Bruce Group (4)[2]

Bruce claims Nos. 1 to 9 inclusive comprise part of the holdings of Goldway Peak Mines, Limited. They lie 1¼ miles slightly south of east from Goldway Peak, and were staked by J. W. Burton, J. Lawlor, and C. French during July 1946. The underlying formations include greenstones of the Takla group cut by granitic rocks related to the Omineca batholith. The principal known gold deposit is a quartz vein that strikes north to northwest and dips 75 degrees west to southwest. It is exposed for about 85 feet on the steep northern side of Goldway Creek Valley. The northern 50 feet of the vein is in granitic rock, and the southern 35 feet in greenstone. The quartz contains galena and pyrite adjacent to the hanging-wall, and a little visible gold. Three widely spaced channel samples, cut across an average vein width of 15 inches, indicated a fair gold content.

[1] All assays, unless otherwise stated, were made by the Bureau of Mines, Ottawa.
[2] Compiled from data supplied by J. W. Burton, Springer Sturgeon Gold Mines, Limited.

Ginger Group (5)

The Ginger group of thirty-two claims is 4½ miles about east-southeast of Goldway Peak. It was staked for Springer Sturgeon Gold Mines, Limited, by L. Lawlor, J. W. Burton, C. French, W. Charlie, D. F. Kidd, J. Thomas, and J. Bob between July 26 and September 10, 1946. The rocks have a general northerly trend and are mainly dark green tuffs of the Takla group. A quartz vein, discovered by the Geological Survey (Lord, 1946, p. 7), is partly exposed for a length of about 70 feet and probably ranges from 2½ to 3 feet in width. It strikes about north 25 degrees west and dips about 80 degrees west. Pyrite occurs as streaks in the quartz, and has partly replaced the wall-rock for several inches on either side of the vein. A grab sample of mineralized quartz and wall-rock contained: gold, 0·26 ounce a ton. Two channel samples, 20 feet apart, and cut from vein widths of 17 and 20 inches, contained respectively[1]: 0·67 and 0·64 ounce of gold a ton. The owners report that another quartz vein about a foot wide occurs in a strong northeast shear zone, and that it provided a grab sample that assayed 3·04 ounces of gold a ton.

Shell Group (6)[2]

The Shell group, owned by Springer Sturgeon Gold Mines, Limited, lies 10 miles east-southeast of Goldway Peak. It embraces twenty-eight claims staked by N. Hals, W. French, J. Dumbrille, J. Bob, and S. Hoy between July 22 and September 12, 1946. More than a score of mineral occurrences have been found on Shell Nos. 1, 3, 4, and 27 claims, which are underlain by volcanic members of the Takla group and by granitic and other dykes. Many of these deposits are of unknown shape and size, containing abundant chalcopyrite and lesser amounts of pyrite, pyrrhotite, magnetite, malachite, azurite, and quartz. An exceptionally well exposed occurrence of this type is a vein of nearly solid sulphide minerals, at least 4 feet wide in places, that has been traced for a length of 150 feet. Near its widest exposure it afforded a grab sample from about 4 feet of vein material that assayed: gold, 0·48 ounce a ton; silver, 4·00 ounces a ton, and copper, 16·25 per cent. A grab sample from an additional 1½ feet of oxidized material at the same place contained: gold, 0·36 ounce a ton; silver, 1·20 ounces a ton; and copper, 1·90 per cent. Other mineral occurrences are quartz veins in a shear zone or zones that strike northwesterly. These veins contain a little pyrite and chalcopyrite, range up to 5 feet in width, and have provided rich gold samples.

Cariboo Heart Range

Quartz float was found in talus on the northeast slope of the Cariboo Heart Range 2½ miles east of the north end of Nanitsch Lake. Bedrock is green and purple andesitic breccia of the Takla group. The quartz, which is crystalline and accompanied by calcite and pyrite, probably came from a nearby undiscovered vein 3 inches or more in width and provided a selected sample containing: gold, 0·71 ounce a ton; silver, 5·43 ounces a ton.

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[1] Data supplied by J. W. Burton, Springer Sturgeon Gold Mines, Limited.
[2] Compiled from data supplied by J. W. Burton, Springer Sturgeon Gold Mines, Limited.

Copper and Silver

The most widespread economic minerals of the map-area are those containing copper. Chalcopyrite is most common; others include bornite, chalcocite, and native copper. They are most abundant in lavas, tuffs, and similar rocks of the Takla group, where they generally occupy parts of sheared zones or narrow crustified quartz veinlets, or have partly replaced favourable tuff beds. A few samples from these deposits were assayed, but none contained appreciable gold. One from the Omineca fault zone, and another from the Motase claims, contained, respectively, 83·20 and 14·98 ounces of silver a ton.

Omineca Fault

A veinlet about half an inch wide was found in sheared volcanic rocks of the Omineca fault zone 2 miles southeast of longitude 127 degrees. It contains chalcopyrite, malachite, azurite, unidentified soft grey minerals, calcite, and a few quartz crystals. A picked sample contained: gold, 0·205 ounce a ton; silver, 83·20 ounces a ton; and copper, 8·31 per cent.

Dewar Peak

A single piece of float, about 5 inches in diameter and comprising nearly solid bornite, was found on the valley floor about 1½ miles southeast of Dewar Peak. In addition to copper it contained 0·005 ounce gold and 4·56 ounces of silver a ton.

Menard Creek

A sheared and brecciated zone about 5 feet wide trends northwesterly across the top of the ridge just west of the source of Menard Creek. Adjoining this zone on the northeast is a 15-foot rusty band that, with the brecciated zone, extends well down both sides of the ridge. Adjacent rocks are greenstones of the Takla group. The sheared zone contains a little limonite, malachite, chalcopyrite, and crystalline quartz, and a grab sample from it assayed: gold, 0·13 ounce a ton; silver, 3·59 ounces a ton; and copper 5·18 per cent.

North of Sustut Lake

Other copper deposits occur 7 miles slightly east of north from the outlet of Sustut Lake. A small stock of medium-grained porphyritic diorite or quartz diorite, correlated with the Omineca intrusions, has invaded dark green, porphyritic, basaltic lavas of the Takla group. Epidote occupies widely spaced irregular seams and knots in both rocks, and forms amygdules in the lava. The intrusion holds scattered blebs of bornite and secondary malachite, generally less than one-quarter inch in diameter, and somewhat greater concentrations of these minerals in the epidote-rich seams. One of these seams, a few inches wide, provided a picked sample that assayed: gold, 0·01 ounce a ton; silver, 0·51 ounce a ton; and copper, 3·98 per cent. A similar sample from an epidote stringer in the adjacent lava contained: gold, 0·01 ounce a ton; silver, 0·78 ounce a ton; and copper, 7·90 per cent.

Similar but gently inclined lavas, 2½ miles southeast of the above locality, are traversed by a shear zone about 5 feet wide trending north 50 degrees west and dipping 75 degrees northeast. The zone is exposed for a length of 50 feet and contains scattered knots of epidotized rock with a little bornite, malachite, and azurite. A picked sample of the mineralized materials assayed: gold, 0·01 ounce a ton; silver, 0·30 ounce a ton; and copper 3·30 per cent. About 630 feet above this occurrence a vertical fault strikes north 55 degrees west through the same lava assemblage. The fault zone is about 20 feet wide, with a sharp, slick northeast wall, and contains sheared and epidotized volcanic rock with a little bornite, malachite, and azurite. It crosses the crest of a precipitous ridge, the sides of which were not examined.

A little native copper is reported[1] from serpentine and red volcanic rock 1½ miles north and 2½ miles northeast, respectively, of the east end of Sustut Lake.

West of Bear Lake

Many small veinlets of chalcopyrite, pyrite, galena, sphalerite, specularite, crustified quartz, and calcite were seen in talus fragments of red andesitic tuffs and lavas on the ridge immediately west of Bear Lake. Some of these occurrences are reported to contain appreciable amounts of gold. The largest seen in place by the Geological Survey is 4½ miles southwest of Bear Lake village. It is 3 inches wide and exposed for a length of 10 feet; it contains up to 60 per cent chalcopyrite in addition to banded comb quartz and a little specularite.

Motase Group (7)[2]

The Motase group of thirty-five claims lies astride a mountain about 3 miles northeast of the southeast corner of the map-area. It was staked by M. S. Lougheed, during the summer of 1945, on behalf of Yukon Northwest Explorations, Limited, and prospected and geologically mapped by that company during the same season.

The claims are underlain mainly by red, green, grey, and buff, andesitic lavas, tuffs, and agglomerates of the Takla group. Near the known mineral occurrences these dip about 15 degrees southwest and are cut by steep, light grey feldspar porphyry and quartz porphyry dykes, which may be phases of the Kastberg intrusions.

Two mineralized areas, one about 1,000 feet northwest of the other, occupy parts of the precipitous northeast face of the mountain; and a third lies 1,500 feet southwest on the relatively gentle southwest slope of the hill. The principal minerals, bornite and chalcocite, are associated with[3] a little galena, pyrite, chalcopyrite, and possibly tetrahedrite. These occur mainly in the volcanic rocks. There they occupy minute fractures, or are disseminated throughout an inch or so of rock on either side of fractures, or are scattered through larger masses of rock apparently unrelated to fractures. Less commonly they have partly replaced the borders of porphyry dykes. The minerals are not equally concentrated or abundant in all rock layers.

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[1] Personal communication from the late R. M. Godfrey of Vancouver, who prospected parts of the map-area in 1945.

[2] Description based in part on data supplied by K. J. Springer, Yukon Northwest Explorations, Limited, and in part on observations made by the writer in 1941.

[3] Lougheed, M. S.: Yukon Northwest Explorations, Limited.

It has been suggested[1] that the metalliferous solutions entered the gently inclined volcanic assemblage along steeply dipping fractures or sets of fractures, and spread out from them to deposit their metal content mainly in particularly favourable beds of tuff. None of the mineralized areas is adequately exposed (1945). One, on the northeast face of the mountain, may be 50 feet wide and extend more than 300 feet up the slope. Another, on the southwest side of the mountain, has been observed at intervals for more than 500 feet along a line trending about south, but its width is not known. A selected sample of medium-grained, reddish, mineralized tuff from talus on the northeast side of the mountain contained[2]: gold, 0·005 ounce a ton; silver, 12·76 ounces a ton; and copper, 14·98 per cent. Samples taken by the owners contained somewhat less copper and silver, but, like the above example, carried about 1 per cent copper to each ounce of silver.

Lead and Zinc

Only three small occurrences of galena, sphalerite, and associated minerals were considered to be worth sampling. All are within members of the lower division of the Takla group.

Several white calcite veins cut thin-bedded, black, tuffaceous argillite and tuff 5½ miles west-northwest of the mouth of Quenada Creek. The strata strike north 15 degrees west and dip 20 degrees west. One vein was examined, and strikes north 75 degrees east and dips about 80 degrees south. It is about a foot wide and is exposed for an estimated length of at least 300 feet. The walls are sharp. Sphalerite, chalcopyrite, and galena in places comprise as much as 20 per cent of the vein matter, and are accompanied by much earthy, yellowish brown iron oxide. A selected sample contained: gold, 0·0025 ounce a ton; silver, 0·165 ounce a ton; copper, 0·06 per cent; lead, 0·02 per cent; and zinc, 9·95 per cent. Other veins in the vicinity, although seen only from a distance, appear to be wider than the one examined, but are not known to contain metallic minerals.

A vein of calcite, quartz, sphalerite, and chalcopyrite, 3 miles southwest of the mouth of Quenada Creek, is 6 inches wide and exposed for a length of 2 feet. It provided a selected sample containing: gold, trace; silver, 1·67 ounces a ton; copper, 5·41 per cent; lead, none; and zinc, 14·36 per cent.

Five miles northeast of Mount Carruthers a gabbroic dyke, about 100 feet wide, cuts dark green tuffs of the Takla group. In the dyke are short exposures of two veins, about 5 feet apart, that strike about east and dip 20 degrees south. They are 2 and 1½ inches wide respectively, and are composed of chalcopyrite, galena, sphalerite, pyrrhotite, dark brown limonite, and a little banded crystalline quartz. A selected sample from the widest vein assayed: gold, 0·01 ounce a ton; silver, 9·55 ounces a ton; copper, 0·82 per cent; lead, 7·15 per cent; and zinc, 1·00 per cent.

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[1] Lougheed, M. S.: Yukon Northwest Explorations, Limited.

[2] Sample collected by the Geological Survey in 1941.

Beryllium

Pegmatite dykes occur near the north end of an ultrabasic intrusion close to the source of Dortatelle Creek. The pegmatite was not examined in outcrop, but many loose blocks from it occur in a moraine. The main constituents of the rock are pink feldspar and quartz, but one block, derived from a dyke at least 3 feet wide, also contained a little pyrite, scattered clear brown grains of garnet, and a few crystals of pale green beryl[1] up to $\frac{3}{4}$ inch in diameter.

Chromite

Chromite occurs as grains and as rare blebs as much as $\frac{1}{2}$ inch in diameter in the ultrabasic intrusions west of Carruthers Creek, near the source of Dortatelle Creek, and 7 miles north-northeast of Johanson Lake. At the last locality, several seams of chromite, $\frac{1}{2}$ to 1 inch wide, were found in talus blocks of smooth-surfaced, buff weathering serpentine.

Molybdenite

Molybdenite was found in vein quartz in gneissic granodiorite in a moraine, on the southwest side of the pass extending southeasterly from the head of Dortatelle Creek. The quartz was derived from a vein or veins at least several inches wide, and contains a little pyrite, pyrrhotite, chalcopyrite, and molybdenite. A selected sample contained: gold, trace; silver, 0·05 ounce a ton; molybdenite (MoS_2), 0·14 per cent.

Molybdenite was noted in another moraine on the south side of a lake-studded pass connecting upper Dortatelle Creek with Miller Creek Valley. The mineral is disseminated in small fragments of altered pyroxenite and in fragments of quartz associated with ferruginous carbonate. The quartz probably came from a nearby vein or veins not more than a few inches wide. It provided a selected sample containing 0·70 per cent molybdenite (MoS_2).

NON-METALLIC DEPOSITS

Coal

Jurassic Deposits

Most known coal of the map-area is in strata assigned to the upper, Jurassic division of the Takla group. Essentially all observed exposures of this coal lie within a belt, rarely more than 3 miles wide, that extends northerly from Scallop Mountain to about the mouth of Yuen Creek, and thence northwesterly across Asitka and Sustut Rivers and along the southwest side of Red Creek Valley. All diagnostic Upper Jurassic fossils came from this belt, in addition to several collections of less certain but probable Middle Jurassic age. Accordingly, the coal is most likely of Upper Jurassic age. However, as it occurs in a structurally complex belt, its stratigraphic position relative to diagnostic fossil zones is difficult to determine, and the coal may be within slightly older or younger strata. Exposures of coal and associated coaly, argillaceous rocks are commonly minutely

[1] Identified by E. Poitevin, Mineralogical Section, Geological Survey of Canada.

fractured and deeply covered with local rubble, so that it is generally impossible to measure the widths of the coal seams without considerable stripping or trenching. It is, consequently, possible that careful prospecting would disclose appreciably greater widths than those seen by the writer.

Outcrops of carbonaceous shale and coal are particularly numerous within an area about 3 miles in diameter lying about 3 miles south-southwest of the source of Red Creek. At least four, and probably more, carbonaceous layers are interlayered in places with greywacke and pebble conglomerate, and elsewhere with coarse friable agglomerate containing fragments of silicified and carbonized wood. The interlayered strata are included on lithological evidence with the upper part of the upper division of the Takla group. Accordingly, the coal is probably of Upper Jurassic age. The coal-bearing assemblage strikes northwesterly, and generally dips between 30 and 55 degrees southwesterly. At one place, three carbonaceous layers are separated by two agglomerate layers each about 40 feet thick. Elsewhere the intervening layers of agglomerate or other rocks are probably considerably thicker. The coal-bearing layers range from 10 to perhaps more than 200 feet thick, and comprise thin-bedded black shale, with scattered coal seams up to 5 inches thick. Much of the shale is highly carbonaceous, has a greasy brown streak, and burns with difficulty. The coal has a high lustre, breaks with a conchoidal fracture, and when scratched gives a steely grey streak. One sample, collected from a natural outcrop, proved to be a medium-volatile bituminous coal, which after drying contained[1]: ash, 20·6 per cent; volatile matter, 19·4 per cent; fixed carbon (by difference), 60·0 per cent.

Coal also outcrops on the west bank of Red Creek, about 3 miles from its mouth and ¼ mile upstream from its main southwest fork. The exposed coal-bearing strata comprise about 65 feet of thin-bedded, yellow, grey, and black, carbonaceous shales of the Takla group. They strike south 65 degrees east, dip from 35 to 75 degrees northeast, and are separated from other strata at the south end of the outcrop by a steep fault zone a few feet wide. Most of the coal occurs as crushed seams within the 25 feet of sheared shale outcropping immediately north of the fault. An estimated 20 per cent of this section comprises glistening black coal, in seams as much as 2 inches thick, and dull shaly coal.

Other coal exposures lie above timber-line at the base of abrupt cliffs 3½ miles east of the mouth of Saiya Creek. The lowest strata are greenish grey, yellowish, and black, crumbly argillites enclosing a few specimens of *Belemnites*. They strike northwesterly, dip steeply northeast, and are overlain by about 50 feet of similar rocks enclosing several coal seams, and, above these, by about 20 feet of yellow, shattered, presumably argillaceous rock. This sedimentary assemblage is overlain, apparently conformably, by about 20 feet of coarse, friable, andesite agglomerate, with fragments of carbonized wood, succeeded by compact andesitic breccia. The coal seams are not well exposed, but one of them was estimated at one place to be 10 feet thick but contains an unknown proportion of shaly coal and a few, thin, yellowish, clayey partings. A sample of this coal, after drying, contained[1]: ash, 18·6 per cent; volatile matter, 27·2 per cent; fixed carbon

[1] Analysis by Division of Fuels, Bureau of Mines, Ottawa.

(by difference), 54·2 per cent. It is a high-volatile bituminous coal. An adjacent similar seam, not sampled, is about 4 feet thick.

A little coal was found 1½ miles southeast at about the same stratigraphic position, and other apparently smaller occurrences are shown on the accompanying map.

Upper Cretaceous and Paleocene Deposits

Coal is present in both the Upper Cretaceous and Paleocene sandstones of the Sustut group, but, with one known exception, occurs as minor, widely scattered lenses, very few of which exceed a length of 5 feet or a thickness of an inch.

The exceptional occurrence is 3½ miles west-northwest of the mouth of Asitka River, on the southwest slope of a ridge. The principal formations are sandstones and pebbly sandstones of probable Upper Cretaceous age. A few feet of coal-bearing strata overlie these conformably. The whole assemblage strikes about south 70 degrees east and dips 55 degrees southwest, about parallel with the surface on which the coal occurs. The coal-bearing strata thus form a thin sheet resting on a dip slope, and an unknown thickness of their upper members has been removed by erosion. The outcrop is thickly strewn with fragments of black and light grey shale and coal, and the thickness and number of coal seams is unknown. The coaly fragments are made up of alternating bands of glistening black coal and dull black shaly coal.

PROSPECTING NOTES

McConnell Creek map-area has provided ample evidence to warrant an intensive search for ore-deposits, but, as previously mentioned, very little efficient prospecting was done prior to 1946. Theoretical factors favouring the occurrence of sizeable mineral deposits include: (1) the presence of granitic intrusions of at least two distinct ages (Omineca and Kastberg intrusions), suggesting that metalliferous solutions may have entered the formations at least twice during the geological history of the area; (2) the complex structure impressed on a heterogeneous assemblage of strata, a situation generally providing numerous channelways, such as faults and shear zones, for rising solutions; and (3) the many square miles of formations that border and overlie the Omineca batholith and thus lie more or less directly in the path of such mineral-bearing solutions as may have risen from the underlying magma. The known mineral occurrences, some of which have been described above, provide concrete evidence that solutions containing valuable metals reached this favourable terrain; but only a careful, intelligent, and persistent search can prove or disprove the presence of orebodies.

Most of the known metalliferous deposits are in volcanic members of the Takla group (units 3A and 4 on the accompanying map) and, accordingly, areas underlain by these rocks afford promising prospecting ground. Most gold-bearing veins reported to the end of the 1947 prospecting season occur in Takla volcanic rocks of the lower division lying east of a line extending northerly from the source of Mesalinka River, through Dortatelle Peak to McConnell Lakes. These deposits are presumably of Mesozoic age, genetically related to the Omineca intrusions. Perhaps the most promising part of this belt lies east and southeast of Goldway Peak, an area first outlined by the Geological Survey (Lord, 1946, p. 7). Deposits of copper, some with important amounts of silver, have been found within volcanic members of the upper and lower divisions of the Takla group, and appear to be most numerous in these rocks: (1) on the southern half of McConnell Range and its southern extension to Johanson Creek; (2) within an area bounded by latitudes 56°30′ and 56°45′, and longitudes 126°45′ and 127°; and (3) southwest of Bear Lake.

Near Niven River, at longitude 127 degrees, a rich, silver-bearing seam occurs in a post-Paleocene fault, and on the Motase claims silver-bearing copper deposits have replaced[1] dykes probably related to the Tertiary, Kastberg intrusions. Other evidence of Tertiary mineralization in this general part of British Columbia is found about 140 miles south-southeast in the Houston (Lang, Hanson, and Phemister, 1942) and Fort Fraser (West Half) (Armstrong, 1941) map-areas: there, many deposits of silver and other metals are associated with small Tertiary intrusive bodies and some occur in Tertiary volcanic or intrusive rocks. Furthermore, cinnabar (mercury) deposits of probable Tertiary age (Armstrong, 1942) occur in the nearby Takla and Fort Fraser (East Half) map-areas in rocks of, or related to, the Pinchi fault zone, a structure believed to be continuous with the Omineca fault zone. Thus, the possibility of important Tertiary deposits of silver, mercury, or other metals in McConnell Creek map-area should not be neglected by prospectors. Careful attention should be paid to the fault zones and adjacent rocks, as these afforded Tertiary channelways and contain silver (near Niven River) and mercury (Takla map-area) deposits. The magma from which the Kastberg intrusions were derived is the most likely known source of Tertiary mineralizing solutions; therefore, formations adjacent to these intrusions, and especially volcanic members of the Takla group, should be examined.

The sandstones of the Sustut group afford a possible source of the vanadium detected in the black sand concentrate from the McConnell Creek placer operations. Yellow stains or encrustations on these rocks, especially if accompanied by carbonized matter, should be carefully scrutinized as possible occurrences of carnotite or other vanadium minerals.

The most promising known coal deposits lie southwest of upper Red Creek and along the northeast side of Saiya Creek Valley. Trenching and stripping will be required before much is known of the size and quality of the seams.

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[1] Lougheed, M. S.: Yukon and Northwest Explorations, Limited

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