GEOLOGICAL SURVEY OF CANADA

DEPARTMENT OF MINES AND TECHNICAL SURVEYS

MEMOIR 312

WHITEHORSE MAP-AREA, YUKON TERRITORY

105 D

J. O. Wheeler

Price $2

1961

WHITEHORSE MAP-AREA,
YUKON TERRITORY
105 D

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Plate I. *Rock glacier on Mount Ward across Wheaton River valley. Note smooth upland in middle distance with jagged Coast Mountains in the far distance.*

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PREFACE

Geological investigations have been carried on in Whitehorse map-area, mainly by the Geological Survey of Canada, starting with G. M. Dawson's historic journey in 1887. By 1924, initial mapping of the area had been completed, but since then many new geological methods and concepts have been introduced.

Accordingly, when this important area—it contains the Wheaton and Windy Arm mineral districts and the Whitehorse copper belt—was made more accessible by the building of the Alaska Highway, and a good topographic base became available, geological mapping on modern standards was carried out.

This report and accompanying map embody the results of this study.

J. M. HARRISON,
Director, Geological Survey of Canada

OTTAWA, June 25, 1959.

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WHITEHORSE MAP-AREA, YUKON TERRITORY

Abstract

Whitehorse map-area covers some 4,800 square miles of mountainous terrain in southern Yukon Territory, partly in the Coast Mountains and partly in the Yukon Plateau.

The southern part of the map-area contains metamorphic rocks of the Yukon group, most of which are probably of late Palæozoic age but which may be, in part, Precambrian. In the southeast corner are Permian, possibly in part Pennsylvanian, mainly non-clastic sediments and volcanic rocks of the Taku group. Elsewhere most of the layered rocks are Upper Triassic volcanic and sedimentary rocks of the Lewes River group overlain in places by the Jurassic, partly non-marine and locally coarse-grained sediments of the Laberge group. The Upper Jurassic(?) and Lower Cretaceous non-marine sediments of the Tantalus formation overlie or are faulted against these. Volcanic rocks of the Hutshi and Skukum groups of Cretaceous and Tertiary age, and the Pleistocene Miles Canyon basalt, all lie more or less horizontally on the older formations.

A granitic plutonic complex underlies much of the southwest half of the area and is, in part at least, of Cretaceous age. Somewhat older are bodies of ultramafic rocks which, however, cut rocks as young as the Jurassic Laberge group.

The late Palæozoic and Mesozoic rocks of Whitehorse map-area were laid down in what is known as the Whitehorse trough. They have subsequently been folded into a northwesterly trending synclinorium which has been intruded by granitic plutons and is bounded on each side by a granitic plutonic complex containing older metamorphic rocks. Many minor complex structures are present.

Deposits of base metals and gold are widely scattered throughout the area, and such important areas as the Whitehorse copper belt have been recognized for many years.

Résumé

La carte de Whitehorse couvre une superficie de quelque 4,800 milles carrés de terrain montagneux dans le sud du territoire du Yukon; elle comprend une partie de la chaîne Côtière et une partie du plateau du Yukon.

La partie sud de cette région renferme des roches métamorphiques du groupe Yukon, dont la plupart remontent probablement à la fin du Paléozoïque, tandis que les autres peuvent appartenir au Précambrien. Dans le coin sud-est, on rencontre surtout des sédiments non clastiques permiens et peut-être aussi en partie pennsylvaniens, ainsi que des roches volcaniques du groupe Taku. Ailleurs, la plupart des strates sont formées de roches volcaniques du Trias supérieur et de roches sédimentaires du groupe de la rivière Lewes, recouvertes, en certains endroits, de sédiments jurassiques du groupe Laberge qui sont partiellement d'origine non marine et à grains grossiers. Les sédiments d'origine non marine du Jura supérieur (?) et du Crétacé inférieur qui appartiennent à la formation Tantalus recouvrent ces strates ou s'y appuient à la suite d'une faille. Les roches volcaniques des groupes Hutshi et Skukum, qui remontent au Crétacé et au Tertiaire, ainsi que le basalte pléistocène du canyon Miles, reposent tous plus ou moins horizontalement sur les formations plus anciennes.

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Les assises d'une bonne partie de la moitié sud-ouest de cette région forment un complexe granitique plutonien qui remonte, en partie tout au moins, au Crétacé. Il existe des massifs un peu plus anciens constitués de roches ultramafiques qui coupent cependant des roches aussi jeunes que le groupe jurassique Laberge.

Dans la région de Whitehorse, les roches de la fin du Paléozoïque et du Mésozoïque ont pénétré dans ce qu'on est convenu d'appeler l'auge de Whitehorse. Ces roches ont par la suite été plissées en un synclinorium orienté vers le nord-ouest et qui a été le siège d'une intrusion de plutons granitiques. Cette formation est bordée de chaque côté d'une complexe granitique plutonien qui renferme des roches métamorphiques plus anciennes. On y relève plusieurs structures mineures complexes.

Des gîtes d'or et de métaux communs se rencontrent cà et là sur toute l'étendue de cette région, et l'on connaît depuis plusieurs années des régions importantes telles que la zone cuprifère de Whitehorse.

Chapter I

INTRODUCTION

Location and Access

Whitehorse map-area covers about 4,800 square miles in southwestern Yukon between north latitudes 60 and 61 degrees and west longitudes 134 and 136 degrees. The area has an important airport at Whitehorse, and is also accessible by motor vehicle via the Alaska Highway, and by rail via the White Pass and Yukon Railway from Skagway, Alaska.

The main gravel roads within the map-area may be travelled by car, but a truck or four-wheel-drive vehicle is necessary on many of the side roads, particularly in the spring and during periods of wet weather. Most of the map-area, except the rugged southern region west of the head of West Arm, is suitable for horse travel. Trails are few but are generally in fair condition; elsewhere the valleys can be travelled by horses. All of the map-area can be traversed on foot, but in the southwestern part the mountains are precipitous and contain small glaciers, locally requiring roped parties and mountaineering techniques to be negotiated.

Freight canoes powered by outboard motors can be used on Marsh, Tagish, and Bennett Lakes. In order to travel on the lakes in rough weather canoes must be completely covered with tarpaulins. Storms arise very suddenly, often within 10 or 15 minutes, generated by winds sweeping down from the Coast Mountains northward to Yukon Plateau. The larger rivers such as the Takhini, Teslin, and lower M'Clintock, and the Yukon except for Miles Canyon and Whitehorse Rapids, are safely navigable for outboard-powered freight canoes. Aircraft with floats are available for charter at Whitehorse, and may be used for landings on many of the lakes in the map-area.

Climate

The climate of Whitehorse map-area is fairly typical of southern Yukon (*see* Table I). The winters are harsh but the summer months are generally pleasant, enhanced by long periods of daylight; during June and July daylight lasts for 20 and 18 hours respectively.

The rivers are open from early May until late October or even November. Ice remains in the larger lakes until the first week in June and in the smaller lakes at higher elevations until late June or early July. Slack water freezes over after the middle of October.

Precipitation in the map-area is variable, with about half falling as rain during the summer months. In the surrounding mountains, especially the Coast Mountains, precipitation is much greater than at Whitehorse (Kendrew and Kerr, 1955, Fig. 50, p. 158)[1].

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[1]Names and dates in parentheses refer to publications listed in the References.

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Table I

Climatological Table for Whitehorse
(Elevation 2,289 Feet Above Mean Sea-level)
(Kendrew and Kerr, 1955, p. 221)

Month	Air Temperature			Precipitation		Number of Days of					Percentage of Time with	
	Daily Mean (°F)	Mean of Daily		Mean (Total of All Forms) (inches)	Mean Snowfall (inches)	Rain (0.1 inch)	Snow (depth 0.1 inch)	Frost (in screen)	Fog (vis. 1 knot)	Thunder	Clear Sky (2/10 overcast covered)	Overcast Sky (8/10 covered)
		Max. (°F)	Min. (°F)									
January	5	13	−3	0.6	6	0	11	31	4	0	22	61
February	7	16	−2	0.5	5	0	9	28	2	0	26	59
March	21	31	12	0.6	6	0	6	30	1	0	24	58
April	32	41	22	0.4	4	1	5	27	1	0	18	63
May	46	57	34	0.6	1	4	1	13	1	0	19	60
June	55	66	43	1.0	0	8	0	1	1	1	16	62
July	56	67	45	1.6	0	13	0	1	1	2	11	68
August	54	64	43	1.5	1	10	1	2	2	1	18	63
September	46	55	37	1.3	1	9	1	7	1	0	18	66
October	34	41	28	0.7	1	4	5	21	2	0	18	64
November	15	21	8	1.0	4	0	12	28	3	0	14	73
December	3	10	−4	0.8	9	1	11	30	3	0	19	66
Mean	31	40	22								19	64
Total				10.6	45	50	61	217	18	4		
Number of years observation	10	10	10	10	10	12	12	11	11	10	10	10

Flora

Forest growth is restricted chiefly to the valley floors but extends up the hillsides to about 4,000 feet above sea-level. The uplands and some of the higher valleys are devoid of timber.

The most common tree is white spruce. It is most plentiful on the valley flats where it attains its largest size; individual trees rarely exceed 12 inches in diameter. Other conifers are lodgepole pine, growing principally on dry sandy terrain; alpine fir, found mostly near timber-line; and black spruce, which are sparse. Of the deciduous trees, aspen poplar and balsam poplar are the most abundant; birch is relatively uncommon.

Willow and dwarf birch are the most prevalent deciduous bushes. Willow is found along streams and mixed with dwarf birch at and above timber-line. In the Coast Mountains alder is a common bush, particularly on slopes swept by avalanches in the spring.

Several varieties of wild fruit abound. Blueberries, cranberries, and raspberries are probably the most common, and currants, strawberries, and Saskatoon berries less so.

Much of the open terrain in the valley bottoms is swampy and supports a mossy and peaty vegetation. Locally however, grassland good for grazing is found up Wheaton River between Becker and Berney Creeks, between Rose Creek and Watson River, and along Watson River.

The upland supports dwarf grasses, moss and heather. These form tussocks where frost action has been active.

Fauna

Grizzly, black, and brown bears and moose live in all parts of the map-area. Dall and Stone sheep live mainly in the southwestern region, where large bands roam the country around the headwaters of Watson and Wheaton Rivers. A few mountain goats frequent the rugged mountains south of Wheaton River and at the head of West Arm. Caribou, in bands of six or less, were observed east of the White Pass and Yukon Railway. Wolves are locally a hazard to livestock and wintering pack animals. Fur-bearing animals in the area include wolverine, beaver, marten, lynx, fox, rabbit, and squirrel.

Eagles, hawks, ducks, grouse and ptarmigan are common and small birds are numerous. For complete lists of birds in the area see Clarke (1946), Rand (1950), and Godfrey (1951).

Lake trout and grayling are the most common fish.

The chief pests are mosquitoes during June and July and black flies in August and September; both cause humans and pack animals much discomfort.

Settlements

The largest settlement in the map-area is the town of Whitehorse with a population of 3,500 (1955). In 1953 Whitehorse became the capital of Yukon

Territory. The town is the transportation hub of the Yukon as it is the terminus of the White Pass and Yukon Railway, the head of navigation down Yukon River, and close to the Alaska Highway. The town of Carcross (population 150) can be reached by road and railway and serves as the connecting point for the transportation of goods between Atlin, British Columbia and the Pacific Coast. Elsewhere in in the area settlements are small; Dundalk and Conrad are now abandoned.

Previous Geological Work

The first recorded geological work in Whitehorse map-area is that by G. M. Dawson in 1887, who, in the course of an exploration of the Yukon, spent 8 days travelling by boat from Lake Laberge to Bennett Lake (Dawson, 1889).

Near the turn of the century prospecting and mining began in the Windy Arm and Wheaton districts which lay just off the route through Whitehorse area used by the gold-seekers en route to the Klondike. Geological work, stimulated by this activity, began in 1905 when R. G. McConnell examined the mineral properties of the Windy Arm district (McConnell, 1906). In the next year D. D. Cairnes investigated the geology and mineral deposits of the Conrad and Whitehorse mining districts (Cairnes, 1908). He was followed in 1907 by McConnell who studied the copper deposits west of Whitehorse (McConnell, 1909). In 1909 and 1915, Cairnes was engaged in geological mapping of the Wheaton district on a scale of 1 inch to 1 mile (Cairnes, 1912, 1916). In the years 1922 to 1924, W. E. Cockfield and A. H. Bell made a reconnaissance survey of the Whitehorse map-area (Cockfield and Bell, 1926, 1944). In September 1940, H. S. Bostock examined the antimony prospects in the Wheaton district in connection with a study of special minerals (Bostock, 1941, p. 33). In 1943 and 1944, H. M. Raup of Harvard University led expeditions making geomorphological, botanical, and archæological studies along the full length of the Alaska Highway. In the course of this work C. S. Denny made a reconnaissance in 1943 of the surficial geology from Whitehorse southeast along the Alaska Highway and around Carcross (Denny, 1952). J. H. Sticht made a similar study in 1944 along the Alaska Highway from Whitehorse westward into Alaska (Sticht, 1951).

Present Geological Work

Geological mapping of Whitehorse map-area on a scale of 1 inch to 4 miles was begun in 1946 by J. G. Fyles and W. E. Cockfield, assisted by J. W. Lee and J. C. Amy (Fyles, 1950). The work was continued by J. R. Johnston, assisted by M. C. Robinson and A. Hall during June 1947, and was completed by the writer during the field seasons of 1948 to 1951. Additional short periods were spent in the map-area in 1952, 1954, and 1955.

Rock exposures are mainly above timber-line and hence most field traverses were made upon steep valley-walls, ridges, and uplands even though felsenmeer and lichen-cover hampered observations (*see* Plate II, facing p. 6). Some streams have cut into bedrock and their canyons provide good exposures.

Acknowledgments

The writer acknowledges courtesies extended by many of the residents of Whitehorse map-area, especially by Mr. and Mrs. C. Veerman of Robinson. Special thanks are due to E. Kohse Sr. and J. G. Souther for help beyond their duties as packers, in carrying out the field work. Able assistance in the field was given in 1948 by L. L. Price, J. D. Aitken, and W. Mudie; in 1949 by L. T. Jory, W. S. Pentland, and L. C. Kilburn; in 1950 by C. E. C. Daw, J. C. Riddle, and G. Skoreyko; in 1951 by W. R. A. Baragar and Z. Nikiforuk; in 1954 by E. M. Manko and G. B. Tallon; and in 1955 by L. G. Ashwell, D. M. Callan, and C. I. McDonald.

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Chapter II

PHYSIOGRAPHY AND GLACIATION

Physiography

Whitehorse map-area lies within two primary physiographic subdivisions of the Canadian Cordillera. The western half south of Takhini River falls within the northern limit of the Coast Mountains (Bostock, 1948b, p. 86), and the remainder, in the western part of Yukon Plateau (Bostock, 1948b, p. 65). The boundary between these two subdivisions is indefinite and much of the western part of the map-area actually lies within a transitional zone between them.

The jagged, alpine topography (*see* Plate I, *frontispiece*), typical of the Coast Mountains farther south, is displayed by the mountains southwest of Takhini Lake (*see* Plate III), by those around the headwaters of Wheaton River including a narrow prong of rugged peaks extending as far north as Mount Skukum, by those overlooking West Arm, and by the highest peaks of the Montana Mountain massif. This mountainous terrain reaches a maximum elevation in the map-area of 8,055 feet above sea-level. It exhibits horns, serrated ridges, and cirques, some of which contain glaciers a mile long, and is irregularly dissected by deep, relatively narrow, U-shaped valleys and their hanging tributaries. The relief in this region is generally between 4,000 and 5,000 feet and is accentuated by the precipitous walls of the glaciated valleys.

The southern part of the transitional zone between the Coast Mountains and western Yukon Plateau—the part south of latitude 60°30′—is characterized by a relatively smooth, gently rolling upland surface, undulating between 5,000 and 7,000 feet, locally surmounted by roughly conical peaks or groups of peaks (*see* Plates I, III). This surface is dissected by U-shaped valleys not more than 3 miles wide, producing an average relief of 3,500 to 4,500 feet. It appears partly to merge with and partly to abut the rugged terrain of the Coast Mountains.

Alpine glaciation has modified the upland surface by incising into it numerous cirques which give the region the aspect of 'biscuit-board' topography, well displayed between Takhini and Primrose Lakes. This process has also modified the shape of the higher peaks surmounting the upland by steepening their northern and eastern slopes.

The northern part of the transitional zone (*see* Plate VI, facing p. 12) is characterized by broad, smoothly rounded ridges at elevations between 5,500 and 6,000 feet, rather than a more or less continuous upland surface. The ridges in this zone here and there rise to higher conical or locally serrated peaks over 7,000 feet in elevation. In other respects this region shows the same sort of topography, relief, and effects of glaciation as the southern part of the transitional zone.

Plate II. *View south to Mount Skukum, showing felsenmeer characteristic of frost-heaved upland areas.*

—USAAF Photo 15-L-64

Plate III. *View southeast across Primrose River valley. This terrain of the transitional zone is underlain by Yukon group (bedded rocks at right) and granitic rocks. Note fault diagonally crossing lower centre of photograph, glaciated U-shaped valleys, hanging tributaries, cirques containing debris, and small glaciers, smooth uplands and more rugged part of Coast Mountains in the distance.*

—*USAAF Photo 28-R-6*

Plate IV. *View northeast across Yukon River valley to northeastern part of Whitehorse map-area. Note smoothly rounded, dissected uplands and broad valleys of Yukon Plateau underlain by Mesozoic rocks. Easterly dipping Upper Triassic limestone is at left of Cantlie Lake.*

The area north of Takhini River and east of the White Pass and Yukon Railway, lying in the western Yukon Plateau (*see* Plate IV), has broad valleys up to 8 or 10 miles wide, the floors of which are 2,000 to 2,500 feet above sea-level. These valleys separate uplands mainly of broad, smoothly rounded ridges between elevations of 5,000 and 6,000 feet, above which a few isolated peaks rise to 6,800 feet. The uppermost few hundred feet of these peaks are locally more rugged. Although small tablelands, characterized by gentle slopes, exist west of the headwaters of Cap Creek and on each side of Taku Arm, most of the terrain in this part of western Yukon Plateau consists of slopes of moderate gradient. This is particularly well illustrated around Mount M'Clintock where interstream areas are slopes of moderate gradient culminating in smooth, narrow ridges. The predominance of moderately steep slopes in western Yukon Plateau contrasts with the extensive, gently sloping, upland areas in the transitional zone to the west.

Cirques in the eastern part of the map-area are few. They hold little debris and exhibit smoothed retaining walls and spurs that have been locally notched by ice-marginal streams. These cirques are very different from the debris-filled cirques in the west, which have freshly scoured retaining walls and serrated spurs devoid of notches.

Drainage

The entire map-area is drained by Yukon River and its tributaries, including Teslin River.

The largest valleys such as those of Yukon, M'Clintock, Watson, and Teslin Rivers are broad, flat-floored trenches 3 to 10 miles wide. They contain little or no outcrop, except on one or two low hills isolated in the valleys and on rock drumlins in the glacially grooved region around Little Atlin and Marsh Lakes, and Teslin River. The valley floors and lower slopes are mantled with unconsolidated deposits of glacial, glaciofluvial, alluvial, lacustrine, and wind-blown material into which the present rivers have entrenched narrow meander belts locally more than 200 feet in depth.

The larger valleys in the western and southern parts of the map-area are narrower than those elsewhere in the area and illustrate well the U-shaped cross-section and steep walls of glaciated valleys. Some of these are occupied by the chain of lakes extending from Bennett Lake to Marsh Lake.

The valley walls are commonly smoothly concave upward, but in some places, as on the east wall of the south fork of Wheaton River, at the forks of Wheaton River, and on the south wall of West Arm, rock benches indicate a trough-in-trough cross-section. Elsewhere the valley walls are marked with kame terraces, lateral moraines, abandoned channels, and shorelines of proglacial lakes. The tributaries of these glaciated valleys are commonly hanging and have cut canyons into bedrock where they debouch into the master valley.

In several places, streams flowing northeast from a divide are longer than those flowing southwest from the same divide. This is probably caused by the greater headward erosion by cirques on the northeast slopes, which has displaced the divide to the southwest. Outstanding examples are the western tributaries of Becker, Fenwick, and Cap Creeks and the south fork of Wheaton River.

Lakes are common throughout the map-area. Some, such as Bennett, Tagish, Primrose, Takhini, and Rose Lakes, occupy parts of valleys that appear to have been deepened by ice as indicated by remnants of rock bars at the lake outlets. Others, such as Fish, Alligator, and Marsh Lakes, and a host of smaller ones, are in parts of valleys that have been dammed by glacial and fluvial materials. Cirque floors contain rock- and moraine-barred tarns in many places.

Glaciers up to a mile long occur in the southwestern part of the map-area and on Montana Mountain; virtually all are in northward- and eastward-facing cirques.

Preglacial Physiography

The gross topographic features such as the uplands, old erosion surfaces, valleys, and drainage pattern were probably developed in the area before the advance and retreat of one or more ice-sheets and subsequent alpine glaciation.

At least two erosion surfaces are indicated in preglacial time. The widespread and undulating uplands in the western part of the map-area, which truncate all rock units except the Miles Canyon basalt, are locally surmounted by higher conical peaks. In some places these uplands abut higher rugged terrain, for example, west of Takhini Lake. Such higher terrain represents remnants of a surface older than the one now forming much of the upland.

The major preglacial valleys probably had the same relative size as they do today. That is, the larger valleys in the southwestern part of the map-area were narrow and deeply incised into the upland, whereas those in the rest of the map-area were wider with more gently sloping walls. The widths of the valleys appear to depend to some degree upon the kinds of rocks in which the valleys have developed. The narrowest valleys are those in terrain underlain mainly by granitic rocks in the southwestern part of Whitehorse map-area and in the southeastern part of the adjoining Dezadeash map-area. Valleys developed in terrain underlain by folded, bedded rocks which underlie most of the rest of the map-area, appear to be wider because they were developed in weaker rocks or along zones of structural weakness where valley-widening processes were more effective than in granitic rocks. Zones of highly folded and sheared, weak rocks, such as the slates, sheared greywacke, and volcanic rocks in the central part of the map-area, appear to have permitted the formation of a broad trench along which lies the valley of Yukon River, and Marsh and Little Atlin Lakes. Valley widening, however, does not appear to have always been most effective in weak rocks. For example, around Mount M'Clintock, unsheared weak argillites and hornfels have been incised by deep, relatively closely spaced valleys that separate interstream areas consisting mainly of moderately steep slopes. Apparently the streams cut down vertically more readily than laterally. What little width the valleys in this area possess is attributable in large measure to the effects of erosion accompanying glaciation which have sharply truncated the spurs along northward-trending valleys between Byng Creek and Mount M'Clintock.

In Whitehorse map-area and in the eastern part of the adjoining Dezadeash map-area, the same valley trends, though not exactly the same pattern, are displayed in terrain underlain mainly by granitic rocks, as in the surrounding bedded rocks. Hence the drainage pattern was probably controlled to some extent by structures common to both rock types when the late Tertiary erosion surface, now forming much of Yukon Plateau, was incised.

This erosion surface truncates all rock units in Yukon Plateau, except the Pleistocene Miles Canyon basalt and its probable equivalents, the Selkirk volcanic rocks. The erosion of this surface took place during the late Tertiary, after Eocene non-marine deposits were laid down in local basins near Yukon River, from Carmacks northwestward beyond Dawson (Bostock, 1936, p. 40), and before the late Pliocene, at which time Yukon Plateau was uplifted and its drainage rejuvenated (Payne, 1955).

Glaciation

One or possibly more ice-sheets covered most of Whitehorse map-area during the Pleistocene. Evidence for more than one period of major glacial advance in Alaska has been presented by Capps (1932) and Péwé (1953). Bostock (1936) records evidence for more than one major advance of the Cordilleran ice-sheet in Carmacks map-area, Yukon. Johnston (1926) also records signs of multiple glaciation in Dease Lake area, British Columbia. In Whitehorse map-area, however, the last advance of the Cordilleran ice-sheet has obliterated any trace of previous advances. All that remains is the record of its retreat with evidence of the accompanying change to conditions of valley glaciation and the effects of alpine glaciation.

The Cordilleran Ice-sheet

Upper Limit of Glaciation

The last major advance of the Cordilleran ice-sheet covered Whitehorse map-area up to an elevation of between 6,000 and 6,500 feet above sea-level; the exact limit is obscure. Erratic and ice-shorn spurs have been noted up to 6,000 feet in northwest and northeast quarters of the area, and a possible erratic of greenstone, similar to inclusions in the underlying granitic terrain, was found by Fyles (1950, p. 8) at an elevation of 6,800 feet on Mount Arkell. Fyles states, however, that this boulder may represent a remnant of an inclusion weathered out from the granitic rocks so that its significance is doubtful.

The Cordilleran ice-sheet at the time of its greatest extent during the last major advance must then have been a mountain ice-sheet (Kerr, 1934, 1936; Davis and Mathews, 1944) out of which peaks more than 6,500 feet high rose as nunataks.

Direction of Movement

Although the movement of the ice-sheet was to some degree influenced by the underlying topography, even at its most extensive stage, evidence from boulder trains and glacial groovings indicate that the ice at higher levels was able to move across and over topographic obstacles.

Most of the ice that covered almost all the northeastern half of the map-area moved in a west-northwesterly direction (*see* Fig. 1, in pocket), apparently flowing from an ice-divide somewhere in or near the Cassiar Mountains. This segment of the Cordilleran ice-sheet will be referred to as the Cassiar lobe. Ice in the southwestern half of the map-area, however, appears to have moved mainly northward and to have flowed from an ice-divide in the Coast Mountains. This northward-flowing ice is termed the Coast Mountains lobe.

Evidence for movement in a west-northwesterly direction lies in the distribution of distinctive erratics and in the direction of prominent upland flutings. Boulders of serpentinized peridotite are scattered along the ridges west of Cap Creek and are particularly numerous between peaks 5,125[1] and 5,635 south of Michie Creek. No such boulders were observed on the ridges west of M'Clintock River below the mouth of Michie Creek. This distribution suggests northwestward movement of the boulders by ice from the body south of Michie Creek and east of peak 5,635, rather than from the body on Jubilee Mountain.

Elsewhere a west-northwestward trend of ice-movement is indicated by the distribution of distinctive pink granophyric quartz-monzonite boulders between Bonneville and Fish Lakes. These were apparently derived from a quartz-monzonite body on Mount McIntyre and on the upland south of it almost to Wolf Creek.

Prominent west-northwesterly trending flutings are displayed on the uplands northwest of Flat Creek and south of Lewes Creek. These flutings are from 500 to 1,000 feet wide and a mile or so in length. They are developed mostly on gentle northwesterly slopes and show no pronounced stoss and lee effects from which direction of ice-movement might be inferred. However, their orientation similar to the direction of transport of erratics, suggests that they too were formed by northwestward-moving ice.

Evidence for northward movement of ice in the southwestern half of the map-area is scanty. Northerly trending flutings on the uplands around Friday Creek give no sense of direction of ice-movement, but they are parallel to northward-trending striae, indicating a northward ice-movement as recorded by Kindle (1953) from upland areas 30 miles to the west in the neighbouring Dezadeash map-area. The absence of boulders or erratics of Mesozoic sedimentary rocks within the terrain underlain mainly by granitic and metamorphic rocks implies that the ice did not move southward. Rather, the predominance of granitic boulders perched on ridges indicates that it moved northward, bringing with it boulders of granitic rocks from the heart of the Coast Mountains.

[1]Peak number is the elevation of the peak marked on the map.

Although few striae were seen on the upland areas in Whitehorse map-area because of the frost-riven nature of much of the outcrop (*see* Plate II), they were observed on many outcrops in the valleys. These, and the orientation of flutings, drumlins, and rock drumlins (Armstrong and Tipper, 1948, p. 290), in which rounded outcrops form the stoss end and a tail of unconsolidated material the lee end, record the direction of movement along the larger valleys, particularly those of Yukon River, Marsh Lake, and Teslin River. In general, at lower elevations the ice flow was controlled by topography, but ice moved westward, northwestward, and northward wherever possible.

Erosion by moving ice and meltwater has accentuated the topographic relief and the angulate character of the drainage. In addition, it has locally formed 'through' valleys by lowering the divides between streams flowing in opposite directions along a trend that is more or less parallel with the direction of ice-movement. Examples are the northeasterly trending 'through' valleys east of Marsh Lake and Yukon River, the valley between Fish Lake and the head of Rose Creek, and the valley between Takhini and Primrose rivers.

Deglaciation

The overall distribution and inter-relationships of proglacial lake shorelines, kame terraces, lateral and end moraines, abandoned lateral overflow channels, and prevailingly-westward-sloping direct overflow channels suggest a retreat of the last ice-sheet towards the southeast in the northeastern half of the map-area. In the southwestern half of the map-area, the ice-sheet probably retreated to the south but evidence is scanty.

Deglaciation Features

Abandoned Channels

Abandoned proglacial drainage channels are the most obvious of all indicators for the pattern of deglaciation. These channels fall into two main classes: (1) direct overflow channels, and (2) lateral overflow channels. Examples are shown in Figure 1 (in pocket).

Direct Overflow Channels—Abandoned channels heading in depressions on a ridge or divide and trending directly down the slope are termed direct overflow channels (Kendall, 1902, p. 481; Watson and Mathews, 1944, p. 38). They indicate that on one side of the divide a proglacial lake or ice-marginal stream overflowed across a depression along the ridge and then cut a channel down the ice-free slope. The prevailingly-westward-sloping, direct overflow channels in Whitehorse map-area indicate that the ice level was, in general, higher east of the ridges that trend northerly, northwesterly, or northeasterly during all stages of retreat of the ice across the northeastern half of the map-area (*see* Plate V). Numerous examples exist, but perhaps a few of the most outstanding are: the west-sloping channels east of Little River, east of the north end of Fish Lake, north of Mount Lorne, south of Mount Byng, at the head of Lewes Creek, and north of Jubilee Mountain.

Most of the direct overflow channels have been cut in unconsolidated material and many have abandoned deltas or alluvial fans at or near their lower end. These deltas and fans indicate where direct overflow streams debouched into proglacial lakes, onto the ice, or spread out onto beds of ice-marginal streams. Their presence further records the approximate difference in elevation between ice surfaces on each side of a divide. For instance east of Arkell Creek (*see* Plate VI), abandoned deltas and fans occur at about 4,700 feet above sea-level and at successively lower elevations, apparently formed by streams overflowing the ridge south of Mount Ingram at about 5,200 and 5,600 feet. They also occur at successively lower elevations east of Fish Lake both northeast and southwest of Mount McIntyre, east of Laberge Creek and north of peak 5,910, southwest of Mount Byng, and east of Cowley Lakes. This suggests that direct overflow streams continued to flow across the divides in the above sectors for a time long enough to allow an appreciable lowering of the ice surfaces west of the divides.

Lateral Overflow Channels—Lateral overflow channels (Watson and Mathews, 1944, p. 38) are those that have been cut diagonally across valley walls by streams that flowed between the ice occupying the valley and the valley wall (*see* Plate VII). These channels have been cut into both bedrock and unconsolidated material. The former have been cut mainly across spurs between minor tributaries to a main valley; they have cut notches in the spurs a few tens of feet to perhaps a few hundred feet deep and perhaps a few hundred feet long. Such features are widespread above timber-line. Locally, as west of the south end of M'Clintock Lakes and north-northwest of Mount Michie, ice-marginal streams were trapped behind rock ridges so that they incised rock-bound gorges 2 to 3 miles long and several hundred feet deep (*see* Plate VII). However, lateral overflow channels more than a mile long are more common in areas of drift at lower elevations in the valleys.

Lateral overflow channels can be subdivided further into 'parallel sequences' and 'aligned sequences'.

Parallel Sequences: Two kinds of parallel sequence of lateral channels occur in Whitehorse map-area. The first is a series of parallel channels a mile or more in length that occur at successively lower elevations along a ridge or spur and are caused by the direct overflow of streams across this local divide as the ice level was being successively lowered. Such parallel sequences occur southeast of Crag Lake, northeast of Mount Byng, northeast and north of Fish Lake, south of Takhini (*see* Plate VI), and west-northwest of Mount Lansdowne. The second kind is a series of parallel channels perhaps several miles in length that occur at successively lower elevations on valley walls, indicating the lowering of the ice level in the valley (*see* Plate VII). Such parallel sequences exist in the larger valleys of Yukon, Takhini, and M'Clintock Rivers and Marsh Lake.

North of Yukon River and south of Cantlie Lake (*see* Plate IV), a series of *en échelon* steep-walled channels have been cut into silt overlying pitted glacial deposits. These channels have narrow muskeg-filled floors generally containing

—*USAAF Photo 28-L-4*

Plate V. *View south to Mount Lorne (left), showing abandoned direct overflow channels in foreground. Meltwater from ice occupying valley north and east of Mount Lorne spilled westward (right).*

Plate VI. *View north across lower Arkell Creek, showing abandoned valley train on valley floor, shorelines of proglacial lakes on east valley wall, and successively lower abandoned deltas (lower right). Note abandoned overflow channels from Takhini Valley (right).*

—*USAAF Photo 28-R-23*

—*USAAF Photo 19A-L-78*

Plate VII. *View south along the east side of upper M'Clintock River valley, showing parallel sequence of abandoned lateral channels. Meltwater flowed north towards the bottom of picture. Note also notched ice-shorn ridges and spurs.*

small, sluggish streams. They approach Yukon River in a westerly direction and terminate some distance above the level of the river. The channels do not appear to be related to a drainage basin although some seem to be connected to small lateral overflow channels west of peak 5,055. This may be fortuitous because the northernmost channels would then have had to be cut in the silt as lateral overflow channels when ice filled the central part of Yukon River valley. This condition was unlikely because the silt beds that were incised by the northern channels extend nearly to the centre of Yukon River valley, and show no sign of having been overlain by ice.

It seems more likely that the channels were cut into the silts by processes similar to those now operating on the silt terrace upon which the Whitehorse airport is built. The incision of the Yukon River meander belt and consequent lowering of the base level of erosion at the mouths of these channels probably intensified the gullying process.

Aligned Sequences: These sequences consist of successions of diagonal channels along a hillside interrupted locally by kame terraces as on the east side of Yukon River valley and at Marsh Lake, or by lake terraces as south of Nares Lake near Carcross and west of Arkell Creek.

Proglacial Lakes

Shorelines of proglacial lakes are evident at several places in the map-area. They are characterized by horizontal benches, locally several in succession one below the other, and are composed principally of moderately well-rounded gravel. These benches are in some places associated with abandoned deltas at the mouths of abandoned overflow channels. Few of the old shorelines extend far.

The largest proglacial lake was glacial Lake Carcross (*see* Plate IX, facing p. 16) at its maximum extent when it formed beaches at an elevation of about 2,500 feet. Arms of this lake occupied the lowermost parts of Wheaton River and Watson River valleys and eastward along the valley of Tagish Lake. The lake was apparently trapped between ice-masses to the south and east in the valleys of Bennett Lake, Windy Arm, and Taku Arm; the higher elevations in Wheaton River valley; and a stagnant ice-mass near Lewes Lakes. Another proglacial lake in Watson River valley south of Alligator Lake is marked by old beaches and deltas between elevations of about 3,600 feet and 3,200 feet. This lake appears to have been penned between an ice tongue penetrating westward up Watson River valley and either a topographic high or stagnant ice between Watson River and Rose Creek.

As indicated by the distribution of shorelines of limited extent, small proglacial lakes occurred in three different ways: (1) they probably existed between the ice in the main valleys and embayments in the valley walls as marked by old beaches west of Arkell Creek, north of Takhini River west of Flat Creek, and north of Wheaton River near Vesuvius Hill; (2) they developed where the ice in north-sloping tributaries had retreated southward from the main ice-mass in the master valley, as on Becker Creek and Arkell Creek (*see* Plate VI); and (3), they appear to have formed between the southeastwardly retreating ice-front and the heads of south- or east-sloping valleys. Such lakes lay in Upper Sheldon Creek, southwest of Flat Mountain, and just north of the map-area north of Joe Mountain.

Widespread well-bedded silt deposits, locally more than 200 feet thick, in the valleys of the Yukon, Takhini, lower M'Clintock, and Watson Rivers, indicate the sites of proglacial lakes. The exact extent of the silt deposits has not been determined and consequently the extent and configuration of the lakes cannot be inferred. It is however, apparent that they occupied much of the central part of these valleys. In the valleys of M'Clintock and Takhini Rivers, and in Yukon River valley near Whitehorse, the silts abut areas containing numerous kettles, pitted outwash, and esker complexes, all regarded by Mannerfelt (1945) as deposition of debris associated with masses of stagnant ice.

The proglacial lake in lower M'Clintock River valley was apparently trapped between stagnant ice around M'Clintock Lakes, stagnant ice or an ice tongue in upper Michie Creek, and an ice tongue whose terminus was near the mouth of M'Clintock River.

The silt deposits in Takhini River valley appear to be more or less continuous with those to the west in the valleys of the Mendenhall and Dezadeash Rivers. Hence the proglacial lake in which they formed was probably part of glacial Lake Champagne, most of which was in the adjoining Dezadeash map-area to the west (Kindle, 1953, p. 15).

Terraces underlain by silt occur on both sides of Watson River valley for about 12 miles downstream from a point due south of Alligator Lake. These deposits may represent the sediment that accumulated when the lake level was between 3,200 and 3,600 feet as previously described.

Silt deposits in the Yukon River valley east and south of Whitehorse, are capped by a few feet of sand and gravel to form terraces at an elevation of 2,300 feet. They abut a large esker complex east of Yukon River, a smaller one east of Miles Canyon, and pitted outwash southeast of MacRae. Insufficient work has been done to determine their northward extent and whether they connect with those of glacial Lake Champagne.

The silt in Yukon River valley south of Cantlie Lake occurs at a higher level than the silt east and south of Whitehorse and may therefore have been deposited in a separate lake basin, perhaps even at a later time when the ice-front in the valley was near the outlet of Marsh Lake.

Eskers

Eskers occurring singly or as compound units are widely scattered throughout the map-area. The single eskers are narrow, sinuous, undulating ridges of sand and gravel generally elongated parallel with the trends of the valleys in which they have accumulated, but, in some cases, at a marked angle to the trend. Single eskers are particularly common between Fish Lake and Rose Creek where they trend both parallel with and normal to the valleys. Elongate drift ridges shown in Figure 1 (in pocket), whose origin cannot be determined from air photographs, probably include more single eskers.

Compound eskers comprising undulating and anastamosing ridges, most showing a pronounced direction of elongation, are intimately associated with pitted hummocky terrain. These areas have been mapped as esker complexes. In most cases the trend of the esker ridges within the complex is more or less parallel with the trend of the valley in which they have been deposited. Such complexes were regarded by Mannerfelt (1945) to represent accumulations of debris deposited by streams flowing upon, within, or below stagnant ice. In Whitehorse area such streams appear to have flowed more or less parallel with the valley.

In contrast, in two areas—one southwest of Fish Lake and the other near Lewes Lake—are esker complexes in which the esker ridges are aligned generally northwest in a direction markedly different from the trend of the valleys in which they were deposited. In each case the esker trend is parallel to and almost continuous with direct overflow channels to the southeast. These channels were entrenched in broad depressions through which tongues of the southeasterly retreating ice-front had penetrated. It appears that meltwater from these ice-fronts escaped northwestward across these broad depressions, in the first case between Mount Granger and Friday Creek and in the second around the headwaters of Lewes Creek, and deposited debris in braided channels upon ice-masses at a lower level in the valley southwest of Fish Lake and along lower Watson River respectively.

Moreover, debris lying on the ice must have been thicker on those parts of the ice where the braided streams flowed, and these more thickly covered areas would ablate more slowly. Ice remnants left by this selective process must have had their effect on the course of the proglacial drainage. The eskers themselves may have formed in the following ways. As long as meltwater was being supplied from the southeastwardly retreating ice-front, the debris-laden streams may have cut their way beneath or through the ice remnants to redeposit the basal drift as eskers (Flint, 1947, p. 154). On the other hand, the stranded, gravel-filled stream channels on top of the ice, cut off from a meltwater source by retreat of the ice to positions southeast of the divides south of Mount Granger and that at the head of Lewes Creek, may then have sunk to the valley floor as the ice remnants wasted away.

Elongate Drift Ridges

Ridges and elongate mounds of unconsolidated material are scattered over most parts of the map-area except the heavily-glacier-scoured southwestern part. The elongate mounds are locally aligned to form discontinuous ridges near the limit of thick drift-cover, generally near timber-line. In most cases it has not been possible to differentiate those that are lateral moraines from those that are remnants of kame terraces as few have been examined in the field.

A few, stubby, irregular ridges oriented transverse to the trend of the valleys in which they were deposited are interpreted as end moraines rather than eskers which generally have a thinner and more sinuous outline.

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Dunes

Dunes occur east of Yukon River north of Whitehorse, at Carcross, and to a limited degree at the north end of Millhaven Bay (*see* Plates VIII, IX). They form relatively narrow lobes and hooked ridges whose highest points are generally at the lobes and whose steepest slopes are on their convex sides. Thus, they have the aspect of parabolic dunes (Hack, 1941). The parabolic dunes at Carcross and at Millhaven Bay were formed by the prevailing southwesterly winds blowing up Munroe and Bennett Lakes respectively. The orientation of the dunes north of Whitehorse suggests, by analogy with the orientation of the dunes at Carcross, that they were formed by southerly winds. Such winds, though not strong today, were probably more powerful when ice lay farther south in Yukon Valley. At that time, down-flowing or katabatic winds (Flint, 1947, p. 42) probably blew off the ice in a northerly direction and formed the dunes on a vegetation-free outwash plain or dried-up lake beds lying north of the ice-front.

Summary of Deglaciation

The paucity of information on the Pleistocene stratigraphy and on the correlation of glacial features, even from one part of the map-area to another, does not permit the formation of a continuous picture of events accompanying the deglaciation of the map-area as a whole. However, the general pattern and sequence of drainage changes in various parts of the area can be established.

At its greatest extent, the last ice-sheet probably covered the northern and northwestern parts of the map-area to an elevation of 6,500 feet. The ice level was probably higher to the south and southeast, nearer the centres of accumulation.

During deglaciation, the ice level of the Cassiar lobe, which occupied all but the southwest quarter of the map-area, was lowered progressively across the map-area from northwest to southeast. The ice-sheet was then progressively segmented into numerous valley glaciers, but in such a way that the ice level was, in general, always lower in the west and northwest than in the east and southeast.

In any particular area within that part of the map-area occupied by Cassiar ice, the proglacial drainage during the early stages of deglaciation was characterized by both lateral and direct overflow streams. As the ice level was lowered, however, so that valley glaciers restricted mainly to the largest valleys became prominent, direct overflow streams fed by the melting ice could only escape from the valleys through the lowest divides. As these were few, direct overflow streams were rare at this stage. Lateral overflow streams, on the other hand, were common; they became well entrenched, and locally took sinuous courses around topographic obstacles.

Proglacial lakes were more extensive during the later phases of deglaciation. Lakes formed between the ice and embayments in the valleys, between the major ice-streams and the ends of southerly retreating tributary glaciers, and at the heads of southeastwardly sloping valleys down which the ice had retreated. During the

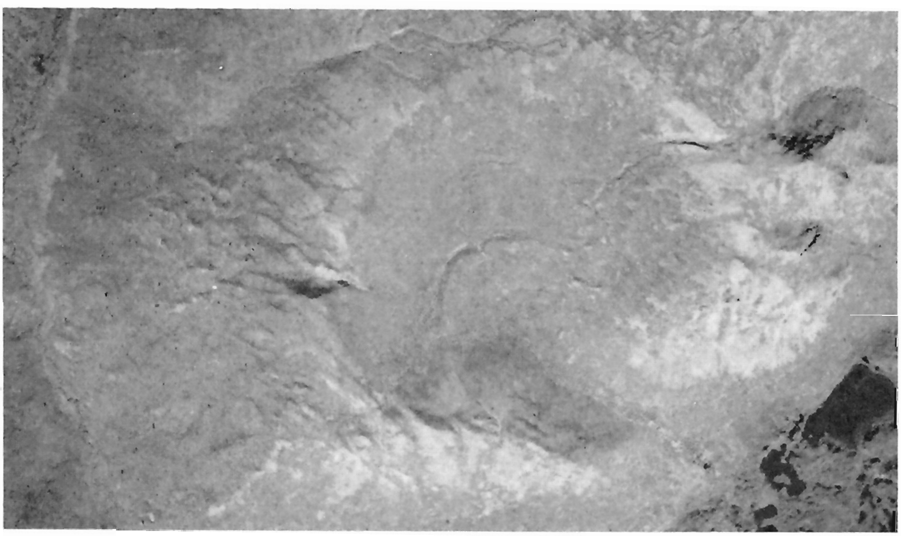
Plate VIII.

View south up Yukon River, showing field of parabolic dunes, formed by wind blowing from upper left to lower right. Takhini River enters from right.

—*USAAF Photo 19A-L-89*

—*RCAF Photo T52-R-25*

Plate IX. *View northeast to Caribou Mountain (upper right). Note granodiorite stock (upper right), showing fretted topography, intrusive into the Laberge group. Parabolic dunes and blow-out are at end of Bennett Lake (lower left). Note old shorelines (left) of glacial Lake Carcross.*



—RCAF Photo A-10553-121

Plate X. *Vertical air photograph of an 'old' cirque southwest of Coal Lake reoccupied by ice of Cassiar lobe but subsequently not rejuvenated. Note notched bounding-spurs and lateral overflow channel traversing back of cirque.*

later stages of deglaciation, lakes appear to have formed in the larger valleys between the southeastwardly retreating ice-front and remnant ice-masses in the valleys to the north and northwest.

Stagnant ice-masses that acted as dams for proglacial lakes also caused changes in the proglacial drainage. For example, a stagnant ice-mass along the east side of Yukon River valley between Whitehorse and Chadburn Lake diverted streams to the west side of Yukon Valley and caused them to cut into the Miles Canyon basalt. The streams became so well entrenched in the basalt that Yukon River was able to maintain its channel through Miles Canyon rather than taking a course through unconsolidated material to the east after the ice near Chadburn Lake had gone.

After the proglacial lake that extended northward from Whitehorse into Laberge map-area had drained, southerly winds, blowing off the ice near Whitehorse, created parabolic dunes near the mouth of Takhini River.

Proglacial lakes also appear to have formed between the easterly retreating southwestern margin of the Cassiar lobe and either slightly more elevated ground or southerly- and westerly-retreating tongues of Coast Mountains ice. Such lakes occupied Watson River valley south of Alligator Lake and formed glacial Lake Carcross.

Continued deglaciation drained these lakes as streams flowed northward along Watson River and the valley occupied by Annie Lake. Later, alluvial fans from streams northwest of Annie Lake blocked north-flowing streams so that Wheaton River was diverted southward. For reasons which are not clear Watson River also began to flow southward after glacial Lake Carcross was drained.

Subsequently the larger modern streams, such as Takhini, Watson, M'Clintock, and Yukon Rivers, entrenched narrow meander belts in unconsolidated glacial and glacio-fluvial deposits. Wheaton River on the other hand maintains a braided channel that for most of its course is not entrenched.

Alpine Glaciation

It has been pointed out earlier that many of the cirques in the southwestern part of the map-area look fresher than those elsewhere, particularly those to the north and northeast. The 'fresh' cirques have the following characteristics: they commonly contain alpine moraines and locally even small glaciers, although the volume of morainal debris is only a fraction of that removed during the excavation of the cirque; the walls are commonly fretted, locally bearing actively breaking, lichen-free rock; most of the cirques face north or east, their floors being between 5,500 and 6,800 feet; a few cirques face south or west, but only in the high country around the headwaters of Wheaton River where they occur not lower than 6,500 feet above sea-level. Some cirques have been carved into the undulating upland to give the aspect of 'biscuit-board' topography, whereas elsewhere, particularly at the higher elevations, the cirques are bounded by narrow, serrated ridges.

The other cirques in the map-area, in contrast with the 'fresh' cirques, contain little or no morainal material, and the walls, floors, and parts of some of the surrounding ridges appear to have been scoured and rounded by ice. Some of these cirques show evidence of having been occupied by parts of the Cassiar ice lobe. For example, a small southeastward-facing cirque 1½ miles west of the south end of Coal Lake (*see* Plate X), has notches across its bounding spurs and there are an abandoned lateral channel and a kame terrace along the back of the cirque. Cirques west of the headwaters of Byng and Cap Creeks have similar notched 'bounding' spurs. These features indicate that ice extended from outside into the embayment of the cirque, and that ice-marginal streams flowed into the cirque and out again. The floors of the scoured cirques range in elevation from 4,500 to about 5,500 feet.

Evidence that ice reached an elevation of at least 6,500 feet demonstrates that cirques whose floors were below this level were occupied by ice of the Cassiar and Coast Mountains lobes. The scoured appearance of many of the cirques, particularly those within the limits of the Cassiar lobe, indicates that they were formed before the last advance of the Cordilleran ice-sheet reached its greatest extent, and that with few exceptions only those lying in the southwestern quarter of the map-area were rejuvenated.

That cirques within the limits of the Cassiar lobe were not rejuvenated suggests that deglaciation there was not accompanied by alpine glaciation. This, in turn, suggests that during deglaciation of the Cassiar lobe within the map-area the firn line was higher than the higher peaks in the northeastern half of the map-area—that is, about 7,000 feet. It must then have retreated rapidly in response to a rapidly ameliorating climate and its effects were probably restricted to a zone around the Cassiar ice-centre or divide. It appears, then, that alpine glaciation within the limits of the Cassiar lobe in the map-area either belongs to a preceding glacial cycle in which the retreat of the firn line was not so rapid, or that periods of alpine glaciation were restricted to times preceding or contemporaneous with the advance of the ice-sheet.

Cirques in the southwestern quarter of the map-area, whose floors are at about the same elevation as those of the scoured cirques to the northeast, have apparently been rejuvenated. This might have resulted from one of two conditions or a combination of both, which are: (1) the firn line during the retreat of the Coast Mountains lobe was perhaps lower or retreated less rapidly than that of the Cassiar lobe, so that alpine glaciation was effective; and (2) the rejuvenation of the cirques was related to a later period of glaciation (Little ice age) subsequent to the retreat of the Coast Mountains ice. This local glaciation must have been restricted to zones of greatest elevation, lowest summer temperature, and greatest precipitation, which in the map-area were the Coast Mountains (Kendrew and Kerr, 1955, p. 188); it was absent in the part of the map-area formerly occupied by Cassiar ice.

The dating of the 'Little ice age' in the northwestern Cordillera has not everywhere been well defined. Matthes (1942), who first proposed the name, estimated that it took place about 4,000 years ago, basing his conclusion on an estimate by Hanson (1933) of the rate of growth of the Bear River delta in the Portland Canal area, British Columbia. The glacial and interglacial chronology in southern Alaska correlates closely with radiocarbon-dated North American continental chronology and European late- and post-glacial chronologies, as dated from Scandinavian varve sequence, and archæological and historical records. In southern Alaska, the 'Little ice age' has been dated as beginning about 5,500 years ago (Karlstrom, 1955). In southeastern Alaska, however, Heusser (1952, 1953, 1954) has determined from pollen studies that a cooler and wetter climate fostering glacial readvance began about 2,000 years ago. He estimates that beginning about 5,000 years ago the climate in this region became warmer and drier. This contrasts strongly with the southern Alaskan chronology.

Although the pollen studies by Hansen (1953) of post-glacial forests along the main highways in Yukon and Alaska revealed little or no evidence for climatic trends, except perhaps a general amelioration throughout the time represented, evidence is plentiful in the Cordillera for glacial readvances since the retreat of the last ice-sheet (Mathews, 1951). It seems reasonable that such readvances also took place in Whitehorse map-area and caused the rejuvenation of cirques in zones having a suitable climate and sufficient elevation to support small ice-caps and glaciers (Manley, 1955).

Rock Glaciers

Prominent rock glaciers and a host of smaller ones, occur in the southwest part of the map-area. The two largest—one on the northeast face of Mount Ward (*see* Plate I, *frontispiece*) the other on the western slope of Gray Ridge—are each about half a mile long; they descend for between 1,500 and 2,000 feet from sharply excavated bowl-like depressions which contain no permanent snow. In the lower parts of these depressions are concentric ridges evidencing flowage of the whole mass.

Solifluction

Much of the upland above timber-line shows evidence of soil creep affected by the alternate freezing and thawing of the surface layer. This process develops lobate tongues and crude terraces on slopes supporting tundra vegetation. These forms are accentuated by the growth of small bushes of arctic birch or willow or grasses on the crest of the embankment supporting the lobe or terrace. Elsewhere on sloping terrain having little vegetation, the surface layer forms stone stripes in which lines of coarse material are separated by wider strips of finer debris. On flattish ground, crude polygonal areas are outlined by a network of coarse debris, generally cobbles or boulders, surrounding a central mound composed mainly of soil or pebbles. Much of the flatter upland areas just above timber-line is characterized by unstable tussocks of grass, moss, and heather.

Thaw Lakes and Depressions

Some pitted areas, particularly south of Takhini River opposite the mouth of Little River, may be marked by thaw lakes and depressions (Wallace, 1948; Hopkins, 1949). There, the margins of numerous shallow lakes bear trees that have fallen inward toward the centres of the lakes. This is characteristic of lakes that formed in depressions where permafrost beneath them has thawed. Thaw lakes may occur elsewhere, particularly in swampy, pitted areas such as that north of the mouth of Michie Creek. Shallow pitted terrains such as that near the mouth of Takhini River may represent ancient thaw depressions rather than kettles.

Chapter III

GENERAL GEOLOGY

Consolidated formations in Whitehorse map-area range in age from possibly Precambrian to Pleistocene. The southwestern part of the map-area contains rocks of the Yukon group in a northwesterly trending belt, isolated within granitic rocks. These are probably of late Palæozoic age, but may be, in part, Precambrian. They consist predominantly of quartzose metamorphic rocks. Similar rocks occur in the extreme northeast corner of the map-area. In the southeast corner of the map-area are Permian and, possibly in part, Pennsylvanian, mainly non-clastic sedimentary and melanocratic volcanic rocks of the Taku group, faulted against rocks of the Laberge group.

The rocks in the rest of the map-area are chiefly Mesozoic, the bedded rocks being deformed, for the most part, into northwesterly trending folds. They comprise Upper Triassic melanocratic volcanic and marine sedimentary rocks of the Lewes River group, overlain, in places disconformably, by Jurassic marine and partly non-marine, locally coarse-grained sedimentary rocks of the Laberge group. The Upper Jurassic(?) and Lower Cretaceous Tantalus formation is faulted against other Mesozoic rocks, but in areas to the north it lies conformably on the Laberge group.

Flat-lying and gently deformed volcanic rocks of the mid-Cretaceous Hutshi group overlie the folded and faulted Mesozoic rocks with angular unconformity. Slightly younger or possibly contemporaneous, gently deformed pyroclastic and flow rocks, ranging in composition from basalt to rhyolite, of the Skukum group, unconformably overlie the Yukon group and granitic rocks. The Pleistocene Miles Canyon basalt unconformably overlies all other rocks and is intercalated with Pleistocene sediments in Yukon River valley.

Intrusive rocks are principally ultramafic and granitic. Ultramafic rocks intrude highly deformed, weak rocks as young as those of the Laberge group. A granitic plutonic complex, forming the northern extension of the Coast intrusions, underlies much of the southwestern half of the map-area. Elsewhere granitic plutons cut folded Mesozoic rocks and the Hutshi group. The youngest felsic intrusions, granite porphyry and rhyolite, occur as small stocks and dykes in one place possibly as a ring-dyke surrounding a subsided area of Skukum volcanic rocks.

Unconsolidated Pleistocene and Recent deposits mantle the lower slopes and valley floors in most parts of the map-area.

Table of Formations

Era	Period or Epoch	Formation (thickness in feet)	Lithology
Cenozoic	Pleistocene and Recent		Glacial drift, alluvium, loess, volcanic ash
			Basalt; minor pyroclastic rocks
	Unconformity		
	Tertiary		Granite porphyry, rhyolite
		Intrusive into lower part of Skukum group	
		Skukum group (4,000+)	Andesite, basalt, rhyolite, and trachyte breccias, tuffs, and flows; 'granitic agglomerate'
Unconformity			
Mesozoic	Late Lower or early Upper Cretaceous	Coast Intrusions	Pink granophyric quartz monzonite
			Intrusive contact with granodiorite
			Leucogranite, biotite granite, alaskite, kali-alaskite
			Intrusive contact
			Hornblende-biotite-oligoclase granodiorite, biotite-hornblende quartz diorite, biotite granite, hornblende diorite, gneissic porphyritic granodiorite, pegmatitic syenite
		Intrusive contact	
		Hutshi group (4,000+)	Basalt, andesite, porphyritic andesite, quartz latite, and rhyolite flows, breccias, and tuffs; minor greywacke and argillite; conglomerate locally at base
		Angular unconformity (granitic intrusion ?)	
			Peridotite, dunite, serpentine, and pyroxenite
	Relations unknown. Ultramafic rocks in contact with Laberge group		
	Upper Jurassic(?) and Lower Cretaceous	Tantalus formation (2,500)	Arkose, siltstone, conglomerate, argillite; coal
	Lower Jurassic and later	Laberge group (9,500+)	Conglomerate, greywacke, arkose, quartzite, siltstone, argillite, hornfels
	Disconformity (local conformity (?), local angular unconformity(?), local granitic intrusion(?))		
	Upper Triassic	Lewes River group (10,000)	Volcanic greywacke, siltstone, argillite, limestone, limestone breccia, conglomerate; volcanic breccia, agglomerate, tuff; andesite, porphyritic andesite, and basalt
Relations unknown			
Palæozoic	Pennsylvanian (?) and Permian	Taku group	Limestone, limestone breccia, chert; greenstone and (?) pyroclastic rocks
Relations unknown			
Precambrian and later		Yukon group	Quartz-mica, quartz-chlorite, and mica schists; quartzite; feldspathic hornblende gneiss, amphibolite, epidote-amphibolite, crystalline limestone; feldspathic gneiss, *lit-par-lit* gneiss; gneissic porphyritic granodiorite and quartz diorite

Layered Rocks

Yukon Group

The Yukon group includes tracts of metamorphic rocks in the Yukon which originally were thought to be Precambrian (Cairnes, 1914, pp. 40-44) but were later shown to contain both Precambrian and Palæozoic rocks (Mertie, 1930, pp. 17-20).

Distribution

Predominantly quartz-rich metamorphic rocks contiguous to those called Yukon group in Dezadeash map-area (Kindle, 1953, p. 37) and different from metamorphic equivalents of Palæozoic and Mesozoic rocks farther east, comprise the Yukon group in Whitehorse map-area. They occur in discontinuous outcrops, totalling about 100 square miles, in a northwesterly trending belt from West Arm to north of Primrose Lake. A small area of such rocks also occurs northeast of Teslin River.

Lithology

The western outcrops of this belt from Mount Skukum to Rose Lake are interbedded schist, quartzite, gneiss, limestone, and amphibolite. The isolated outcrops in the northeastern part are mainly quartzite with minor schist and limestone, except southwest of Alligator Lake, where they are feldspathic gneiss and gneissic porphyritic granodiorite and quartz diorite.

Mount Skukum - Rose Lake Belt

The following section from near the head of Watson River 2½ miles north-northwest of Mount Skukum, though lacking epidote-amphibolite, is typical of the lithology in the western outcrops of the Yukon group.

Top of section Skukum group	Thickness (feet)
Angular unconformity	
Grey, crystalline limestone	360
Interbedded grey, banded quartzite and dark grey, garnetiferous quartz-mica schist	110
Interbedded grey and white, crystalline limestone and dark grey to black, graphitic quartzite (Z)[1]	135
Grey, garnetiferous quartz-mica schist	180
Interbedded grey and white, crystalline limestone	135
Grey to silvery-brown, garnetiferous quartz-mica schist	90
Greyish brown, limy quartz-mica schist (Y)	110
Silvery-brown, garnetiferous quartz-biotite schist (X)	45
Interbedded grey-green quartzite, biotite schist, and greenish feldspathic biotite quartzite (W)	140
Dark green hornblende gneiss containing feldspar augen	20
Crumpled and crenulated, greyish quartz-mica schist	100
Dark grey, platy micaceous quartzite	120
Dark grey and brownish, crumpled mica schist	90
Light grey, banded quartzite (U) containing 2-foot bands of quartz-oligoclase-hornblende gneiss (V) and augen gneiss	360
Quartz-hornblende-feldspar augen gneiss with augen of potash feldspar (T)	100
Interbedded dark grey, banded quartzite and grey and silvery quartz-mica schist	400
Base not exposed	
Thickness of exposed section	2,495

[1] Letters T to Z indicate the position in the section of the samples in Table II.

Table II

Volume Percentage of Essential Constituents of Metamorphic Rocks of the Yukon Group

Specimen	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y	Z	a	b	c	d	e	f
Quartz	59	—	28	60	25	42	95	86	—	—	87	52	24	—	4	32	23	29	57	15	83	19	41	35	30	77	33	60	—	5	10	43
Potash feldspar	x	—	36	—	—	10	1	6	—	—	9	1	12	—	—	1	1	—	—	48	10	9	—	1	13	—	—	1	—	—	—	8
Plagioclase	6	19	32	—	28	31	2	3	20	25	—	9	38	14	—	27	4	57	—	25	3	17	43	16	20	—	x	6	24	20	—	34
Biotite	10	—	4	—	47	17	—	—	—	—	—	23	23	22	17	34	3	13	18	—	4	4	13	46	12	—}	60}	31	—	—	—	14
Muscovite	23	—	—	—	—	—	2	5	—	—	4	—	—	63	69	6	—	x}	—	—	—	—	—	—	—	4}			—	—	—	—
Hornblende	—	77	—	—	—	—	—	—	40	75	—	—	—	—	—	—	69	x} 1	—	12	—	52	—	—	—	—	—	—	75	75	—	—
Epidote	x} 1	—	—	—	—	—	—	—	40	—	—	—	—	—	8	—	—	—}	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Iron ores	x}	4	—	40	—	—	x	x	—	x	—	15	3	1		—	—	x}	11	—	x	—	1	—	—	19	x	—	—	—	—	1
Garnet	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2	2	—	—	7	2	1	—	—	—
Cordierite	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	12	—	—	—	—	—	—	—	—	—	—	—	—	—
Carbonate	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	25	—	—	—	—	—	90	—

Key—
- x: less than 1%.
- Mica schist: N, O.
- Quartz-mica schist: A, C, E, L, M, P, R, X, Y, a.
- Gneiss: Q, T, V.
- Quartzite: D, F, G, H, K, W, Z, b, f.
- Amphibolite: B, I, J, c, d.
- Siliceous limestone: e.

Note: Compositions were obtained from traverses with a point counter normal to the foliation (point spacing 0.33 mm, traverses 1 mm apart). Slides were stained with sodium cobaltinitrite (Chayes, 1952). Some slides were so small that only about 400 points were counted. Textures in these slides are fairly uniform so that percentages, after counting 200 or 300 points, are within 2 or 3 per cent of those at 400.

Location of specimens is shown in Figure 14, (p. 96).

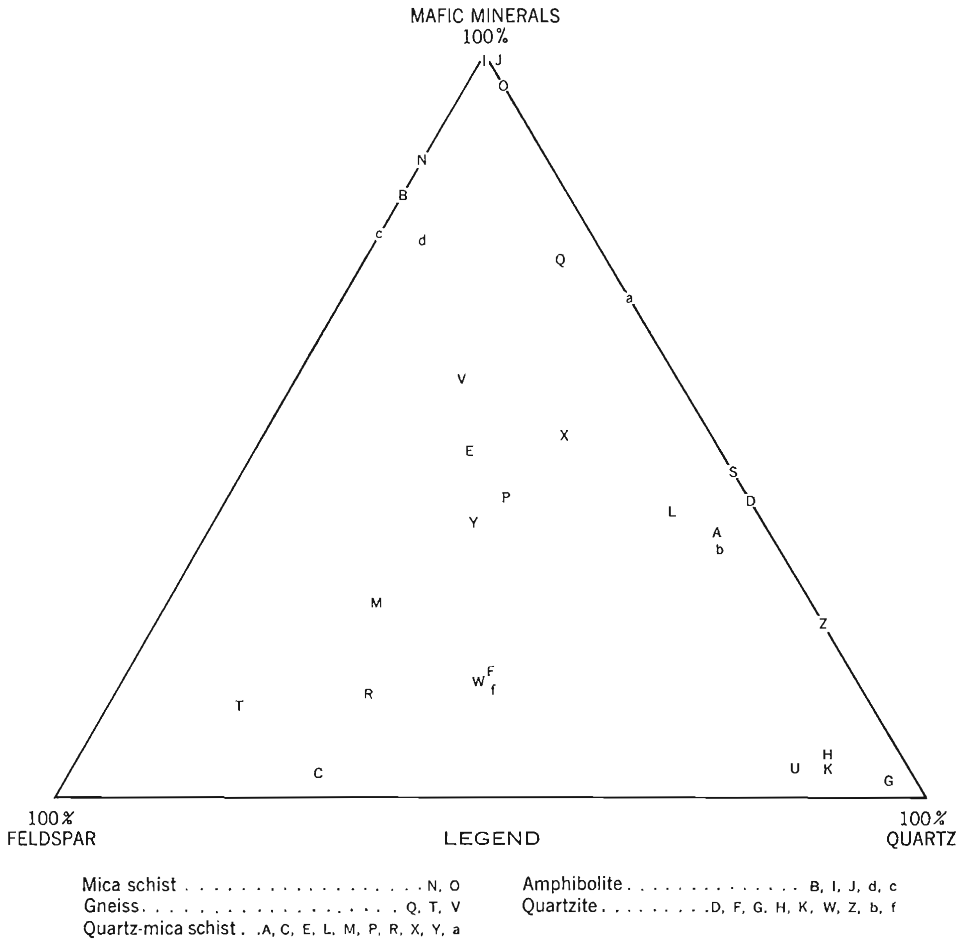


Figure 2. *Plot of the mineralogical compositions (volume per cent) of rocks of the Yukon group, Whitehorse map-area.*

Quartzose schists, the most common rocks in the Mount Skukum - Rose Lake belt, are greyish green, speckled black and silver, and rusty brown. They consist of a granoblastic aggregate, locally with a directional fabric, of quartz, oligoclase, and subordinate potash feldspar, and contain lepidoblastic biotite, white mica, and rarely, nematoblastic hornblende. Garnet occurs as porphyroblasts and poikiloblasts. Accessory minerals are mainly iron ores, sphene, and minor apatite and tourmaline.

The next most abundant rocks are quartzites—chiefly grey, white, or green, massive, dense, vaguely banded rocks occurring in beds up to 30 feet thick. As the amount of micaceous material increases the quartzites grade through schistose quartzites to quartzose schists. The quartzites are composed mainly of a granoblastic mosaic, locally with a directional fabric, of quartz with minor potash feldspar and untwinned plagioclase, probably oligoclase, and some lepidoblastic chlorite, white mica, and biotite.

Feldspathic hornblende gneiss occurs principally in the lower part of the section along upper Watson River. Oligoclase prevails as xenoblastic crystals, locally with quartz and potash feldspar, in zones between idioblastic hornblende, and in some places it forms augen.

Amphibolite consists mainly of green hornblende and subordinate oligoclase, or, of equal amounts of epidote and hornblende with minor plagioclase, apatite, sphene, and iron ores. It occurs in layers, locally more than 100 feet thick, parallel with the bedding in the quartzite and limestone strata, and the schistosity in the schists. In no place were the amphibolites seen to grade into limestones and thus they probably represent metamorphosed melanocratic igneous rocks or volcanic greywacke.

Outcrops Southwest of Alligator Lake

Feldspathic gneiss, gneissic porphyritic granodiorite and quartz diorite, and subordinate schist occur in a northwesterly trending belt from Vesuvius Hill to a point 5 or 6 miles west of Alligator Lake.

The feldspathic gneiss, locally containing aplitic layers 2 to 3 inches thick, has plagioclase ranging from oligoclase to andesine, potash feldspar, quartz, biotite, tan to brown hornblende, and clinopyroxene.

The gneissic porphyritic granodiorite and quartz diorite, whose foliation strikes N10°W and dips vertically, parallel with that in the associated gneisses, has feldspar crystals up to 2 inches long by 1 inch wide. Some are lenticular, parallel with the foliation, whereas others are tabular crystals whose long axes may deviate considerably from the foliation. The large feldspar crystals are commonly fractured normal to their length, and locally, parts of the crystals have been displaced. In thin section the large crystals, some of which are bent and broken, are seen to consist of potash feldspar and zoned sodic plagioclase showing bent twinning. They are surrounded by fine, granular plagioclase, greenish brown biotite, epidote, and locally blue-green hornblende. Coarse, partly strained mosaics of quartz occur between the coarse feldspar. In some localities the coarse crystals persist to the margin of the granodiorite where the latter makes a sharp contact with the gneiss. In others the number of large crystals decreases towards the margin of the granodiorite until the foliated matrix merges with the gneiss.

The following evidence suggests that the granodiorite may have been deformed and granulated after its consolidation or as a crystal mush during a late stage in its emplacement.

1. Bent and fractured coarse feldspar crystals, fragments of which have separated.
2. Bent twins in plagioclase.

3. Granulation and reduction of grain size in zones surrounding the large feldspar crystals.

Original Composition

A comparison of Figure 2 and Figure 10 (p. 70) shows that the quartzose metamorphic rocks of the Yukon group contain considerably more quartz than the arenites of the Lewes River and Laberge groups. Clay minerals, muscovite, and finely comminuted feldspar and quartz in the matrix part of the mafic etc. end-members in Figure 11 would however, when reconstituted by metamorphism, supply constituents to the feldspar and quartz end-members, and there would therefore be more visible quartz in the metamorphic rocks than in the original rocks from which they were derived. Billings (1937, Table 17) shows a maximum increase of 20 per cent in the quartz content of rocks metamorphosed in the Littleton-Moosilauke area, New Hampshire.

The evidence suggests, however, that the Yukon group was probably derived mainly from quartz-rich rocks and is not a metamorphic equivalent of Mesozoic rocks. The average quartz content of the Yukon group is more than 40 per cent greater than the average for the Lewes River arenites and about 35 per cent more than the average for the Laberge arenites, both considerably more than the 20 per cent increase found by Billings. The quartzose schists show no evidence that quartz was introduced during their development. On the other hand, poikiloblastic garnet and hornblende containing randomly oriented quartz and plagioclase inclusions suggest that the rocks originally contained appreciable quartz and plagioclase.

Quartzite, in beds up to 30 feet thick, is in some places a fairly pure rock having an average grain size of 0.05 mm. In the absence of evidence for cataclastic reduction in grain size it seems that these beds may have recrystallized from chert. Other coarser quartzites may be derived from quartz arenites.

Although the schists and gneisses may have been quartz-bearing igneous rocks prior to metamorphism, their association with much quartzite and limestone indicates more probably that they were originally impure quartzose sedimentary rocks.

In summary, the Yukon group probably was originally a sedimentary sequence comprising quartz arenite, chert, limestone, and impure clastic sedimentary rocks containing bodies of melanocratic igneous rocks or volcanic greywacke.

Internal Structural Relations

Rocks of the Yukon group have been deformed into northwest-trending folds. The folds, marked by beds of quartzite and limestone, are irregular and overturned both to the northeast and the southwest. The schistosity is parallel with the bedding virtually everywhere.

External Structural Relations

The Yukon group locally grades into foliated quartz diorite characterized by melanocratic lenses, but it is commonly intruded by non-foliated granodiorite, granite porphyry plugs, and andesite, basalt, and rhyolite dykes.

The Yukon group is overlain with angular unconformity by the Hutshi group and younger formations and possibly by the Tantalus formation. It is adjacent to but not in contact with unmetamorphosed chert and quartzite-pebble conglomerate about 3 miles east of Carbon Hill. Such conglomerates occur in the Tantalus formation and in Palæozoic formations in adjacent map-areas (Aitken, 1953, p. 13; Mulligan, 1955, p. 5; Poole, 1955). As chert-pebble conglomerate other than that in the Tantalus formation, is unknown in Whitehorse map-area and as remnants of unmetamorphosed chert, limestone, and volcanic rocks similar to those in the Taku group are absent near Carbon Hill, the conglomerate probably belongs to the Tantalus formation. As evidence for a fault contact between the conglomerate and Yukon group is lacking, an unconformity between the two is indicated.

Age and Correlation

The Yukon group, except those components near Alligator Lake, was probably derived from quartz-rich rocks at least older than the Tantalus formation. Their dissimilarity, however, to Triassic and Jurassic formations makes them more probably pre-Mesozoic.

Some of the quartzites may have been recrystallized from chert, possibly of the Taku group or its equivalents. Although no quartzite or impure quartzose sedimentary rocks occur in the Taku group in Whitehorse map-area, chert, quartzitic siltstone, limestone, and greenstone comprise Permian rocks in Atlin map-area (Aitken, 1955), Permian and Mississippian formations in Teslin map-area (Mulligan, 1955), Mississippian beds in Wolf Lake map-area (Poole, 1955), and pre-Permian rocks in Stikine River (Kerr, 1948a, p. 22) and Taku River (Kerr, 1948b, p. 22) map-areas.

Quartzose metamorphic rocks in the southwest part of Carmacks map-area are considered to be pre-Middle Cambrian, probably Precambrian (Bostock, 1936, p. 19). Similar rocks have been traced through the Aishihik area (Cockfield, 1927, p. 4a) into Dezadeash map-area where the rocks contiguous to the Yukon group in Whitehorse map-area are termed Precambrian (Kindle, 1953, p. 27).

The Yukon group in Whitehorse map-area, therefore, is possibly Precambrian in part but also probably contains late Palæozoic strata.

The gneiss and gneissic porphyritic granodiorite, which appear to have been deformed since their emplacement, may represent earliest Jurassic or older granitic rocks deformed during mid-Cretaceous folding.

Taku Group

Name and Distribution

Cairnes (1913, pp. 51-52) described the Taku group as "mainly cherts and slates . . . . which underlie the Carboniferous(?) Braeburn limestones." Cockfield and Bell (1926, p. 14), recognized that limestones traced from Braeburn, in Laberge map-area, to Taku Arm, were not all of the same age and dropped the name Braeburn. Studies since their report have shown that the limestone in the

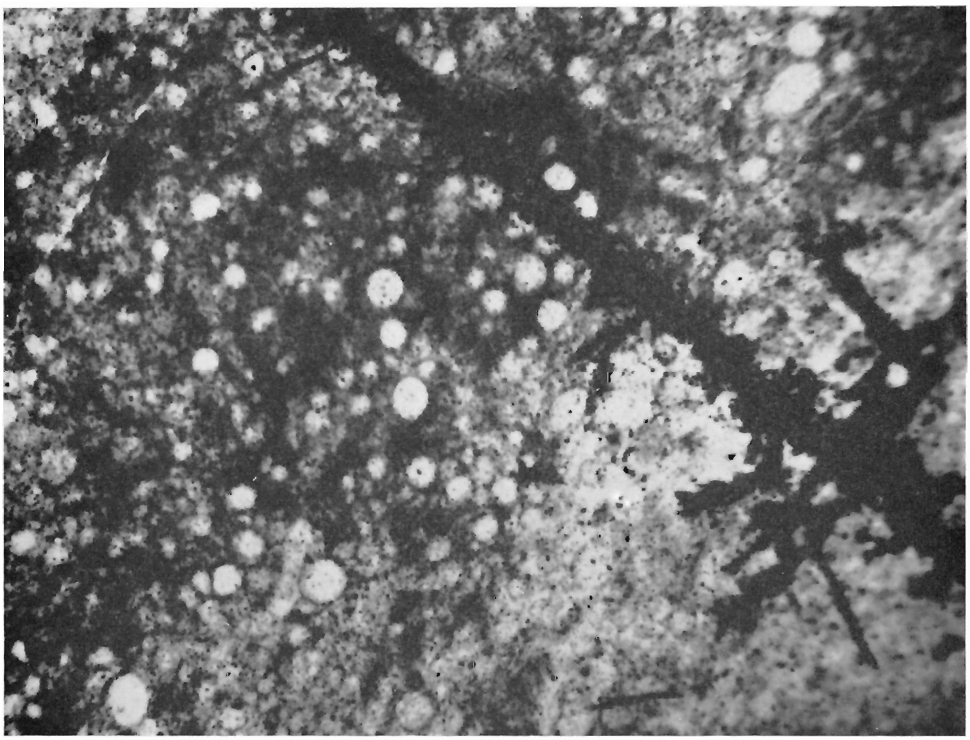


Plate XI. *Photomicrograph of radiolaria(?) in ribbon chert of the Taku group. (Plain light x 28.)*

western part of Laberge map-area and in Whitehorse map-area north of Tagish-Carcross road is probably all Upper Triassic, whereas around Tagish Lake and Taku Arm it is mainly Permian. The present study revealed no evidence that the cherts and slates underlie Permian limestone. Chert, slate, and greenstone, however, are locally interbedded with Permian limestone and consequently the Taku group is redefined to include all these rocks.

The Taku group, underlying about 320 square miles, is restricted entirely to the southeast corner of the map-area.

Lithology

Sedimentary Rocks

Limestone, the predominant rock, is commonly a poorly bedded, massive, grey or white crystalline rock displaying few primary structures. In some places it comprises a breccia of angular limestone fragments 4 to 6 inches across; elsewhere it contains abundant crinoid stems or fusilinids, and in one locality east of Taku Arm, a brachiopod coquina associated with ripple-marked strata.

Chert, the next most abundant sedimentary rock, occurs in four ways: (1) as contorted beds of varicoloured ribbon chert associated with greenstone; (2) as massive grey beds interbedded with limestone; (3) as pods aligned along the bedding in the limestone but spatially related to greenstone bodies; and (4) as massive, varicoloured lenses in greenstone. Ribbon chert and chert interbedded with limestone contain circular structures 0.1 to 0.15 mm. in diameter that may be radiolaria(?) (*see* Plate XI). They are similar to radiolaria from the Franciscan chert (Davis, 1918, Pl. 30).

Volcanic Rocks

Several rudely tabular greenstone bodies are intercalated in limestone. They include flows, one of which has a gastropod coquina upon it, volcanic breccia, and possibly some sills.

The lavas are locally vesicular, even scoriaceous, and amygdaloidal with fillings of quartz, calcite, albite, epidote, and chlorite. They are so altered that augite, as relict phenocrysts partly replaced by chlorite or aggregates of chlorite, carbonate, and some acicular actinolite, is the only remaining pyrogenetic mineral. The groundmass of both the lavas and volcanic breccia consists essentially of an assemblage, without a distinctive texture, of chlorite, epidote, carbonate, subordinate albite, white mica, iron ores, and actinolite.

Volcanic breccia west of Lime Mountain is composed of epidote-rich greenstone fragments 2 to 3 inches across in a darker-green, sheared matrix.

Altered Volcanic Rocks Probably Belonging to the Taku Group

Around Windy Arm, on Nares Mountain, and near Jubilee Mountain, a sheared and disrupted block of chert and dioritic rocks of heterogeneous texture and composition is associated with ultramafic rocks, ribbon chert, and some slate and limestone.

In general, greenstone in the altered volcanic rocks is of two types: (1) a massive, non-fragmental rock composed of partly or wholly uralitized clinopyroxene phenocrysts in a groundmass either mainly of chlorite and some untwinned calcic plagioclase, or of an aggregate of clinozoisite, actinolite, and some anomalous blue birefringent zoisite; and (2) a fragmental rock in which somewhat rounded, cracked, and broken fragments of clinopyroxene, altered sodic plagioclase, and volcanic rocks composed of saussuritized feldspar and quartz, lie in a chloritic groundmass. The latter type north of Jubilee Mountain is associated with breccias characterized by variously oriented lenticular and angular fragments of chert and disrupted bodies of ribbon chert in a sheared matrix. These bodies appear to be along zones of disruption. Prehnite, quartz, epidote, and carbonate veinlets that traverse both types of greenstone seem to be most prevalent in the disrupted zones.

Dioritic rocks of variable composition, ranging from augite-rich clots to rocks composed mainly of plagioclase, are irregularly associated with greenstone. The texture of these varies from aphanitic to pegmatitic. The equigranular parts are a poorly foliated ophitic assemblage of about equal proportions of mafic minerals and plagioclase. The mafic minerals consist of augite, partly altered to pale-yellow-green chlorite and carbonate, or to uralite, and locally to green hornblende. The original plagioclase, about oligoclase-andesine, is altered to a mottled aggregate of chlorite and clinozoisite(?). Ilmenite is partly altered to leucoxene and partly to sphene. The diorite is also veined by prehnite, epidote, clinozoisite, and carbonate.

These altered volcanic rocks probably belong to the Taku group because they are associated with the same rock types as those related to the fossiliferous Permian limestone. It is not known whether the last-named volcanic rocks overlie or underlie the fossiliferous limestone or whether they are merely a volcanic facies of the Taku group.

Internal Structural Relations

Folds in the Taku group are irregular. They are outlined on a broad scale where massive limestone beds are folded with volcanic rocks and chert, and on a small scale where ribbon cherts are crumpled.

In the western part of the Taku group, tight upright folds with steep limbs and a prevailing northwesterly strike, parallel the trends in the Mesozoic rocks flanking them on the southwest, in Bennett map-area.

In the eastern part, however, trends are markedly different. The folds there are more irregular than those to the west and have a westerly radiating pattern. The westerly trend of the folds in the eastern part is a continuation of the trend in Teslin (Mulligan, 1955) and Atlin (Aitken, 1955) map-areas, where the beds sweep around the northern border of granitic bodies in the northern part of Atlin map-area.

External Structural Relations

The contact between the Taku group and Mesozoic rocks is nowhere exposed in the map-area. The Taku and Laberge groups, for instance, appear to be separated by a fault extending from east of the north end of Tagish Lake westward along Crag Lake valley.

East of the north end of Tagish Lake, altered volcanic rocks, probably belonging to the Taku group, strike west and dip steeply north; whereas less than one quarter of a mile to the north, greywacke and slate, typical of the Laberge group, strike north and dip west suggesting that there also, a fault separates the two groups.

Crag Lake valley terminates the north-northwesterly trending, steeply-east-dipping beds of the Taku group. North of the valley is the Laberge group in complex northeasterly trending folds. Clearly, the two groups are separated by an unconformity or a fault along the valley. If it is an unconformity, then most or all of the Upper Triassic Lewes River group was removed prior to the deposition of the Laberge group as none is present along Crag Lake valley. Rocks belonging to the Lewes River group, however, do occur along the east shore of Bennett Lake, and probably Lewes River rocks occur near Lansdowne. The Upper Triassic rocks, only 4 or 5 miles to the east of these occurrences, therefore, must have been removed if this is an unconformity.

Elsewhere in the map-area, the disconformity between the Lewes River and Laberge groups is greatest near the margins of the area in which the Mesozoic bedded rocks are exposed. There, about 700 feet of Upper Triassic beds have been removed. Towards the centre of the Mesozoic belt, which is where the Crag Lake valley lies, it is much less. This suggests a fault contact rather than an unconformity. Further support for this is that no sedimentary evidence of an unconformity was seen in the Laberge group. Conglomerate beds, characterized by granitic material, are thicker and more numerous around Caribou Mountain than they are farther east, and do not decrease in number and thickness northward as would be expected if an unconformity lies along Crag Lake valley. The lack of evidence for an unconformity suggests, therefore, that the Taku and Laberge groups are separated by a fault along Crag Lake valley, and it is so shown on the map.

No fresh volcanic rocks or lenses of limestone that characterize the Upper Triassic Lewes River group east of Bennett Lake were recognized in the altered volcanic rocks west of Windy Arm and north of Montana Mountain. The latter probably belong to the Taku group and their relationship to the Laberge group is not known.

The only ultramafic rocks that may be intrusive into the Taku group cut the altered volcanic rocks (described above) which probably belong to the Taku group. These appear to have been emplaced along the most intensely sheared zones.

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All major rock types in the Taku group are cut by granitic intrusions. These granitic plutons are surrounded by contact metamorphic haloes in which melanocratic volcanic rocks have been metamorphosed to amphibolite, chert has been recrystallized to quartzite, and limestone has been recrystallized to marble and locally altered to wollastonite and skarn.

Sedimentary and Tectonic Environment

The lithology of the Taku group suggests that the sedimentary and volcanic material of which it is composed accumulated in shallow seas some distance from terrigenous source areas.

Limestone was probably precipitated in seas that were, at least in part, shallow enough to have fostered coral growth and to have allowed the accumulation of a gastropod coquina upon a lava flow, and elsewhere, layers of broken crinoid stems and brachiopod shells lying with their convex sides up.

From time to time volcanic eruptions extruded lava, apparently partly on the sea floor. This is indicated by the interbedding of lavas and clastic marine sedimentary rocks. Volcanic breccia, probably constituting both flow breccia and pyroclastic rocks, is not abundant, implying that explosive volcanism was not particularly active in this area during the Permian.

The paucity of clastic sedimentary rocks—except for minor sedimentary limestone-and-chert breccia, volcanic conglomerate, and thin arenaceous beds of detrital carbonate and albite interbedded with lava flows—is evidence that the region was tectonically quiet. Most of the clastic material probably resulted from the erosion of volcanic piles or limestone reefs that were built up above wave base; terrigenous sources were probably distant. Such an environment was probably favourable for the rhythmic precipitation of chert (Davis, 1918).

Age and Correlation

Fusilina, collected by Dawson (1889) from the limestone, was regarded as Carboniferous, and partly on this basis he correlated the limestone and chert with the Cache Creek group of southern British Columbia.

Fusilinids from limestone of the Taku group were dated by P. Harker as Permian. Fusilinids collected from adjoining limestone in Bennett and Atlin map-areas were identified by M. L. Thompson of the University of Kansas, who reported that these collections contained a Guadalupian (Upper Permian) fauna. Collections made by Thompson himself, in Teslin map-area, from limestone adjoining that in Whitehorse map-area were regarded by him to range, within half a mile, from Middle Pennsylvanian to Upper Permian.

The Taku group is therefore Permian and possibly, in part Pennsylvanian. It is correlative, at least in part, with the Cache Creek group.

Lewes River Group

Name and Distribution

Sedimentary and volcanic rocks of the Upper Triassic Lewes River group outcrop over an area of 650 square miles in the north-central and eastern parts of the map-area. Earlier workers mapped rocks of this group as the "Porphyrites" (McConnell, 1909) and the "Older Volcanics" and Laberge Series (Cockfield and Bell, 1926).

Cockfield found Triassic fossils in clastic beds at Maunoir Butte on the east side of Lewes River in Laberge map-area, and suggested the name "Lewes River series" for these rocks (Lees, 1934, p. 11). As the Lewes River assemblage was mapped as a rock unit and not as a time-rock unit, the older term "series" has been replaced by the term "group". Sedimentary and volcanic rocks containing Upper Triassic fossils and immediately underlying the Laberge group are, in Whitehorse map-area, mapped as the Lewes River group.

Age

In 1953, E. T. Tozer restudied the Lewes River group in Laberge map-area. There he established the following faunal succession:

Top
Spondylospira lewesensis fauna
Monotis subcircularis fauna
Halobia fauna
Mysidioptera cf. *poyana* McLearn fauna
Lower(?) Karnian fauna

All these faunas except for the *Mysidioptera* cf. *poyana* McLearn fauna were recognized by Tozer in the collections from Whitehorse map-area. A summary of Tozer's report, including Tables III and IV, is as follows:

Lower(?) Karnian fauna

(1)[1] GSC No. 17565: from limestone at elevation 3,200 feet, 4 miles northwest of peak 5840.
Mysidioptera sp.
Small smooth ammonites, indet.
Echinoid radiole

The above fauna is not dated very satisfactorily, but in Laberge map-area it suggests an early Karnian age. The collections from Laberge and Whitehorse areas are correlated as they have in common a very distinctive, large, echinoid radiole.

[1]Numbers in parentheses indicate fossil localities on accompanying geological map.

Table III

Halobia Fauna

Localities	2	3	4	5
Halobia sp.	x	–	x	x
Posidonia sp.	x	–	–	–
Juvavites sp.	–	–	x	–
Juvavites(?) sp.	x	–	–	–
Juvavites-like ammonite indet.	–	x	–	–
Tibetitid(?)	x	–	–	–

(2) GSC No. 14859: from lower limestone on east side of Ibex River valley.

(3) GSC No. 24386: from elevation 5,750 feet on east side of Ibex River valley.

(4) GSC No. 24379: from limy argillite and siltstone at elevation 5,000 feet on east wall of Ibex River valley.

(5) GSC No. 24380: from limy argillite at elevation 4,920 feet on east wall of Ibex River valley.

***Monotis subcircularis* fauna**

(6) GSC No. 17557: from sandy shales beneath limestone containing *Spondylospira lewesensis* (Lees) at elevation 5,000 feet, 4 miles southwest of junction of Michie Creek and M'Clintock River.

Monotis cf. *subcircularis* Gabb

Table IV

Spondylospira lewesensis Fauna

Localities	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Corals indet	–	–	–	x	–	x	–	–	–	–	–	–	–	–
Spondylospira lewesensis (Lees)	–	x	–	x	x	x	–	–	–	x	x	–	–	x
Ostrea cf. *monti-caprilis* Klipstein	x	–	x	–	–	–	–	–	–	–	–	–	–	–
Modiola n. sp.	x	–	x	–	–	–	–	–	–	–	–	–	–	–
"*Pecten*" (*Variamusium*) cf. *Klushaensis* Lees	x	–	–	–	x	–	–	–	–	–	–	–	–	–
"*Pecten*" *yukonensis* Lees *non* Smith	–	x	–	–	–	x	x	x	x	x	–	–	x	–
"*Neomegalodus*" n. sp.	x	x	–	x	x	–	–	–	–	–	–	–	–	–
"*Trigonia*" *textilis* Lees	–	–	–	–	–	–	–	–	–	–	–	x	–	–
"*Trigonia*" *textilis* Lees?	x	–	–	–	–	–	–	–	–	–	–	–	–	–

(7) GSC No. 14860: from limestone, 2¾ miles northeast of north end of Fish Lake.
(8) GSC No. 14868: from limy beds on low ridge 2 miles east of north end of Fish Lake.
(9) GSC No. 14861: from limestone ½ mile northeast of Lake Louise.
(10) GSC No. 14871: from limestone 1¾ miles east of Ibex River, 1 mile south of Jackson Creek.
(11) GSC No. 14862: from limestone at northeast end of mountains between Takhini River and Whitehorse.
(12) GSC No. 24389: from limestone 1 mile west of north end of Fish Lake.
(13) GSC No. 17567: from sandstones at elevation 4,000 feet, 4½ miles northwest of Mt. M'Clintock.
(14) GSC No. 17568: from sandstones at elevation 4,020 feet, 4½ miles northwest of Mt. M'Clintock.
(15) GSC No. 20286: elevation 5,300 feet, 4 miles east of peak 5635, northeast of M'Clintock River.
(16) GSC No. 17577: from limestone at elevation 3,500 feet, 6½ miles northwest of Joe Mountain.
(17) GSC No. 17576: from west slope of Canyon Mountain at elevation 3,100 feet, in limestone.
(18) GSC No. 17569: from west slope of Canyon Mountain at elevation 3,100 feet, in limestone.
(19) GSC No. 17551: in limestone, east of Cap Creek at elevation 5,400 feet, 6 miles south of Joe Mountain.
(20) GSC No. 26655: in limestone 6 miles west of mouth of Michie Creek.

***Spondylospira lewesensis* fauna**

In addition to those listed in Table IV, the following two collections probably represent *Spondylospira lewesensis* fauna.

(21) GSC No. 25057: from limestone 3 miles from Carcross southwest along White Pass and Yukon Railway.
Astarte cf. *appressa* Gabb
Palaeocardita(?) sp.

(22) GSC No. 25048: from limestone 4 miles N70°E of point where Alaska Highway crosses Judas Creek.
small gastropods indet.
small brachiopods indet.
fragment of *Palaeocardita*(?)

All four faunas from Whitehorse map-area are probably of Upper Triassic age and are dated as follows:

Spondylospira lewesensis fauna—late Norian
Monotis cf. *subcircularis* fauna—Norian, probably late Norian
Halobia fauna—early Norian or late Karnian
Lower(?) Karnian fauna.

Stratigraphy

The area over which the Lewes River group outcrops is divided arbitrarily into three belts in order to bring out variations in the stratigraphy across strike. Each belt is further subdivided for descriptive purposes as the paucity of fossils and the erratic distribution of volcanic rocks along strike makes direct correlation difficult. Rough stratigraphic sections were compiled in a few areas, but in most, the structural complexity and discontinuity of outcrop leave doubt as to the thickness and relative stratigraphic position of the strata.

Western Belt

The western belt embraces those outcrops of the Lewes River group lying west of Yukon River and the White Pass and Yukon Railway. The best exposed section lies east of Ibex River and to this section others in the belt are related on the bases of lithology and to some extent on the position of the *Spondylospira lewesensis* fauna.

Ibex River Area—In the following section—from the east wall of Ibex River valley, south of Jackson Creek on the west limb of the Fish Lake syncline—the clastic beds in Division B are evidence of rapid deposition under disturbed conditions. A slab of interbedded argillite and siltstone occurs in gritty greywacke about 4 feet stratigraphically above continuous beds of interbedded argillite and siltstone. Conditions were apparently turbulent enough to have stripped off slabs of the underlying argillaceous sediments and to have redeposited them elsewhere.

The contact between the Lewes River group and the Laberge group conglomerate is masked by vegetation on the grass- and heather-covered upland above the steep eastern wall of Ibex River valley. The beds above and below the contact are roughly parallel, but in detail, limestone containing *Spondylospira lewesensis* strikes into conglomerate of the Laberge type. As no evidence for a fault was seen, the Laberge group appears to overlie the Lewes River group disconformably. In so doing, at least 700 feet of the Lewes River group were removed before the Laberge conglomerate was deposited.

	Thickness (feet)
Laberge group	
Disconformity	
Dark green tuff	10+
Division E.	
Pale grey, massive limestone containing *Spondylospira lewesensis*	500
Division D.	
Green and dark purple volcanic greywacke, conglomerate with fragments up to a foot across mainly of volcanic, some granitic, rocks; subordinate volcanic breccia	1,000–1,500
Division C.	
Purple, grey, and green volcanic breccia containing blocks up to 2 feet across and a few rounded pebbles and boulders, volcanic greywacke; 60 feet of purple and grey amygdaloidal andesite and basalt flows about 700 feet above base; at base, purplish conglomerate 50 feet thick composed of purple basalt, greenstone, and limestone cobbles	1,500–1,000
Disconformity	
Division B.	
Pale grey and pale pink crystalline limestone in discontinuous lenses (10 feet)	75–100
Limestone breccia, with a few volcanic fragments 3 to 4 inches across (5 feet)	
Conglomerate, in lenses 10 feet thick, comprising rounded cobbles 2 to 3 inches across of purple volcanic rocks (10 feet in lenses)	
Limestone breccia, containing corals and brachiopods (5 to 10 feet)	
Conglomerate containing greenstone, purplish basalt, and feldspar porphyry cobbles	
Purplish limestone breccia and purplish greywacke grading upward into purple conglomerate	
Grey-green, limy greywacke, interbedded with siltstone and argillite, containing *Halobia*	100
Interbedded limy greywacke, in part gritty, and banded greyish green argillite, thin conglomerate beds containing pebbles of greenstone, greywacke, and limestone; some lenses of limestone about 10 feet thick	60
Interbedded grey-green, locally pebbly greywacke and banded argillite (lower part contains more argillite than greywacke)	100
(Division B thins northward and pinches out so that Division A merges upward with Division C)	
Division A.	
Greenstone, locally containing phenocrysts of chloritized hornblende and pyroxene, volcanic breccia of green fragments in a green or purplish matrix; minor conglomerate and siltstone	200
Base not exposed	

Haeckel Hill and Whitehorse Copper Belt—This area comprises the outcrop extending from northeast of Jackson Creek to Haeckel Hill, southeast from there along the Whitehorse copper belt, and southwest from there to the head of McIntyre Creek.

Fyles (1950, p. 20) tentatively separated the rocks in this area into two main divisions. The upper division forms most of the outcrops. It consists of purplish and greyish brown volcanic greywacke, siltstone, and argillite, discontinuous bodies of grey limestone, and a few thin beds of conglomerate. Some of the limestone contains *Spondylospira lewesensis*. The conglomerate comprises purplish basalt, feldspar porphyry, and limestone pebbles.

The lower division is restricted chiefly to the west and northwest of the granite south of Haeckel Hill. It comprises grey and purple volcanic breccia containing fragments 3 to 12 inches across, conglomerate, and volcanic greywacke. The conglomerate is composed mainly of volcanic fragments, but also contains a few of granitic composition.

Outcrops are scarce along the southern part of the Whitehorse copper belt. Rocks along it comprise limestone, containing *Spondylospira lewesensis* at one locality. This limestone is separated from the overlying Laberge group by greywacke and is underlain by grey-green greywacke with locally intercalated andesite of unknown origin. The greywacke was originally mapped as porphyrite (McConnell, 1909, p. 9), but Fyles (1950, p. 16) established it as sedimentary because of its bedding and content of pebbles and clastic grains.

In summary, the conglomerate and volcanic breccia (Division D), which underlies the *Spondylospira lewesensis* limestone in the Ibex River section, is replaced by greywacke, siltstone, and argillite (upper division) beneath the same limestone in this area (*see* Fig. 3, in pocket). The coarse fragmental rocks of the lower division may be in part equivalent to Division C in the Ibex River section. The disconformity between the Lewes River and Laberge groups decreases from the Ibex River section eastward to the copper belt. At the former, the upper limestone is missing, whereas at the latter, not only is it present but some greywacke above it is also present below the Laberge conglomerate.

Mount Ingram Area—The following succession of southeasterly dipping beds on Mount Ingram (Fyles, 1950, p. 24) is faulted against the Laberge group. Its upper part, however, appears to be present south of the fault beneath the Laberge group.

	Thickness (feet)
Laberge group	
Unconformity(?)	
Banded cherty argillite or tuff, chert; minor limestone, conglomerate containing a few granitic fragments, and volcanic breccia	500
Purplish basalt flows and breccias	1,500
Relations not clear	
Arkose and conglomerate bearing many granitic boulders (may be a faulted part of Laberge group?)	unknown

The relatively fresh flows are typical of those of Division C in the Ibex River section and the overlying clastic rocks may be part of Division D.

Area Between Takhini and Ibex Rivers—The structure is not sufficiently known for a section to be established in this area. Grey-green greywacke, perhaps partly tuffaceous, is associated with subordinate amounts of volcanic breccia, basalt, conglomerate, siltstone, and grey-green cherty tuff and argillite. Toward the mouth of Ibex River these rocks grade into metamorphic rocks adjacent to the Coast intrusions. Volcanic breccia, with mostly angular but a few rounded purple fragments in a dark green matrix and relatively fresh basalt resemble rocks in the Mount Ingram section and in Division C of the Ibex River area.

Though most of the conglomerates in this area are composed almost entirely of volcanic fragments, a few, especially one about 2 miles south of Takhini, contain abundant granitic boulders averaging 8 to 10 inches in diameter and reaching a maximum of 4 feet across. The abundance of coarse, granitic debris in conglomerate is typical of the conglomerates of the Laberge group and hence these 'granitic' conglomerates are more probably infolded remnants of the overlying Laberge group than an unusual 'granite'-rich conglomerate in the Lewes River group.

Area North of Takhini River—North of Takhini River are interbedded limestone, purple volcanic greywacke, and maroon conglomerate. These contain fossils of probably Upper Triassic age but none is diagnostic of a specific faunal zone. The limestone southwest of Upper Laberge is at or near the top of the Upper Triassic section and is probably equivalent to limestone containing *Spondylospira lewesensis* fauna near the top of the section in the Whitehorse copper belt. The stratigraphic position of the beds north of Takhini Hotspring is not known.

Areas Mainly of Volcanic Rocks Between Two Horse Creek and Bennett Lake—Several disconnected areas of purplish, grey, and green volcanic breccia locally including blocks 4 feet across, subordinate volcanic greywacke, and lenses of grey and pinkish, massive limestone, extend from Bennett Lake northwest to Two Horse Creek. The coarse clastic rocks are similar to those of Division C in the Ibex River section whereas some of the pinkish limestone is like that of Division B. The limestone near Millhaven Bay and in lower Watson River is similar to late Norian limestone in the Whitehorse copper belt and to probably late Norian limestone east of Bennett Lake.

Rocks outcropping in the uplands north of Friday Creek and southwest of Ibex Mountain probably belong to the Lewes River group but may include sedimentary rocks of the Laberge group and volcanic rocks of the Hutshi group. They comprise green porphyritic augite andesite and volcanic greywacke or tuff with minor argillite and conglomerate.

Low-grade Metamorphic Rocks in the Western Belt—Greenstone, greenstone breccia, chloritic and micaceous schist, and minor gneiss are associated with limestone and sheared conglomerate in and near the western plutonic complex. They consist mainly of the following minerals: albite, chlorite, actinolite, epidote, zoisite, clinozoisite, muscovite, and minor biotite and quartz—all characteristic of the greenschist facies. The greenstones resemble altered parts of the Lewes River group between Takhini and Ibex Rivers.

Similar rocks between Alligator Lake and the mouth of Wheaton River were called the Mount Stevens group (Cairnes, 1912, p. 40). He regarded them as pre-Devonian because of their lithological similarity to metamorphic rocks containing Silurian fossils in southeastern Alaska (Cairnes, 1912, p. 46). These low-grade metamorphic rocks were probably derived from a terrain comprising melanocratic volcanic rocks, limestone, and clastic rocks—a terrain more like a volcanic-rich part of the Lewes River and Taku groups than that of the older quartz-rich rocks from which the Yukon group was probably derived.

Isolated patches of greenstone and 'granite'-bearing conglomerate within the plutonic complex may belong to the Hutshi group.

SUMMARY—The Lewes River group in the western belt consists of at least 4,000 feet of melanocratic fragmental and flow rocks, clastic sedimentary rocks, and limestone. West of a line from Takhini to Golden Horn Mountain, the fragmental rocks between the *Spondylospira lewesensis* and *Halobia* zones are coarse, carrying blocks up to 4 feet across, whereas east of this line the beds beneath *Spondylospira lewesensis* are mainly arenaceous (*see* Fig. 3, in pocket).

Central Belt

The central belt lies east of Yukon River and west of a line running southeast from M'Clintock Lakes to the head of Michie Creek. The area east of Laberge Creek, which contains Lower(?) Karnian strata is described first, followed by descriptions of several areas which have beds with a *Spondylospira lewesensis* fauna.

Area East of Laberge Creek—Dark grey limestone that forms part of a discontinuous band east of Laberge Creek contains an echinoid radiole like those characteristic of the Lower(?) Karnian faunas in Laberge map-area. This limestone and its associated limestone breccia and conglomerate is overlain by greyish brown or black, locally thin-bedded argillite, and is underlain by similar argillite, and limy arenite. The argillite is partly metamorphosed to hornfels. The rocks associated with this limestone assemblage are finer grained than those associated with similar-looking limestone that bears *Spondylospira lewesensis* fauna. They may be a fine-grained facies of the latter but more probably are a sequence lower in the Lewes River group, possibly of early(?) Karnian age.

Canyon Mountain and the Area East of Cowley Creek—On the western slopes of Canyon Mountain, limestone containing a *Spondylospira lewesensis* fauna is overlain by, and folded with, rusty and brownish weathering greywacke and argillite containing poorly preserved ammonites that may be of Jurassic age.

East of Cowley Creek are grey to green greywacke, containing angular fragments of dense, banded, aphanitic rock, locally oriented parallel with the bedding, and some conglomerate containing pebbles of chert, quartzite, and greenstone. These are overlain by tightly folded crystalline limestone that may be a continuation of that on Canyon Mountain. Black slate and argillite, similar to that in the Laberge group west of Marsh Lake, appear to overlie the limestone conformably.

The lack of conglomerate in the Jurassic beds in this area, the structural parallelism of the Upper Triassic and Jurassic(?) rocks on Canyon Mountain and their apparent conformity east of Cowley Creek, suggest that the Laberge group lies conformably on the Lewes River group in the eastern part of the central belt.

Upper Joe Creek and Area East of Cap Creek—Pale-grey-weathering, dark grey limestone containing a *Spondylospira lewesensis* fauna extends from north of Joe Creek southeast along the east side of Cap Creek. It is apparently underlain by grey-green greywacke, minor argillite, conglomerate, and limestone, on the western slopes of Joe Mountain and overlain, north of Joe Creek, by dark grey argillite, limy greywacke, and two bands of conglomerate. The conglomerates are composed mainly of melanocratic volcanic rocks, some limestone, chert, and a few granitic pebbles.

Along the east side of Cap Creek, *Spondylospira lewesensis* limestone is underlain by black argillite and grey limestone and is overlain by 1,100 feet of poorly exposed black argillite, volcanic greywacke, and conglomerate. The underlying argillite and limestone are faulted against volcanic rocks belonging either to the lower part of the Lewes River group or to the Hutshi group. The conglomerate forms the lowest outcrops in Cap Creek valley and probably belongs to the Laberge group. It consists of fragments, up to 6 inches across, of green andesite, feldspar porphyry, and subordinate chert, limestone, and a few of granitic composition.

The relationship of the limestone southwest of the southernmost fossil locality in this belt is not known.

No determinable fossils were obtained from the limestone at the head of Cap Creek or from a westerly trending band 1 mile east of peak 5,840. These limestones contain, however, subrounded nodules of black chert one half to three quarters of an inch across, characteristic of Upper(?) Karnian limestone in the Laberge map-area (E. T. Tozer, personal communication, 1956).

Area South of Cap Creek—Upper Triassic rocks are exposed discontinuously in a southwesterly dipping homocline forming the northeastern slopes of the mountains south of Cap Creek and west of M'Clintock River.

The following section is from the northeast-trending ridge 4 to 5 miles west of the mouth of Michie Creek. It contains diagnostic fossils and is fairly typical of the succession in this region.

The lower part of the succession varies considerably along strike. On Cap Mountain and on the ridges south of it, the lower beds contain greenstone and conglomerate with volcanic, greywacke, chert, and limestone pebbles. Southwest of the mouth of Michie Creek, the lower beds include limestone that contains colonial corals. This limestone crosscuts the trend of the sedimentary rocks and is probably a bioherm, possibly a reef, that grew in a direction transgressing the bedding of the associated clastic rocks.

	Thickness (feet)
Volcanic rocks (Hutshi group ?)	
Unconformity	
Grey limestone containing *Spondylospira lewesensis* fauna	400
Greenish grey siltstone and argillite containing *Monotis subcircularis* fauna	400
Mainly discontinuous outcrop of grey-green greywacke; some interbeds of siltstone about 5 inches thick	4,200
Limy greywacke and some thin lenses of limestone	1,000
Graded-bedded, greyish green greywacke and 3-inch beds of siltstone about 12 inches apart	2,000
Gap	1,400
Dark grey argillite	50
Grey-green, massive greywacke	800
Base not exposed	

As the limestone on peak 6,010 contains large gastropods that in the Telegraph Creek area, British Columbia, are typically associated with the *Spondylospira lewesensis* fauna (E. T. Tozer, personal communication, 1956), it is probably the same bed as that at the top of the above section. If so, a right-hand cross-fault must lie along the northeasterly trending valley southeast of peak 6,010. The repetition of conglomerate on Cap Mountain and on the ridge south of it suggests that another right-hand cross-fault lies along the northeasterly trending valley southeast of Cap Mountain.

The upper limestone at the southeast end of the above area is terminated abruptly, probably by a fault, against volcanic rocks that elsewhere unconformably overlie the *Spondylospira lewesensis* limestone.

Area East of Marsh Lake—*"Pecten" yukonensis* Lees *non* Smith of the *Spondylospira lewesensis* fauna occurs in limestone 4 miles east of peak 5,635. A discontinuous, westward-dipping bed of similar limestone extends from between peaks 5,125 and 5,635 almost to Mount Michie. This bed thins southeastward and is missing on Mount Michie, but reappears in poorly exposed outcrops in the low timbered hills north of Judas Creek. There it is a westerly trending bed containing small indeterminate gastropods and brachiopods, and *Palæocardita*(?) that probably belongs to the *Spondylospira lewesensis* fauna.

The limestone north of Mount Michie is underlain on the east by as much as 600 feet of black argillite and slate, locally including some greywacke and melanocratic volcanic rocks, and an unknown thickness of sheared and altered volcanic rocks. The latter comprise saussuritized, amygdaloidal, and porphyritic mafic lavas and breccias composed of fragments of green volcanic rocks and chert in a sheared, epidote-rich matrix. The rocks a few hundred feet beneath the limestone abruptly become sheared and altered. The slaty cleavage and shearing parallels the strike of the limestone but dips vertically, in contrast with the moderate westerly dips of the limestone and overlying beds.

Although there is no physiographic expression for a fault contact between the altered volcanic rocks and the sedimentary rocks to the west, a fault is suggested for two reasons: (1) the rocks become sheared abruptly near the altered volcanic rock - sediment contact; and (2), to have a thick volcanic assemblage only 600 feet beneath *Spondylospira lewesensis* limestone would require an improbably rapid facies change southeastward from the thick clastic assemblage underlying this zone west of M'Clintock River. This is rendered even more improbable by the presence once more of a clastic assemblage apparently underlying the limestone north of Judas Creek. It is suggested, therefore, that the altered volcanic rocks east of the divide between peak 5,125 and Mount Michie are faulted against the upper part of the Lewes River group, and may themselves belong to the greenstones exposed in Michie Creek and M'Clintock valleys. These rocks appear to be low in the Lewes River group, beneath the thick section of clastic sedimentary rocks.

SUMMARY—The central belt contains different parts of the Upper Triassic section isolated from each other by more recent formations or by terrain whose structure and relation to Upper Triassic formations are unknown.

Possible Lower(?) Karnian limestone, limestone breccia, and conglomerate, and associated argillite and limy greywacke occur east of Laberge Creek.

Two areas of limestone containing black chert nodules, exposed between Joe and Cap Creeks, may be equivalent to similar chert-bearing Upper(?) Karnian limestone in Laberge map-area.

West of M'Clintock River the Lewes River group consists of *Spondylospira lewesensis* limestone near the top of the section, underlain first by fine clastic beds containing *Monotis* cf. *subcircularis* Gabb, and then by as much as 6,000 feet of fine clastic rocks, many of which show graded bedding. Conglomerate and biohermal limestone occur locally in the lower beds and greenstone in the lowest.

East of Marsh Lake a thin, discontinuous limestone bed containing a *Spondylospira lewesensis* fauna is locally underlain by clastic beds and locally appears to be faulted against sheared, altered volcanic rocks slightly different from, but perhaps related to, those in the lowest beds west of M'Clintock River.

The limestone containing *Spondylospira lewesensis* fauna appears to be thicker in the western and northern parts of the central belt (*see* Figure 3, in pocket).

Northeastern Belt

The northeastern belt embraces those outcrops of the Lewes River group in the northeastern corner of the map-area that extend from the hills north and west of Sheldon Creek southeastward to the hills northeast of the head of Michie Creek. The complex, closely folded structure and the similarity of the rocks of the Lewes River group to those probably of the Laberge group, have made it impossible to show the two groups separately on the map.

Thin limestone lenses characteristic of the Lewes River group elsewhere in the map-area, are scattered from Sheldon Creek to the head of Michie Creek.

The following section was measured from steep cliffs on the east side of the north-flowing stream 3 miles east of Byng Creek; this section provided the only diagnostic fossils in this belt.

	Thickness (feet)
Conglomerate (probably basal Laberge group)	
Disconformity(?)	
Rusty, sheared limestone, partly covered by talus	100
Dark grey, bulbous-weathering, pyritic limestone	110
Interbedded argillite, siltstone, and greywacke	150
Dark grey, coralline limestone	75
Dark grey siltstone, argillite, and greywacke with interbeds of dark grey limestone about 4 feet thick	120
Finely banded argillite and siltstone	150
Rusty-brown-weathering, pyritic, bluish grey siltstone and limy greywacke containing "*Pecten*" cf. *yukonensis* Lees *non* Smith of the *Spondylospira lewesensis* fauna, and interbedded coralline limestone	110
Dark grey, sheared limestone	10
Interbedded greywacke and dark grey argillite	80
Concealed	50
Dark grey and white massive limestone, partly composed of numerous crinoid fragments	170
(The following is below this limestone but farther southeast)	
Gritty, green greywacke, banded argillite, and limy greywacke and limestone lenses	400
Dark grey argillite with poorly preserved fossils	150
Sheared, dark grey argillaceous limestone	110
Grit with pea-size conglomerate	10
Grey banded argillite	80
Conglomerate with 1/4- to 1/2-inch pebbles of greenstone and chert	150
Limy argillite	Unknown
Base not exposed	
Total	2,025+

Toward Augusta Mountain, limestone lenses near the top of the section are underlain by grey-green greywacke and argillite, as much as 4,000 feet thick, but outcrops are too poor for the section there to be compared with that above.

SUMMARY—The Lewes River group is not as well exposed in the northeastern belt as it is in other belts. The *Spondylospira lewesensis* faunal zone occurs in fine clastic beds rather than in limestone. It is overlain by about 700 feet of interbedded limestone, argillite, siltstone, and greywacke, and underlain by interbedded limestone and clastic rocks including at least two zones of conglomerates associated with gritty beds (*see* Fig. 3, in pocket).

Lithology

The nature of the greywacke, volcanic breccia, conglomerate, and melanocratic volcanic rocks helps in the determination of the sedimentary environment and source area of the Lewes River group. It is described below.

Greywacke

The arenites of the Lewes River group are poorly sorted. Grains of various size-grades up to 3 mm, are embedded in a matrix commonly occupying 30 to 40 per cent of the rock volume and locally as much as 70 per cent (*see* Table V).

Table V

Volume Percentage of Essential Constituents of Arenites of the Lewes River Group

	Whitehorse Map-area																						Laberge Map-area	
Specimen	1[a]	2[a]	3[a]	4[a]	5[a]	6[a]	7[a]	8[a]	9[a]	10[a]	11	12	13	14[a]	15[a]	16	17	18	19	20	21	22[a]	17270	17236
Quartz	0.5	—	5	—	4	2	3	5	0.5	—	—	10	—	2	0.5	3	—	—	—	11	—	—	—	1
Potash feldspar[b]	—	—	1	7	—	—	—	—	—	—	—	—	—	14	—	—	20	2	—	5	—	—	3	5
Plagioclase	52	55	49	57	49	42	51	21	23	24	35	70	37	43	21	53	11	35	45	35	33	37	33	34
Biotite	—	—	—	—	8	—	—	3	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	9
Hornblende	—	16	5	6	—	—	7		6	2	—	—	2	—	—	—		8	19	8	12	18	—	
Matrix	47	18	36	30	38	53	25	70	51	71	55	20	51	29	70[c]	35	67	31	25	19	55	45	39	40
Rock fragments	0.5	11	4	—	1	3	16	1	19.5	3	10	—	10	12	8.5	9	—	24	11	22	—	—	25	11

[a] Counted with an integrating stage; minimum length of traverse 100 times width of largest grain in slide. Remainder counted with point counter; point spacing 0.33 mm. spacing 1 mm. Between 500 and 800 points counted for most arenites.
The difficulty of distinguishing in many cases between matrix, aphanitic rock grains, and altered plagioclase introduced errors into the analyses. On slides counted both by J. D. Aitken and the writer, differences of 2 to 5% were registered on feldspar content depending on the amount of alteration, and differences of 5 to 10% on aphanitic rock grains and matrix.
As secondary minerals like the micas, chlorite, and carbonate are restricted to the matrix they were included with the matrix. Samples with more than 12% secondary material, including all but one from the northeastern belt, were discarded.

[b] Obtained by re-counting slides stained with sodium cobaltinitrite (Chayes, 1952).

[c] Carbonate.

Location of samples is shown on Figure 9 (p. 68).

The individual grains are angular to subangular. The corners of crystals or angular fragments are more or less rounded and the grains themselves are cracked and broken. Feldspar and mafic grains are commonly euhedral whereas quartz and rock fragments generally occur as irregular equidimensional grains. The most common shape for quartz is triangular though some grains are crescentic.

Quartz rarely forms more than 10 per cent of the arenites of the Lewes River group and is commonly absent (*see* Table V). Most of it is unstrained and clear, though some of the arenites contain minute brownish inclusions whose refractive index is less than quartz.

Potash feldspar occurs in a few arenites, mainly in those from the *Halobia*-bearing Division B of the western belt. Plagioclase, however, is a prominent constituent, prevailing as saussuritized grains, and subordinately as fresh, twinned and zoned grains as calcic as andesine.

Detrital mafic minerals, chiefly green hornblende with sparse clinopyroxene and biotite, commonly form 5 or 6 per cent of the rocks and in some cases as much as 18 per cent.

Rock fragments are mainly volcanic, including equigranular and porphyritic basalt and greenstone, with subordinate crystal tuff, greywacke, argillite, chert, and rarely quartzite.

The matrix is composed of finely comminuted feldspar, chlorite, mica, and locally some carbonate. The matrix also includes minor constituents, generally less than 5 per cent, comprising epidote, clinozoisite, zoisite, iron ores, leucoxene, sphene, apatite, and zircon. The accessory minerals are commonly euhedral.

As rock fragments could not reliably be distinguished from matrix, the two are combined with mafic minerals to form one end-member in Figure 4, the other two being quartz and feldspar.

Several triangular diagrams have appeared in the literature in the last few years, principally those of Krynine (1948, p. 150); Pettijohn (1949, p. 227); Dapples, Krumbein, and Sloss (1953, p. 305); Folk (1954, p. 354); Packham (1954, pp. 472, 474); and Gilbert *in* Williams, Turner, and Gilbert (1954, pp. 292-93). The one best suited to the Whitehorse arenites is that of Dapples *et al.*, modified slightly by the addition of mafic constituents to the rock-fragments-plus-matrix end-member and the substitution of the term quartz arenite (Gilbert, *in* Williams, *et al.*, 1954, p. 293) for the term orthoquartzite (*see* Fig. 4). In this report quartzite is used to describe metamorphic rocks composed essentially of quartz.

Some of the arenites may be tuffs. This is suggested by their content of angular volcanic fragments, spherulites, and some indeterminate brownish material that may be devitrified glass, and by their association with volcanic breccia, probably of pyroclastic origin. Shards, however, are absent. On the other hand, most of the arenites examined under the microscope show abundant evidence of abrasion and limited rounding of grains. This and the presence of conglomerates suggest that the arenites were transported in water. Some of the arenites, therefore, were probably initially pyroclastic and later were reworked by water, and some were probably derived from weathering and erosion of volcanic terrain, including some sedimentary rocks.

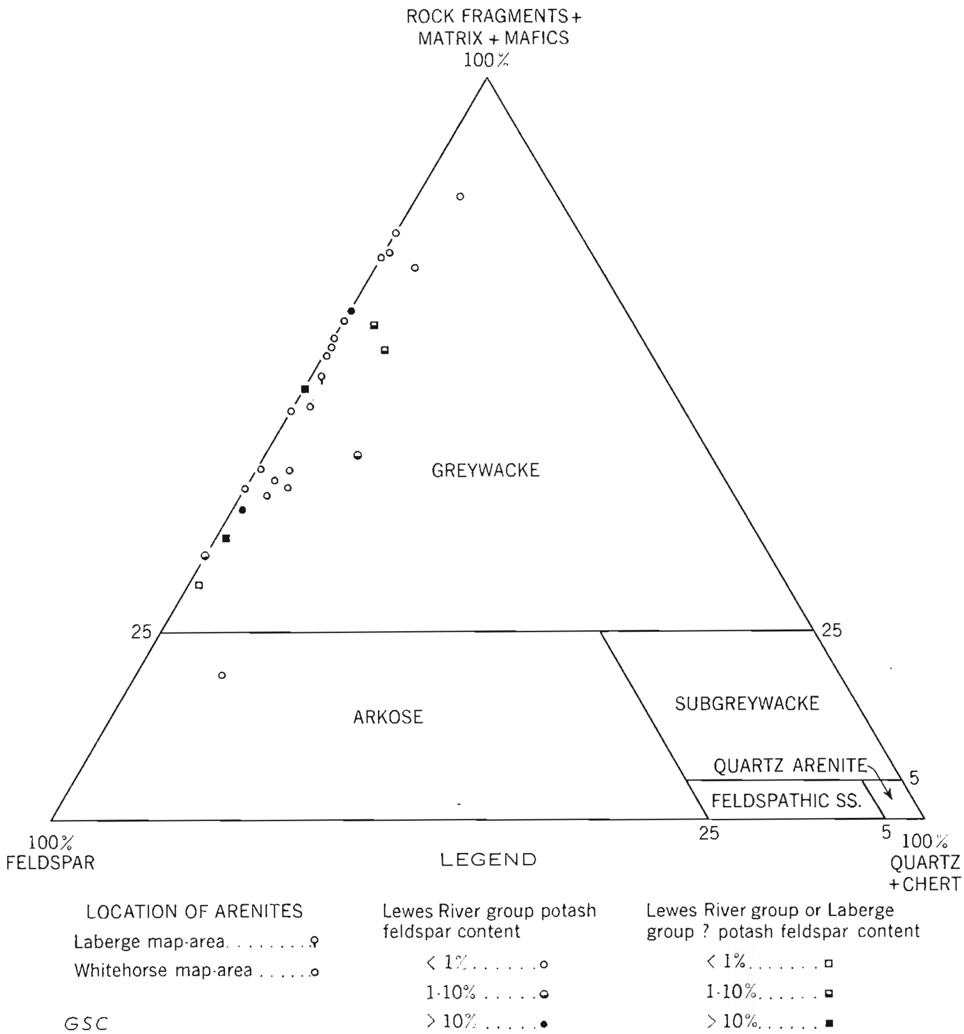

Figure 4. *Plot of the compositions (volume per cent) of arenites of the Lewes River group.*

All but one of the arenites of the Lewes River group fall into the greywacke field in Figure 4. The compositions of the arenites are different from those plotted by Dapples *et al.* (1953, p. 305), which are richer in quartz, but are close to their single plot of a tuff. The greywackes of the Lewes River group and associated rocks fall into the field of "labile greywacke" of Packham (1954, p. 472) and into the field of "volcanic wacke" of Gilbert (Williams *et al.*, 1954, p. 292). They might well be termed volcanic greywacke and probably grade in places into tuffaceous sandstone (Gilbert, *in* Williams *et al.*, 1954, p. 304).

Arenites associated with limestone contain much carbonate. The carbonate, however, is not simply a filling, because less carbonate-rich phases of the same rock have a matrix of chlorite, white mica, and carbonate. Apparently, the sediments were not cleaned by winnowing of the fine material and the spaces between the grains later filled with carbonate to cement the rock, but rather the matrix and some of the detrital grains themselves were replaced, perhaps diagenetically, by carbonate. Such replacement is regarded by Dapples (1956) as characteristic of intermediate grades of diagenesis.

Table VI

Volume Percentage of Essential Constituents of Arenites of the Lewes River or Laberge Group

Specimen	23[a]	24[a]	25	26[a]	27
Quartz	0.5	1	2	5	1
Potash feldspar	13	16	—	7	4
Plagioclase	29	45	67	30	30
Biotite	—	—	12	—	—
Hornblende	—	19		—	17
Matrix	57.5	12	5	55	35
Rock fragments	—	—	5	—	13
Epidote	—	2	9	3	—

[a] Counted with an integrating stage; remainder with a point counter. Details same as in Table V.

Location of samples shown in Figure 9.

The arenites above the *Spondylospira lewesensis* zone, designated Lewes River or Laberge group (?) (*see* Table VI and Figure 4) are similar to those in the Lewes River group but have more potash feldspar and epidote.

Volcanic Breccia and Conglomerate

The size and character of the fragments in the volcanic breccia and conglomerate of Divisions C and D of the Ibex River section and elsewhere in the western belt, give some idea of the source of these rocks. The volcanic breccia contains angular lithic fragments, from a fraction of an inch to 4 feet across, of dark green and purple to maroon, melanocratic volcanic rocks in a grey, pale green, or purple matrix. The nature of the breccia was not determined, but its wide extent in the western belt, its minimum thickness of about 100 feet, and its maximum thickness of over 1,000 feet, suggest that much of it is pyroclastic.

Rounded fragments, mixed with volcanic breccia, become more abundant upwards in the Ibex River section. The composition of the conglomeratic part is more diverse than that of the volcanic breccia and comprises fragments of volcanic rocks, greywacke, argillite, feldspar porphyry, and a few of a granitic nature.

Direction and Distance of Source—The coarseness of the lithic fragments, averaging about 8 inches, in both the breccia and the conglomerate, and their decrease in size eastward, demand a relatively close westerly source. The proximity of this source may be gained from a study of the size of recent volcanic debris from known sources.

In Katmai district, Alaska, fist-size lithic fragments occur half a mile from their source on Novarupta volcano (Fenner, 1923, pp. 53-55). During the Mont Pelée eruptions of 1929-32, a cottage-size boulder was carried about 3 miles by a *nuée ardente* that travelled 5 miles from its source to the sea (Perret, 1935, p. 45). During the eruptions of Tarawera in New Zealand in 1886, scoriaceous stones were blown 8 miles (Smith, 1886, pp. 27-29). When Krakatau erupted in 1883, about two thirds of the ejecta fell within a radius of 9 miles (Williams, 1941, p. 256); within 2 miles of the source, the average size of most blocks is less than 1 foot in diameter although a few lithic fragments are 10 feet across. Around Crater Lake (Williams, 1942, p. 77) lithic fragments 2 inches across on Timber Crater were carried 5 miles, though most of the associated material was only about one quarter of an inch in diameter. Lithic chips half an inch across were carried 30 miles from their source, though the average size of the associated pumaceous material was 1 to 3 mm. When Hekla erupted in Iceland on March 29, 1947, "tephra" (airborne ejectamenta), whose median grain size is 15 mm, was found 2.1 miles from the source; that with a grain size of 1 mm, was found about 30 miles from the source. (Thorarinsson, 1954, p. 31).

No evidence was seen for the deposition of material by *nuées ardentes* in Whitehorse map-area, although mud flows and submarine slumps may have moved the blocks beyond the place where they were first deposited.

The source of much of the volcanic breccia and conglomerate in the western belt of the Lewes River group, therefore, was probably not more than 5 miles west of its present position, and that of the arenaceous tuffs probably not more than 30 miles distant.

Volcanic Rocks

The only relatively fresh volcanic rocks in the Lewes River group are those on Mount Ingram and along Ibex River valley. They comprise black, purple, maroon, grey, and green basalt and andesite flows, breccia, and related tuff. The flows are massive, locally porphyritic with phenocrysts of clinopyroxene, and subordinate labradorite and hornblende. In other places they are amygdaloidal with fillings of calcite, quartz, epidote, and chlorite.

Elsewhere, as east of Bennett Lake and in the lower parts of the section in the central belt, the volcanic rocks are altered to greenstone; plagioclase has been saussuritized and mafic minerals mainly replaced by actinolite and chlorite, leaving but a few phenocrysts of clinopyroxene.

Some of the alteration in the volcanic rocks probably took place before the fragments finally collected to form the sedimentary rocks of the Lewes River group. Evidence for this is as follows:

(1) greywackes of the Lewes River group contain abundant detrital, saussuritized plagioclase and epidote, and altered volcanic rock fragments mixed with detrital fresh andesine, mafic minerals, and volcanic rock fragments;

(2) volcanic rocks of the Lewes River group include both greenstone and relatively unaltered andesitic and basaltic lavas.

The alteration may have resulted from autometamorphism during the cooling history of the mafic magma, or from the reaction between mafic magma and wet sediments or sea water (Turner and Verhoogen, 1951, p. 209), or from irregularly effective low-temperature hydrothermal metamorphism of wet sediments and volcanic rock containing much water unrelated to igneous activity (Coombs, 1954).

Summary

In discussing the stratigraphy of the Lewes River group, the reader is referred to the fence diagram (Fig. 3, in pocket). This diagram was constructed from data gained from the best exposed sections and those containing diagnostic fossils. Thicknesses were, for the most part, computed from the map. Non-fossiliferous parts of the group are correlated with lithologically similar parts of known sections. Those parts of the group that belong probably to the lower faunal zones, whose stratigraphic relations to the rest of the group are unknown, are included in the diagram but are not discussed below.

The establishment of the sequence of *Spondylospira lewesensis, Monotis subcircularis,* and *Halobia* faunas in the Laberge map-area by Tozer (1958) permits to some extent the resolution of the late Upper Triassic stratigraphy in Whitehorse map-area.

In the western belt, late Norian *Spondylospira lewesensis* limestone is underlain by 2,500 feet of conglomerate and volcanic greywacke grading downward into volcanic breccia with intercalated andesite and basalt flows. These rocks lie disconformably on clastic beds containing an early Norian or late Karnian *Halobia* fauna. The Norian rocks probably had their source about 5 miles to the west of Ibex River, since beds beneath *Spondylospira lewesensis* limestone grade eastward from those containing fragments a foot across, into arenites (*see* Fig. 3, in pocket).

In the central belt around Cap Creek, *Spondylospira lewesensis* limestone is underlain by as much as 6,000 feet of graded-bedded greywacke, siltstone, and argillite containing Norian or late Norian *Monotis* cf. *subcircularis* Gabb near the top of the section. Conglomerate and biohermal limestone occur locally in the lower beds, and greenstone in the lowest. This indicates that during most of the Norian, at least, fine clastic sediments were deposited in this area.

The thick clastic assemblage that underlies *Spondylospira lewesensis* west of M'Clintock River appears to continue east of Marsh Lake to Judas Creek. The continuity of its outcrops is broken where altered volcanic rocks, perhaps related to the greenstones in the lowest zones west of M'Clintock River, appear to be faulted against the upper beds of the Lewes River group.

In the northeastern belt, late Norian clastic beds containing *Spondylospira lewesensis* fauna are interbedded with coralline limestone and are underlain by at least 1,200 feet of interbedded gritty greywacke, argillite, crinoidal limestone, and some pea-sized to walnut-sized conglomerate. Such a Norian or late Norian assemblage was probably deposited nearer to shore than the Norian graded-bedded, fine clastic sequence around Cap Creek.

The record of the early upper Triassic in Whitehorse map-area is fragmentary. Volcanic rocks were laid down mainly in the western belt, and volcanic rocks, limy muds, and sands were deposited in the rest of the area. The record for late Upper Triassic time is more complete. During the late Karnian or early Norian, limy muds and rapidly deposited sands and gravel derived from a mafic volcanic terrain were deposited in areas in the western belt. Meanwhile, graded beds of mud, silt, and sand, minor gravel, some reef limestone, and possibly some volcanic rocks, accumulated in the central belt. Part of the western belt may have been emergent in the early Norian.

During most of the Norian, clastic sediments, partly of volcanic origin were deposited in a basin or trough whose borders were near the western and northeastern limits of Upper Triassic outcrops.

In the late Norian, clastic debris ceased to be supplied to the basin, except locally from the northeast. Instead, limy muds were deposited completely across the basin.

Laberge Group

Distribution

The Jurassic Laberge group is mainly restricted to a belt about 25 miles wide extending southeast from the northern border of the map-area west of Lake Laberge to Tagish, and underlies an area of about 640 square miles. Rocks probably belonging to the Laberge group, but not differentiated from the Lewes River group, occur near Teslin River and east of Marsh Lake.

Age

The Laberge group in the Lewes and Nordenskiöld Rivers coal district was first described by Cairnes (1910, p. 30) as the Laberge series, of Jurassic or Cretaceous age. S. S. Buckman reported that the fossils in the Laberge series of the Whitehorse district ranged from middle Lias to lower Middle Jurassic (Cockfield and Bell, 1926, p. 21).

Fossil collections from Whitehorse map-area are as follows, including Tables VII, VIII, IX and X.

Probably Lower Lias

(23) "*Arnioceras*"(?) sp.: from limy argillite 2½ miles northeast of Takhini Hotspring. F. H. McLearn dated this collection as probably lower Lias.

Table VII

Middle Lias Fossils

Localities	24	25	26	27	28	29	30	31
Pelecypods	–	–	–	–	–	–	–	x
Amaltheus stockesi (J. Sowerby)	–	x	x	x	–	x	–	x
Arieticeras algovianum (Oppel)	x	x	x	x	x	x	x	x
Leptaleoceras pseudoradians (Reynès)	–	x	x	–	–	x	x	–
Belemnite fragment	x	–	–	–	–	–	–	–

Collections 24 to 31 (GSC Nos. 24830 to 24837) are from ten different frost-shattered outcrops of argillite, siltstone, and greywacke at elevation 5,200 feet on the ridge between Idaho Hill and Mount Bush.

The fossils were examined by H. Frebold who stated that *Amaltheus stockesi* (J. Sowerby) indicates clearly the presence of the upper part of the Pliensbachian stage (middle Lias). In most of the collections this species is associated with *Arieticeras algovianum* (Oppel) and *Leptaleoceras pseudoradians* (Reynès) which in certain parts of Europe are common in beds with *Amaltheus.*

Table VIII

Upper Lias Fossils

Localities	32	33	34	35	36	37	38
"*Harpoceras*" sp.	x	x	x	–	–	–	–
"*Harpoceras*" gen. et sp. indet.	–	–	–	x	x	x	x
Dumorteria ?	–	–	–	x	x	x	–

(32) From black, rusty-weathering argillite 3½ miles northwest of the junction of Lewes and Takhini Rivers.
(33) From black argillite 1 mile west of south end of Fish Lake.
(34) From shales 4½ miles southeast of the junction of Ibex River and Jackson Creek.
(35) No. 17322; from argillite and siltstone at elevation 5,700 feet, 3 miles northeast of Dundalk.
(36) No. 20318; from siltstone at elevation 6,500 feet, 3 miles northeast of Dundalk.
(37) No. 20307; from argillite 2½ miles east-southeast of Mount Lorne.
(38) No. 20306; from argillite at elevation 3,500 feet, east of Annie Lake.

F. H. McLearn examined collections 32 to 34. H. Frebold reported on collections 35 to 38. The ammonites in collection 35 according to Frebold are for the most part indeterminable Hildoceraceae. Besides, *Dumortieria* or *Catulloceras* has been found. The age of this fauna is upper Lias, probably late Toarcian.

Of collections 36 to 38, Frebold stated that the fossils are poorly preserved so that detailed determinations could not be made. Most of the ammonoids, however, belong to the Hildoceraceae, and several genera are present. The frequence of ammonoids is remarkable.

According to Frebold "the fauna belongs to the upper part of the Lower Jurassic, the Toarcian."

McLearn examined and dated the following collections.

Table IX

Lower Jurassic Fossils

Localities	39	40	41	42	43	44	45	46
"*Lioceras*" sp	x	x	x	–	–	–	x	–
"*Deroceras*" ? sp	–	–	–	x	–	–	–	–
"*Arietites*" ? sp	–	–	–	–	x	x	–	–
"*Arnioceras*" ? sp	–	–	–	–	–	–	–	x
Dactylioceras ? sp	x	–	–	–	–	–	–	–

(39) From cherty argillite 2¾ miles south of north border of map-area, 4½ miles west of south end of Lake Laberge.
(40) From argillite 3¼ miles south of north border of map-area, 6 miles west of south end of Lake Laberge.
(41) From argillite 4 miles south of north border of map-area, 6½ miles west of south end of Lake Laberge.
(42) From argillite 1¼ miles south of north border of map-area and 4 miles west of Lake Laberge.
(43) From argillite ¾ mile southeast of Fish Lake.
(44) From argillite 1¾ miles east-northeast of south end of Fish Lake.
(45) From silty argillite 1½ miles west of south end of Fish Lake.
(46) From greywacke near west shore of central part of Fish Lake, near base of group.

Table X

Probable Lower Jurassic Fossils

Localities	47	48	49
Posidonia n. sp	–	x	x
Dactylioceras sp	x	–	–
Dactylioceras ? sp	–	–	x

(47) From dark shale 4 miles northwest of the junction of Lewes and Takhini Rivers.
(48) From cherty argillite 3½ miles east of Fish Lake and 3 miles south of Mount McIntyre.
(49) From cherty argillite 1½ miles south of Golden Horn Mountain.

Late Lower or Early Middle Jurassic Fossils

(50) *Coeloceras* ? sp. From argillite ¾ mile south of the north border of the map-area, 7 miles east of Little River.
(51) *Stephanoceras* ? sp. From argillite 1½ miles east-southeast of the south end of Fish Lake.

In summary, the Laberge group in Whitehorse map-area contains fossils ranging from lower Lias to early Middle Jurassic.

Stratigraphy

The area over which the Laberge group outcrops is divisible into two belts. Only the western belt contains fossiliferous rocks. The variable stratigraphy both along and across strike necessitates the subdivision of these belts into several areas for description purposes.

Western Belt

The western belt lies west of Yukon River and Marsh Lake. In the following, a comparison is made, with the aid of a few diagnostic ammonites, of the gross character and stratigraphy in the different parts, beginning with the northernmost area.

Area North of Takhini River—Northeast of Takhini Hotspring the Laberge group is deformed into a broad northwestward plunging syncline. Farther northeast the folds are tighter, until near Lake Laberge, folds cannot be recognized for lack of features to identify tops of beds. The following section is from the south limb of the broad syncline.

Top not exposed	Thickness (feet)
Massive, poorly bedded grey-green greywacke; possibly crystal tuff, argillite, and graded-bedded siltstone and argillite	5,000+
Conglomerate, containing principally volcanic and granitic fragments up to 2 feet across and including lenses of greywacke	1,000–1,500
Greyish green, well-bedded greywacke	300–500
Upper Triassic limestone	
Total	6,500+

In the upper part of the section, the outcrops are mainly of greywacke, but softer argillaceous rocks may underlie much of the intervening drift-covered areas.

Conglomerate lies 1,200 feet stratigraphically below probably upper Lias "*Harpoceras*" sp. on the south limb of the syncline. Similar conglomerate is only 200 feet below lower Lias *Arnioceras* ? sp. 2½ miles to the northwest. It appears then, that in this sector, only about 1,000 feet of fine clastic rocks was laid down during the middle Lias.

Conglomerate, similar to that in the above section but locally including boulders 4 feet across (*see* Fig. 6), occurs on the northeast limb of the broad syncline and in the closely folded rocks west of Upper Laberge.

An isolated section 4 miles west of Flat Mountain comprises 800 feet of argillite containing *Coeloceras* ? sp. or a similar genus of late Lower (?) or early Middle Jurassic age. This argillite is overlain by 1,700 feet of interbedded argillite, quartzose siltstone, greywacke, and chert, and quartz-pebble conglomerate in one or more beds about 50 feet thick. The greywacke is commonly in graded beds 4 to 6 inches thick, locally containing platy fragments of argillite stripped from the top of the underlying bed.

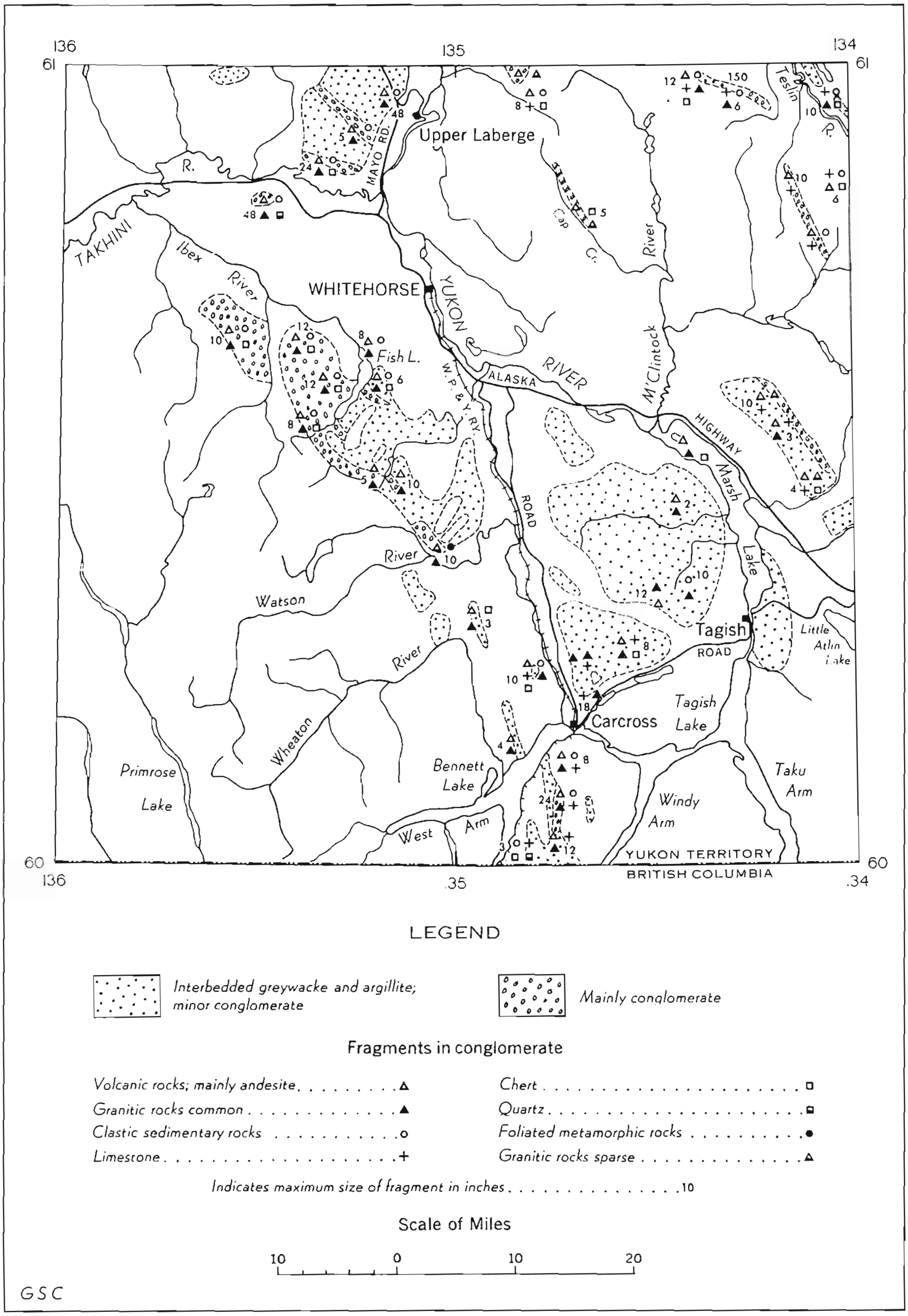

Figure 6. *Map showing distribution, composition, and maximum fragment size of Lower Jurassic conglomerates in Whitehorse map-area.*

Fish Lake Syncline and Surrounding Area—This includes the part of the Laberge group west of Ibex River, in the Fish Lake syncline, and northeast of Fish Lake.

The most complete sections are on the limbs of the Fish Lake syncline, and the following is from the southwest limb west of Fish Lake.

	Thickness (feet)
Top not exposed	
Various amounts of greyish green greywacke and argillite; subordinate arkose and conglomerate containing upper Lias "*Harpoceras*" sp. in the lower part	1,000-2,500+
Principally cobble conglomerate, locally with boulder beds; minor greywacke and argillite layers containing upper Lias "*Harpoceras*" sp. in upper part	4,500
Disconformity	
Lewes River group	
Total	6,500

The lower part of the section on the northeast limb west of Fish Lake contains more argillite and greywacke, and less conglomerate, than on the southwest limb. Argillite near the base of the group has *Arnioceras* ? sp.

Nonfossiliferous, northeasterly dipping beds west of Ibex River are described by Fyles (1950, p. 34) as follows:

	Thickness (feet)
Top not exposed	
Yellow- and brown-weathering quartzose sandstone, quartz-pebble conglomerate, and greywacke	500-1,000
Argillite; minor greywacke and arkose	1,000-1,500
Mainly cobble and boulder conglomerate, including subordinate greywacke	4,000+
Base not exposed	
Total	6,000+

The coarse conglomerate is similar to that in the lower division of the southwest limb of the Fish Lake syncline, west of Fish Lake. The quartz-pebble conglomerate is like that west of Flat Mountain.

Isolated outcrops of boulder-conglomerate, which carry abundant granitic fragments and probably belong to the Laberge group, are those associated with Lewes River group rocks south of Takhini, those isolated in drift south of Jackson Lakes, and those above Upper Triassic limestone east and northeast of Fish Lake.

The following section is from the southwest limb of the Fish Lake syncline.

	Thickness (feet)
Top not exposed	
Argillite, quartzite, quartzitic siltstone; minor conglomerate	300
Mainly brown sandstone, siltstone, quartzite; minor quartz-pebble conglomerate and argillite	300
Principally argillite; some sandstone, siltstone and greywacke	1,000
Greywacke, some argillite	400
Conglomerate, greywacke, and arkose	2,000
Rusty-brown-weathering black argillite	2,000
Conglomerate; minor greywacke	1,500-2,000
Base not exposed	
Total	8,000+

Ammonites found in the argillites beneath the quartz-pebble conglomerate are so poorly preserved that their identification and the consequent assignment of age to the beds containing them is uncertain. They include a *Stephanoceras* ? sp. or similar genus of late Lower or early Middle Jurassic age, and a questionable *Arietites* ? sp. dated merely as Lower Jurassic by McLearn but which appears to be stratigraphically above the *Stephanoceras* ? sp. Ordinarily *Arietites* sp. lies well below *Stephanoceras* sp. This apparent reversal in the stratigraphic position of the fossils may be due to the presence of an unrecognized fault separating the beds containing them, or more probably, to an incorrect palæontological identification, due to the poor preservation of the fossils.

The amount of conglomerate in the lower part of the section decreases southward toward Watson River. At the mouth of Two Horse Creek, the boulder-conglomerate is only 1,500 feet thick. There, it disconformably overlies the Lewes River group and is succeeded by an unknown thickness of poorly exposed argillite, siltstone, and greywacke, in the centre of the syncline.

Quartz-pebble conglomerate near the top of the exposed section extends as far southeast as Double Mountain. It may be Middle Jurassic as it lies several hundred feet above *Stephanoceras* ? sp. or similar genus, and is similar to conglomerate overlying late Lower or early Middle Jurassic *Coeloceras* ? sp. or similar genus, west of Flat Mountain.

On the northeast limb of the syncline, on the east side of Fish Lake, Fyles (1950, p. 33) measured the following incomplete section.

	Thickness (feet)
Top not exposed	
Mixed argillite, sandstone, siltstone, quartzite, and fine conglomerate	1,000
Principally sandstone, siltstone, quartzite, and quartz-pebble conglomerate	500
Conglomerate and greywacke; a few thin beds of argillite	2,500
Total	4,000

The lowest conglomerate in this section thins toward Golden Horn Mountain and is missing southeast of it, where interbedded argillite and siltstone overlie the Lewes River group.

The northeast limb of the Fish Lake syncline is about half as thick as the southwest limb. Southeast of Fish Lake the greater thickness of the southwest limb is probably caused by repetition of beds, as evidenced by two boulder-conglomerates, each overlain by argillaceous rocks. West of Fish Lake the southwest limb may be repeated by faults, or the northeast limb may have moved differentially up with respect to the southwest limb along a fault near the axis of the syncline.

In summary, the lower part of the Laberge group northwest of Fish Lake underlies beds containing upper Lias fossils. It is chiefly conglomeratic, and more than 4,000 feet thick (*see* Fig. 5, in pocket).

Conglomerate beds thin toward the northeast, east, and southeast of Fish Lake. Evidence for this is the lesser amount of conglomerate in the northeast limb than in the southwest limb of the syncline; it decreases from 2,500 feet to nothing in the 3 miles toward Golden Horn Mountain, and to 1,500 feet near the mouth of Two Horse Creek. A quartz-pebble conglomerate that may be of Middle Jurassic age, occurs near the top of the exposed section. This conglomerate is separated from the thick conglomerate lower in the group by about 1,500 feet of upper Liassic argillites and arenites.

Annie Lake Area—West of Annie Lake valley the Laberge group is isolated by granitic intrusions and volcanic rocks. A prominent band of rusty argillites, locally metamorphosed to hornfels, extends from Red Ridge to the east ridge of Mount Perkins but does not appear on Idaho Hill or Mount Follé. There, poorly bedded greywacke predominates. Middle Lias ammonites were obtained from Idaho Hill. The lower slopes at the north end of Gray Ridge reveal the following section.

	Thickness (feet)
Hutshi group	
Angular Unconformity	
Interbedded greywacke and argillite in upper part; in lower part, argillites and siltstones containing upper Lias *Hildoceraceae*	3,300
Conglomerate with granitic, volcanic, and chert fragments; interbeds of greywacke	700
Volcanic breccia (Lewes River group(?))	Unknown

Isolated exposures at the south end of Gray Ridge comprise friable quartzose sandstone and 'granite'-bearing conglomerate overlying volcanic breccia probably of the Lewes River group.

Mount Lansdowne Area—This area is bounded by the White Pass and Yukon Railway, the Alaska Highway, and Carcross-Tagish road. Though outcrops are sparse, folding appears to be more intense in the eastern part near Marsh Lake. There, argillaceous beds and, to some extent greywacke, are characterized by slaty cleavage that strikes parallel with bedding, but dips in different directions.

In general, in the western part of this area the Laberge group comprises quartz-bearing greywacke, locally graded in beds up to 20 feet thick, and minor interbedded argillite and siltstone in graded layers about an inch thick. These contain upper Lias *Hildoceraceae*. Two types of conglomerate—one mainly of granitic and volcanic rocks, the other also including limestone—occur in the southwestern part of this area (*see* Fig. 6). Their stratigraphic position is not known.

An incomplete section from the southern slopes of Mount Lansdowne is typical of the western part of this area.

	Thickness (feet)
Top not exposed	
Quartz-bearing greywacke	1,100
Banded grey to black argillite and siltstone (argillite mainly in upper part)	1,500
Coarse grit comprising angular quartz and feldspar grains and rock fragments including a few rounded pebbles, grading upward from pebbly quartz-bearing greywacke to conglomerate composed principally of volcanic pebbles up to 2 inches and some interbedded argillite	200
Gritty quartz-bearing greywacke with faint traces of bedding	1,100
Conglomerate with boulders up to 12 inches—half porphyritic andesite with phenocrysts of hornblende and feldspar, and half granitic rocks; basal part contains beds of argillite and has an argillaceous matrix	700
Gritty, green, quartz-poor greywacke	Unknown
Base not exposed	

The upper and middle Lias ammonites collected by Cockfield and Bell (1926, p. 21) came from argillites on the west slope of Mount Lansdowne, probably corresponding to the argillite division above the upper conglomerate.

The lowland west of Marsh Lake and east of Tagish contains less conglomerate (*see* Fig. 5, in pocket) and greywacke, and more argillite, in thinner, graded beds, than farther west. The graded sequence includes abundant load casts, small-scale channelling and scour, slump structures like those described by Kuenen (1953, pp. 1054-1055), crossbedding restricted to beds a few inches thick, and greywacke beds containing unoriented angular fragments half an inch across with a random orientation. These all indicate disturbed conditions during sedimentation. Northward, the outcrops are mainly slate and argillite.

Montana Mountain Area—This area embraces the Laberge group between Bennett Lake and Windy Arm. The following section 3 miles southeast of Watson, on the east shore of Bennett Lake, contains the only Jurassic fossils in this area.

Top not exposed	Thickness (feet)
Purple greywacke	150+
Conglomerate with greywacke interbeds, one of which shows crossbedding and current-ripple marks	1,670
Coarse brown sandstone grading upward into finely banded sandstone	670
Thin-bedded, platy argillite; limy siltstone, and siltstone containing upper Lias (probably late Toarcian) ammonites	190
Grey, massive greywacke	60
Dark grey-green argillite	330
Interbedded, thin-bedded argillite and greywacke	240
Massive, grey, gritty greywacke	190
Interbedded argillite and greywacke	240
Grey and brown argillite	145
Grey-green greywacke, some conglomerate comprising volcanic fragments	95
Thin-bedded, grey argillite and limy siltstone containing upper Lias (Toarcian) *Hildoceraceae* in upper part	670
Massive, grey-brown, coarsely jointed greywacke	45
Gap in outcrops	480
Rusty-brown sandstone and slaty argillite	45
Limy, grey greywacke and siltstone	10
Disconformity (?)	
Lewes River group volcanic breccia	
Total	5,230+

The rocks show a rapid variation in stratigraphy along strike (*see* Fig. 7). North of this section, more argillite and less greywacke underlie the upper conglomerate, which splits into two tongues that wedge out northward and are separated by greywacke.

South of the section, the top of the middle conglomerate in Figure 7 is parallel with the bedding of the overlying rocks whereas its base is convex downward. The shape of the cross-section of this lens suggests that the conglomerate, the central part of which is 900 feet thick, was deposited in a channel cut into the underlying strata.

Figure 7. *Sketch from vertical air photograph of terrain underlain mainly by Laberge group east of Bennett Lake. Note trough-like cross-section of the middle conglomerate body and more widespread conglomerate above. Topography illustrated by form lines.*

Farther south, 2½ miles southwest of Montana Mountain, 'granite'-bearing conglomerate overlies volcanic rocks that probably belong to the Lewes River group. The relationship of this conglomerate to those in the section southeast of Watson is not known.

Purplish greywacke, similar to that above the upper conglomerate in the foregoing section, is interbedded with argillite and siltstone north and east of Montana Mountain. Interbedded brownish greywacke, siltstone, and argillite, and some conglomerate devoid of granitic fragments, comprise the Laberge group near the southern border of the map-area.

Eastern Belt

The eastern belt of the Laberge group lies east of Yukon River and the Alaska Highway. It includes nonfossiliferous sedimentary strata marked at their base by widespread conglomerate that overlies the uppermost faunal zone (*Spondylospira lewesensis*) of the Lewes River group. The conglomerate is locally 500 feet thick and contains volcanic, greywacke, limestone, chert, and granitic cobbles and boulders (*see* Fig. 6). It extends for 40 miles over much of this belt. This conglomerate probably marks a break, or at least a distinct change in the sedimentation, related to similar changes in the western belt at the end of the Triassic.

Western Zone—The Laberge group in the centre of the syncline north of Joe Creek and in the lowest outcrops in Cap Creek consists of conglomerate. Fragments in the conglomerate are up to 8 inches across and are composed of melanocratic volcanic rocks, feldspar porphyry, minor greywacke, chert, and limestone, and a few of granitic rocks.

Similar conglomerate, up to 500 feet thick, outcrops discontinuously from peak 5,125 to a point 4 miles northwest of Mount Michie. It is overlain by a west-dipping, apparently homoclinal sequence of argillite and subordinate siltstone. This sequence, which locally contains graded beds, is possibly as thick as 5,000 feet. Float, similar to the uppermost siltstone, contains poorly preserved ammonoids considered by H. Frebold to be a little older than the Toarcian (upper Lias).

Conglomerate, similar to that of the widespread basal bed, occurs 2 miles west of Mount Michie. However, as several hundred feet of sediments separate the uppermost Lewes River limestone from this conglomerate, it probably is higher in the Laberge group.

Teslin River Area—A conglomerate of variable composition and texture (*see* Fig. 6) overlies the upper faunal zone of the Lewes River group and extends for 12 miles into the adjoining Teslin map-area (Mulligan, 1955, p. 9). It marks the base of the Laberge group and contains fragments of green volcanic rocks, greywacke, chert, limestone similar to that in the underlying Lewes River group, and in the northern outcrops, some granitic rocks. The size of the layer fragments ranges from 6 to 12 inches, except north of Sheldon Creek where the conglomerate contains limestone blocks more than 12 feet across (*see* Fig. 6).

In several places, the conglomerate is overlain by a graded sequence of greywacke, siltstone, and argillite.

Relations to Other Formations

On the southwest limb of the Fish Lake syncline the Laberge group disconformably overlies the Lewes River group, cutting out at least 700 feet of beds including limestone containing *Spondylospira lewesensis* fauna. The disconformity is less on the northeast limb where arenaceous beds separate the Laberge conglomerate from the *Spondylospira lewesensis* limestone. On Canyon Mountain and east of Cowley Creek the two groups may be conformable.

Conglomerate at the base of the Laberge group extends from north of Joe Creek southeastward for nearly 40 miles, almost to Mount Michie. Mostly it lies more than 1,100 feet above discontinuous beds of the uppermost limestone in the Lewes River group, but locally it lies directly on them. If the limestone beds are all of the same age along this belt, the Laberge group probably lies disconformably on the Lewes River group. If not, a disconformity is not necessarily indicated. The abrupt change in the character of the sedimentation, however, probably records a disconformity elsewhere to the east.

In most places in the part of the eastern belt near Teslin River, the structures in both the Lewes River and Laberge groups are parallel. Lees (1936, p. 11) stated that, on Sheldon Creek, the two groups are separated by an angular unconformity, but the present study did not confirm this, as conglomerate overlying limestone appears to follow around the nose of a southeast-plunging fold. In view of the complex structure in this region, angular discordance is difficult to recognize. Disconformity, at least, between the two groups is indicated north of Sheldon Creek where locally-derived blocks of limestone, more than 12 feet across, are mixed with basal Laberge conglomerate.

Although the Laberge group is overlain apparently conformably by the Tantalus formation in the Carmacks map-area (Bostock, 1936, p. 28), the two units are in fault-contact on the southwest limb of the Fish Lake syncline and their relations are obscure west of Annie Lake where the Laberge group is poorly bedded. It appears that part of the Laberge group is missing west of Annie Lake because not more than 2,500 feet of strata, including mainly greywacke and a thin bed of limestone near the top, can be accommodated between fossiliferous middle Lias rocks and the fossiliferous Neocomian (early Lower Cretaceous) or possibly Portlandian (late Upper Jurassic) Tantalus formation (Bell, 1956, p. 27). This is in contrast to the 3,000 feet or so of beds that overlie upper Lias fossils across the valley, east of Annie Lake. There is no physiographic expression for a fault, and therefore, the Tantalus formation may lie unconformably on the Laberge group in this locality. The Laberge group is overlain with angular unconformity by the Hutshi group west of Lake Laberge, on Gray Ridge, and on Montana Mountain.

The Laberge group is intruded by sheared serpentinite west of Lake Laberge, by serpentinized dunite north of Montana Mountain, and by granitic rocks in many places.

Plate XII. *Conglomerate from the northeast limb of the Fish Lake syncline west of Fish Lake. Note abundance of granitic rocks and the rounded character of the cobbles.*

Lithology

The conglomerates and greywacke merit special description in order to resolve the sedimentary and tectonic history of the Laberge group.

Conglomerate

The following description includes all the conglomerates except the quartz-pebble conglomerate which is possibly of Middle Jurassic age.

The conglomerates are poorly sorted and show no imbrication. Their fragments are moderately well rounded (*see* Plate XII), the granitic fragments being better rounded and more spherical than the others. They are coarse, the fragments being principally cobbles and boulders. Some rounded boulders in the western belt are 4 feet across.

In general, green volcanic rocks are the most abundant (*see* Fig. 6). These include greenstone, green porphyritic andesite with plagioclase, augite, or hornblende phenocrysts, porphyritic basalt with plagioclase phenocrysts, and greyish green banded tuffs. Granitic fragments are locally more abundant than volcanic fragments, but generally less so (*see* Plate XII). They include both foliated and non-foliated, equigranular rocks resembling in the field all the granitic intrusions except the latest leucocratic granites and the pink quartz monzonite. Micrometric analyses of typical samples from the granitic fragments (*see* Table XI, and Fig. 12, p. 94) show that their compositions fall entirely within the granodiorite and quartz diorite fields and do not approach those of the latest intrusions.

Table XI

Volume Percentage of Essential Constituents of Granitic Fragments from Conglomerate of the Laberge Group, Whitehorse Map-area

Specimen	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
Quartz	22	17	16	32	21	18	35	15	21	17	15	19	25	20	15
Potash feldspar	5	27	5	30	—}	77	3	13	17	3	31	15	30	10	28
Plagioclase	64	46	76	38	75}		55	58	55	72	43	62	39	65	48
Biotite	1	x}	2	—	3	3	7	3	3	4	0.5	—	1	3	4
Hornblende	8	8}		—	—	—	—	9	3.5	4	8.5	3	3.5	1.5	4
Accessory minerals	—	2	1	—	1	2	—	2	0.5	—	2	1	1.5	0.5	1
Percentage An* in plagioclase	?	36	29	15	30?	20	?	32	35?	?	6	32	?	25?	30?

NOTE: Stained thin sections (Chayes, 1952) counted with a point counter (point spacing 0.33 mm., traverse spacing 1 mm.; a minimum of 600 points counted).

*Determined by Michel-Levy method of maximum extinction angles of albite twins in sections normal to (010).

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In the western belt, volcanic and granitic rocks locally comprise as much as 60 per cent of the volume of the conglomerate. The remaining common fragments are greywacke, argillite, limestone, grey and greyish green chert, quartzite, and, rarely, foliated metamorphic rocks. The matrix which is in general a greyish green greywacke but may locally be arkosic, commonly occupies about 10 to 20 per cent of the rock by volume. Some beds or elongate lenses of greywacke and argillite, 10 to 20 feet thick, are sparsely scattered through the conglomerates.

Origin of the Conglomerates in the Western Belt—Ammonites in beds associated with the conglomerates indicate that at least part of the conglomerates were deposited in marine waters. On the other hand some conglomerate, such as that east of Bennett Lake, was deposited in a restricted channel and was probably a river deposit. The conglomerates overlying this body have a wider lateral extent and may be parts of an alluvial fan. Conglomerate in the northwestern part of the Fish Lake syncline wedges out, both along and across the strike, and as the conglomerates in the lower part of the group in this region are more widespread than those in the upper part, they probably constitute a lens representing several coalesced alluvial fans or deltas. The large size and roundness of the fragments suggests that the fans formed at the mouths of large streams with steep gradients that carried detritus to the coast from nearby highlands.

Some of the thinner bodies may be marine conglomerates formed by wave action along a rugged coast.

The Laberge group lacks obvious primary structures indicating the direction from which its sediments were transported. However, as the sections near Yukon River valley contain less conglomerate than those farther west and as individual beds of conglomerate wedge out in the same direction, the conglomerates were probably derived from the west.

Some idea of the distance the fragments in these conglomerates were transported can be gained by comparing the Laberge conglomerate with the Uslika formation in Aiken Lake map-area, British Columbia (Roots, 1954, p. 187). The Uslika formation, provisionally of late Lower Cretaceous age, consists mainly of conglomerate at least 4,200 feet thick. This is composed principally of well-rounded volcanic and granitic fragments up to 10 inches in diameter. The granitic fragments are similar to rocks of the Omineca intrusions and have been derived from them at a time when they were less extensive than they are now. The conglomerate is about 20 miles east of the central part of the intrusions and, as Roots favours an hypothesis in which the Uslika formation moved eastward along a thrust fault, fragments 10 inches across were probably transported less than 20 miles. Some of the conglomerates in the western belt are as thick as the Uslika conglomerate and a few contain boulders considerably larger—some four times as large—as those in the Uslika conglomerate. Hence, the fragments in the conglomerates of the western belt, which were probably deposited under much the same conditions as those of the Uslika conglomerate, were probably transported eastward much less than 20 miles, perhaps only half that distance.

Conglomerates of the Eastern Belt—The following evidence suggests that the conglomerates in the eastern belt were derived from the east or northeast.

(1) Limestone blocks 12 feet across indicate that some of the conglomerate is of local derivation, perhaps as talus at the foot of a cliff along a sea-coast.

(2) Maximum fragment size of the conglomerates in the western part of this belt increases eastward.

(3) The amount of granitic material in the conglomerates also increases northeastward.

(4) The granitic material could not have come from the west because the thick conglomerates in the Fish Lake syncline wedge out and disappear toward Yukon River valley.

The form of the conglomerate in the eastern belt is different from that in the west. The basal conglomerate in the former is about 600 feet thick in the Mount M'Clintock region, about 500 feet thick around peak 5635 east of Marsh Lake, and about 150 feet thick north of Joe Creek. If the conglomerate at each locality is part of a single body, it is more probably in a thin sheet than a series of thick lenses, as is the conglomerates in the western belt.

Quartz- and Chert-pebble Conglomerate of Possible Middle Jurassic Age—The possibly Middle Jurassic quartz- and chert-pebble conglomerate in the upper beds of the Fish Lake syncline and west of Flat Mountain are well-sorted and contain well-rounded pebbles up to 2 inches in diameter. It probably accumulated in a less-active tectonic environment than did the coarse lenses lower in the Laberge group, or from a more distant, quartz-rich source.

Greywacke

The greywacke of the Laberge group resembles that of the Lewes River group in that it is poorly sorted, most of its grains are only slightly rounded, and it contains abundant volcanic-rock fragments. On the other hand it differs by being less indurated, lighter coloured, of slightly different composition, and by containing oval concretions of limy greywacke up to several feet across.

The most ubiquitous minerals in the Laberge group greywackes are quartz and feldspars. The average content of quartz is about 10 per cent, though locally it is more than 20 per cent (*see* Table XII). Of the feldspars, mottled, saussuritized plagioclase is the most prevalent, but slightly sericitized sodic plagioclase and potash feldspar are also prominent. The potash-feldspar content apparently bears no direct relationship to the amount of quartz in the host rock (*see* Fig. 8). Mafic minerals —hornblende predominating over biotite—constitute in one instance 19 per cent of the rock but rarely exceed 4 or 5 per cent.

Minor amounts of detrital epidote, iron ores, leucoxene, sphene, apatite, zircon, and rutile(?) are widespread. Volcanic-rock fragments are abundant but fragments of argillite, greywacke, chert, and some quartzite also occur. The matrix is

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Table XII

Volume Percentage of Essential Constituents of Arenites from Laberge Group

	Whitehorse Map-area																											
Sample	29[a]	30[a]	31[a]	32[a]	33[a]	34[a]	35[a]	36[a]	37[a]	38[a]	39[a]	40[a]	41[a]	42[a]	43[a]	44[a]	45[a]	46	47	48	49	50	51	52	53	54	55	56
Quartz	9	5	7	8	7	20	14	18	14	9	21	20	8	12	5	8	15	3	12	13	5	8	7	8	8	22	13	6
Potash feldspar	3	5	—	—	—	15	10	9	17	6	2	5	22	—	8	1	12	5	7	—	4	—	10	—	—	5	9	4
Plagioclase	34	36	40	58	49	49	38	37	32	36	40	54	29	37	33	18	40	26	40	30	44	42	42	41	38	46	44	30
Biotite	—	—	—	—	—	—	—	—	—	—	—	—	—	8	—	—	1	—	1	2	1	1	2	—	—	—	—	—
Hornblende	3	12	—	9	11	—	—	—	1	—	—	—	—		—	—		—	—	—	—	—	—	11	—	3	—	8
Matrix	36	42	34	25	33	16	37	35	33	38	34	16	41	28	43	73	18	31	33	30	30	31	34	40	28	11	33	39
Rock fragments	15	—	19	—	—	—	1	—	3	1	3	5	—	15	11	—	14	35	7	25	16	18	5	—	26	13	—	13
Iron ores	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Epidote	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—

	Whitehorse Map-area																				Laberge Map-area				Bennett Map-area	Atlin Map-area				
Sample	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	172 04	172 05	172 16	172 31	49-2[b] −15	94-[c] 4a	43A[c] −5	9A[c] −8	43A[c] −3	9a[c] −15
Quartz	11	10	5	7	9	6	10	1	12	7	11	15	15	11	4	7	7	—	8	8	3	7	13	6	7	7	3	4	5	10
Potash feldspar	6	4	11	8	—	—	12	—	17	8	6	8	10	6	12	3	6	—	—	12	6	17	5	11	33	—	1	2	—	26
Plagioclase	27	34	32	25	42	53	39	27	30	43	27	24	26	21	18	35	27	39	54	37	45	38	54	28		32	34	11	49	
Biotite	—	—	—	—	—	9	—	—	—	—	—	—	—	—	—	—	—	7	4	1	4	2	—	1	3	1	—	—	—	1
Hornblende	5	3	9	12	2	—	4	14	10	1	1	0.5	1	2	19	8	5	—					10			8	—	—	—	
Matrix	23	30	28	38	24	32	21	30	19	35	32	33	34	29	43	32	31	28	33	41	29	20	15	34	38	52	30	58	15	29
Rock fragments	25	7	15	—	23	—	14	28	13	6	22	19	12	29	4	15	24	23	1	1	13	16	3	20	19	—	32	25	31	32
Iron ores	—	12	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Epidote	3	—	—	—	—	—	—	—	—	—	1	0.5	2	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—

[a] Counted with an integrating stage, remainder counted with a point counter. (For details see Table V.)
[b] Thin section kindly loaned by R. L. Christie. [c] Counted by J. D. Aitken.

Location of samples in Figure 9, p. 68.

similar to that of the Lewes River greywacke, consisting essentially of finely comminuted plagioclase and quartz, and a shreddy mass of chlorite and secondary white mica.

Samples taken across strike along the section northeast of Takhini Hotspring (*see* Fig. 9, samples 46 to 50) and the section east of Bennett Lake (Fig. 9, samples 67 to 73) showed no progressive change in composition with time. The sampling was however too limited to be considered conclusive.

The samples of arenites from the Laberge group in adjacent areas have compositions similar to those from Whitehorse map-area (*see* Fig. 8).

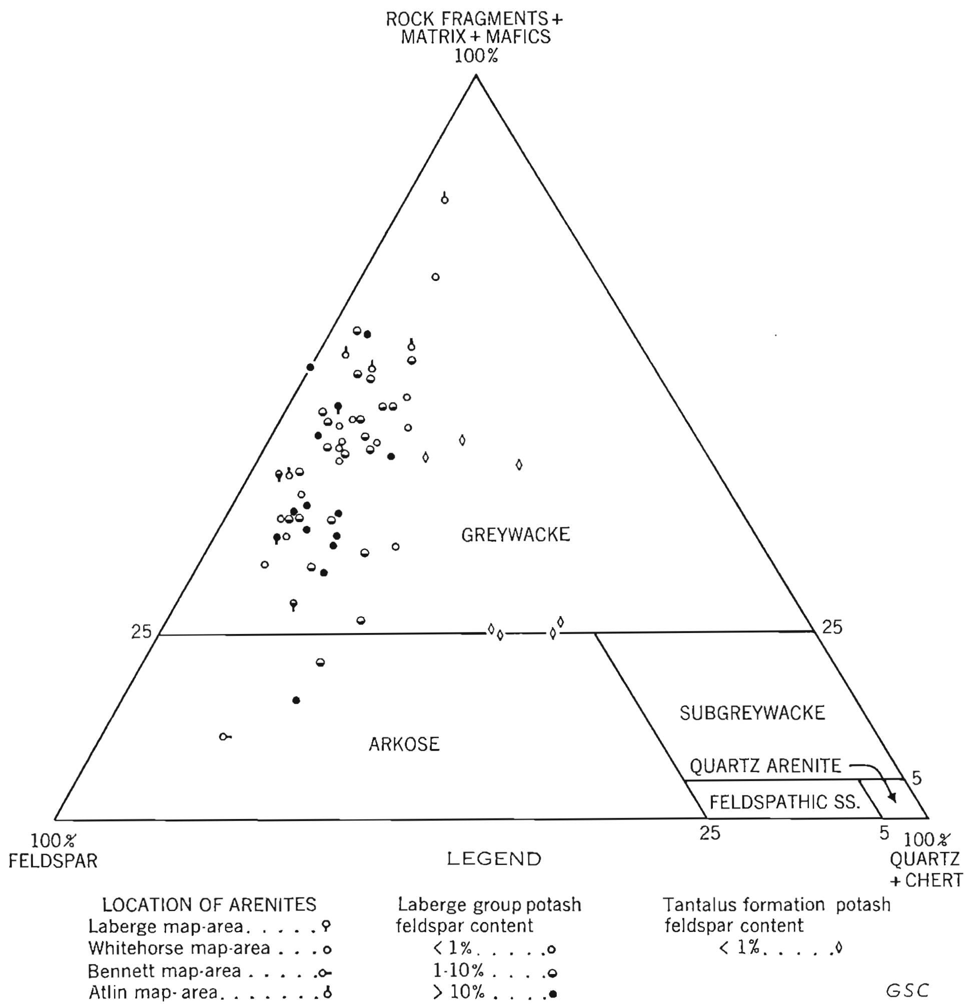

Figure 8. *Plot of the compositions (volume per cent) of arenites of the Laberge group from Whitehorse and adjacent map-areas.*

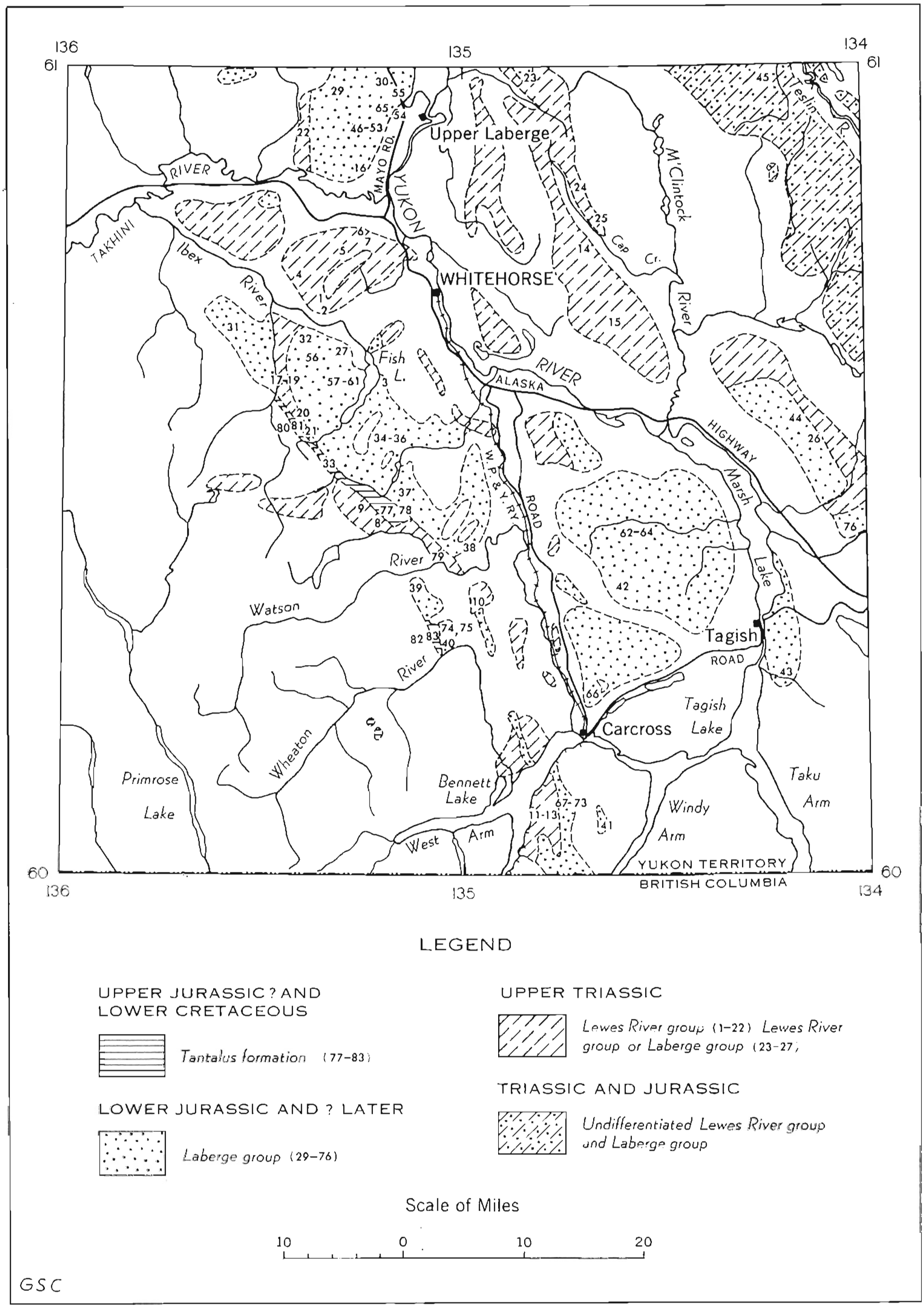

Figure 9. *Map showing location of Mesozoic arenites selected for micrometric analysis.*

Greywackes of the Laberge group contain, on an average, 6 or 7 per cent more quartz and about 5 or 6 per cent more potash feldspar (*see* Figures 4, 8, and 10) than those of the Lewes River group. This may be accounted for by a dilution of volcanic detritus by debris from a granitic or metamorphic terrain. The paucity of micaceous minerals and of strained elongated quartz grains in the greywacke, and the almost complete absence of metamorphic rocks in the conglomerates compared with the abundance of granitic debris, implies that the dilution was caused by material from a granitic terrain.

The dilution by granitic material even affected sediments deposited under the relatively quiet tectonic conditions existing east of Bennett Lake before either of the conglomerates at the top of the upper Lias strata were laid down. This is also true of those sediments interbedded with or overlying the conglomerates in the areas to the north.

In the upper part of the broad syncline northeast of Takhini Hotspring are some thick beds of grit containing angular quartz, euhedral, slightly altered plagioclase, hornblende, and about 40 per cent matrix material. Rock fragments are absent and they may be crystal tuffs.

Summary

The Laberge group in the western belt lies disconformably on the Lewes River group, and at least 700 feet of the underlying Upper Triassic rocks have been removed. Eastward the disconformity decreases until in Yukon River valley the Lewes River and Laberge groups may be conformable. The unconformity again increases northeastward, and near Teslin River it may be angular.

The sedimentary record of the Laberge group in the western belt is marked by coarse conglomerates, locally more than 4,500 feet thick, wedging out eastward and replaced by finer clastic rocks, which in some places are graded. It indicates that the coarse conglomerates represent mainly coarse alluvial fans at the mouths of powerful eastward-flowing streams draining highlands of volcanic and granitic rocks perhaps 10 miles from the coast. Some of the smaller bodies may be marine conglomerate formed by wave action along a rugged coast.

The conglomerates probably formed in response to rapid uplift, not everywhere synchronous, as is evidenced by their presence in the lower Lias northeast of Takhini Hotspring, throughout most of the Lias northwest of Fish Lake, and in the upper Lias or possibly the early Middle Jurassic east of Bennett Lake (*see* Fig. 5, in pocket).

The abrupt basal contacts and the coarseness of these conglomerates suggest that the uplifts began suddenly and were relatively rapid. Well-sorted and thin beds of quartzose conglomerate in the upper part of the Laberge group, except east of Bennett Lake, suggest that, by the Middle Jurassic, uplift or subsidence was slower, and the source, now rich in quartzose rocks, was perhaps more distant than before.

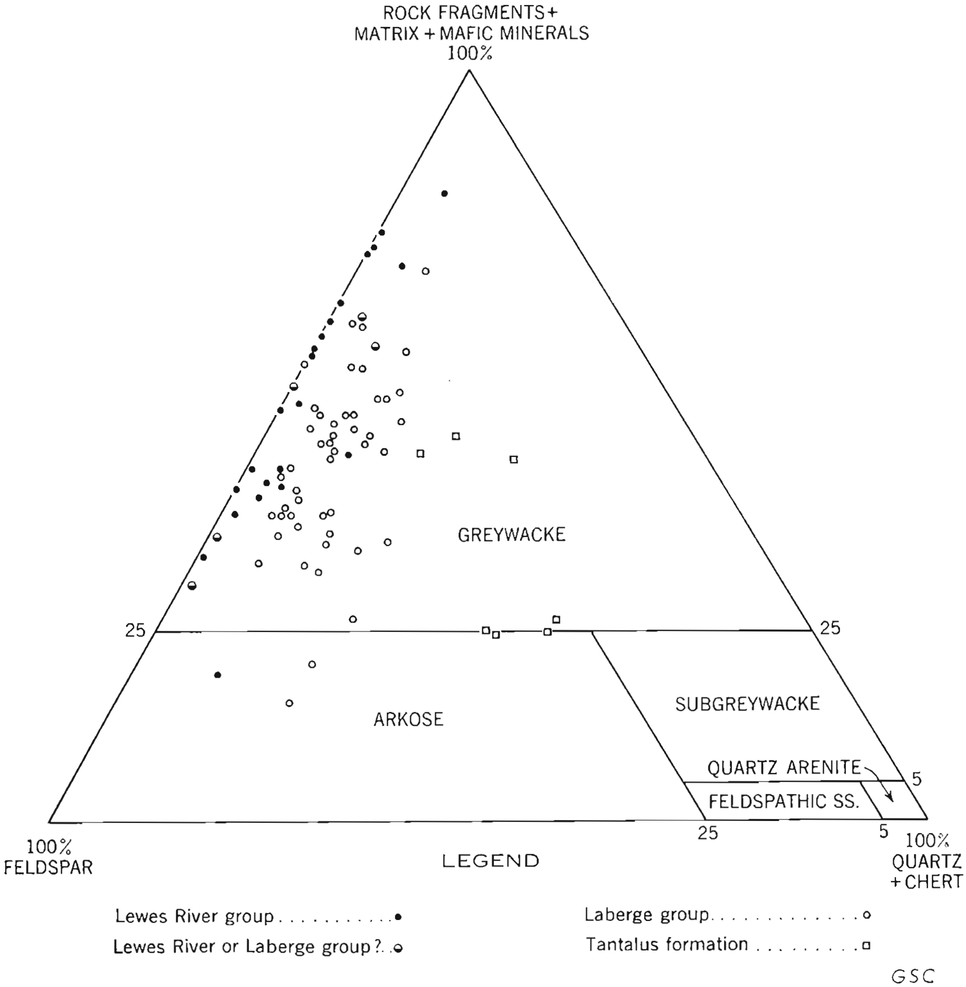

Figure 10. *Plot of the compositions (volume per cent) of Mesozoic arenites from Whitehorse map-area.*

The tectonics of the eastern belt during the Jurassic will remain obscure until it is known whether the basal conglomerates of the Laberge group, not more than 600 feet thick, are parts of the same bed in the northeastern and western parts of the belt. If so, a thin sheet is indicated, implying that the Laberge group lapped up onto the Upper Triassic and associated rocks to the northeast. If the age of the conglomerate in the two parts of the belt is different, then offlap is implied, in response to uplift of the eastern margin.

The basal conglomerate was probably derived from a source to the northeast, composed of volcanic rocks, limestone, and minor granitic rock with a lower relief than the source in the west.

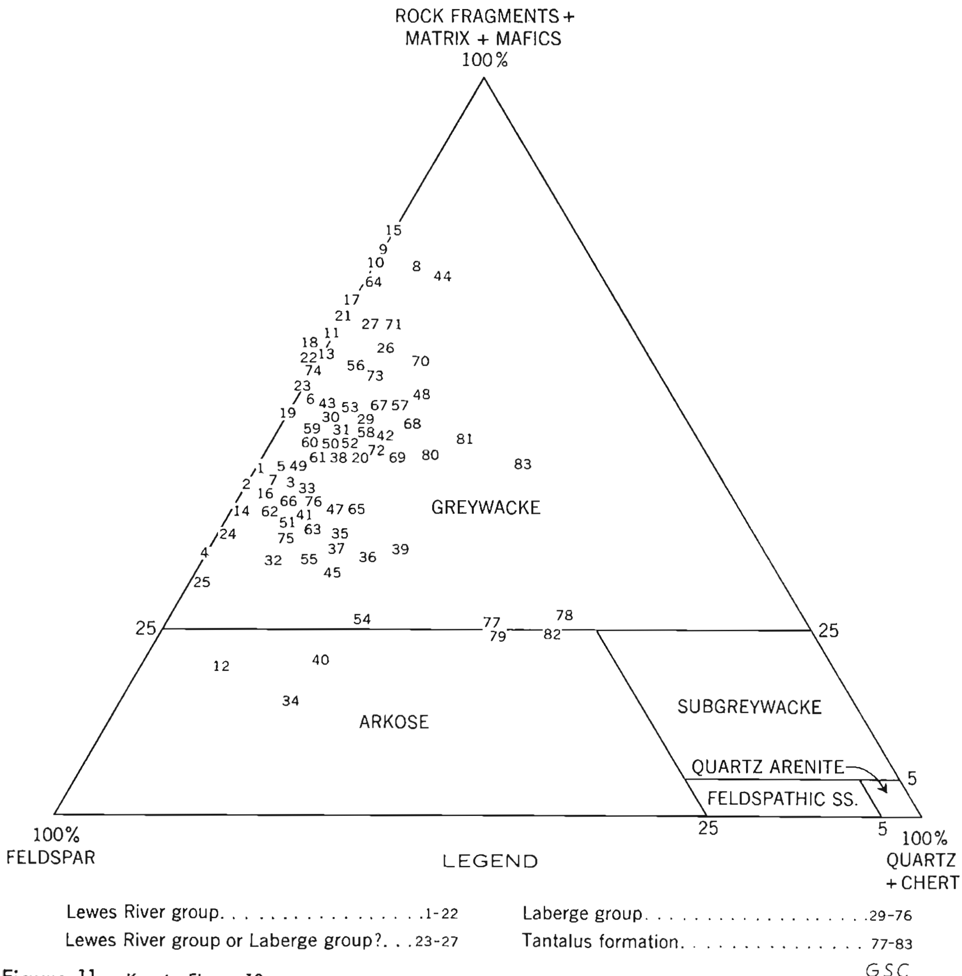

Figure 11. *Key to Figure 10.*

Tantalus Formation

Distribution

Interbedded quartzite- and chert-bearing conglomerate, sandstone, shale, and coal occur in discontinuous outcrops from Ibex River southeast to the mountains west of Annie Lake. Isolated outcrops of conglomerate, like those in this belt, are exposed on Carbon Hill. This assemblage was designated "Tantalus conglomerates" by Cairnes (1910, p. 38), as he regarded them to be part of the Tantalus conglomerate in the Lewes and Nordenskiöld Rivers coal district.

About 800 feet of strata are exposed east of Ibex River; about 5,000 feet, near Double Mountain; and 1,700 and 1,800 feet, west of Annie Lake (Cairnes, 1912, p. 58). The thick section near Double Mountain is possibly repeated by folding or faulting, as a characteristic conglomerate occurs at the base of the section and again in the middle. Outcrops are too sparse for the stratigraphy above each conglomerate to be compared.

Lithology

The following unpublished section, measured by J. G. Fyles east of Ibex River, illustrates the lithology of the formation.

Top not exposed

	Thickness (feet)
Quartzose sandstone	20
Conglomerate containing quartzite, quartz, and chert pebbles	50
Black, fissile shale	10
Pebble-conglomerate	50
Pea-sized conglomerate, gritty sandstone; minor black shale	75
Black shale	20
Grit, locally containing quartz pebbles	20
Shale	20
Conglomerate	unknown

Base not exposed

The conglomerates are well sorted and generally contain well-rounded pebbles commonly 1 inch and rarely 2 inches across. These pebbles are composed of white and grey quartz, quartzite, black and grey chert, one fragment of which contains radiolaria (?), and minor argillite. Some subangular chert occurs west of Annie Lake. Southwest of Fish Lake syncline the rocks are friable, whereas west of Annie Lake they are well indurated and thoroughly cemented with silica. The matrix comprises finely comminuted quartz, chert, quartzite, sodic plagioclase, and white mica.

The arenaceous rocks are pale grey, grey, or greyish brown, and are commonly speckled with black chert grains. They contain subangular to subrounded grains of slightly sericitized sodic plagioclase, quartz, quartzite, minor feldspar porphyry, much chert, and siltstone in a matrix of finely comminuted quartz, plagioclase, white mica, and biotite. The quartz occurs both as clear, unstrained grains and as mosaics of anhedral crystals showing strain shadows.

The arenites of the Tantalus formation differ from those of the Lewes River and Laberge groups by containing much more quartz, no potash feldspar or mafic minerals except a little biotite, and some iron ore (*see* Table XIII, and Figures 4, 8, and 10).

Poorly preserved plant fragments are common, particularly near seams of coal. Some of these coal seams are locally as much as 10 feet thick (Cockfield and Bell, 1926, p. 52).

Structural Relations

The Tantalus formation is bounded by faults against the Lewes River and Laberge groups southwest of the Fish Lake syncline. West of Annie Lake it is faulted against volcanic rocks of uncertain age and appears to be either faulted against or to lie unconformably upon the Laberge group.

Table XIII

Volume Percentage of Essential Constituents of Arenites from the Tantalus Formation

Specimen	77[a]	78	79[a]	80	81	82	83
Quartz	38	45	39	19	25	45	30
Potash feldspar	—	—	—	—	—	—	—
Plagioclase	36	29	36	32	29	30	22
Biotite	—	—	—	—	—	—	—
Hornblende	—	—	—	—	—	—	—
Matrix	23	21	21	32	29	10	13
Rock fragments	3	6	4	17	21	15	35

[a] Counted with an integrating stage; remainder with a point counter. (For details see Table V).

For location of samples see Figure 9.

East of Carbon Hill, conglomerate like that of the Tantalus formation lies with probable angular unconformity on the Yukon group. In the Carmacks map-area (Bostock, 1936, p. 28) the Tantalus formation apparently overlies the Laberge group conformably.

Origin

That the Tantalus formation was probably deposited in a non-marine environment is indicated by its content of fossil plant fragments and coal and the absence of any marine fossils.

In contrast to the Lower Jurassic marine and coarse deltaic sediments which contain volcanic and granitic debris, the non-marine sediments of the Tantalus formation contain abundant quartz, quartzite, chert, and sodic plagioclase and only a few beds, up to 50 feet thick, of relatively well-sorted conglomerate. Such a change may only be partly accounted for by increased chemical weathering causing the complete destruction of mafic minerals and rocks. The paucity of coarse sediment and the presence of coal and plant fragments in the Tantalus formation do, however, indicate less-rapid uplift of the source area under a more humid climate than before, which in turn would promote greater chemical weathering. This environment, however, does not explain the presence of abundant chert and chemically unstable sodic plagioclase, and the absence of the more stable potash feldspar (Goldich, 1938, p. 55). This is not what would be expected if the source area of the two sedimentary units had essentially the same composition, that is, if they were both volcanic terrains containing bodies of granitic rocks. The abundance of chert and quartz, however, in the upper part of the Laberge group and in the Tantalus formation, suggests that the source areas at those times may have been composed principally of such siliceous material. The source rocks may then have been the quartz-rich Yukon group and the radiolarian chert of the Taku group, both of which were exposed in the core of the eroded tectonic land in later Jurassic and early Cretaceous time.

This hypothesis implies that the Tantalus formation overlapped the Laberge group westward, and is supported by the relationship east of Carbon Hill where conglomerate, probably belonging to the Tantalus formation, appears to overlie the Yukon group unconformably.

It may be concluded that, although chemical weathering may have been an important factor in determining the ultimate composition of the Tantalus formation, the principal factor was the exposure in the core of the tectonic highland to the west, of siliceous rocks that previously were buried by volcanic material.

Age

No diagnostic fossils were collected from the Tantalus formation in Whitehorse map-area during the present work. However, a collection of plant fossils was made by Cairnes (1916, p. 41) from coal-bearing beds east of Mount Bush, west of Annie Lake. These were examined by F. H. Knowlton who reported that they were Jurassic (*in* Wilson, W. J., 1916, p. 207, Pal. Ref.). W. A. Bell (1956, pp. 26-29) re-examined the flora from the Tantalus formation in the Yukon; all but one species identified came from the Mount Bush collection. He tentatively considered the Tantalus flora to be Neocomian (early Lower Cretaceous) in age, but a Portlandian (late Lower Jurassic) age was possible. He stated that the plant material so far gathered was too meagre for a precise age to be satisfactorily assigned.

As the Tantalus formation is conformable with the nonfossiliferous upper part of the Laberge group, Upper Jurassic strata may also be present. Hence the age of the formation is regarded as Upper Jurassic(?) and Lower Cretaceous.

Hutshi Group

The name Hutshi group was first applied by Cairnes (1910, p. 41) to volcanic rocks younger than the Tantalus formation that were intruded by granitic rocks. Rocks of this type occur in Whitehorse map-area west of Lake Laberge, at the head of Byng Creek, on Gray Ridge, and on Montana Mountain. They lie unconformably on earlier Mesozoic rocks and are cut by granitic intrusions. Elsewhere, relatively fresh volcanic rocks similar to those in the above areas have been mapped provisionally as the Hutshi group, but these may belong in part to volcanic rocks of the Lewes River group or to the Skukum volcanic rocks. Part of the rocks mapped as Hutshi group were included previously in the Laberge "series" or in the "Older Volcanics" (Cockfield and Bell, 1926).

Volcanic rocks mapped as Hutshi group outcrop over a total area of about 160 square miles.

Lithology

The Hutshi group comprises mainly flat-lying, gently dipping, locally slightly sheared, flows and flow breccias that range in composition from basalt to rhyolite, and agglomerate, tuff, and minor clastic sedimentary rocks.

Area West of Lake Laberge

Around Flat Mountain and west to Little River, Fyles (1950, p. 42) records the presence of flows and breccias of dark green, black, grey, purple, or brown colours. These are aphanitic, fine grained, and commonly porphyritic, the phenocrysts being generally feldspar, pyroxene, hornblende, or biotite. Thin sections reveal that most of the darker rocks are slightly altered hornblende andesites and basalts, composed mainly of a microcrystalline aggregate of labradorite and clinopyroxene, or with phenocrysts of labradorite and augite.

The more felsic rocks are greyish and form distinctive fine-grained flow breccias unlike the massive basaltic and andesitic flows. The flow breccias are made up of fragments of various aphanitic rocks less than 2 inches across, broken crystals of feldspar, and phenocrysts of feldspar and mafic minerals—all in a felsitic groundmass. All grades exist; from flows containing a few fragments, to breccias in which fragments and phenocrysts make up a greater part of the rock. Microscopic study by Fyles has shown that some of the more felsic rocks are quartz-latite breccias and rhyolite.

Some conglomerate, greywacke, and argillite are associated with volcanic rocks between the head of Flat Creek and Little River. These are similar to sedimentary rocks in the Laberge group, and Fyles states that the field relations are such that some or perhaps all of them may belong to the Laberge group rather than the overlying Hutshi group.

Northeast Quarter

East of the head of Byng Creek, the Hutshi group rests with angular unconformity on the Lewes River group. The basal beds of the Hutshi group comprise conglomerate and breccia, made up of green volcanic, greywacke, and limestone fragments, up to a foot across. Overlying these are green andesites, tuff, and pale grey and dark green breccias. The breccias are composed of angular fragments and broken feldspar crystals, which give them a speckled appearance. The fragments are of porphyritic lava with plagioclase phenocrysts.

Some graded beds of tuff or greywacke are associated with these breccias. They consist principally of plagioclase grains that have been so altered that crystals of clinozoisite and actinolite cut across both the matrix and the plagioclase grains. As no detrital clinozoisite or epidote was observed in these rocks, the alteration probably was effected entirely after their deposition as fragmented crystals, very likely from contact metamorphism related to the granodiorite at the head of Byng Creek.

Gray Ridge and Watson Valley

The Hutshi group on Gray Ridge overlies the highly folded Laberge group with angular unconformity. The basal part of the group consists of breccia composed of angular fragments, up to 6 inches in size, of feldspar porphyry, limestone, dark grey-green andesite, and basalt. The basal breccia is overlain by porphyritic basalt intercalated with more breccia, characterized by purplish porphyritic basalt fragments 1 inch to 2 inches across in a pale grey-green matrix. The upper part of the sequence is exposed north of the granodiorite contact and consists of dark green, massive, altered volcanic rocks composed of a crystalloblastic aggregate of plagioclase and olive-green biotite. Pale purple trachyte breccias are intercalated in the green altered volcanic rocks.

Dark grey-green basalt, porphyritic basalt with plagioclase phenocrysts, and minor tuff and breccia make up the outcrops of volcanic rocks in the Fish Lake syncline north of Watson River and also east of the White Pass and Yukon Railway. They appear to overlie rocks of the Laberge group and are cut by granitic rocks, and are therefore assigned to the Hutshi group.

Montana Mountain Area

On Montana Mountain a sequence of green and grey-green breccias, andesitic and basaltic lavas, and some graded-bedded tuff or greywacke is intruded by granodiorite and by dykes of rhyolite. It overlies unconformably rocks that probably belong to the Laberge group which are cut by serpentinized peridotite.

The basal beds contain conglomerate and also breccia composed of fragments up to 6 to 8 inches in size of pale grey felsite, feldspar porphyry, and dark grey chert and argillite. The succeeding rocks higher in the section comprise alternating layers several hundred feet thick of breccia characterized by fragments of light grey or green cherty rock and dark green andesite and porphyritic augite andesite.

Near their northern contact, the volcanic rocks dip about 40°S. Near the southern limit of these rocks, distinctively coloured bands can be seen in cliff faces, and these mark a section across a gentle synclinal warp in the volcanic rocks, so that the Hutshi group there seems to form a basin. Along their southern contact the volcanic rocks appear to be separated by a fault from the Laberge group; the gently dipping volcanic rocks, if projected southward, would abut highly deformed rocks of the Laberge group. Their northeastern contact, however, is obscure because of the difficulty of distinguishing the altered Hutshi rocks in the vicinity of the mineralized area south of Pooly Creek from the regionally metamorphosed rocks to the north.

Although the Hutshi group, which appears to be at least 3,000 feet thick in this area, may be a down-faulted part of a more extensive volcanic terrain, the abundance of breccia, the basin-like structure, the faulted contact on the south, and the great thickness of volcanic rocks for so restricted an area all suggest the subsidence of a volcanic centre into a caldera.

Structural Relations

The Hutshi group shows a paucity of structural features, but meagre evidence from a few attitudes on bedded tuffs indicates that the rocks in most of the areas have been gently deformed, as few dip more steeply than 40 degrees.

In the southern part of the Montana Mountain area the Hutshi rocks are marked by a nearly vertical northerly trending cleavage more or less parallel with that in the altered volcanic rocks that probably belong to the Taku group. The direction of this cleavage may be related to movement of the Taku group block, which, on the basis of the inferred fault along Crag Lake valley, must have moved upward with respect to the Mesozoic rocks to the north and west. No single fault or lineament has been recognized along the border zone between the Palæozoic and Mesozoic rocks west of Windy Arm. So, as the shearing occurs in both blocks, the movement between the two may have been taken up along this broad zone.

The absence of structural features near the contacts with granitic intrusions made it impossible to determine the structural effects of these bodies upon the Hutshi group.

The Hutshi group lies with angular unconformity upon the Laberge group and older rocks, and is intruded by granodiorite, leucocratic granite, pink quartz monzonites, and granite porphyry and rhyolite dykes.

Age

The Hutshi group cannot be dated on palæontological grounds. The following relations, however, suggest it is broadly mid-Cretaceous in age. The group is younger than the folding of Lower Cretaceous and older rocks and is intruded by granodiorite and pink granophyric quartz monzonite. In the western plutonic complex, similar granodiorite is cut by leucocratic granites. These leucocratic granites have the following features in common with the distinctive quartz monzonites of Taku River (Kerr, 1948b, p. 46) and Stikine River (Kerr, 1948a, p. 63), which occur as boulders in late Upper Cretaceous conglomerates (Kerr, 1948a, p. 66). Both are the youngest major intrusions in each area and both are leucocratic rocks rich in potash feldspar and characterized by smoky quartz and abundant miarolitic cavities. Hence, if such distinctive late plutonic rocks can be regarded as broadly synchronous in the belt of Coast intrusions in this region, the youngest major plutons in Whitehorse map-area, the leucocratic granites, are older than late Upper Cretaceous. The granodiorites are older than these rocks, and the Hutshi group older still. The Hutshi group is, therefore, probably post-early Lower Cretaceous, pre-early Upper Cretaceous or broadly mid-Cretaceous.

Volcanic Rocks of Uncertain Age (Map-unit B)

Mafic flows and breccias in the southwestern part of the map-area, locally containing granitic fragments and isolated from or faulted against bedded rocks, may belong to either the Lewes River or the Hutshi group. Those south of the head of West Arm may belong to the Hutshi group or to an early basaltic phase of the Skukum volcanic rocks.

Massive, green augite andesite, breccia, and bedded tuffs, faulted against the Lewes River group east of Cap Creek, are lithologically similar to the Hutshi group around Mount Byng. However, the bedded tuffs dip steeply in places, and hence the assemblage may be a relatively unaltered equivalent of the Lewes River greenstone that outcrops along the walls of Michie Creek valley.

Green, saussuritized basalt flows, dark green and maroon breccias, and bedded tuffs or greywackes, form the summits of the hills west of lower M'Clintock River. These appear to overlie the Lewes River group, but in one place are separated from it by a steep fault. The actual contact of the volcanic rocks overlying the Lewes River group is obscured by vegetation. Near fossil localities 6 and 20, the rocks along the contact zone are not sheared and the volcanic rocks may overlie the Lewes River group with structural conformity. But about 2 miles to the southeast the rocks in the contact zone are sheared along planes striking northwest and dipping moderately southwest, suggesting that the volcanic rocks are thrust onto the Lewes River group from the southwest.

Similar rocks appear to overlie sediments of the Laberge group on the island at the north end of Marsh Lake and extend along the east side of Marsh Lake as far south as latitude 60°30′′. Southeast of this, the rocks are metamorphosed to sheared greenstones and chlorite schist.

If the volcanic rocks are not thrust onto the Lewes River group they may belong to the Hutshi group, and may represent a more highly deformed part that lies along the valley of Yukon River and Marsh Lake. If so, these features have been the locus of movement or shearing in post-Hutshi time. If they are thrust onto the Lewes River group the volcanic rocks in the whole belt along the northeast side of upper Yukon River valley and Marsh Lake may be older than those in the upper part of the Lewes River group. A third possibility is that they may be equivalent to deformed volcanic rocks of unit 9 in Teslin map-area (Mulligan, 1955, p. 10), which possibly overlie Upper Triassic or younger rocks.

Skukum Group

The name Skukum group is applied to the brightly coloured andesitic, felsitic, and basaltic breccias, tuffs, and lavas so well displayed on Mount Skukum and the surrounding mountains. The mafic rocks were formerly described as the "Carmacks basalts" (Cairnes, 1912, p. 64), and "New Volcanics" (Cockfield and Bell, 1926, p. 34). The felsic rocks were formerly the "Wheaton River Volcanics" (Cairnes, 1912, p. 68) and "Acid Volcanics" (Cockfield and Bell, 1926, p. 34). As the rocks included in these formations compose only part of the volcanic sequence described here, these older terms are not considered suitable.

Volcanic rocks of similar composition and brightly coloured appearance occur west of the head of Watson River, west of Alligator Lake, and around Macauley Creek west of the head of West Arm. They also include subordinate clastic sedimentary rocks.

Small patches of breccias with a felsitic groundmass west of Rose Creek, and small areas of flow-banded rhyolites east of Byng Creek are also grouped with the Skukum group.

Lithology

The Skukum group is composed principally of pyroclastic rocks and subordinately of lavas. In a general way, the group may be subdivided into three divisions: a basal division of mixed, but mainly andesitic rocks; a middle division mainly of felsic rocks; and an upper division mainly of basaltic rocks. The upper division is not present in the Mount Skukum area.

Mount Skukum Area

The basal beds of the Skukum group, where they overlie granitic rocks of the western plutonic complex as on Chieftain Hill and west of Vesuvius Hill, contain an abundance of granitic debris in addition to melanocratic volcanic fragments and minor metamorphic rocks. On Chieftain Hill, particularly, the granitic fragments are very large, being more than 4 feet across. Although the larger blocks are angular, much of the material a foot across is rounded.

On Mount Skukum and northward along the east side of upper Watson River valley the basal beds contain abundant fragments of metamorphic rocks from the underlying Yukon group and volcanic rocks, but they contain little granitic material.

The coarse basal breccia and conglomerate are overlain by finer-grained breccias and conglomerates. These contain fragments of volcanic rocks of various shades of grey and green, up to 6 or 8 inches in diameter. The fragmental rocks are interbedded with layers, up to 50 feet thick, of pale-purple and brownish felsitic rocks, green and white spherulitic andesite, and dark grey and purple porphyritic basalt. On the southeast face of Chieftain Hill the above assemblage is about 400 feet thick.

In the Mount Skukum area the beds described above are overlain by brightly coloured breccias and tuffs containing fragments, ranging in size from one quarter of an inch to 4 or 5 inches, of pale-purple, grey, sea-green, turquoise, and dark green volcanic rocks. These are intercalated with flows of dark grey and purple porphyritic basalt with plagioclase phenocrysts, pale-green andesite, dark green porphyritic andesite, and buff to pale-brown rhyolite. The flows are mainly massive, although locally they exhibit flow banding and vesicular or amygdaloidal structures.

In most cases it is not possible to tell from the frost-shattered outcrops whether the exposure is that of a flow or a sill.

The breccias on the southwest face of Chieftain Hill contain appreciable amounts of native copper, and those overlooking Watson Valley about 4 miles north of Mount Skukum contain fragments of deep-orange and vermilion jasper. The breccias and intercalated lavas are estimated to be about 1,500 feet thick.

The exposures on the highest parts of Chieftain Hill and on the flattish ridges north of Mount Skukum are of the middle division of the Skukum group. They are principally pale-purple and brown breccias, tuffs, and trachyte and rhyolite flows. Also present in minor amounts are dark green porphyritic basalt and green andesitic breccia. Similar rocks form most of Vesuvius Hill and the terrain lying between Butte Creek and the granite porphyry body to the north. Parts of this assemblage, particularly the rhyolitic members, are rich in pyrite and these have weathered readily to produce characteristic rusty-orange zones visible from afar.

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Macauley Creek Area

The base of the sequence in the Macauley Creek area and its relationship to the underlying granitic rocks has been observed at only one locality—along its eastern contact south of Macauley Creek. There, at an elevation of about 5,100 feet, volcanic breccia composed of fragments of greenish-brown-weathering felsite, pale-purple felsite, and altered granodiorite, overlies shattered granodiorite. The contact dips moderately to the west. Flow banding, along which small tabular fragments are oriented, dips gently, to the west, with slight undulations. About 200 feet above the base is a band of spherulitic felsite. About 300 feet above the base is a fragmented bed of quartzite 1 foot to 2 feet thick, overlying purple and grey volcanic breccia. The quartzite is in turn overlain by about 20 feet of breccia and conglomerate made up wholly of granitic fragments. At one place the quartzite is separated from the bed of breccia and conglomerate by a 4-foot lens of greywacke. The basal 6 inches of the granitic breccia-bed generally comprises fragments less than half an inch in size, but here and there rounded granitic boulders appear in the underlying quartzite. These evidently sank into the sand from which the quartzite originated at about the time of deposition. Above the basal 6-inch zone, the breccia contains fragments of granitic rocks several inches across, exhibiting both angular and rounded shapes. The upper contact of the breccia is irregular and lumpy. It is overlain by volcanic breccia also containing light-coloured fragments but in a much darker matrix than that beneath the quartzite bed.

Prevailingly-light-coloured breccias of the middle division of the Skukum group overlie the breccias with the dark matrix belonging to the lower division. The felsic breccias are about 1,500 feet thick. Some of the fragments are brilliant shades of green, bluish green, and reddish brown, but most are pale-purple, buff, brown, or grey felsite. Some fragments of jasper occur here and there. Some of the breccia is very coarse, containing blocks of purple feldspar porphyry and dark green augite andesite as large as 15 feet long, 4 feet wide and 6 feet high. Patches of 'granitic breccia', composed wholly of granitic and aplite fragments in a green fragmental matrix, occur amidst outcrops of volcanic breccia. Some of these patches contain aplite fragments arranged in such a way that they appear to have been displaced only a short distance from their original position in a sinuous dyke.

The uppermost beds of the volcanic sequence south of Macauley Creek, near the summit of peak 7,300, belong to the upper division; they consist of at least 2,000 feet of dark green or bluish green breccias and tuffs whose fragmental texture is in some places difficult to detect because of the similarity of the basaltic fragments to the matrix. These rocks differ markedly from the felsitic breccias because of their smoothly jointed habit, in contrast with the rough weathering of the latter.

North of Macauley Creek, the lower division consists of porphyritic basalt overlain by chocolate-brown-weathering breccias. The overlying middle division is at least 3,000 feet thick. Its lower part is composed of breccias and tuffs containing abundant grey, purple, and green andesitic fragments, granitic pebbles and cobbles, and fragments of cherty rocks up to 5 inches across. Its upper part is paler in colour, consisting of white, grey, and pale-green or brown breccias, tuffs, and flows. The breccias occur interlayered with tuffs and rhyolite flows, and contain fragments of pink and brown felsite, green andesite, mica and quartz-mica schists, granitic rocks, and chert up to 5 inches in size. The rhyolites and some of the breccias contain considerable pyrite which has weathered to give the rocks a distinctive orange colour easily observed from a distance.

Rocks similar to those described in the Macauley Creek area occur on and near Mount Macauley and on the southwest wall of Partridge River valley. Characteristically in each of these areas the volcanic breccias contain granitic debris and locally 'granitic breccia', including in some places granitic fragments extremely irregular in outline.

South of West Arm, about 2 miles east of the mouth of Partridge River, the lowermost volcanic rocks are flat-lying massive basalts. They form rugged cliffs more than 500 feet high, which culminate in serrated ridges. They may represent a restricted outpouring of basalt lava in this sector while pyroclastic rocks accumulated west of Partridge River, or they may belong to an older group of volcanic rocks.

Other Localities

Volcanic rocks of the same general character as those around Mount Skukum outcrop west of Watson River and west of Alligator Lake. West of Rose Creek, volcanic rocks that may be related to the Skukum group, comprise breccia and conglomerate composed of basaltic, felsitic, and granitic fragments and cobbles in a buff to rusty-brown matrix.

Small areas of felsite-bearing breccia and grey, flow-banded, devitrified rhyolite flows form the upper parts of the mountains east of Byng Creek. East of the south end of Baker Lake, dacite carrying a few pebbles of granitic rocks featured by bleached biotite, forms a veneer on the wall of Teslin River valley (Lees, 1936, p. 21). Rocks from both these areas are tentatively correlated with the more felsic members of the Skukum group.

Structural Relations

The scarcity of attitudes in the Skukum group makes it difficult to more than generalize that the rocks are mainly flat-lying or gently dipping, rarely at more than 35 degrees. One exception is south of the map-area west of Partridge Lake, where R. L. Christie (personal communication, 1956) has recorded dips up to 60 degrees.

The Skukum group has been observed to lie unconformably upon granodiorite on Chieftain Hill, north of Mount Skukum, and on Vesuvius Hill; upon shattered granodiorite south of Macauley Creek, and on Chieftain Hill; upon metamorphic rocks of the Yukon group around Mount Skukum, and east of the head of the south fork of Wheaton River; upon volcanic rocks of uncertain age on Chieftain Hill; and upon the Hutshi group east of Byng Creek.

In some places, the contact of the Skukum group with the older rocks dips gently or moderately, for example, north of Mount Skukum and south of Macauley

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Creek. But in others, such as on the southeast face of Chieftain Hill, east of Vesuvius Hill, and on both sides of Partridge River valley, it dips steeply. In some places this may result from faulting, as for instance at the head of Watson River where the volcanic rocks have been down-faulted as a block into the Yukon group. Moreover, east of Partridge River, gently dipping rocks of the Skukum group occur at the same level as, or lower than rocks of the Yukon group and altered deformed volcanic and sedimentary rocks. As the change from younger to older rocks takes place in less than a mile, the steep contact may well be a fault that has down-dropped the Skukum group to the west.

The fact that the Skukum group, both in the Mount Skukum area and around Macauley Creek, occurs over a relief of 4,000 feet and yet is surrounded by older rocks at elevations as high as those at which the upper members of the Skukum group lie, suggests that both areas of volcanic rocks occupy depressions that are roughly circular or elliptical in plan.

With the exception of a small area west of the head of Byng Creek, in the northeastern part of the map-area, all exposures of shattered granodiorite and 'granitic breccia' lie within the areas in which Skukum volcanic rocks outcrop. Both rock types appear to be spatially related to the Skukum volcanic rocks and, in order to understand better the nature of the volcanic sequence, the shattered granodiorite and 'granitic breccia' will be discussed at this point.

Shattered granodiorite and 'granitic breccia' are best exposed in the floor and walls of Partridge River valley and at the head of the south fork of Wheaton River. A small patch of 'granitic breccia' also occurs on the southeast face of Chieftain Hill, underneath the Skukum group.

The lowest outcrops in Partridge River valley are composed mainly of shattered granodiorite. This pale-grey-green and slightly brownish granodiorite is seamed by numerous chloritic veinlets, locally accompanied by epidote, and contains abundant irregularly shaped, brownish- and greenish-weathering andesitic and basaltic dykes. In many places the shattered granodiorite exhibits fragmented and jostled aplite dykes and quartz veins. Here and there the shattered granodiorite contains broad zones of steeply dipping flow-banded andesitic and basaltic rocks. As the overlying volcanic rocks are gently dipping, these steeply dipping zones are regarded as feeders for the overlying volcanic rocks. Near these broad feeders the granodiorite is particularly shattered, forming a true breccia with discrete angular fragments of granodiorite in a greenish chloritic matrix.

In some places on the walls of Partridge River valley, the shattered granodiorite appears to grade upward into 'granitic breccia'. The latter is composed of angular, rounded, and locally very-irregularly-shaped fragments ranging from individual crystals of feldspar to blocks more than a foot across. The blocks are of granodiorite, diorite, and syenite (*see* Plate XIII), and are in a chloritic, fragmental matrix.

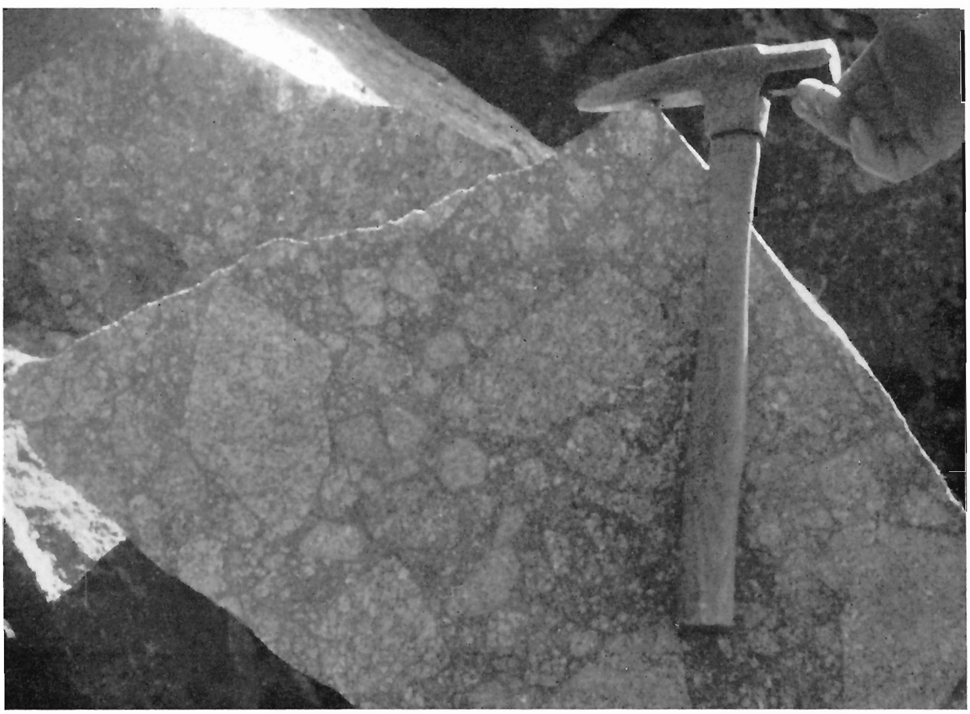


Plate XIII. *'Granitic breccia' at the head of Byng Creek.*

Plate XIV. *Dykes of 'granitic breccia', 1 inch to 2 inches wide, cutting granodiorite north of Mount Macauley. Note rounded character of some of the granitic fragments.*

As described on page 80, a bed of 'granitic breccia' is incorporated within the pyroclastic sequence, which elsewhere overlies shattered granodiorite and 'granitic breccia'.

Dyke-like bodies of 'granitic breccia' are common. In some cases, as in the Bennett map-area, dyke-like bodies that widen upwards apparently represent fillings of openings exposed at the surface (R. L. Christie, personal communication, 1956). Elsewhere they appear to be truly intrusive. Vertical or steeply dipping bodies of 'granitic breccia', composed principally of rounded granitic fragments and subordinately of cherty and gneissic rocks, outcrop amidst flat-lying pyroclastic rocks north of Macauley Creek. At the south end of Partridge Lake, 'granitic breccia' separates volcanic breccia from unshattered granodiorite and has apparently been intruded along the contact between the two rock types. East of the south end of Partridge Lake an andesitic sill carrying abundant granitic fragments has been intruded along the contact between 'granitic breccia' and the underlying weathered granite. Dykes of 'granitic breccia' carrying metamorphic fragments cut shattered granodiorite on the floor of Partridge River valley. 'Granitic breccia' dykes, without metamorphic fragments, cut unshattered granodiorite near Mount Macauley (*see* Plate XIV). Some of these have been intruded along faults, as evidenced by the termination of earlier basaltic dykes against one wall of the 'granitic breccia' dyke. The fragments of granitic rocks in the dykes commonly show some degree of rounding (*see* Plate XIV) and occur, together with numerous fragments of feldspar crystals, in a chloritic, fragmental groundmass. It appears that the granitic fragments were plucked from the walls of the fissure and then were comminuted and rounded during their upward passage.

The Skukum group is traversed by numerous dykes of basaltic, andesitic, and rhyolitic composition, that can be related to flow rocks in various parts of the volcanic sequence. They are also sparingly intruded by bodies of diorite and quartz diorite. Such dykes occur both north and south of Macauley Creek and 4 miles west of Vesuvius Hill. It is perhaps significant that the Skukum group in the Macauley Creek area are ringed on the north by a discontinuous, steeply-outward-dipping, arcuate band of granite porphyry. This pattern is highly suggestive of intrusion along a ring-fracture.

Origin

The Skukum group accumulated principally in response to intermittent explosive volcanism and subordinately from the extrusion of lava, as evidenced by the predominance, in them, of pyroclastic material over effusive rocks. Explosive volcanism was also particularly effective in disturbing, and to some degree in mobilizing, the underlying rocks. This is indicated by the shattered and jostled nature of the underlying granodiorite and 'granitic breccia', to their restriction within structural depressions containing the Skukum volcanic rocks, and by the occurrence of 'granitic breccia' both as layered units in the overlying volcanic rocks and as dykes cutting both granodiorite and volcanic rocks.

It is suggested that, in the Macauley Creek area, volcanism began locally with the rapid passage of hot gases through granodiorite containing inclusions of metamorphic rocks, the whole being at or near the surface. The sudden release of hot gases through the granodiorite to the surface may have partly shattered the rock. Material plucked from the walls of fissures was carried upwards by the up-rushing gases and then expelled at the surface to form agglomerate composed almost entirely of granitic fragments, some of which were rounded from attrition during their ascent through the fissures (Reynolds, 1954, 1956). In this way, granitic material expelled at the surface also filled cracks in the granodiorite open at the surface.

Subsequently, magma rose through fissures in the granodiorite and was extruded as lava from vents and volcanic piles. These magmas and lavas, when chilled, provided material for later explosive eruptions in which granitic material was subordinate in amount, or absent. From time to time, until well into the period when the material extruded was mainly felsic, up-rushing gases were powerful enough to transport granitic debris and metamorphic rocks from the underlying terrain, through the volcanic rocks, finally to deposit at the surface, 'granitic agglomerate' at some places and a mixture of volcanic, granitic, and metamorphic fragments at others. Some of the larger fragments of the 'granitic agglomerate' appear to have been forced on impact into the underlying well-bedded sediments. The well-bedded sediments probably comprise tuffaceous material that was deposited in water, perhaps in a lake occupying a caldera.

Some of the well-bedded layers and the bodies of 'granitic breccia' give evidence of having suffered disruption and jostling since their deposition. Such movements may have accompanied later explosive activity or have been caused by the subsidence of material into a caldera.

The arcuate trend of the slightly sinuous, steeply-outward-dipping granite porphyry bodies north of the Macauley Creek area suggests that they were intruded along a ring-fracture. If this is true then subsidence of the inner part along ring-fractures may well have formed one or more calderas, which received and preserved from subsequent erosion much of the material forming the Skukum group. Such subsidence, perhaps complicated by later faulting, could account for the present down-dropped position of the Skukum group with respect to the surrounding granitic and metamorphic terrain. It may also partly account for the basin-like structure exhibited by these rocks around Partridge Lake in the adjoining Bennett map-area. A subsidence of this type would have made room for the intrusion of granite-porphyry ring dykes, which probably accompanied the middle or felsic phase of volcanism. This phase succeeded the earlier mixed, but mainly andesitic, phase, including the earlier explosive 'granitic agglomerate', and preceded the apparently final basaltic phase.

In the Mount Skukum area the sequence of events is not so clear. It is apparent that the late basaltic phase of the Macauley Creek area did not take place there or, if it did, that it was subsequently removed by erosion. The earlier mixed but mainly andesitic volcanism was centred around Mount Skukum and the later felsic phase was concentrated a few miles to the northeast, north of Butte Creek and on Vesuvius Hill.

Age

A specific age cannot be assigned to the Skukum group. In the southwestern part of the map-area these rocks unconformably overlie granitic rocks of the Coast intrusions, volcanic rocks of uncertain age, and the Yukon group. They are themselves intruded, at least in the lower half of the succession, by basalt, rhyolite, diorite, and quartz-diorite dykes. In the northeastern part of the map-area east of Byng Creek, rhyolitic rocks correlated lithologically with those in the southwestern part of the map-area, overlie volcanic rocks regarded as belonging to the Hutshi group. It is not, however, certain that the rhyolites there represent a period of eruption synchronous with the felsic phase in the southwestern part of the area. The Skukum group, therefore, may be equivalent in part to the Hutshi group or they may be entirely younger. Bostock and Lees (1938, p. 21) correlate the dacite east of Baker Lake with the Carmacks volcanics of Eocene or later age (Bostock, 1942).

Miles Canyon Basalt

The youngest consolidated rock in the map-area is the Miles Canyon basalt, typically exposed at Miles Canyon south of Whitehorse, and sparsely scattered over the west-central part of the map-area. For the most part, it consists of flows and little pyroclastic material. The largest flows occur north of Alligator Lake and west of MacRae respectively. Elsewhere, except on Ibex Mountain, the outcrops are remnants of small individual flows. Virtually all the flows are less than 150 feet thick. Air photographs reveal that northwest of the summit of Ibex Mountain, the basalt has formed a small cone into the northeast side of which a small cirque has been excavated.

Lithology

The basalt is generally grey or black, but most of the scoria, flow tops, and subordinate intercalated breccia and tuff is reddish. The upper part and the bottoms of the flows are particularly vesicular.

In some places the basalt contains olivine. Flows west of the south end of Fish Lake, and one 3 miles west of Golden Horn Mountain, contain olivine as phenocrysts, and as clots in the former, and in the groundmass. Other minerals include small phenocrysts of labradorite, which, together with the olivine, occur in an aphanitic groundmass of labradorite, augite, olivine, and magnetite. The flows at Miles Canyon and north of Alligator Lake apparently contain no olivine but comprise phenocrysts of augite in a matrix of augite, calcic plagioclase, and magnetite. Coarser phases are equigranular and commonly exhibit a diabasic texture.

West of Fish Lake the basal part of the flows contains pebbles and fragments of the underlying unconsolidated material, for example pebbles of chert like those in the Tantalus formation, and of granitic rocks.

Structural Relations

The upper flow at Miles Canyon exhibits well-developed columnar jointing that grades upward into poorly developed curvi-columnar and pseudo-columnar jointing (Tomkeieff, 1940, p. 101). On the west side of the river below the 'cauldron'—where the channel opens out a few hundred feet downstream from the foot bridge—the upper flow displays, in the canyon wall, vertically radiating columnar joints. Such a radiating pattern was regarded by Bucher (1948, p. 111) as having developed in that part of a lava flow overlying a feeder. The lava probably remained hot longer at this point and hence the cooling surface in the lava was raised to form a hump over the feeder. Columnar joints, forming at right angles to the cooling surface, would therefore exhibit a radiating pattern where the cooling surface bulged upward. It is therefore inferred that feeders to the flows along Yukon River existed in the valley bottom, and that consequently all the lava did not emanate from the slopes of Golden Horn Mountain.

The large flow terminating at the head of Friday Creek exhibits two interesting features: (1) roughly rectilinear zones, 15 feet high and 50 feet long, somewhat like squashed pillows, comprise massive conchoidally-fractured basalt surrounded by an envelope of scoria, 6 inches to a foot thick; and (2), in some places at the bottom of the flows the viscous lava has apparently been rolled up like a jelly roll by movement of the upper part of the flow.

At the head of Miles Canyon, the basalt is intercalated with sand and gravels, but at the 'cauldron' it lies directly on rotten, weathered granodiorite. This testifies to the irregular surface upon which the lavas in Yukon Valley were extruded.

In some other places the original flow-tops are preserved, but generally the surfaces of the flows are strewn with glacial erratics and locally are striated.

Characteristically the basalt conforms to the present topography except where it has been modified by glaciation. For example, north of Ibex Mountain a flow is cut off by a U-shaped valley (Fyles, 1950, p. 77) and hence was extruded at least before the last phases of glaciation. As mentioned previously, cirque action has modified a cone on Ibex Mountain.

Age

Recent diamond-drilling by Northwest Power Company has revealed that the basalt at the head of Miles Canyon is intercalated with sands, gravels, and even some peat layers. Two samples kindly sent to the Geological Survey of Canada by J. M. Wardle of Northwest Power Company were examined by J. Terasmae. The results of his pollen analyses follow.

Miles Canyon: Sample No. 3. DD hole 1M.

	No. of Pollen Grains or Spores
A. Peaty Layer	
Spruce pollen (white spruce type)	48
Spruce pollen (black spruce 2)	6
Fir (Abies)	28
Pine	5
Douglas Fir	7
Birch	7
Alder	8
Willow	3
Mountain Hemlock	3
Western Hemlock	7
Cedar (tentative identification) present	
Total	122
Non-arboreal Pollen (NAP)	
Unidentified	5
Cyperaceae	2
Spores	
Equisetum	1
Lycopodium	1
Selaginella	1
Fern spore (Polypodiaceae)	1
Total	11
B. Sandy Layer	
Spruce pollen (white spruce type)	20
Spruce pollen (black spruce type)	1
Fir	17
Pine	5
Douglas Fir	4
Birch	2
Alder	3
Willow	2
Western Hemlock	3
Total	57
Non-arboreal pollen	
Unidentified	4
Grass	2
Spores	
Equisetum	1
Fern	1
Total	8

Fungus: remains are rather abundant.

Interpretation—Terasmae states that the microfossil assemblage from sample No. 3 (A and B) can be matched with similar modern assemblages from Western Canada. Pollen or spore types that can be identified as Cretaceous are very rare and can be explained by secondary deposition (the sample is chiefly silt).

The assemblage of microfossils further suggests forested conditions at the time when the analyzed silt was deposited. Spruce and fir were the dominant trees with Douglas fir and hemlock being well represented.

The deposit is not Cretaceous, and a Tertiary age is improbable. A Pleistocene age for the silt and plant debris is supported by the microfossil assemblage, the presence of uncompressed spruce needles, and the unconsolidated nature of the deposit.

Intrusive Rocks

Ultramafic Rocks

Several ultramafic bodies occur, ranging in size from lenses a few hundred feet long and 25 feet wide to masses 5 square miles in area. They are restricted to zones of tight folding and intense shearing in Mesozoic and older rocks. These bodies are exposed in five places in the map-area: on Jubilee Mountain and west of Little Atlin Lake, north and northeast of Montana Mountain, on both sides of Michie Creek, west of Lake Laberge, and south of Tally-Ho Mountain in the Wheaton River district.

Jubilee Mountain Area

Numerous bodies of rusty reddish-brown or greenish-brown-weathering serpentinite and serpentinized peridotite and dunite occur in the altered and sheared volcanic rocks that probably belong to the Taku group, north and northeast of Jubilee Mountain.

The ultramafic intrusions appear as elongate lenses and dykes ranging from 25 to several hundred feet in width. They are generally in contact with thoroughly sheared volcanic rocks. Some of the smaller bodies are massive, coarsely jointed, slightly sheared rocks; others, particularly the more serpentinized ones and the largest mass north of Jubilee Mountain, are abundantly sheared, and slickensided.

The study of thin sections of specimens of these intrusions reveals them to be steatitized serpentinized peridotite and dunite. Most of the rock comprises bladed serpentine altered to a felt of talc, and remnant anhedral crystals of olivine and orthopyroxene showing no signs of granulation and only vague undulose extinction. Accessory minerals are chromite, dark brown spinel, and magnetite.

Some of the dyke-like bodies of serpentinized peridotite southeast of Jubilee Mountain contain veinlets of clear serpentine whose trend is more or less parallel with the attitude of the body itself.

Toward the granite body east of Jubilee Mountain, the ultramafic rocks become increasingly steatitized, and within a few hundred feet of the contact they are converted to rocks containing abundant tremolite that commonly occurs in rosettes of radiating crystals.

Montana Mountain Area

Several irregular, apparently elongate, greenish- and yellow-brown-weathering, steatitized, serpentinized peridotite bodies are poorly exposed east of, and about 3 miles north of Montana Mountain. They are found indiscriminately in altered volcanic rocks probably belonging to the Taku group, and also with altered quartz-bearing greywacke similar to that in the Laberge group. The largest body, which is about a mile north of Montana Mountain, is composed of sheared, partly steatitized serpentinized dunite and peridotite. It is bounded on two sides by granodiorite and on the west side is separated from granodiorite by a sliver of metamorphosed greywacke. It is overlain apparently unconformably by volcanic rocks correlated with the Hutshi group. The ultramafic rocks have a patchy appearance produced by bluish grey and pale-reddish-brown speckled inclusions in a pale-reddish-brown, dense matrix. Many of these inclusions are irregular and roundish in outline, although some are distinctly angular. The rock is cut by an indistinct, almost vertical shearing, which trends N25°W.

Microscopic study of specimens of the inclusions shows that they are composed mainly of olivine aggregates 2 to 3 mm across, in interlocking anhedral crystals. They consist of numerous slightly elongated grains, 0.05 to 0.1 mm in size, separated by clear, colourless serpentine. The large anhedral crystals form an interlocking mosaic with no particular fabric, and show no granulation along crystal boundaries. The smaller constituent grains within these anhedra have their longest dimension more or less parallel with the attitude of the shearing, yet individual grains extinguish at different times when the microscope stage is rotated slightly. In addition to olivine and clear serpentine, the inclusions contain bluish grey nodules of radiating antigorite needles and chromite, and a few crystals of tremolite and talc. The matrix is composed of serpentinized olivine having the texture described above. Clots of talc show as pinkish areas on the weathered surface. Disseminated talc is confined principally to areas of serpentine, minor tremolite, and chromite.

In parts of the body where the shearing is more pronounced, clear serpentine veinlets are oriented parallel with the shearing and the dunite is made up wholly of small crystals. The larger anhedral crystals, typical of the 'patchy' dunite, are lacking.

Toward the margins of the body, and hence nearer to the granitic intrusion, the serpentine is mainly bladed antigorite that has been partly altered to talc. These border zones also contain radiating groups of tremolite and some crystals of clinopyroxene. Locally, as at the western contact of the body, the rock is converted to a fine-grained aggregate composed principally of clinopyroxene and chromite. These minerals were probably developed within the aureole of contact metamorphism surrounding the granodiorite body north of Montana Mountain. Within this zone, quartz-bearing greywacke has been metamorphosed in varying degrees to pyroxene hornfels and biotite hornfels, and andesitic volcanic rocks have been converted to amphibolite.

Michie Creek Area

An ultramafic body about 5 square miles in area, the largest in Whitehorse map-area, is exposed about 4 miles north of Mount Michie. The rocks include reddish-brown- and greenish-brown-weathering serpentinized dunite and peridotite. They are traversed by a prominent set of joints that strike northwesterly, about parallel with the longest dimension of the body, and dip 45 to 60°NE. Most of the shearing in the body follows this prominent joint direction; along the shear planes, serpentine veinlets half an inch to an inch wide are most conspicuous. Locally, however, the rocks are shattered and show an irregular grid of closely-spaced slickensided joints filled with serpentine that is rarely asbestiform.

Thin-section study indicates that the serpentinized dunite consists principally of islands of olivine surrounded by clear serpentine, and subordinately of chromite and picotite. Most of the olivine extinguishes sharply and few crystals show undulose extinction.

The serpentinized peridotites are composed essentially of olivine with, in some places orthopyroxene and in others clinopyroxene. Serpentine, chromite, and picotite are also present. The olivine crystals are bounded by zones of bladed serpentine in crystals oriented more or less at right angles to the borders of the olivine crystals. The meeting plane of two such zones of bladed serpentine bordering olivine crystals is the locale for trains of magnetite crystals. The peridotites also contain grains showing the cleavage and form of pyroxene crystals now completely altered to pseudomorphs of serpentine or an aggregate of serpentine and a fuzzy, birefringent mass of carbonate(?). Around the outer edges of some of these grains is a dusting of magnetite crystals. Grains may be altered clinopyroxene, perhaps diallage. In the peridotite, relict clinopyroxene appears to be more common than relict orthopyroxene.

Some of the peridotite is cut by coarsely crystalline, sinuous, locally branching dykes of pyroxenite up to 6 inches wide. The contacts of the dykes are sharp and the pyroxenite remains coarsely crystalline to the very edges of the body.

Microscopic study shows that the pyroxenite is principally composed of allotriomorphic orthopyroxene with a low birefringence, and contains lamellae and rhomb-shaped inclusions of clinopyroxene.

The ultramafic rocks in this sector are not in visible contact with the country rocks. The latter, however, become more highly deformed east of the Upper Triassic *Spondylospira lewesensis* limestone, toward the ultramafic body. The greenstones west of the mouth of Byng Creek contain at least one body of steatitized, partially serpentinized dunite.

Area West of Lake Laberge

A dark green- to black-weathering serpentinite body, more than 2 miles long and 30 to several hundred feet wide, is exposed west of the south end of Lake Laberge. It lies parallel with the bedding of the Laberge group in the northern part of the map-area, where it is most highly deformed.

The serpentine is thoroughly sheared in most places, with a northwest strike and a vertical dip parallel with the attitude of the body. The serpentinite body, however, contains a few roundish, unsheared serpentine 'boulders' as large as 2 or 3 feet across. Thin-section study reveals that the 'boulders' consist of 'mesh-structure' serpentine, plates of serpentine (which may be bastite), and chromite. The sheared matrix, on the other hand, is made up of clear bastite and 'mesh-structure' serpentine enclosed in a finely comminuted hash of serpentine and iron ores. The iron ores occur in *en échelon* and dendritic patterns as if single bands or clots had been displaced along parallel slip planes.

In one place, at least, the serpentinite body splits and encloses a block, several square feet in area, of a relatively unsheared rusty-weathering, dark grey-green aphanitic rock. A zone about 8 inches wide next to the border of the inclusion is grey to white and grades into shades of dark green toward the centre of the inclusion. Thin sections of samples from the zone of whitish rock show that it is composed of a confused aggregate of an irregular, shreddy, birefringent mineral, much like epidote, in an isotropic base which may be garnet. This aggregate is traversed by veinlets of vesuvianite, prehnite, and carbonate, and also contains euhedral crystals of a colourless garnet. The aphanite shows a fragmental texture in plain light, but under crossed nicols it exhibits areas of clear serpentine and tremolite, in a dense indeterminate matrix. The texture suggests that the rock may be a tuff. The mineral composition of the whitish rock and its position at the contact between the aphanite and the serpentinite suggest that it is a rodingite (Grange, 1927) formed from the alteration of the aphanite.

Tally-Ho Mountain

Cairnes (1916, p. 41) reported pyroxenite in a small area south of Tally-Ho Mountain where it is apparently intrusive into green schists.

Age

The time of intrusion of the ultramafic rocks cannot be dated conclusively. The sheared and deformed character of most of the smaller bodies and much of the larger masses, suggests either that they were involved in the folding of the rocks they intrude, possibly having been moved from their original position of emplacement prior to the folding, or that they were intruded during the period of mid-Cretaceous folding.

Ultramafic intrusions in Atlin map-area that are on strike with those in Whitehorse map-area are regarded as Permian by Aitken (1953, p. 125), on the basis of their irregular form within Permian greenstones and their virtual restriction to the latter. In Teslin map-area, Mulligan (1955, p. 11) records that ultramafic rocks appear to intrude Triassic and/or Jurassic rocks but are probably older than the granitic intrusions west of Teslin Valley. The diversity of opinion as to the time of intrusion of ultramafic rocks in the same general part of northwestern British Columbia and southern Yukon can best be reconciled if the ultramafic rocks are assumed to have been originally emplaced during the Permian, but to have later been squeezed, as solid intrusions or in small fault slices, into the younger rocks at the time of the mid-Cretaceous deformation.

Granitic Rocks

Nearly half the map-area, or about 2,000 square miles, is underlain by granitic rocks. They occur in two ways: (1) as a plutonic complex occupying most of the western part of the map-area, which for the most part belongs to the Coast intrusions (Lord, 1947, p. 243); and (2), as individual plutons intrusive into the Hutshi group and older folded rocks.

The mapping of this large area of granitic terrain, much of which is drift covered or has been disturbed by frost heaving, is not sufficiently detailed to permit the proper interpretation of the petrological history and mode of emplacement of these rocks. Their approximate composition, extent, form and contact relations where exposed, and age relations, are outlined in the following sections.

Western Plutonic Complex

The largest area of granitic rocks lies mainly west of the belt of folded, bedded Mesozoic rocks. In most places within this complex it has been impossible to separate and delineate granitic rocks of dissimilar composition into distinct plutonic bodies. Consequently, the main rock types are described in the order of their decreasing abundance.

Granodiorite

The most common rock type is a medium- to coarse-grained, grey, and grey and light brown, equigranular, non-foliated granodiorite in which biotite generally predominates over hornblende (*see* Table XIV, specimens 20-22, 32, 33, 37-42). In thin sections, specimens of the granodiorite exhibit a hypidiomorphic texture in which mafic minerals and plagioclase occur as euhedral and subhedral crystals, whereas quartz and potash feldspar appear in anhedral patches interstitial to the plagioclase. The plagioclase is commonly zoned and in some slides is saussuritized. Potash feldspar, locally showing a turbid alteration to clay minerals, is commonly perthitic but mostly contains less than 20 per cent albite and rarely as much as 50 per cent. Mafic minerals show some degree of alteration to chlorite. Biotite locally shows pleochroic haloes around zircon crystals. Accessory minerals are iron ores, zircon, leucoxene, sphene, apatite, and locally allanite. Over much of the area the composition of the granodiorite appears in the field to be fairly uniform, although roundish inclusions of biotite diorite a few inches across and a few pegmatitic clots and lenses occur here and there.

Fyles (1950, p. 62) reports gneissic porphyritic granodiorite west of the mouth of Little River (*see* Table XIV, specimens 30, 31). It is characterized by pink orthoclase and, locally, by white plagioclase crystals 1 to 5 cm. long in a medium- to coarse-grained matrix of euhedral to subhedral plagioclase, hornblende,

Table XIV

Volume Percentage of Essential Constituents of Granitic Rocks from Whitehorse Map-area

Specimen	1	2	3*	4	5	6	7*	8	9[a]	10[a]	11[a]	12[a]	13[a]	14	15	16*	17	18	19	20	21*	22*	23
Quartz	19	26	26	8	19	31	36	28	33	36	28	27	35	13	13	24	24	25	24	28	16	17	37
Potash feldspar	35	23	42	22	45	43	31	36	65	47	42	45	63	29	20	14	52	34	30	22	9	11	18
Plagioclase	39	45	29	31	32	25	33	34	—	15	26	22	—	50	56	48	21	36	40	42	57	57	38
Biotite	5	6	1	x	2	x	x	2	2	2	4	6	2	—	2	12	2	4	4	6	12	11	1
Hornblende		—	2	3	1	—	—	—	—	—			—	4	9	1	0.5	1	2	2	6	3	5
Accessory minerals	1	—	—	3	1	1	—	—	—	—	—	—	—	1	...	1	0.5	—	—	—	—	1	1
Granophyre	—	—	—	33	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Percentage An[b] in plagioclase	12	14	16–24	5	10	18–23	10	28	—	2–3	15 18	20–25	—	16	26	26	20–30	23	28	34	20?	24–36	16

Specimen	24	25	26	27*	28*	29	30[a]	31[a]	32[a]	33[a]	34[a]	35[a]	36	37*	38*	39*	40	41*	42	43	44	45
Quartz	30	21	24	29		24	27	26	17	17	16	5	9	25	21	21	33	20	14	6	36	23
Potash feldspar	23	14	8	35	70	23	33	40	25	16	—	21	3	13	23	29	29	35	7	x	2	6
Plagioclase	40	53	53	34	10	44	27	12	51	48	77	53	69	43	42	44	34	41	68	66	61	53
Biotite	6	6	7	1	10	5	—	20	-	19	8	6	6	5	8	3	3	2	5	5	1	3
Hornblende	0.5	6	7	1	10	3	13		7			13	12	10	5	3	—	1	4	22	—	13
Accessory minerals	0.5	—	1	—	—	1	—	2	—	—	—	2	1	4	1	—	1	1	2	1	—	- -
Granophyre	—	—	—	—	—	—	—	—	—	—	—	. .	—	—	—	—	—	—	—	—	—	—
Percentage An[b] in plagioclase	30?	25	15	18–22	4	27	35–40	25–40	25–35	40	38	32 35	30?	10	46	25	22?	10–30	32	35	35	20

[a] Analyses by integrating stage (Fyles, 1950), remainder counted using point counter (point spacing 0.33 mm, traverse spacing 1 mm). Minimum of 1,000 points counted except for samples marked with * in which 500 to 800 points counted. Slides were stained with sodium cobaltinitrite (Chayes, 1952).

[b] Determined by Michel-Levy method of maximum extinction angles of albite twins in sections normal to (010).

Location of specimens in Figure 14.

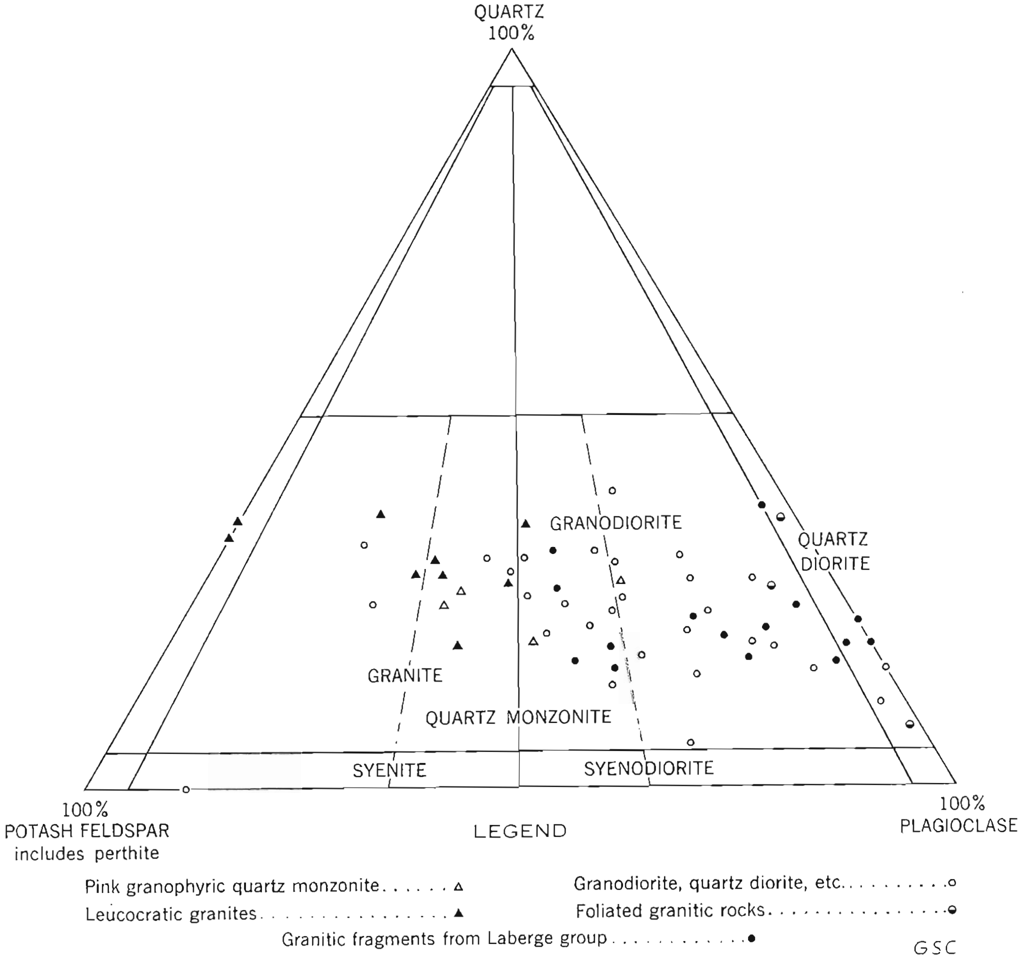
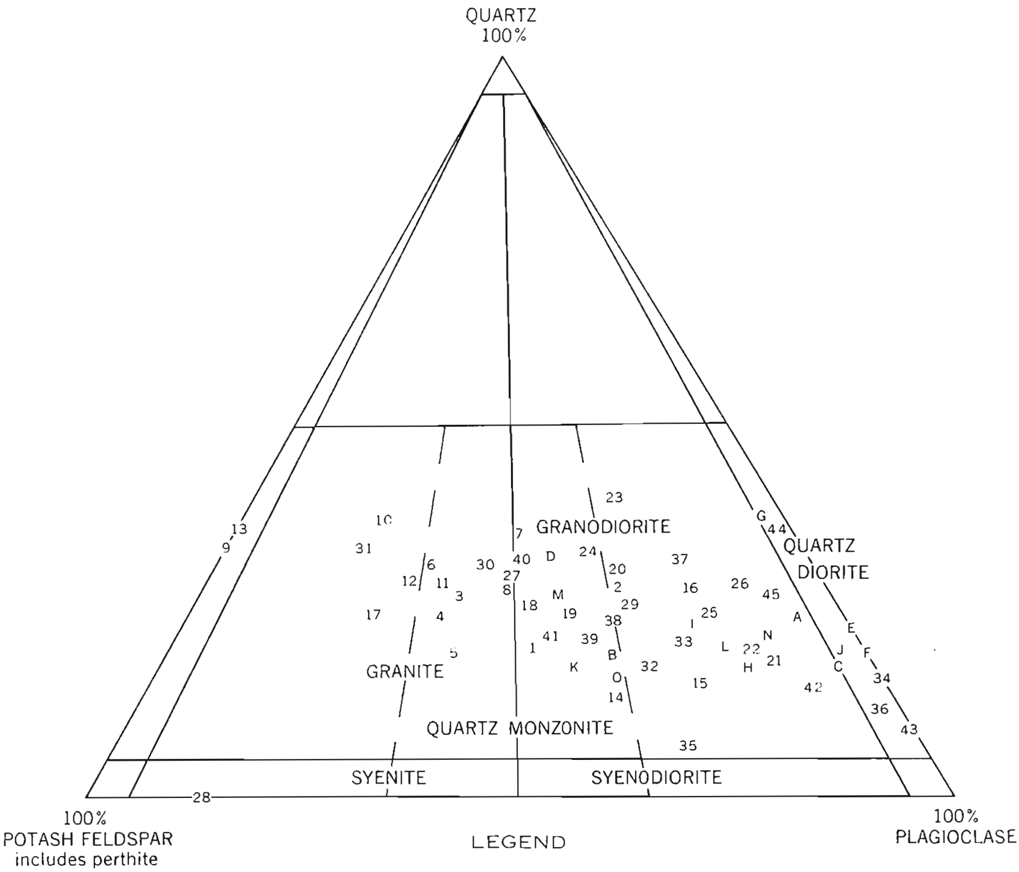


Figure 12. *Plot of the mineralogical compositions (volume per cent) of granitic fragments of the Laberge group and of plutonic intrusions from Whitehorse map-area.*

and biotite. Also present are large anhedral orthoclase crystals enclosing some smaller crystals of plagioclase and mafic minerals, and lenses of quartz nearly parallel with the foliation. These rocks contain abundant dioritic inclusions which increase in number toward the contact with the greenstones. Similar rocks occur around the southern part of Bennett Lake, West Arm, and 5 miles southeast of Carbon Hill (Table XIV, specimens 14, 15).

The contact between the granodiorite and the rocks it intrudes is rarely well exposed, but in a few good exposures in cirques near the heads of Watson and Wheaton Rivers the nature of the contact with metamorphic rocks of the Yukon group is revealed. The non-foliated granodiorite makes a sharp contact



LEGEND

Pink granophyric quartz monzonite 1–4
Leucocratic granites. 5–13
Granodiorite, quartz diorite, etc 14–42
Foliated granitic rocks. 43–45
Granitic fragments from Laberge group. . . . . .A–O

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Figure 13. *Key to Figure 12.*

either with the metamorphic rocks where it may locally penetrate along directions parallel with the foliation of the schists or, more commonly, cut across it, or with foliated quartz diorite containing characteristic elongated lenses of more mafic-rich material. The foliated quartz diorite appears to grade into schistose metamorphic rocks in several places. In all cases the granodiorite maintains its coarse grain to the very edge of the body.

In some places near its contact with metamorphic rocks the granodiorite contains abundant inclusions, both angular and roundish, of disoriented metamorphic rocks. This cannot in all cases be attributed to movement of blocks of country rock resulting from the permeation of the granodiorite by mobile granitic magma. Breccia zones containing disoriented blocks occur in several places within the metamorphic rocks and these breccia zones can be projected

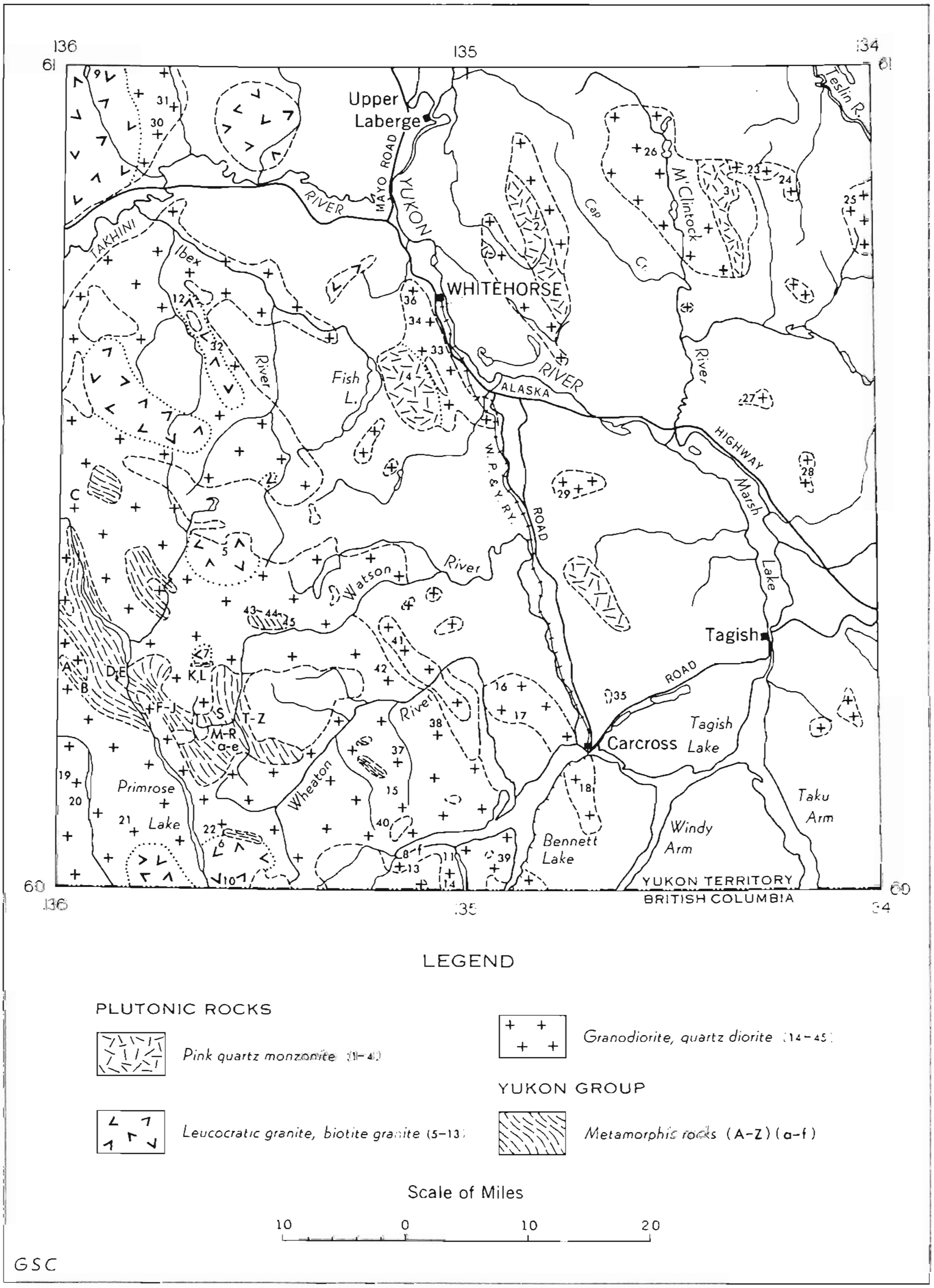

Figure 14. *Map showing location of plutonic and metamorphic rocks selected for micrometric analysis.*

along the dip of the foliation or bedding into zones in the granodiorite containing abundant disoriented inclusions. Apparently granitic material has penetrated the country rock along permeable zones of brecciation without necessarily disturbing the blocks of country rock. Many of the breccia zones result from the rotation and dislocation of blocks broken from thin competent quartzite beds within thicker incompetent micaceous schists.

Little is known of the form of the granodiorite bodies within the intrusive complex, except near the head of Watson River, where cliffs reveal that the contact with the Yukon group is locally very steep, and near the head of Wheaton River, where it dips gently to form the base of a roof pendant of Yukon group rocks. The contact in the latter place is irregular and is characterized by numerous pegmatite and aplite dykes that pass from within the granodiorite into the metamorphic rocks. Near the west end of this roof pendant most of the aplite dykes follow gently-east-dipping thrust faults with a few feet of displacement. The displacement can be clearly seen in thin quartzite beds in the east wall of a glacier-filled cirque south of the headwaters of the west fork of Wheaton River.

Granodiorite between Gold Hill and Pugh Peak is separated on the west from another body of granodiorite containing less potash feldspar, by an almost vertical, narrow belt or 'screen' of low-grade metamorphic rocks. This belt extends from Tally-Ho Mountain northward almost to Alligator Lake.

Elsewhere the granodiorite cuts greenstone, volcanic rocks of uncertain age, and the Laberge group sharply. It appears to send dykes into the Hutshi group east of Little River.

Leucocratic Granite

The next most abundant rock type within the plutonic complex is a leucocratic granite characterized by smoky quartz that is in contrast to the clear or glassy quartz of the granodiorite. The leucocratic granite includes biotite granite, leucogranite, alaskite, and kalialaskite (Table XIV, specimens 5-13) (Johannsen, 1931, 1932). The leucocratic granite forms distinctive bodies readily distinguishable from a distance in the southwestern part of the map-area by their brown colour and bold, coarsely jointed topography.

The leucocratic granite is cream and pale-brown in colour and is characteristically a coarse-grained, equigranular rock of hypidiomorphic texture. It comprises rare biotite and some muscovite, slightly sericitized plagioclase as sodic as An_{2-3} (Fyles, 1950, p. 56), turbid potash feldspar much of which is perthitic, and smoky quartz occurring as anhedral and in places rounded crystals. In general, this rock type has more quartz and potash feldspar, less mafic minerals, and plagioclase with a lower anorthite content, than the granodiorites. The leucocratic granite commonly contains miarolitic cavities lined with crystals of 'pyramidal' quartz, potash feldspar, and locally, octahedral fluorite.

The leucocratic granite intrudes both granodiorite and quartz diorite. Its border zone next to the granodiorite ranges from 2 to 50 feet in width and is characterized by an absence of biotite, a fine-grained granophyric groundmass

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containing miarolitic cavities, coarse pegmatitic clots, and large crystals with rounded corners, of potash feldspar and smoky quartz.

Plutons of leucocratic granite are circular or elongate in plan and have almost vertical walls and flat tops. Their contacts are sharp and generally fairly regular, although locally, granophyric apophyses surround and invade fractured, angular blocks of intruded rock.

A few aplite dykes cut the leucocratic granite bodies but rarely extend beyond them into the country rock.

The leucocratic granite appears to be more susceptible to weathering than the other granitic rocks in the map-area. Locally, it readily disintegrates into a coarse grit or sand. This is particularly noticeable on south- and west-facing slopes at the higher elevations. The problem of the weathering of granitic rocks in the map-area was studied by Fyles (1950) who concluded that the leucocratic granite disintegrated more readily than the other granitic rocks because most of it contains large pores.

Quartz Diorite

Quartz diorite, in which hornblende predominates over biotite, forms small masses irregularly distributed throughout the complex. One such body, which superficially resembles dark granite or granodiorite, forms the tops of the ridges on the northwest side of Mount Ingram. This body and its contact relations were studied by Fyles (1950, p. 73), and a summary of his petrographic description follows. The body is composed of rocks that are generally pale-grey or green, medium to coarse grained, and locally contain greenish streaks or bands. In some places, on clean, weathered surfaces, vague outlines of pebbles are visible; elsewhere, pale 'eyes' of quartz, feldspar, or both, may also be remnants of pebbles.

Thin-section study shows that this rock consists essentially of andesine, quartz, and smaller amounts of hornblende, chlorite, calcite, and epidote. The andesine occurs as slightly recrystallized, euhedral crystals featuring serrated crystal boundaries. Quartz appears as lenticular patches 5 to 8 mm long, made up of interlocking crystals; it penetrates the interstices between the surrounding andesine crystals. Chlorite, calcite, and epidote form patches and veinlets, and are younger than the felsic minerals. The rock, then, has the composition of quartz diorite with a metamorphic texture.

On the northwest slope of Mount Ingram, the quartz diorite is in contact with Mesozoic arkose and arkosic conglomerate containing granitic pebbles. The contact zone, several hundred feet wide, conforms closely with the bedding of the arkosic rocks and consists of several bands or lenses of granitic rock intercalated with bands of conglomerate and arkose. In many places close to the contact, arkose and granitic rocks are similar in appearance, and some of the conglomerate can only be distinguished from adjoining granitic material by the presence of faint outlines of pebbles. Locally, the contact between arkose or conglomerate and granitized rocks appears to be gradational, but elsewhere it is sharp, and there the granitic rocks show evidence of chilling.

Fyles (1950, p. 75) concluded that some, if not all, of the quartz diorite in this locality is the metamorphosed equivalent of conglomerate, arkose, and possibly other Mesozoic rocks associated with them, although some intrusive material may be mixed with the metamorphic rocks.

Miscellaneous Plutons, Mainly in the East Half of the Area

The plutons cutting the Hutshi group and older folded rocks are mainly granodiorite (*see* Table XIV, and Fig. 13, Nos. 16-18, 23-26, 34-36) of the same general character as that in the western plutonic complex. They are locally porphyritic, particularly the body underlying the southern part of Gray Ridge and the area south of Carcross. The plutons west of Cap Creek, around M'Clintock Lake, and part of the one at the head of Byng Creek, have a steeply dipping and westerly trending foliation. Those along the Whitehorse copper belt, in the Fish Lake syncline, north of Mount Lorne, on Mount M'Clintock, and most of the body at the head of Byng Creek, show no readily discernible foliation. Hornblende and augite diorite occur as small bodies mostly marginal to, and apparently older than, some of the larger bodies of granodiorite in the copper belt and northeast of Whitehorse. A somewhat altered and sheared diorite outcrops in the valley east of Canyon Mountain, and small areas of a heterogeneous assemblage of greenstone and diorite occur within granodiorite west of Cap Creek and east of M'Clintock River.

Plutons of biotite granite featured by smoky quartz and probably related to the leucocratic granites of the western intrusive complex invade Mesozoic sedimentary rocks north of Takhini River and south of Haeckel Hill. Other small bodies occur southwest of Cap Creek, south of Michie Creek, around Jubilee Mountain, and southeast of Fish Lake.

Two small areas of coarse-grained pegmatitic syenite occur east of Marsh Lake.

Four distinctive bodies of pink granite or quartz monzonite (*see* Table XIV, specimens 1-4), characterized by both colourless and smoky quartz, by pink, turbid, locally perthitic potash feldspar, and by white sodic plagioclase, occur west of Cap Creek, west of Byng Creek, on Mount McIntyre, and west of Mount Lansdowne. Parts of these bodies, particularly the one south of Mount McIntyre, contain much granophyre composed of an intergrowth of potash feldspar and quartz. The pink quartz monzonite cuts foliated granodiorite northeast of Whitehorse, and volcanic rocks of the Hutshi group east of Byng Creek.

The larger plutons are, with few exceptions, elongated slightly west of north, and generally transect the regional structure at a slight angle. Some plutons, such as those within and north of the Fish Lake syncline, however, are elongated at right angles to the regional structure.

The walls of the plutons are rarely well-exposed, but on Gray Ridge, southeast of Mount Byng, and on Caribou Mountain (*see* Plate IX), exposures on steep slopes show that some, at least, are vertical or 'overhanging'. The border phase of the granitic bodies commonly contains a few roundish mafic inclusions and is generally no finer grained than the interior. The contacts of the plutons with the invaded rocks are, for the most part, sharp and sinuous, with few apophyses.

No detailed information was obtained on the structural effects produced by plutons upon the invaded rocks. On a broad scale, some plutons, such as those in the copper belt, those north of Mount Granger, and the pink quartz monzonite east of Canyon Mountain, have caused little or no deviation in the attitudes of the host rocks. Others however, such as the body near Mount M'Clintock, have caused the bedding in the folded rocks to diverge around them.

The bedding in the rocks around the plutons north of Mount Lorne and around peak 5635, south of Michie Creek, conforms in part to the trend of the contacts. Apparently some plutons have been emplaced without disturbing the folded rocks, whereas others probably shouldered them aside. Both types of intrusion are later than the folding.

Metamorphism of Intruded Rocks

It is apparent in the field that some of the host rocks are more altered than others. East of the mouth of Ibex River, greenstones of the Lewes River group comprise saussuritized plagioclase and uralitized pyroxene. They grade northwestward into a schistose and locally gneissic assemblage of chlorite, quartz-sericite, and quartz-biotite schists, amphibolite, and hornblende-feldspar gneiss. Another area of similar rocks lies northeast of Joe Mountain, where mafic and intermediate volcanic rocks of uncertain age have been metamorphosed to amphibolite.

Elsewhere, however, metamorphism by individual granitic plutons is relatively light. In general, the principal change observed in arenaceous rocks several hundred feet from the contact is the development of much shreddy, brown biotite, probably derived from the reconstitution of the chloritic matrix. However, a few feet from the granodiorite north of Montana Mountain, greywacke has been transformed to a pyroxene hornfels composed of quartz, plagioclase, biotite, and clinopyroxene. Argillaceous rocks have been converted to hard hornfels; mafic volcanic rocks have been reconstituted to greenstone comprising saussuritized plagioclase and uralitized pyroxene several thousand feet from the contact, and to actinolite-biotite-plagioclase hornfels within 200 or 300 feet of the contact. The biotite is characteristically olive-green. Limestone has been locally metasomatized to skarn, particularly along the Whitehorse copper belt, and between Ibex and Takhini Rivers. The skarn is composed chiefly of the following silicates: garnet, tremolite, actinolite, diopside, epidote, and in a few places scapolite and cancrinite (McConnell, 1909, p. 32). Serpentinized ultramafic rocks appear to have been altered to talc and tremolite and locally to clinopyroxenite near granitic intrusions.

Age of Granitic Intrusion

Granitic rocks were intruded in pre-Jurassic time, and from late Lower to early Upper Cretaceous time. Granitic rocks that were exposed to erosion in the earliest Jurassic probably existed in a belt now largely occupied by the western plutonic complex. Although pre-Jurassic granitic rocks have not been recognized in the map-area[1], gneissic porphyritic granodiorite and quartz diorite in the Yukon group southwest of Alligator Lake, which have apparently been shattered since their emplacement, may be remnants of such older plutons.

There is no direct evidence that any plutons were intruded during or after the deformation of the Lower Cretaceous rocks and prior to the extrusion of the Hutshi group. Nonetheless some may be contemporaneous with the deformation.

Granodiorite and pink granophyric quartz monzonite cut the Hutshi group and older rocks. Granodiorite in the western plutonic complex is cut by leucocratic granites.

From these relations, and assuming that the leucocratic granites in Whitehorse map-area were intruded at the same time as the distinctive quartz monzonites in Stikine River area, much of the granitic intrusion in Whitehorse area must have taken place after the extrusion of the Hutshi group but before the late Upper Cretaceous—that is, between the late Lower Cretaceous and early Upper Cretaceous.

Minor Intrusive Rocks

Most of the minor intrusive rocks occur as aphanitic or porphyritic dykes that are feeders to flows of the Hutshi group, the Skukum group, and Miles Canyon basalt. These dykes are composed of dark grey to black basalt and porphyritic basalt with grey plagioclase phenocrysts, dark green to bluish green andesite and porphyritic andesite with plagioclase phenocrysts, rusty-brown, pale-pink, buff, and cream-coloured rhyolite, and pale-purple trachyte. Some of the rhyolite dykes, if glassy, have a greenish caste but are paler if devitrified.

Other dykes, less abundant than the aphanitic types, are medium- to fine-grained equigranular and porphyritic rocks ranging in composition from diorite to quartz monzonite. Of these, three types are most common: hornblende-quartz diorite, or locally diorite, featured by needles of black hornblende about 2 mm long; feldspar porphyry with plagioclase phenocrysts up to 5 mm in size, set in a speckled quartz-monzonite matrix; and hornblende diorites with more or less equidimensional mafic crystals.

Aplite dykes are found near the margins of some of the granodiorite and leucocratic plutons.

Granite Porphyry

Of the minor intrusive rocks, granite porphyry forms the largest and most important bodies. This is a pale-brown rock characterized by pale-brown phenocrysts in a slightly darker aphanitic or fine-grained groundmass. The phenocrysts consist mainly of microperthite, and subordinately of sodic plagioclase up to 5 or 6 mm across and rounded quartz up to 2 or 3 mm across. Examination of

[1] K-Ar age determination on biotite from an isolated granodiorite outcrop where the road crosses Flat Creek gave an age of 223 m.y. (Permo-Triassic) (Age Determinations by the Geological Survey of Canada, Report 1—Isotopic Ages; *Geol. Surv., Canada,* Paper 60-17, pp. 7-8 (1960)—comp. by J. A. Lowdon).

thin sections shows that the microperthite consists mostly of orthoclase with less than 10 per cent sodic plagioclase as irregular anastomosing veinlets. The terminations of pyramidal quartz phenocrysts have been rounded, apparently by resorption of some of the quartz by the matrix. The matrix consists of irregularly intergrown crystals of quartz, microperthite, and sodic plagioclase. Some microperthite phenocrysts, where they are in contact with sodic plagioclase of the matrix, are partly bordered by a zone of myrmekite.

The granite porphyry occurs as small stocks and dykes which, north of the Skukum group in Macauley Creek area, have an arcuate alignment suggesting that they were intruded along a ring-fracture. Other dykes have been intruded along faults. In addition, the granite porphyry bodies show the same general distribution as the felsic volcanic rocks and the youngest equigranular granitic rocks—the pink granophyric quartz monzonite and the leucocratic granites. The granite porphyry bodies have been found adjacent to but never in visible contact with these potash-rich granitic rocks. Although the granite porphyry bears a distinct textural and compositional similarity to the fine-grained and porphyritic border phases of the leucocratic granites, it cannot be demonstrated that the two are genetically related.

The granite porphyry and rhyolite bodies are the youngest intrusive rocks in Whitehorse map-area. If they are genetically related to the leucocratic granites, and if these rocks in turn are correctly assigned to a later Lower or early Upper Cretaceous age, then the granite porphyry must likewise be late Lower or early Upper Cretaceous. The granite porphyry and rhyolite dykes are, however, also identical with rocks in Carmacks and McQuesten map-areas that are considered to be partly younger than and partly contemporaneous with the Eocene or younger Carmacks volcanic group (Bostock, 1936, p. 44; 1942; 1948a, p. 6). Probably most of the bodies in Whitehorse map-area are of Eocene or later age, but some closely related to the leucocratic granites may be late Lower or early Upper Cretaceous.

Chapter IV

STRUCTURAL GEOLOGY

The scale of mapping has not permitted the detailed study needed to solve many of the structural problems in Whitehorse map-area—problems made difficult by the lack of horizon markers and the erratic distribution of volcanic rocks and conglomerates. In general however, the late Palæozoic and Mesozoic rocks have been folded into a northwesterly trending synclinorium which has been intruded by granitic plutons and is bounded on each side by a granitic plutonic complex containing older metamorphic rocks.

Folds

With a few exceptions, all rocks older than the Hutshi group are deformed into northwesterly trending folds.

Folds in the Yukon and Taku groups are irregular, but in general maintain the northwesterly trend. An exception is the westerly radiating pattern of the folds in the Taku group east of Taku Arm, where the beds sweep around the northern border of granitic bodies in the northern part of Atlin map-area (Aitken, 1955; Mulligan, 1955). This exceptional trend may have been produced by the forceful intrusion (Aitken, personal communication, 1955) of these granitic bodies.

Except for an area west of lower Ibex River and another north of Crag Lake, all the folded Mesozoic rocks trend northwesterly. The area underlain by these rocks is arbitrarily considered in two halves separated by the valley of Yukon River and Marsh Lake.

In the western half, the axial planes of the folds are either vertical or dip steeply northeast. Folds such as the Fish Lake syncline and those west of Lake Laberge are slightly asymmetrical. Folds on Canyon Mountain (*see* Plate IV, and cross-section on map) and east of Mount Lorne and Mount Lansdowne, are overturned. The character of the folds probably has been controlled to some extent by the competence of the rocks. This is suggested by the presence of such open folds as the Fish Lake syncline and the syncline northeast of Takhini Hotspring, where competent rocks, such as conglomerate and greywacke, are thick; and by tightly folded beds displaying slaty cleavage in the valley of Yukon River and Marsh Lake where the rocks are mainly incompetent limestone and interbedded argillites and arenites. This weak zone has also been the site of intense shearing and a locus for ultramafic intrusion.

The configuration of the folds in the eastern half of the area is not as well understood as in the western half. Asymmetrical folds whose axial planes dip steeply southwest may be present. This is suggested by moderately-westward-dipping homoclines, east of the valley of Yukon River and Marsh Lake and northeast of Mount Byng, which are associated with some steeply-eastward-dipping strata.

Local deviations from the prevailing northwest trend are probably effected by the intrusion of granitic plutons. The northeasterly trending folds north of Crag Lake, however, may be related to the fault that probably lies along Crag Lake valley.

Faults

Strike faults may be more prevalent than shown on the map. The only exposed strike fault is on the west limb of the Fish Lake syncline where the Lewes River and Laberge groups are thrust against the younger Tantalus formation along a steeply-eastward-dipping fault. Another inferred strike fault separates the Tantalus formation from the Lewes River group southwest of Coal Lake and at the mouth of Two Horse Creek. Unrecognized strike faults probably exist in the Fish Lake syncline near its axis along Bonneville Lakes valley, and along its southwest limb, where strata of both the Laberge group and the Tantalus formation south of Fish Lake may be repeated.

The nature of many of the northward-trending faults is not clear, except for two near the head of Byng Creek that are normal faults. Several of the cross-faults are also normal faults. Others, on the limbs of folds, may be normal or they may be small tear-faults associated with over-folding or thrusting. Several valleys normal to the structural trend east of Yukon River may have developed along cross-faults.

A fault extends from Watson River valley to Primrose River (*see* Plate III). South of the mouth of Rose Creek the rocks along this fault are highly sheared and brecciated, but the magnitude and direction of movement was not determined.

Stratigraphic and structural data suggest that a fault separates the Taku and Laberge groups along Crag Lake valley. The upward movement of the Palæozoic block south of this fault appears to have been absorbed westward in a broad zone of sheared Mesozoic and Palæozoic rocks, as there is no evidence for a fault west of Windy Arm. That the block north of the fault may have moved east with respect to the block to the south is suggested by the presence of northeastward-plunging folds north of Crag Lake that are overturned to the southeast and by the northeasterly trending slaty cleavage on both sides of the fault southeast of Tagish. Both of these phenomena trend differently from the regional trend and they are spatially related to the fault.

The faults are of several ages. Reverse faults, some of the northerly trending faults not affecting the Hutshi group, and the cross-faults, were probably involved in the deformation of the Tantalus and older rocks in later Lower Cretaceous time. Some are probably younger. The arcuate pattern of granite-porphyry dykes surrounding the Skukum group in the Macauley Creek area suggests that they were emplaced along ring-fractures formed by subsidence during the volcanism. Other linear faults cutting the Hutshi and Skukum volcanic rocks indicate that block-faulting accompanied or followed the extrusion of these formations. Granite-porphyry and rhyolite dykes have been intruded along a fault between the Skukum group and the Yukon group at the head of Watson River, and suggest therefore that some block-faulting took place before the emplacement of felsic rocks had ceased.

Chapter V

MESOZOIC TECTONIC HISTORY OF WHITEHORSE MAP-AREA AND ADJACENT REGION[1]

A trough extending southeast from Fort Selkirk, Yukon Territory, through the northeastern and central parts of Whitehorse map-area into northwestern British Columbia, received sediments and volcanic material from late Triassic to early Cretaceous time. This trough, called the Whitehorse trough, was a northern segment of a much larger furrow within the eugeosynclinal belt in British Columbia (Stille, 1941; Kay, 1947, 1951). This belt of Mesozoic rocks—called the Tagish belt—is 50 to 60 miles wide in southernmost Yukon (*see* Fig. 16).

The following account attempts to describe the tectonic setting prior to the development of the Whitehorse trough, and the succeeding geological history of this trough and the region lying northwest of a line joining the south end of Atlin Lake with Teslin, Yukon Territory. The stratigraphy for southern Yukon is summarized in Figure 17.

Tectonic Setting Prior to the Development of the Whitehorse Trough

The eugeosynclinal belt in this region (Kay, 1951, p. 35) was, during the Palæozoic, a zone of volcanic and tectonic activity. This is evidenced by several unconformities and the abundant volcanic and coarse sedimentary rocks in its marginal zones (Eardley, 1947, 1948; Kay, 1951; Muller, 1954; Moffit, 1954; Gabrielse, 1955; Poole, 1955).

By the Permian, however, the central part of this belt, later the zone in which the Whitehorse trough formed, was probably tectonically quiet. Non-clastic sediments accumulated in seas receiving volcanic material, mainly lavas, but little terrigenous detritus. This is evidenced by the predominance of non-clastic material in the Taku and Cache Creek groups and their equivalents in southern Yukon and northern British Columbia (Aitken, 1955; Mulligan, 1955; Watson and Mathews, 1944, pp. 15-17). That similar conditions existed at this time in parts of the western margin of this belt is indicated by the presence of Permian assemblages like those in the central part (Buddington and Chapin, 1929, p. 118; Watson, 1948, p. 19; Kindle, 1953, p. 29). However, in the northwestern part of the western margin—in the St. Elias Mountains—disturbed conditions probably existed during this time. Testimony of this is the abundance of pyroclastic rocks, lava flows, and coarse sedimentary rocks associated with chert, quartzite, argillite, and limestone (Muller, 1954, pp. 2-3; Moffit, 1954, p. 104).

Permian rocks have not been recognized along the eastern margin of the eugeosynclinal belt in this region.

[1]Areas covered by geological maps are shown in Figure 15.

INDEX TO MAP-AREAS

1. Eastern Alaska Range
2. Chitina Valley
3. Sixtymile and Ladue Rivers
4. Ogilvie
5. McQuesten
6. Mayo
7. Upper Beaver River
8. Northern Selwyn Mountains
9. Upper Stewart River
10. Macmillan River
11. Selwyn River
12. Carmacks
13. Glenlyon
14. Pelly River
15. Canol
16. Laberge
17. Teepee Lake
18. Kluane Lake
19. Aishihik
20. Kaskawulsh
21. Dezadeash
22. Teslin
23. Wolf Lake
24. Gulf of Alaska
25. Squaw Creek-Rainy Hollow
26. Bennett
27. Atlin
28. Tuya-Teslin
29. McDame
30. Southeastern Alaska
31. Taku River
32. Lower Stikine and Western Iskut River
33. Dease Lake
34. Northeastern British Columbia
35. Stikine River area

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Figure 15. *Index to map-areas in the northwestern Canadian Cordillera and eastern and southeastern Alaska, U.S.A.*

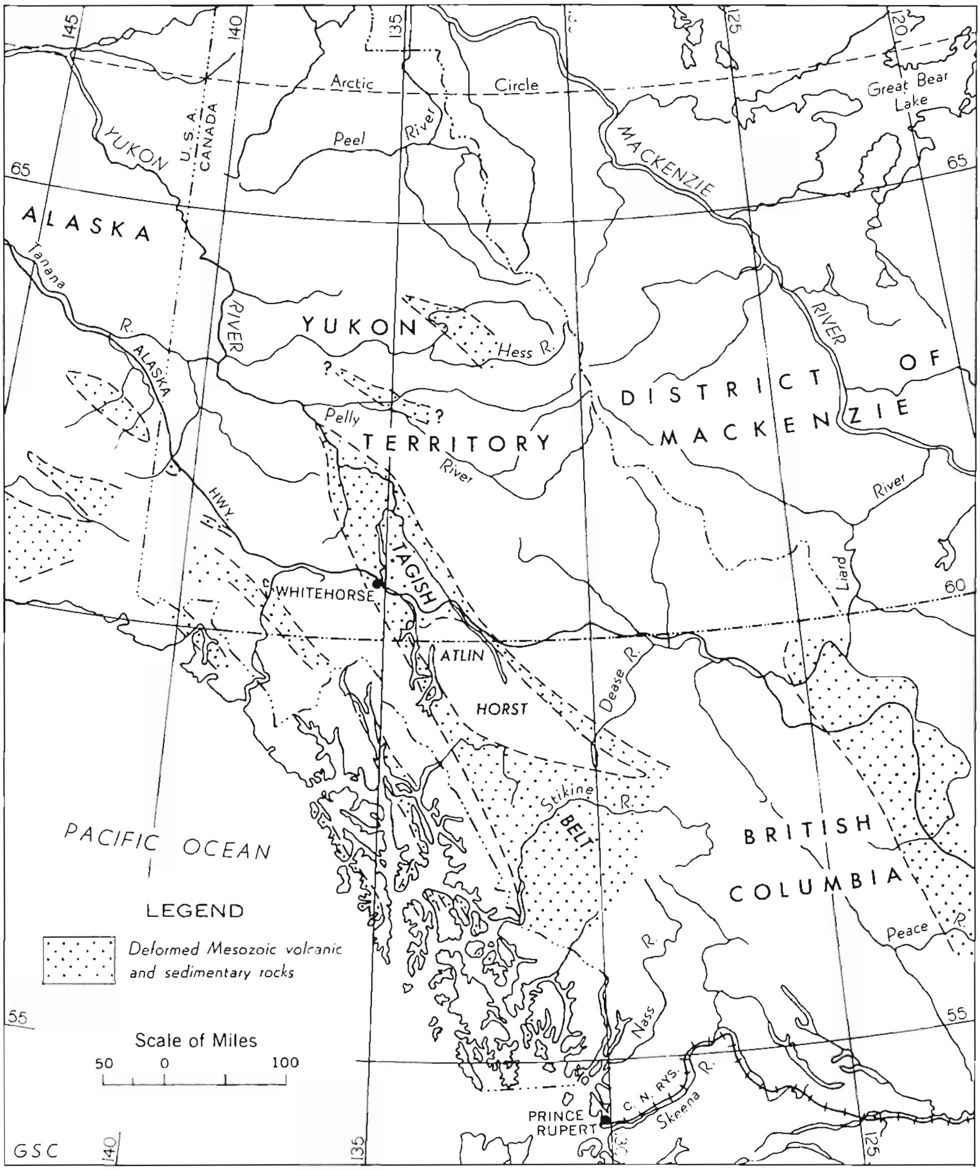

Figure 16. *Map showing distribution of deformed Mesozoic volcanic and sedimentary rocks in northwestern Canada and eastern and southeastern Alaska, U.S.A.*

Although the relations between the Upper Triassic and Permian formations are not displayed in the region under discussion, information on these relations has been obtained in eastern Alaska, southwestern Alaska, and northwestern British Columbia. In eastern Alaska, Martin (1926, p. 129) interpreted the absence of Lower and Middle Triassic and the presence of volcanic rocks and a local

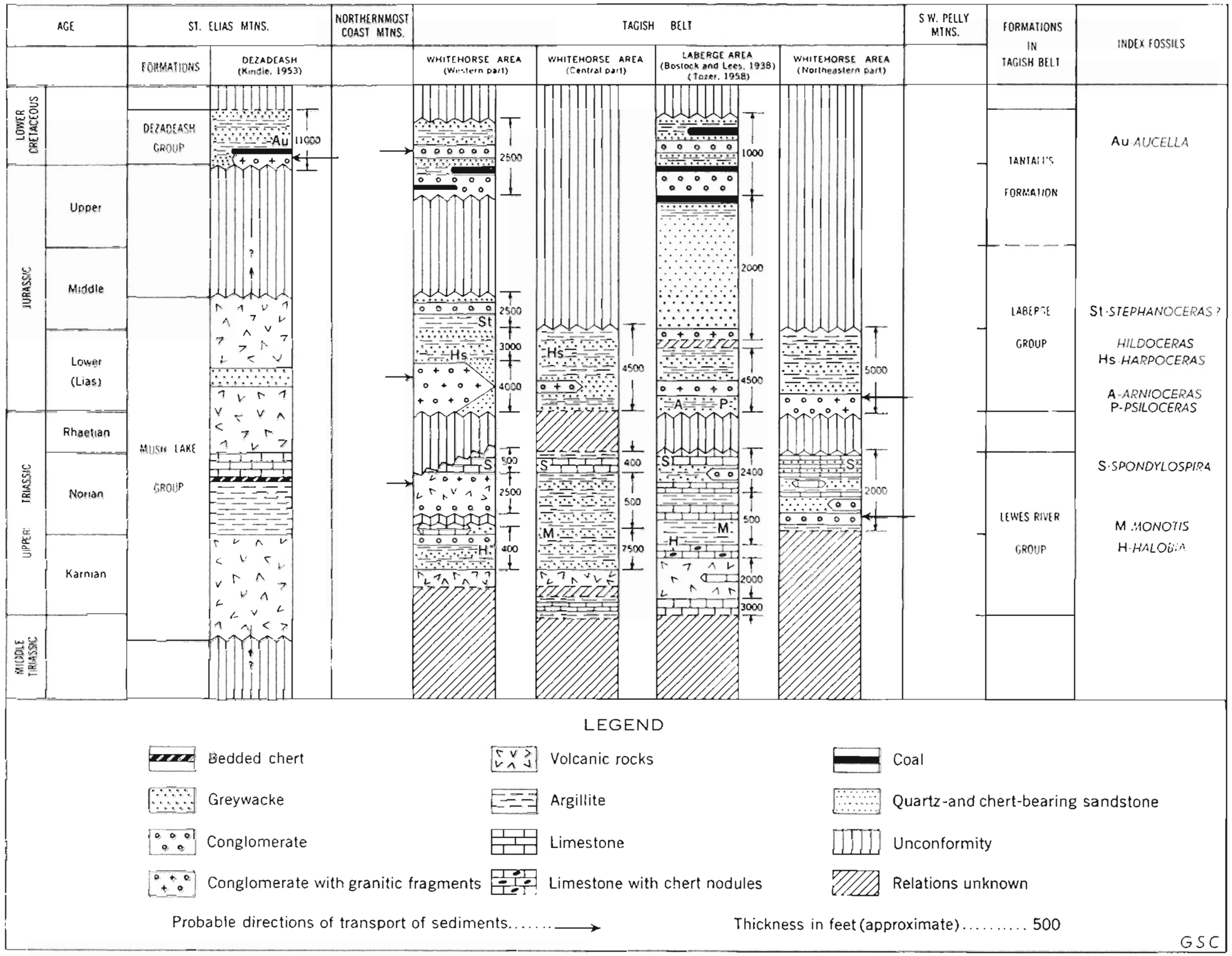

Figure 17. *Correlation chart of deformed Mesozoic rocks in central southern Yukon Territory.*

unconformity between the Upper Triassic and Permian as evidence for a period of emergence accompanied by volcanism. Similar relations prevail in southeastern Alaska (Buddington and Chapin, 1929, p. 285) and in northwestern British Columbia (McLearn, 1953, p. 1207). Furthermore, Upper Triassic basal conglomerate is widespread in northwestern British Columbia. All this suggests that a widespread emergence also took place in the region in which the Whitehorse trough subsequently developed.

Whitehorse Trough

Data on the early history of the Whitehorse trough is fragmentary. The late Norian (late Upper Triassic) stratigraphy of Whitehorse map-area, however, indicates that the structure had been initiated by that time. It appears to have been of about the same width and in the same place then as a relatively well-defined trough in early Jurassic time, but its shape and extent is not known. The stratigraphy along the east flank of the Coast intrusions, however, as far southeast as Stikine River area, is similar to that in the western margin of the trough in Whitehorse map-area, and suggests that the structure may have extended along the east side of the Coast intrusions during the late Triassic.

Distribution of Upper Triassic Volcanic Rocks

In the eugeosynclinal belt the Upper Triassic sections that contain the most volcanic rock are those flanking the Coast intrusions from latitude 61° southeast (McLearn, 1953, pp. 1213-1214; Buddington and Chapin, 1929).

Upper Triassic volcanic rocks may be present in the southern part of the St. Elias Mountains in the Squaw Creek - Rainy Hollow area (Watson, 1948, p. 23) and in the Mush Lake group in Dezadeash map-area (Kindle, 1953, p. 34). They are absent northwestward in the northern St. Elias Mountains (Muller, 1954, p. 3), in eastern Alaska (Moffit, 1938, p. 44; 1954, p. 119), and northward on Beaver River, Yukon (Keele, 1906, p. 17; McLearn, 1953, p. 1213).

As Upper Triassic volcanic rocks are thinner and less abundant north of Whitehorse map-area (Tozer, 1958) and are altogether absent northeast of Mayo map-area, it is questionable if the sedimentary and volcanic rocks unconformably overlying Carboniferous strata and intruded by granitic rocks in McQuesten (Bostock, 1948a, p. 5), Mayo (Bostock, 1947), and Glenlyon (Campbell, 1954), are really Triassic as has been suggested. They may be equivalent to other volcanic rocks in Yukon that are late Carboniferous, Jurassic or Cretaceous in age.

Upper Triassic volcanic rocks occur along the eastern margin of the Tagish belt in Whitehorse and Teslin (Mulligan, 1955, p. 8) map-areas.

Upper Triassic Sedimentary Rocks Along the Western Margin of the Tagish Belt

In addition to containing the greatest abundance of volcanic rocks in the Upper Triassic of this region, the stratigraphic sections along the western margin of the Tagish belt also contain the coarsest sedimentary rocks. For example, the Upper Triassic sequence in the western part of Whitehorse map-area comprises volcanic breccia and conglomerate from a nearby westerly source, andesitic and basaltic lavas, volcanic greywacke low in quartz, and limestone, and the sequence is interrupted by one disconformity (*see* Fig. 17). A 10,000-foot assemblage of Upper Triassic rocks in Taku River map-area (Kerr, 1948b, pp. 23-29) is composed of andesite flows, volcanic breccia and conglomerate of local origin, arenites grading from tuffs to limy volcanic greywacke, and limestone. The sequence is also interrupted by one or possibly two disconformities.

Tectonic Conditions Along the Western Margin of the Trough During the Late Triassic

The late Triassic stratigraphy in the above region indicates that a source area for the volcanic and coarse clastic material lay along the axis of the Coast intrusions and underwent intermittent uplift. This caused periodic incursion of coarse volcanic detritus into the Whitehorse trough, and also, occasionally, flows of andesitic and basaltic lava. Such a source was probably a volcanic island arc (Eardley, 1947), similar to modern island arcs, which Kay (1951, p. 72) regarded as the typical environment within eugeosynclines. Although the volcanic arc was probably active during much of the late Triassic, supplying volcanic material and coarse sedimentary debris to the trough, by latest Triassic time it appears to have been dormant, for as much as 1,000 feet of limestone and fine clastic rocks occur at the top of the Upper Triassic sections in Whitehorse and Taku River (Kerr, 1948b, p. 28) map-areas.

The Whitehorse Trough During the Jurassic

The quiet period at the end of the Triassic was abruptly terminated by sudden and rapid uplift of parts of the volcanic arc. At intervals throughout the Lias (Lower Jurassic), coarse detritus was supplied to parts of the western margin of the Whitehorse trough, and finer detritus farther east. Some detritus was apparently also derived from the northeast.

Volcanic activity almost ceased in the Whitehorse trough from latest Triassic to mid-Cretaceous, in contrast to the intermittent volcanism in the continuation of the trough in northwestern British Columbia (Frebold, 1953, pp. 1235, 1240; Kerr, 1948b, p. 30).

Shape of the Trough in the Early Jurassic

The western border of the trough is defined by coarse Lower Jurassic conglomerates, from Carmacks, southeast to Stikine River area (*see* Fig. 18). These were deposited at or near the sea-coast a few miles east of a source area of high relief (Bostock, 1936, p. 22; Bostock and Lees, 1938, p. 14; Aitken, 1953, p. 31; Kerr, 1948b, p. 52; 1948a, p. 32).

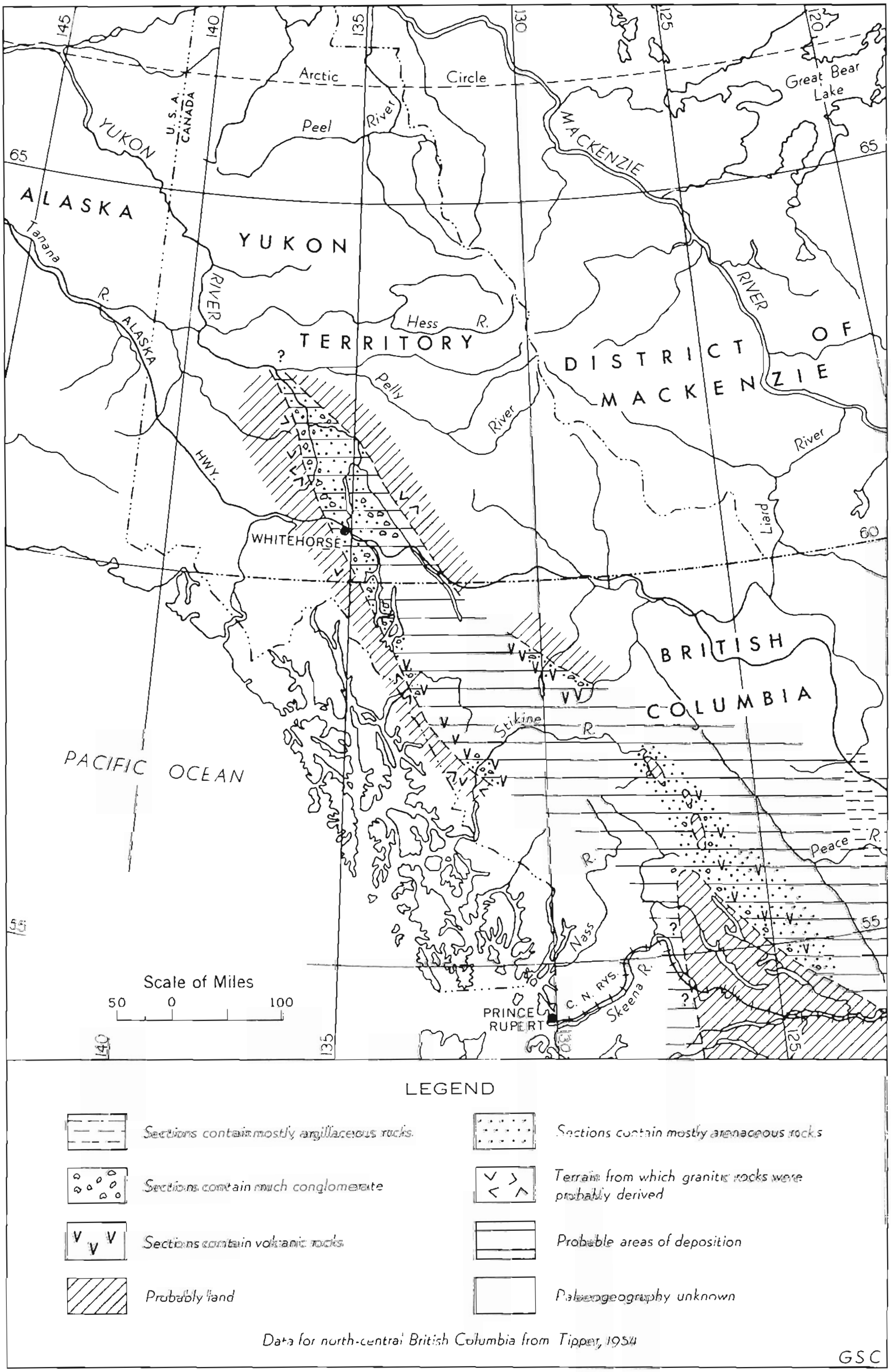

Figure 18. *Provisional palaeogeographic map of the northwestern Canadian Cordillera for early Jurassic (upper Lias).*

The eastern border is more difficult to define, because conglomerate is scarcer and the rocks, being poorly fossiliferous, are not well dated. It is in places defined by conglomerates, probably derived from the northeast, overlying the latest known Triassic east of Yukon River (Cockfield, 1929, p. 6), and along Teslin Valley in Whitehorse and Teslin (Mulligan, 1955, p. 9) map-areas. Similarly it is defined by conglomerate at the base of the Jurassic McLeod group in Eagle-McDame area (Hanson and McNaughton, 1936, p. 6), and its possible equivalent in the Nazcha formation on Ichthyosaur Mountain in Tuya-Teslin area (Watson and Mathews, 1944, p. 19; Kerr, 1926, p. 90).

In early Jurassic time the trough was narrower towards the northwest and perhaps terminated near Carmacks, because Jurassic outcrops which end there, are marked by conglomerates of local origin (Bostock, 1936, p. 22). Moreover, the nearest area along strike that may contain Jurassic rocks, is the Kandik segment of the Kuskokwin geosyncline, 300 miles to the northwest (Payne, 1955). The trough appears to have been wider in northwestern British Columbia. A large area in the centre of the trough is now occupied by a fault block of late Palæozoic rocks—the Atlin horst. In early Jurassic time, Mesozoic sediments probably extended from one margin of the trough to the other before being stripped off the elevated fault block.

The relation between the Jurassic and the Triassic, exposed for the most part along the margins of the trough, is that "of a disconformity, or more rarely that of an erosional unconformity" (McLearn, 1953, p. 1207). In Whitehorse map-area the disconformity is greatest at the margins of the trough and decreases toward the centre where the Jurassic may lie conformably on the Triassic.

The uncertainty as to the stratigraphic position of the conglomerates in the eastern part of the trough hinders the drawing of an accurate cross-section of the trough. As thicker and coarser conglomerates occur in the western part of the trough, it may have received sediments and subsided more rapidly than the eastern part, and may, therefore, be slightly asymmetrical (*see* Fig. 19, in pocket.)

Lower Jurassic Conglomerates Along The Western Margin

The Lower Jurassic conglomerates, marking the western margin of the Whitehorse trough, are similar to those in the western part of the map-area. They probably represent coarse alluvial fans at the mouths of powerful easterly flowing streams that drained partly-timbered highlands. These highlands were perhaps 10 miles from the coast and were composed principally of melanocratic volcanics and granitic rocks with some sedimentary rocks. This interpretation is suggested by the lenticular shape of the conglomerate bodies, and by their texture, coarseness, and composition; also by the way in which they thin out and disappear eastward, and their association with strata containing both marine fauna and plant fragments, woody material, and locally fossil logs (Bostock, 1936, p. 24; Bostock and Lees, 1938, p. 13; Cairnes, 1910, pp. 31, 33; Kerr 1948b, p. 32) (*see* Fig. 17). Some thin conglomerate beds may, however, be essentially marine and formed by wave action upon a rocky coast.

Deposits in the Central Part

Fine detritus accumulated in the central part of the trough in Whitehorse map-area during the Lower Jurassic. These beds, which form a disturbed graded sequence associated with thin layers of granitic-pebble conglomerate and slabs of argillite, were evidently laid down under turbulent conditions. Such conditions may have been created by the slumping of unstable, rapidly deposited deltas along the western margin of the trough, which in turn generated turbidity currents (Kuenen and Carozzi, 1953).

Early Jurassic Tectonic Conditions Along the Western Margin

In early Jurassic time, along the western margin of the Whitehorse trough, coarse gravels were deposited in some localities while elsewhere fine detritus was accumulated. Later, in some areas that previously received fine debris, coarse gravels were deposited, and in other parts the reverse happened. Thus it is that the coarse conglomerates that mark the western margin of the trough appear at different stratigraphic levels in different places. Examples from Whitehorse map-area were given previously; those from other areas follow. Conglomerate overlies beds containing lower Lias *Psiloceras* sp. and *Arnioceras* sp. in Laberge map-area (Lees, 1934, p. 22). Conglomerates occur above and below late Lower or early Middle Jurassic Hildoceratids in Carmacks map-area (Bostock, 1936, p. 27), above and below upper Lias fossils in Bennett map-area (R. L. Christie, personal communication, 1955), and well above lower Lias *Arnioceras* sp. in Atlin map-area (J. D. Aitken, personal communication, 1955). Conglomerates in Taku River map-area are restricted mainly to the lower part of the Lower Jurassic (Frebold, 1953, p. 1235). This variation in the time and place of deposition of the coarse gravels implies variations in the rate of uplift of the western margin of the trough at different times and at different places, and possibly also of local changes in the direction of stream flow that lasted long enough to allow the alluvial fans to form in a new place.

The abrupt change from limestone and fine clastic rocks in the latest Triassic, to coarse conglomerates in the earliest Jurassic, and similar changes from fine clastic rocks to coarse conglomerates within the Jurassic, suggest that uplifts were relatively rapid and spasmodic. In the early Jurassic, subsidence appears to have kept pace with the accumulation of coarse conglomerate, for upper Lias marine fossils occur above thick conglomerates in several places in Whitehorse map-area and elsewhere.

Character of the Northeastern Margin in the Early Jurassic

The stratigraphy along the northeastern margin of the Tagish belt is uncertain, and little can be said of the tectonics of this zone during the early Jurassic. The composition, thickness, and basal position of the conglomerates along this margin indicate that the source to the northeast, composed of volcanic and sedimentary rocks with minor granitic masses, had a lower and less spasmodic uplift than the western margin.

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Tectonic Conditions in the Whitehorse Trough from the Middle Jurassic to Early Cretaceous

By the middle or late Jurassic, the Whitehorse trough was probably cut off from the sea. The character of the source areas on each side of the trough had changed from terrains composed of volcanic and sedimentary rocks containing bodies of granitic rocks, to those composed of Palæozoic cherts and chert-pebble conglomerate (Campbell, 1954), and quartz-rich metamorphic rocks of the Yukon group. The rate of uplift of the western source was also probably less. These conditions are suggested by the absence of large lenses of coarse conglomerate bearing granitic fragments in late Jurassic and early Cretaceous sediments and the presence of quartz-rich arenites, shales, coal, and a few beds of conglomerate up to 50 feet thick that are composed principally of quartz, chert and quartzite pebbles. Moreover the rocks contain fossil plants but no marine fossils (Bostock, 1936, p. 28; Lees, 1934, p. 23; Cairnes, 1910, p. 35).

The source areas in the late Jurassic and early Cretaceous were probably farther from the axis of the trough than they were in early Jurassic time. This conclusion is supported by the finer texture and better sorting of the non-marine upper beds compared with the marine lower beds, and the probable overlap of Lower Cretaceous over Lower and Middle Jurassic in the western part of Whitehorse map-area.

As 3,000 to 4,000 feet of strata were laid down in the western part of the trough during the late Jurassic and early Cretaceous compared with 5,000 to 6,000 feet during the early and middle Jurassic (Bostock, 1936, pp. 25, 28; Bostock and Lees, 1938, pp. 15, 16; Cairnes, 1910, p. 32), less debris was probably supplied to the trough during the later stages than during the earlier stages of its sedimentary history. Even with this decreased rate of supply the base level of deposition was above sea-level, and hence the rate of subsidence of the trough was much less at this time than earlier in the Jurassic. This decrease in the rate of subsidence may have been a precursor to the deformation of the trough, which followed in mid-Cretaceous time.

Early Cretaceous Palæogeography

In the early Cretaceous the Whitehorse trough appears to have been a restricted, non-marine basin whose extent is masked by the fragmentary distribution of the Tantalus formation in the Yukon. Recent mapping in northwestern British Columbia reveals that marine and non-marine Lower Cretaceous sediments near Telegraph Creek become coarser toward a probable source to the north (J. G. Souther, personal communication, 1957). If so, a land area in northwestern British Columbia may have partly or wholly separated the non-marine basin in the Yukon from the marine environment to the southeast, and this accounts for the termination of the Tantalus formation near the Yukon-British Columbia border.

The western limit of the source area west of the Whitehorse trough in the early Cretaceous can be delineated by the occurrence of basal Lower Cretaceous conglomerate in the St. Elias Mountains.

Coal-bearing conglomerate at the base of a thick succession of interbedded greywacke, slate, and minor tuff containing Neocomian (early Lower Cretaceous) *Aucella* east of Alsek River is missing at the base of the Lower Cretaceous section west of the river (Kindle, 1953, pp. 35-36). This conglomerate, which probably accumulated at or near a sea-coast, may mark the eastern shoreline of the Neocomian sea, in which sparsely fossiliferous greywacke and slate were deposited in the St. Elias and Chugach Mountains, eastern Alaska Range, and in parts of southeastern Alaska (Imlay and Reeside, 1954, pp. 227-235).

The eastern limit of the non-marine basin can only be assumed from the eastward extent of the Tantalus formation.

Change in Composition of Arenites During the Sedimentary History of the Trough

This change (illustrated in Figure 10, p. 70) was effected by the change in composition of the western source area from a volcanic arc in the late Triassic, from which quartz-poor arenites were derived, to one in the early Jurassic containing granite rocks, from which arenites containing appreciable amounts of quartz and potash feldspar were derived. Finally, the source area in late Jurassic and early Cretaceous time was the exposed core of siliceous sediments that apparently underlay the volcanic arc. The last relationship implies that the volcanic arc was but a veneer upon a siliceous basement.

Kerr (1948b, p. 29) comments on a similar increase in Taku River map-area —in the amount of quartz in Jurassic arenites over that in Triassic arenites.

Geotectonic Classification of the Trough

As a geotectonic element (Cady, 1950) the Whitehorse trough has affinities with idiogeosynclines (Umbgrove, 1947, p. 49) and epieugeosynclines (Kay, 1951, p. 56).

In the late Triassic, the Whitehorse trough lay east of a volcanic arc probably extending along the axis of the Coast Mountains. In the early Jurassic, parts of the volcanic arc were spasmodically uplifted and coarse sediments poured into the trough on the east. Granitic rocks, either older than the volcanic rocks and perhaps correlative with pre-Permian rocks in Atlin map-area or the pre-Upper Triassic granitic rocks in Telegraph Creek map-area (J. G. Souther, personal communication, 1957), or intrusive into them, were exposed along with the volcanic rocks of the island arc just prior to or during this uplift, as in modern volcanic arcs (Umbgrove, 1947, p. 167). The Whitehorse trough is like the idiogeosynclines in the East Indies; it is about the same size, occupies a similar position between the volcanic arc and the craton, and has a similar, though more violent, sedimentary history. All the troughs started with relatively rapid subsidence which slowed up towards the end of their sedimentary history and perhaps stopped just prior to the deformation of the sediments within them (Umbgrove, 1938, pp. 39-45). Plutonic rocks intrusive into the Whitehorse trough are however calcalkaline types in contrast to those in the idiogeosynclines which are rich in potash and deficient in silica (op. cit., p. 167).

The history of the Whitehorse trough is similar in some respects to the western Californian geosynclines younger than the Nevadan orogeny (Kay, 1951, p. 48). Both types of geosyncline began with sedimentation accompanied by volcanism in troughs east of a belt of linear islands (Taliaferro, 1943). In their later history, sedimentation continued without much associated volcanism in troughs retaining about the same trend as before (Jenkins, 1943; Kay, 1951, p. 48).

Although the Whitehorse trough began in a eugeosynclinal environment, its later sedimentary history is similar to that of the late Palæozoic epieugeosynclines in New England States and the Maritime Provinces (Kay, 1951, p. 56) which are marked by deeply subsiding elongate basins containing both marine and non-marine sediments with minor volcanic rocks. These are separated from adjacent marine areas by highlands. The later history of the Whitehorse trough illustrates well the segmentation of the earlier continuous trough into smaller differentially-subsiding basins.

Deformation of the Trough

As much of this region has only been mapped on a reconnaissance scale and as many of the earlier maps record no structural symbols, only general statements based mainly on mapping in Whitehorse and adjoining map-areas, can be made regarding the deformation of the Whitehorse trough. Evidence from these areas indicates that the Whitehorse trough was probably deformed during the mid-Cretaceous (Kerr, 1948b, p. 38). The folds in Mesozoic rocks of the Tagish belt are mainly parallel with the trend of the belt, except where they have been deflected by subsequent intrusions or where they are related to subsequent faulting. From the character of the folds in Whitehorse map-area the belt appears to be a synclinorium in which the axial planes of the folds dip toward the centre. Open folds prevail in thick accumulations of competent conglomerate and greywacke, whereas tight folds occur in incompetent limestone and interbedded slate and greywacke.

The terrain adjacent to the trough was probably also deformed to some extent because unconformities are widespread in the late Lower Cretaceous in eastern and southeastern Alaska (Imlay and Reeside, 1954), and consequently some of the granitic rocks in the western part of Whitehorse map-area may have been sheared at this time.

The relative upward movement of the Atlin horst was completed sometime after the rocks in the trough had been folded and intruded by granitic plutons. As the area now occupied by the northern part of the Atlin horst appears to have been a relatively elevated region in late Jurassic and early Cretaceous time, this block may have begun to rise in the late Jurassic.

Intrusions in and around the Whitehorse Trough

Ultramafic Rocks

Serpentinized ultramafic rocks are scattered across 250 miles of the northwestern Cordillera, rather than being restricted to certain zones as maintained by Hess (1939, 1955). Along the trend of the Tagish belt the apparent age of these rocks is Permian (Aitken, 1953, p. 125), late Triassic (Kerr, 1926, p. 87), and Jurassic (Mulligan, 1955, p. 11). Although detailed studies of their structural relations in this region are for the most part lacking, some of the apparently late intrusions may have been emplaced tectonically, either in fault blocks or as solid intrusions, and may have originally formed at some previous time. Such displacements or re-intrusion may have taken place more than once in this part of the eugeosynclinal belt, as the sedimentary record indicates that several periods of at least local deformation have occurred since the mid-Silurian, some involving the unroofing of granitic rocks.

Ultramafic rocks were apparently intruded inside the volcanic arc into rocks deposited in the Whitehorse trough. Such a site of intrusion is contrary to the ideas of Hess (1939, p. 269) and Umbgrove (1947), who considered that ultramafic intrusions were restricted to the outer, non-volcanic arc and zone of negative gravity anomalies. Relations similar to those in the Whitehorse trough must have existed for the ultramafic intrusions in three other localities along the inner edge of the eugeosynclinal belt, in McDame (Gabrielse, 1955), Aiken Lake (Roots, 1954), and Slocan (Cairnes, 1934) map-areas. The absence of dykes like those related to the volcanic rocks in the eugeosynclinal belt, in the miogeosynclinal rocks extending to within 20 miles of the eastern border of the eugeosynclinal belt (H. Gabrielse, J. E. Reesor, and E. F. Roots, personal communication, 1955), indicates that at no time did the volcanic rocks extend much farther east than now. Hence the ultramafic rocks were emplaced either into a volcanic arc, or between it and the craton. Ultramafic rocks were similarly intruded into the Franciscan-Knoxville geosyncline in California on the side of a belt of linear islands facing the craton (Taliaferro, 1943).

Ultramafic rocks, therefore, probably existed beneath tectonically active zones, such as island arcs, within eugeosynclinal belts, but were injected higher into the crust at times when the deformation in these zones was sufficiently intense.

Granitic Rocks

Granitic rocks form a plutonic complex of pre-Permian, possibly pre-Jurassic, and mid-Cretaceous intrusions bordering the Tagish belt. Within the belt they occur, for the most part, as simple plutons of broadly mid-Cretaceous age.

Granitic boulders in Lower Jurassic conglomerates along the western margin of the Tagish belt (Bostock, 1936, p. 22; Bostock and Lees, 1938, p. 14; Aitken, 1953, p. 31; Kerr, 1948b, p. 31) suggest that pre-Jurassic granitic rocks may have been intruded into the volcanic arc west of the trough, or faulted against the volcanic rocks of the arc. Perhaps these rocks can be correlated with the pre-Permian granitic rocks in Atlin map-area (Aitken, 1955).

Granitic debris in conglomerates along the northeastern margin of the belt (Cockfield, 1929, p. 6; Mulligan, 1955, p. 9) indicates that granitic rocks existed northeast of the trough, but the nature and time of their emplacement is unknown. Mid-Cretaceous plutons occur also as steep-walled post-tectonic intrusions that cut gently dipping volcanic rocks lying unconformably upon folded rocks within the trough. They also form part of the composite Coast intrusions and part of the granitic terrain east of the trough (Bostock, 1936, p. 39). The younger of these plutons are richer in potash than the older (*see* Fig. 12) (Kerr, 1948, pp. 63-66).

Granitic rocks, then, are most extensive in those areas bordering the Tagish belt that were subject to at least one period of intrusion prior to the mid-Cretaceous. It is interesting to note that although mid-Cretaceous granitic bodies are plentiful within the confines of the Tagish belt, granitic rocks indistinguishable from them are most abundant in the zones bordering the belt where pre-Lower Jurassic granitic rocks are also present (*see* Fig. 18).

Chapter VI

ECONOMIC GEOLOGY

Prospecting began in Whitehorse map-area in 1893. Stimulated by the Klondike gold rush in 1895 to 1898, and by the completion of the White Pass and Yukon Railway in 1903, prospecting activity was greatest during the first few years of the 20th century. During this period numerous prospects were explored in the Windy Arm and Wheaton districts and in the Whitehorse copper belt. Some of these showings were mined and small shipments of ore were made. Since 1920, however, little mining has taken place in the map-area.

Because of this lack of activity the exposures of mineralized rock in most of the properties are poor; trenches and pits have slumped; shafts are filled with water; many of the portals of the adits have caved, and others, particularly those at high elevations, are sealed by ice. The only indication of the nature of the mineralization in many of the workings was to be found in the dumps. The writer's knowledge of the mineral deposits in the map-area has thus been gained from what is still visible in the old workings and from earlier published descriptions.

METALLIFEROUS DEPOSITS

Placer Deposits

Abandoned gold-placer workings exist just above the mouth of the west fork of Sheldon Creek. Lees (1936, p. 25) reported that the creek was worked in the thirties. The west fork of the creek is dammed off from the main channel by glacial gravels and the stream has been forced to cut a new channel across a rock spur. The old buried channel lies to the south of the new one.

Lode Deposits

Gold and Silver

Gold- and silver-bearing quartz veins occur in three types of rocks: metamorphic rocks; granitic rocks; and rocks believed to belong to the Hutshi group.

Quartz Veins in Metamorphic Rocks—Several quartz veins occur in a narrow band of metamorphic rocks of the greenschist facies that outcrops from Mount Stevens northwest to Watson River. The veins strike N30°W, about parallel with the schistosity, and dip steeply northeast except on Gold Hill where they dip steeply southwest. They appear as discontinuous lenses up to, but generally much less than, 200 feet long and 3 feet wide. In some places the lenses are aligned with each other; in other they are arranged *en échelon* and separated by thin strips of schist.

The veins consist chiefly of vuggy, crystalline quartz, some calcite, and metallic minerals. The main metallic constituents are pyrite—found as scattered grains and crystals, thin stringers, and rarely, as massive pods—some finely disseminated galena, minor native gold, and the tellurides sylvanite, hessite, and petzite. The sulphides, tellurides, and gold form only a small part of the vein and their distribution is very irregular. Consequently, it is difficult to obtain representative samples, and only the richest ore-pockets have been extracted.

Quartz Veins in Granitic Rocks—Quartz veins carrying gold and silver are found in granitic rocks of the western plutonic complex and in granodiorite north of Montana Mountain, particularly near their contacts with older formations. These veins have various attitudes: those on the ridge between Skukum and Berney Creeks and on the ridge east of the lower bend in Becker Creek strike about east and are vertical; those near the gulch northeast of Tally-Ho Mountain are nearly parallel in strike and dip with the quartz veins in the metamorphic belt; and those at the head of Watson River and north of Montana Mountain have gentle dips.

The walls of the veins are generally smooth and commonly carry some gouge, and at the gulch northeast of Tally-Ho Mountain the wall-rocks are brecciated. The veins are interpreted as fault-fissures, but as good markers are lacking the amount and direction of movement are unknown. The quartz veins vary in width from a few inches to as much as 4 feet, and are remarkably persistent in that several of them have been traced for as much as 1,000 to 2,000 feet horizontally and 500 feet vertically. The vein quartz is vuggy and crystalline, and in several places shows a coarse comb-structure. The sulphides are mainly galena, with lesser amounts of pyrite. Native gold is rare. The galena is coarse grained where it forms massive lenses in the quartz, but in other places it is finely divided or appears as thin veinlets. The pyrite occurs either disseminated or as veinlets, and is associated with the galena. The sulphides form irregular bodies in the quartz that pinch and swell or split into thin veinlets, or they occur in sparsely scattered grains. Their appearance is that of discontinuous lenses in the persistent quartz veins.

In the Mount Stevens district mineralization is confined to granite porphyry dykes that intersect green schists and greenstones.

The dykes are cut by later basalt dykes and cross-faults and seamed by numerous quartz veinlets so that they resemble breccias. The sulphides consist of galena and pyrite, and minor native gold, and are most plentiful at the intersection of cross-faults with the dykes.

Quartz Veins in Possible Hutshi Group Rocks West of Windy Arm—West of Windy Arm, several gold-silver deposits occur along two sets of veins in rocks that may belong wholly or partly to the Hutshi group or may be partly older, altered volcanic rocks. One set strikes northerly and dips about 50°W, the other set strikes east and dips about 45°N. The veins show many of the same characteristics as those found in the granitic rocks. They may extend as far as 3,000 feet along strike. The walls are smooth, gently sinuous, and carry gouge, and the sulphide bodies within the vuggy, coarsely crystalline quartz veins pinch and swell irregularly from a few inches to 6 or 7 feet. In the Venus mine, however, old stopes indicate that lenses that pinch out along strike in a short distance were mined down the dip for more than 100 feet.

The sulphides are mainly massive galena, with lesser amounts of pyrite, arsenopyrite, ruby silver, grey copper, jamesonite, and sphalerite.

Mount Stevens District

A wagon road, about 3¾ miles long and now much overgrown, joins the road from Robinson to Wheaton River and extends to timber-line on Mount Stevens. All the workings in this district were abandoned at the time of the writer's visit in 1949; the pits and trenches were sloughed in, and none of the veins were exposed. The following descriptions are therefore taken from the literature.

Hawk Eye Group (1)[1]

Reference: Cairnes, 1912, p. 106.

The Hawk Eye group of three claims lies on the Wheaton River slope of Mount Stevens. Two quartz veins, 20 inches and 3 to 4 feet wide respectively, lie parallel with the schistosity of the enclosing green schists. The quartz is slightly impregnated with galena and chalcopyrite.

Acme Claim (2)

References: Cockfield and Bell, 1926, p. 42; 1944, p. 14.

The Acme claim, situated on the top of Mount Stevens, contains the largest quartz lens noted in the Wheaton district. The lens, which occurs in chloritic and sericitic schists, is up to 30 feet wide and more than 100 feet long. A little galena and pyrite occur in some places.

Midnight Group (3)

References: Cockfield, 1923, pp. 6-7. Cockfield and Bell, 1926, p. 42; 1944, p. 15.

The Midnight group of six claims lies on the southeast side of Mount Stevens overlooking the Wheaton River valley. Green schists and greenstones, probably belonging to the Lewes River group, are cut by dykes of granite porphyry 25 to 50 feet wide, which in turn are cut by either dykes of basalt 7 feet wide or by a series of parallel cross-faults. The granite-porphyry dykes are highly sericitized and seamed by myriads of quartz veinlets locally containing native gold and gold-bearing pyrite and galena. Significant gold values are found only where gold or sulphides are visible. Cockfield regarded the intersection of the cross-faults and the granite-porphyry dykes as the most favourable location for ore shoots.

[1]Number in parentheses indicates the site of the property on the accompanying geological map.

Hidden Ore Group (4)

Reference: Bostock, 1941, p. 26.

The Hidden Ore group adjoins the upper side of the Midnight group, on the southeast face of Mount Stevens. The group lies near the contact of a granodiorite body with green schists, where the schists are intruded by numerous granite-porphyry and quartz-porphyry dykes. The dykes are altered and highly fractured so that the quartz-filling forms a network of veins one-quarter inch to 2 inches wide, giving the rock the appearance of a breccia. The quartz is accompanied by native gold, galena, pyrite, and in places by sphalerite and chalcopyrite. Locally gold occurs in cubical cavities with limonite. Workings that expose the mineralized and fractured dykes are distributed from the summit of the ridge at an elevation of 5,500 feet, to below 2,600 feet on the Midnight and Hidden Ore groups.

Buffalo Hump Group (5)

References: Cairnes, 1912, p. 107; 1916, p. 44. Cockfield and Bell, 1926, p. 42; 1944, p. 14.

The Buffalo Hump group consists of three claims (Golden Slipper, Sunrise, and Wheaton) which adjoin each other on an eastward-trending line across the north end of Mount Stevens. On the Golden Slipper claim, quartz float can be found lying on granitic rocks near the summit of Mount Stevens. The quartz contains small amounts of disseminated galena, free gold, and sylvanite.

The Sunrise claim is the most persistent and apparently the best mineralized vein in the group. This is a quartz vein in a fissure in the granodiorite that strikes N45°W and dips 20 to 35°NE. It attains a maximum width of 7 feet but averages 2 to 3 feet over some 50 feet of exposed length. The quartz carries some sparsely distributed galena, pyrite, and native gold. No telluride minerals are present and gold is erratically distributed.

Wheaton Mountain (6)

References: Cairnes, 1912, p. 108; 1916, p. 44. Cockfield and Bell, 1926, p. 42; 1944, p. 15.

Several claims on Wheaton Mountain attracted attention around 1910. The most important were the McDonald fraction, the most promising prospect on the hill, and the Gopher and Silver Queen claims.

On the McDonald fraction, near the western edge of Wheaton Mountain, is a quartz vein in a fissure in granodiorite. The vein strikes N47°W and dips vertically or steeply northeast. The quartz in the vein is locally massive and elsewhere shows distinct comb-structure. In places, argentiferous galena constitutes most of the vein which, in some places, shows a banded structure. Samples taken by Cairnes from the dump outside a 20-foot shaft assayed less than 0.05 ounce a ton, gold and silver combined.

The Gopher claim, also on the western part of Wheaton Mountain, contains an irregular lens of quartz up to 7 feet wide in greenstone and green schist. The quartz, which is massive, contains disseminated galena.

On the Silver Queen claim on the northern part of Wheaton Mountain, is a quartz vein in granodiorite about 3 feet thick. It contains galena and pyrite.

Tally-Ho Gulch (7)

References: Cairnes, 1912, pp. 108-110; 1916, p. 44. Cockfield and Bell, 1926, p. 43; 1944, p. 15.

Eight claims, all developed on one vein, lie on the west side of Tally-Ho Gulch. The mineralization occurs in a brecciated fault zone in granodiorite of the Coast intrusions. The zone, which is 4 to 12 feet thick, strikes northwest and dips 60 to 70°NE. Workings in 1910 consisted of a 290-foot drift, a 40-foot raise, and a 15-foot crosscut. The portal had completely caved however, and the workings were inaccessible when visited in 1948.

Both walls of the fault zone are coated with a clayey gouge, a quarter of an inch to an inch thick, and similar material occurs in seams distributed through the brecciated central part. Some quartz has been introduced between the granitic fragments in the central part of the fault zone, but mostly it is restricted to the foot-wall where it occurs as a vein that ranges from 6 inches to 3 feet wide. Argentiferous galena is fairly evenly disseminated through the quartz. Cairnes reports assays averaging $20 a ton in gold and silver in 1912. The galena has been altered to cerussite ($PbCO_3$) within 8 or 10 feet of the surface in some places.

Gold Hill District

The following prospects lie in a northwest-trending belt from Gold Hill to the Watson River slope of Mount Hodnett. They occur either in a narrow belt of greenstone and green schists, or in the granitic rocks close to their contacts with this belt of older rocks.

Gold Reef Claim (8)

References: Cairnes, 1908, pp. 18-19; 1912, pp. 112-113. Cockfield and Bell, 1926, p. 43; 1944, p. 16.

The Gold Reef claim lies at an elevation of 5,500 feet on the northeast side of Gold Hill about 18 miles by road and trail—now partly overgrown—from Robinson. The showing consists of a fairly regular vein striking N55°W and dipping 50 to 60°SW, more or less parallel with the foliation in the narrow belt of enclosing greenstones and green schists. When the vein was being explored in 1909 it was traced for over 1,000 feet, and throughout this distance it averaged 4 to 5 feet in width. In detail, the vein follows the foliation in the surrounding schists for some distance, then in places it cuts across the schists for a few feet, and once more resumes its former course.

The quartz in the vein is massive and generally the only visible metallic mineral is pyrite. Locally, however, there are rich pockets of native gold, sylvanite, hessite, petzite, and telluric ochre. Gold occurs mainly in the pockets either as small, spongy masses, or in minute, bright, solid particles.

In 1909 the property contained several hundred feet of drifts, crosscuts, and shafts, but less than a ton of ore was shipped. In 1948 only one crosscut was exposed and the cabins were demolished.

Dail Creek Showing (9)

Reference: Cairnes, 1916, p. 43.

A vein striking N82°W and dipping 75 to 85°S occurs in a fissure in granitic rocks at an elevation of 4,800 feet on the south side of Gold Hill at the head of Dail Creek. The vein is 8 to 20 inches wide in Dail Creek and consists mainly of somewhat iron-stained white quartz. In most places it contains disseminated galena, and locally some sylvanite. Three samples taken from the vein by Cairnes assayed as follows:

Sample	Gold (oz./ton)	Silver (oz./ton)
1. Average across vein where it is 14 inches wide	0.25	0.75
2. Average across vein where it is 20 inches wide	0.11	1.99
3. Average of a number of particularly well mineralized specimens	1.51	15.74

Lucky Boy (10)

Reference: Cairnes, 1912, pp. 112-113.

This showing is on the upland surface on the east side of Mineral Hill. A quartz vein that strikes northwest in green schists contains chalcopyrite, chalcocite, and malachite. Only 6 or 7 feet square were uncovered in 1909. Difficulty was encountered with frozen felsenmeer.

Legal Tender (11)

References: Cairnes, 1908, p. 19; 1912, p. 112. Cockfield and Bell, 1926, p. 44; 1944, p. 16.

This occurrence lies on the north face of Mineral Hill about 1,000 feet above Watson River. The vein is in granodiorite and strikes northwesterly and dips steeply northeast to vertical. The vein is composed of finely crystalline quartz, locally exhibiting coarse comb-structure. Through this is disseminated argentiferous galena and some chalcopyrite. The metallic minerals show a crude banding. In 1909, the only working was a drift about 100 feet long.

Isolated Deposits in Granitic Rocks

The following properties are scattered over the southwestern part of the map-area and are relatively isolated from each other.

Mount Anderson (12)

References: Cairnes, 1912, p. 110; 1916, pp. 45-46. Cockfield and Bell, 1926, p. 43; 1944, p. 15.

Workings on the old Becker-Cochran property, forming the Mount Anderson, Whirlwind, and Sheep Mountain groups, occur above timber-line on the west slope of Mount Anderson, overlooking Becker Creek. Numerous pits, excavated by a bulldozer in 1948, are scattered over the upland south of Mount Anderson. Two main veins have been discovered; they extend along the southwest face of Mount Anderson for more than 2,000 feet. Most of the development has been done on the lower vein.

The workings on the lower vein constitute a 172-foot crosscut at the end of which a 165-foot drift follows the vein southeast. A 350-foot drift, collared 150 feet above the crosscut, also followed the vein. The upper drift was caved in 1948, although the vein was well exposed at the portal. The lower vein strikes between west and N60°W and dips vertically to 80°NE. It ranges in thickness from 4 inches to 6 feet and averages about 18 inches. The vein follows a fissure in granodiorite and consists of quartz, galena, and pyrite. It is locally cut by basalt dykes which appear to have no effect on the localization of ore.

At the portal of the upper drift, the central part of the vein comprises about 2½ feet of highly fractured, rusty quartz bounded on both sides by 1- to 2-foot-wide zones of vuggy quartz containing discontinuous lenses and veinlets of galena. These mineralized zones are in turn bounded by sheared wall-rock, mainly granodiorite, but locally basalt dykes. Locally, 6-inch zones of gouge separate the granodiorite from the vein material. Along the drift the sulphides are distributed erratically, so that the vein is barren along much of its length.

To the southeast, a vein has been intermittently exposed for more than 2,000 feet. These exposures may be parts of two or possibly three veins, but are more probably the continuation of the lower vein repeated by faulting. On the Sheep Mountain group near the southeast end of the vein, it is 3½ to 4½ feet thick and well mineralized. The lower vein was reported to contain 8 per cent lead. The gold content was generally low, but locally, samples carried 3 ounces a ton.

The upper vein, which strikes about due west and dips nearly vertically, outcrops about 200 feet above the lower vein. The workings consist of a 35-foot-long crosscut from the end of which a 75-foot-long drift follows the vein. Along this length the vein ranges from 4 to 20 inches thick.

A small concentrator stands in the gulch southwest of the summit of Mount Anderson, and there are some cabins in poor condition on a bench about 200 feet above Becker Creek, near the mouth of this gulch. A trail from the cabins connects with the wagon road in Wheaton River valley.

Mount Reid (13)

References: Cockfield, 1923, pp. 7-8. Cockfield and Bell, 1926, p. 44; 1944, p. 16. Bostock, 1938, p. 12.

This property contains two veins on the east ridge of Mount Reid, which are exposed at elevations of 4,800 and 5,600 feet respectively. The veins strike a few degrees north of east and dip steeply southeast. They are about 300 feet apart in the lower workings, but about 600 feet apart in the upper workings. The veins are mainly in granodiorite but also are reported to traverse a body of andesite.

The north vein has about 2 feet of solid vein matter, though in places the fracture zone it follows is about 25 feet wide. Little work has been done on it.

The south vein contains 10 to 15 feet of vein matter and gouge between solid rock walls. In 1937, pits and cuts exposed this vein for a horizontal distance of 1,000 feet and a vertical distance of 650 feet. An adit was started near the lower exposures. The vein maintained a width of 8 to 9 feet for a distance of 135 feet.

In 1948 the pits and cuts had sloughed in and the portal of the adit had caved. The vein was exposed, however, directly above the portal. Two mineralized zones, 7 and 15 inches wide respectively, are enclosed in sheared and brecciated granodiorite. The mineralized zones consist chiefly of quartz, containing irregular stringers of pyrite and arsenopyrite, and blebs and irregular lenses of galena. Cockfield (1923, p. 8) reports stibnite as well. An easterly trending, pale grey-green dyke cuts across the gully 60 feet above the portal; it is not known if this cuts the vein.

Mr. J. O. Stenbraten reported the following assays (Bostock, 1938, p. 12); all but the last seven were taken in 1930.

> Twelve channel samples were taken across widths of from 1 foot to 5 feet from a trench at the upper end of the south vein. Six of these carried more than 0.5 ounce a ton gold. Values for lead varied between 0.2 per cent to 11 per cent; those for zinc from nil to 6.2 per cent. Samples that ran highest in gold and silver carried the most lead and zinc.
>
> Twelve channel samples were taken across widths of from 2 to 5 feet from a cut near the lower end of the south vein. These returned up to 0.765 ounce a ton gold, 59.90 ounces a ton silver, 11.8 per cent lead, and 8.4 per cent zinc. Only one sample returned as low as trace in gold and all showed some silver.
>
> Two samples from vein matter 1,100 feet west of the upper trench on the south vein gave gold 0.23 and 0.25 ounce a ton, and silver 31.60 and 90.80 ounces a ton.
>
> Seven channel samples taken in 1936 averaged 0.277 ounce a ton gold and 17.35 ounces a ton silver.

Mascot Group (14)

References: Cockfield, 1923, p. 5. Cockfield and Bell, 1926, p. 44; 1944, p. 16.

The Mascot property lies in a cirque headwall at an elevation of 6,200 feet near the head of Watson River—about 38 miles by road, wagon road, and trail from Robinson. The showing consists of a vein, well exposed for 2,000 feet in the cliffs in the headwall, that strikes N35°W and dips 40 to 45°NE. It ranges from 6 inches to 20 feet wide but generally is about 18 inches. The vein is parallel with one of the main sets of joints in the dioritic country rock close to its contact with metamorphic rocks of the Yukon group. It is composed of white and rusty-grey quartz seamed by many discontinuous stringers of pyrite. In some places pyrite occurs in irregular bands with disseminated cubes, small blebs, and stringers of galena. Some copper stain was also seen. Locally the borders of the vein are sheared and show some gouge. The dioritic wall-rocks are altered within 5 feet of the vein. In this region, the plagioclase has been saussuritized, and the mafic minerals, chiefly hornblende, have been altered to chlorite. Much epidote occurs in patches and stringers.

At the foot of the cliff an adit was driven, prior to 1922, for 200 feet on the vein. This was blocked with ice when visited by Cockfield in 1922 and by the writer in 1949. According to J. M. Elmer, the vein pinched to 6 inches toward the end of the tunnel and the amount of gold and silver diminished considerably.

The following values are reported from the vein: In 1916, fourteen samples were taken by M. R. Small; the leanest showed a trace of gold, and the richest 1.86 ounces a ton gold. A grab sample by Cockfield, across 6 feet of the vein assayed 0.11 ounce a ton gold, and 1.45 ounces a ton silver; lead was not determined. Twenty-five samples taken by W. M. Ross in 1934, from thirteen trenches along the 2,000 feet of vein, averaged 0.344 ounce a ton gold and 8.36 ounces a ton silver, over an average width of 2.1 feet. The lowest assay for gold was 0.04 ounce a ton and the highest 0.88 ounce a ton.

Big Thing (15)

References: Cairnes, 1908, p. 11; 1917, p. 37. Cockfield and Bell, 1926, p. 39; 1944, p. 12. Bostock, 1937, p. 11; 1938, p. 13; 1941, p. 26.

The Big Thing workings are at elevations of 5,100 and 5,600 feet, about 6 miles south of Carcross by wagon road. Openings were completely iced in 1951 so that this property could not be visited. The original exploration—a 2,320-foot crosscut driven from the lower camp at 5,100 feet, a 450-foot inclined shaft from the upper camp, and four levels of underground workings—was done on a vein in granodiorite striking N55°E and dipping 25 to 35°NW.

East of the inclined shaft the vein is repeatedly faulted in various directions, but west of it the vein is cut by two faults only and is fairly regular. It is generally from 2 to 8 feet wide, with a maximum width of 12 feet, and is composed mainly of quartz with pyrite and arsenopyrite, and subordinate galena, chalcopyrite, and stibnite.

In the late thirties, a second vein was discovered parallel with the original vein. This was traced by open-cuts and trenches for over 6,000 feet. It consisted of quartz containing pyrite, arsenopyrite, and galena. Channel samples revealed values of from $2 to $35 per ton of gold and silver. A grab sample taken in 1951 from an ore-sack assayed 0.28 ounce a ton gold and 29.62 ounces a ton silver.

Jean Claim (16)

Reference: Bostock, 1941, p. 26.

The Jean mineral claim lies a mile southwest of the Big Thing. The vein there was found to be at least 5 feet wide. A sample from 2 feet of the vein is reported to have assayed $50.40 gold to the ton. Several other assays were considerably lower.

89856-9—10

Deposits in Volcanic Rocks West of Windy Arm

Montana Mine (17)

References: Cairnes, 1908, pp. 14-15; 1917, pp. 38-39. Cockfield and Bell, 1926, pp. 39-40; 1944, pp. 12-13.

The Montana Mine is at an elevation of about 5,500 feet about 2½ miles south of the Big Thing. A 5-mile aerial tramway, with some of its towers now collapsed, connected the mine with lake-level at Conrad. A 4-mile trail connects the mine workings with the Big Thing. When visited in 1951, all the workings were blocked by ice and the buildings had collapsed. The showing comprises a quartz vein striking N10°W and dipping at 10 to 15 degrees within porphyritic volcanic rocks. The vein, which is 2 to 5 feet wide, contains a richly mineralized part 8 to 18 inches thick near the hanging-wall.

The metallic minerals are chiefly galena, and subordinate native silver, argentite, pyrargyrite, tetrahedrite, pyrite, and arsenopyrite. Some cerussite also occurs. The main valuable mineral is silver, although pyritic parts contain appreciable gold. A grab sample taken from an ore-sack in 1951 assayed 0.08 ounce a ton gold and 110.14 ounces a ton silver.

Joe Petty (18)

Reference: Cairnes, 1908, p. 15.

This occurrence is on the north side of Pooly Creek about 2,800 feet above Windy Arm. It consists of a vein about 6 feet wide composed of alternating bands of decomposed, iron-stained quartz and mineralized country rock. All pits and trenches had sloughed in when visited in 1951.

Uranus (19)

Reference: Cairnes, 1908, p. 15.

The Uranus property is directly south of the Joe Petty, across Pooly Creek. In 1906, three tunnels revealed a vein 1 foot to 4 feet wide. The workings were inaccessible in 1951, but samples from the dump indicate that the vein was composed of coarsely crystalline quartz, locally having comb-structure and disseminated clots of galena. A sample from the dump assayed 1.37 ounces a ton gold and 49.34 ounces a ton silver.

Thistle and Aurora (20, 21)

Reference: Cairnes, 1908, p. 16.

These showings occur at the head of Pooly Creek at about 5,000 feet elevation. The workings were caved and inaccessible in 1951. Samples from the dump showed that the veins were in green volcanic breccia and were composed of white and grey, coarsely crystalline, vuggy quartz containing pyrite, galena, sphalerite, chalcopyrite, and stephanite.

M and M (22)

References: Cairnes, 1908, p. 15; 1917, p. 39. Cockfield and Bell, 1926, p. 40; 1944, p. 13.

The M and M property lies east of the Joe Petty, on the north side of the canyon of Pooly Creek. The vein, which strikes N20°W and dips 20 to 30°W, is in porphyritic andesite, and has been traced on the surface for 400 feet. It is 6 to 15 inches wide and consists of bands of sulphides in quartz. The sulphides are argentite, pyrargyrite, stephanite, freibergite, and tetrahedrite. The values are mainly in silver and subordinately in gold.

The workings consist of short tunnels, the longest being 90 feet, and some small stopes.

Vault (23)

Reference: Cairnes, 1908, p. 16.

The Vault workings are at elevations of 3,450 and 3,340 feet on the south bank of Pooly Creek. They consist of two drifts at different levels, each about 450 feet long. The lower tunnel is connected by an aerial tramway to the shore of Windy Arm.

The vein strikes northerly and dips 30 to 70°W. It may be a continuation of the vein on the Venus property. The vein is 15 feet wide in a gully above the portal; within the drifts, however, it is only 3 to 18 inches wide. It is composed chiefly of quartz containing lenses of galena 2 to 3 inches thick. Cairnes reports clots of galena 4 to 6 feet thick, and these may have existed where the drift has been enlarged to provide for vertically-pitching stopes 15 to 20 feet deep. A sample taken in 1951 from the vein in the upper level assayed 0.05 ounce a ton gold and 1.43 ounces a ton silver.

Venus (24)

References: Cairnes, 1908, pp. 16-17; 1917, p. 39. Cockfield, 1930, p. 13. Cockfield and Bell, 1926, p. 40; 1944, p. 13. Johnston, 1915, p. 240.

The No. 1 showing on the Venus adjoins the Vault property on the south. Cairnes reports that a shaft was sunk on the vein for 52 feet. From this shaft, drifts each way indicate that down dip the vein thickens from 10 inches to nearly 3 feet. These workings were inaccessible in 1951.

The No. 2 showing adjoins the Venus No. 1 on the south. The workings consist of two levels, one at about 3,300 feet, the other at 3,100 feet. The upper level comprises an adit 80 feet long, from which drifts run 108 feet south and 88 feet north. The lower level has a 450-foot adit, from which drifts run 410 feet south and 485 feet north. Raises and stopes connect the two levels. An abandoned aerial tramway joins the lower adit with a 100-ton mill, now in poor condition, at lake level.

Within the workings the vein pinches and swells between widths of 2 inches and 3 feet. Its strike ranges between N10°E and N50°E but averages about N20°E. Its dip ranges from horizontal to 60°NW but is generally about 35 degrees. At the time of the writer's visit in 1951, most of the ore had been mined.

89856-9—10½

The distribution and form of the stopes at points near bends in the vein suggest that such places were the loci for vertically-pitching ore shoots. The vein is contained in green volcanic breccia which, near the vein, is bleached, sericitized, and pyritized. The walls are commonly slickensided and locally contain gouge. Movement along a fault may have opened spaces at bends in the fault, allowing room for open-space filling.

The vein is composed characteristically of coarsely crystalline quartz, commonly exhibiting comb-structure and containing one or more bands of sulphides, mainly in the central part. The sulphides themselves are crudely banded. Pyrite commonly occurs in the centre, bordered by bands of galena, arsenopyrite, and jamesonite, and locally sphalerite, chalcopyrite, and chalcocite. Non-metallic minerals include cerussite, malachite, antimony ochre and yukonite (Johnston, 1915, p. 240; Cairnes, 1917, p. 40). The valuable mineral is chiefly silver associated with galena. Gold is contained in arsenopyrite.

Cairnes (1917, p. 40) records silver values ranging from less than 1 ounce a ton to more than 100 ounces a ton. Gold values ranged from trace to 5 ounces a ton, though they rarely were more than 2.5 ounces a ton and generally less than 1 ounce a ton. Additional values were lead 15 per cent and copper 0 to 1 per cent.

Cockfield (1930, p. 13) took samples from the north adit that were assayed in 1929 as follows:

Sample	Gold (oz./ton)	Silver (oz./ton)	Lead (%)	Zinc (%)
1	0.14	22.61	7.34	0.61
2	0.06	2.71	0.56	0.59
3	0.06	6.34	1.77	5.12
4	0.02	2.09	0.72	0.40

Selected samples taken in 1951 assayed as follows:

Sample	Gold (oz./ton)	Silver (oz./ton)
From vein in north drift—lowest level	0.17	18.41
From vein in south drift—north stope	0.80	2.74
From vein in south drift—south stope	2.06	290.90

Dail and Fleming Group (25)

References: Cairnes, 1908, pp. 17-18; 1917, p. 42. Cockfield, 1930, p. 14. Cockfield and Bell, 1926, p. 41; 1944, pp. 13-14.

Several claims, generally known as the Dail and Fleming group, lie south of the Venus property. These include the Venus Extension, Red Deer, Humper No. 1 and No. 2, Nipper No. 2, and Beach.

Three principal veins have been found—the Venus, Humper, and Red Deer. The Venus vein has been traced southward from the Venus property into, but not entirely across, the adjoining Venus Extension claim. The vein on the Venus Extension claim is similar in many ways to its segment in the Venus property, except that the southernmost part is flatter and more oxidized. It is generally 1½ to 2½ feet thick in the Venus Extension claim. The vein is composed of quartz gangue containing pyrite, arsenopyrite, and galena, and subordinate yukonite, cerussite, realgar, and orpiment.

Samples taken by Cockfield in 1929 from the Venus vein assayed as follows:

Sample	Location	Gold (oz./ton)	Silver (oz./ton)	Lead (%)	Zinc (%)
1	Extension adit	0.41	0.73	none	none
2	Extension adit	0.41	1.54	0.50	none
3	Extension adit	0.25	4.01	1.37	none
4	Extension adit	0.17	1.82	0.65	none
5	Extension adit	0.30	9.45	3.54	none
6	Extension adit	0.19	3.97	0.66	none
7	Extension adit	0.05	25.36	0.51	none
8	Raise from adit	0.29	0.82	0.09	none
9	Extension shaft	1.64	8.11	2.67	none
10	Extension shaft	0.29	3.04	0.79	none
11	Extension shaft	0.44	3.01	0.73	none
12	Extension shaft	0.76	40.35	7.34	0.61
13	Dail tunnel	0.06	0.46	0.14	none
14	Nipper	0.05	6.07	1.87	none
15	Nipper	0.02	1.57	0.33	none

The Humper vein strikes between due east and N60°E and dips from 35 to 65°N and NW. It ranges from 10 to 24 inches in thickness, and comprises quartz, argentite, pyrargyrite, stephanite, galena, pyrite, and native silver. The Red Deer vein, also in andesite, strikes N30°E and dips 50°NW. It ranges from a few inches to 3 feet thick and is composed of quartz carrying pyrite, galena, and various high-grade silver minerals. Two crosscuts—the lower 170 feet long, and the upper 90 feet long—failed to reach the vein on the Nipper No. 2 claim. The Red Deer vein is exposed in three small open-cuts. The Humper is exposed by two shallow shafts and several open-cuts. The entrances to the shafts are now caved and the open-cuts are sloughed in.

Antimony-Silver

Antimony deposits carrying some silver are found on Carbon Hill, and to the northwest, across Wheaton River, on Chieftian Hill. The veins are in granitic rocks and in volcanic rocks of uncertain age cut by these intrusions.

The veins on Chieftian Hill strike east and are vertical, whereas those on Carbon Hill strike east and southeast and dip steeply south or southwest. They vary in width from a few inches to 4 feet, and on the southeastern slopes of Carbon Hill, split into two or three veins to form a mineralized zone about 12 feet wide. The extent of the veins is not known for they are cut by granite-porphyry and rhyolite-porphyry dykes and are intersected by numerous small slips. In addition, vegetation and talus cover the exposures.

The sulphide bodies exhibit the characteristics of the gold-silver veins in that they form irregular, discontinuous bodies within a gangue chiefly of quartz, with calcite and barite. The sulphides are mainly stibnite, which forms either dense, fine-grained masses or partly radiating groups of prismatic crystals. Other minerals are galena, which occurs intimately with the stibnite, grey copper, and silver-lead-antimony sulphides.

Carbon Hill Area

Becker-Cochran Property (26)

References: Cairnes, 1916, p. 48. Cockfield and Bell, 1926, p. 46; 1944, p. 17. Bostock, 1941, p. 35.

The old Becker-Cochran property, at an elevation of about 5,000 feet on the east side of Carbon Hill, was being explored by J. Cox and the late W. McAllister at the time of the writer's visit in 1951. A bulldozed road via the west side of Becker Creek connected the property with the wagon road in Wheaton River valley. The vein was stripped by a bulldozer where it crosses a gully, and north of this gully it is followed by an adit. In 1951 the portal of this adit had caved. Bostock (1941, p. 35) reports that the adit bears northwest for about 100 feet. It follows an 8-foot shear zone striking N60°W and dipping steeply southwest. The shear zone is mainly gouge with patches and seams of vein quartz and stibnite. In the face, across 4 feet, are three vertical seams of vein matter; two are a few inches wide on the southwest side, and the other is 10 inches wide on the north side. A channel sample across this face gave 5.72 per cent antimony, and a hand-picked sample of vein matter carried 13.28 per cent antimony. A hand-picked sample of the richer sulphide vein matter on the dump outside the tunnel gave:

Bismuth	nil
Arsenic	0.18 per cent
Antimony	30.13 per cent
Lead	nil
Zinc	0.10 per cent
Copper	0.06 per cent
Gold	0.005 ounce a ton
Silver	0.19 ounce a ton

Side-hill cuts farther southeast expose the shear zone where it cuts brownish altered andesite. The cuts show a mineralized zone between 10 and 12 feet wide, composed of several bands of dark greyish blue sticky material 3 to 4 inches thick interlayered with soft brownish clayey material. One of the greyish blue bands contains up to 4 inches of solid stibnite. One of the smaller pits revealed a lens of stibnite about 2 to 3 inches across, but most of the material is clayey and sticky. Two channel samples over 1½ feet in the soft clayey and greyish blue material carried 0.18 and 0.36 per cent antimony respectively, and 0.26 and 0.38 per cent arsenic respectively. A sample of high-grade ore from the dump outside the portal ran 39.68 per cent antimony and 0.14 per cent arsenic.

Fleming Property (27)

References: Cairnes, 1912, pp. 126-128; 1916, pp. 47-48. Cockfield and Bell, 1926, pp. 45-46; 1944, p. 17. Bostock, 1941, pp. 37-38.

Several claims designated at different times as the Porter or Fleming group occur on the west face of Carbon Hill. The workings may be reached by a steep trail from ruined cabins at timber-line on Antimony Creek, accessible in turn by wagon road and trail along Wheaton River valley.

The early exploration of the property revealed several veins in the granitic country rock. Their attitude and correlation was uncertain because the outcrops were small and the trenches exposing them were constantly being filled in again with talus on the steep hillside. The most promising looking vein was 14 inches to 3 feet thick for at least 200 feet on the surface. The vein was chiefly quartz and stibnite with subordinate sphalerite and jamesonite. Parts of the vein contained a thickness of 12 to 14 inches of almost pure stibnite. The other veins, containing disseminated galena and grey copper, were 2 to 12 inches thick but were not so well mineralized. The best showing at the time of Bostock's visit was near the adit. It is an easterly trending vein dipping 60°N and is composed of 8 inches of stibnite, 12 inches of granodiorite, 4 inches of quartz and stibnite, 30 inches of granodiorite, and 12 inches of quartz and stibnite. A channel sample across this vein gave 9.61 per cent antimony. The 8-inch lens of stibnite pinched out in 2 feet.

The workings consist of an adit leading to further underground workings and numerous trenches which in 1948 and 1951 were entirely filled with talus. The underground workings on the Fleming property consist of an adit at elevation 5,250 feet which extends for 337 feet at N21°E with short crosscuts on both sides. Near the end of the adit, winding tunnels have been driven 192 feet northwest and 379 feet southeast respectively. A vein 3 to 8 inches wide, which carries quartz, stibnite, and minor amounts of other sulphides, is intersected by the southeast tunnel about 25 feet from the adit. The vein, which appears on the northeast wall of the tunnel, strikes N55°E and dips 42°NW. It appears to terminate against a shear zone in the back of the drift.

The workings are in granodiorite locally cut by northwesterly trending andesite dykes. The granodiorite is traversed by numerous slips and shears mainly disposed in three sets: a northeast set dipping 40 to 50°SE, a northwest set dipping steeply northeast, and a north-northwest set dipping 40 to 60°SW. In the underground workings, the abundance of these slips and shears, one of which is known to have faulted the vein, suggests that great difficulty may be encountered in establishing the number and extent of the veins found on the surface.

Silver values obtained during the early exploration ran as high as 500 ounces a ton, though generally they were less than 50 ounces a ton even in the richer pockets. Average silver values were traced to 5 ounces a ton. The most promising vein gave 50 to 60 per cent antimony, although Bostock reports picked samples from the underground vein which ran only 28.39 per cent antimony. Gold rarely exceeded 0.1 ounce a ton and generally was 0.05 ounce a ton. Highest lead values were 7 to 15 per cent but generally were less than 5 and often less than 1 per cent.

A vein of quartz, stibnite, and barite, striking north and dipping 25°W, has been exposed at an elevation of 4,650 feet on the south side of Carbon Hill, overlooking the head of Antimony Creek. In one trench the vein is 6 feet 7 inches thick. On the hanging-wall side it shows 2 feet of vein material with no stibnite, then 3 feet of granodiorite in the centre, followed by 1 foot 7 inches of vein material containing a 5-inch seam of stibnite. A channel sample across the foot-wall part of the vein, 1 foot 7 inches thick, gave 16.68 per cent antimony. A hand-picked sample from the stibnite seam gave:

Bismuth	nil
Arsenic	nil
Antimony	31.36 per cent
Lead	0.76 per cent
Zinc	3.40 per cent
Copper	0.05 per cent
Gold	trace
Silver	1.52 ounces a ton

Goddell's Claims (28)

References: Cairnes, 1912, p. 128; 1916, p. 48. Cockfield and Bell, 1926, p. 46; 1944, p. 17. Bostock, 1941, p. 35.

This showing lies between elevations of 4,100 and 4,850 feet on the north-west slope of Carbon Hill, about a mile north of the Fleming property.

Bostock (1941, p. 36) records vein material at several points on the steep slopes of Carbon Hill overlooking Wheaton River. At elevation 4,100 feet, a 13-inch vein in an easterly trending, vertical shear zone in granodiorite carries quartz gangue, stibnite, jamesonite, and arsenopyrite. A channel sample across 13 inches gave 14.19 per cent antimony. This vein is 3 to 6 inches wide over most of its exposed distance of 80 feet.

Vein material is exposed at elevation 4,450 feet where 2 to 3 inches of quartz and stibnite are exposed for a length of 3 feet. A picked sample of the vein matter assayed as follows:

Bismuth	nil
Arsenic	0.11 per cent
Antimony	7.74 per cent
Lead	nil
Zinc	nil
Copper	0.03 per cent
Gold	0.09 ounce a ton
Silver	0.28 ounce a ton

At an elevation of 4,500 feet, about 4 feet of similar mineralization is exposed. At 4,850 feet, 9 inches of vein is exposed and a sample carried 5.49 per cent antimony.

Virtually all the old workings have caved or sloughed in. Cairnes (1912, p. 116) described two parallel veins not more than 30 feet apart, but Bostock thought there were three or perhaps four nearly parallel veins in the shear zone across a width of more than 50 feet.

Chieftain Hill Area

Morning and Evening Claims (29)

References: Cairnes, 1912, p. 129; 1916, p. 47. Cockfield and Bell, 1926, p. 45; 1944; p. 17. Bostock, 1941, pp. 36-37.

The former Morning and Evening claims lay along a vein on the southeast face of Chieftain Hill at an elevation of about 4,700 feet, directly across the Wheaton River valley from Goddell's claims. The vein lies parallel with a set of fractures cutting both granitic rocks and the volcanic rocks of uncertain age. It strikes nearly due east and dips vertically. It occurs in a fracture zone about 40 feet wide that forms a gully now filled with debris. Limited exposures indicate that the vein consists of lumps of quartz containing stibnite and locally some sphalerite in a mass of fractured rock and gouge. A hand-picked sample of stibnite 2 by 3 by 8 inches, taken by Bostock, yielded 49.90 per cent antimony.

Silver-Lead

Although the silver-lead veins have many characteristics in common with the gold-silver quartz veins, they contain a much higher lead content and are the only major ore deposits in the Laberge group.

Annie Lake Area

References: Cairnes, 1908, pp. 19-20; 1912, pp. 130-139; 1916, p. 49. Cockfield, 1930, pp. 10-11. Cockfield and Bell, 1926, pp. 46-47; 1944, p. 18.

Idaho Hill (30)

The property known as Union Mines and later partly restaked as the Export group lies on the east face of Idaho Hill just north of Schnabel Creek. Early exploration of the showing revealed twelve veins, but at the time of the writer's visit in 1948 only three of these were exposed. The veins on the Union Mines property strike north and northwest and dip mainly west. They lie within greywacke of the Laberge group. The veins are fairly regular and tabular, and are generally 4 to 12 inches thick, though locally they contain pods 2 to 4 feet thick and 5 to 20 feet long of mixed rock and ore. The veins can be traced intermittently across the mountainside for several hundred feet.

The veins consist of a gangue of quartz, locally vuggy, and subordinate calcite. They carry galena, either disseminated throughout the gangue or as solid masses, intimately associated with arsenopyrite. Both these sulphides in many places distinctly penetrate and apparently replace the walls of the veins. Additional sulphides include sphalerite, pyrite, and chalcopyrite.

Samples taken during the early exploration gave silver up to 150 ounces a ton, averaging about 50 ounces a ton, and lead up to 70 per cent, averaging 40 per cent. These samples consisted almost wholly of galena. Gold ranged from trace to 0.1 ounce a ton.

The workings consist of a 135-foot crosscut entering the hillside at elevation 3,500 feet and connected by an abandoned aerial tramway to the camp buildings at elevation 2,900 feet on Schnabel Creek. A road leads to the camp from Robinson.

Export Group (31)

Reference: Cockfield, 1930, pp. 10-11.

This group, which partly embodies the former Union Mines ground, is on the southern, eastern, and northern slopes of Idaho Hill. The two upper showings are the most important. The uppermost showing, at elevation 3,600 feet, is 27 feet wide and consists of pyrite, arsenopyrite, galena, and sphalerite in a gangue of quartz and calcite. The best part of the zone is a band about 2 feet wide, 7 feet above the foot-wall. The lower showing, at elevation 3,500 feet, is 22 feet wide and strikes about N80°E with a dip of 50°S. This zone contains three bands, 1½ to 2 feet wide, rich in sulphides.

Several cuts farther down the hillside and some older workings of the Union Mines in Schnabel Creek canyon reveal narrow veins containing bodies of galena. Assays of material picked from these lower veins show values ranging as high as 127 ounces silver, 49 per cent lead, and 6 per cent zinc.

Some exploration of the veins in Schnabel Creek canyon was carried out in 1952 by Yukon Mines Limited.

Cariboo Group (32)

The Cariboo group of three claims is 1½ miles up Schnabel Creek above the Export group. The workings consist of four open-cuts; the lower two indicate a vein striking N35°E and dipping 60°NW. The vein is 7 feet wide in the lower cut and 3 feet wide in the upper. The latter shows a 2-foot zone of copper-stained rock on the hanging-wall. A second vein approximately parallel with the first and about 10 feet higher up the hill is revealed in one of the remaining cuts. Some work was done in 1952 by Yukon Mines Limited.

Other Localities

Mineralized Shear Zone on Mount Ingram

Reference: Fyles, 1950, p. 158.

A rusty shear zone containing pyrite, sphalerite, and galena was noted during the field work in 1946, in a stream bed 0.8 mile northwest of the summit of Mount Ingram. The shear zone cuts granitic rock, which probably is a granitized conglomerate or arkose but which may belong to the Coast intrusions.

The contact between the sediments and the granitic rocks passes close to the mineralized outcrop. As exposed in the stream bed, the mineralized zone is $1\frac{1}{2}$ feet wide and is bounded by 2 feet of rusty sheared granitic rock. It strikes N10°E and dips 80°W. The length of the exposed section was not recorded but it was noted that the degree of mineralization decreases towards one end of the exposure. A selected sample assayed by the Mines Branch, Ottawa, contained the following: gold, trace; silver, 3.23 ounces a ton; zinc, 8.50 per cent; lead, 1.89 per cent; copper, 0.54 per cent.

Showings West of Millhaven Bay

A. E. Aho reports two silver-lead showings along shear zones in low-grade metamorphosed volcanic rocks west of Millhaven Bay.

Copper

Most of the copper deposits in the map-area are of the contact metamorphic type. They are restricted mainly to the Whitehorse copper belt.

Whitehorse Copper Belt

References: McConnell, 1909. Cockfield and Bell, 1926, pp. 48-49; 1944, pp. 18-19. Cockfield, 1928, pp. 14-18.

The deposits of the Whitehorse copper belt lie at or near the contact of the granitic rocks with the limestones of the Lewes River group. The chief ore minerals are bornite and chalcopyrite, which occur most commonly in a skarn composed of brown garnet, diopside, some epidote, and tremolite; they are also found in a magnetite-rich skarn at the Arctic Chief mine in the south-central part of the copper belt. Specular hematite is common in the ore from the Pueblo mine, north of the road leading to Fish Lake.

In most places the contact between the limestone and the granitic rocks is masked by the skarn which occurs partly in the altered granite and partly in the limestone. In the granitic areas the skarn is massive, and grades gradually into dark, dioritic-looking rocks, whereas, in many parts of the limestone areas the skarn shows a distinct banding, probably caused by preferential replacement by certain minerals along planes parallel with the bedding in the limestone. Bodies of copper sulphides, either as massive pockets or disseminated masses, are nearly always found in the skarn along the limestone-skarn contact.

Exposures are not plentiful along the copper belt, and much of the drift-covered area may conceal more deposits. The magnetite-rich skarns of the central part of the belt may lend themselves to magnetic methods of exploration.

At the time of the writer's visits in 1949 and 1952, all but one of the mines were inaccessible because the shafts were flooded or the portals caved. The following description of the more important properties is based on reports by McConnell (1909) and Cockfield (1928).

Properties in the Central Part of the Belt

Arctic Chief (33)

Reference: McConnell, 1909, pp. 33-37.

The Arctic Chief is at an elevation of 3,012 feet above sea-level at the head of McIntyre Creek. It is accessible by a rough road 3 miles long from mile 9134 on the Alaska Highway.

The orebody lies on the west side of a northerly trending limestone body intruded by altered quartz diorite of variable composition. The granitic rocks near the Arctic Chief are strongly mineralized over a width of 400 feet for a length of 1,000 feet along the limestone-quartz diorite contact. The mineralization gradually diminishes away from the orebody. Where most intense, the original limestone and granitic rocks are almost entirely replaced by alternating bands and masses of garnet (brown andradite) and diopside. In addition to these, secondary minerals include epidote, actinolite, scapolite, and magnetite associated with bornite and chalcopyrite. The magnetite occurs as lenses and as disseminated grains.

Several large diorite-porphyry and gabbro-porphyry dykes cut both the limestone and the altered quartz diorite. These dykes have no effect on the mineralization of the region.

The orebody, as defined by the workings on the main level 65 feet below the surface, consists of a northwest-trending mass of magnetite about 230 feet long and from 25 to 40 feet wide. At its northwestern end the orebody curves away from the contact of the granitic rocks and is enclosed almost wholly in limestone. Ore continues for 25 feet in a 50-foot shaft sunk centrally in the orebody from the main level. Another lens of magnetite was encountered in workings connected to the bottom of this shaft. It was not determined whether this was a separate lens or part of the main orebody. A crosscut on the lower level intersected a vein of silver-bearing tetrahedrite.

Copper in the Arctic Chief lode exceeded an average of 4 per cent. Gold ranged from traces to over 2 ounces a ton, but did not bear a direct relationship to the copper content. Silver averaged about 2 ounces a ton although assays of 147 ounces a ton have been recorded from the tetrahedrite vein. A selected shipment of 140 tons, made in 1904, returned 0.39 ounce a ton gold, 2.5 ounces a ton silver, and 7.22 per cent copper. A shipment of 83 tons in 1907 yielded 0.18 ounce a ton gold, 2.00 ounces a ton silver, and 5.37 per cent copper.

The Grafter (34)

Reference: McConnell, 1909, pp. 38-40.

The Grafter lies about a mile north of the Arctic Chief and is accessible by the same rough road. The orebody is near the east end of a band of marble—one of several bands alternating with diorite. The bands are terminated on the east by andradite-diopside skarn and altered quartz diorite.

The workings, which consist of a shaft somewhat less than 100 feet deep sunk on the orebody, and stopes and a 137-foot drift at the 50-foot level, indicate a horseshoe-shaped orebody. The orebody, which has a nearly pure marble core, has a perimeter of about 150 feet and a maximum thickness of 17 feet; except for one lean stretch, it is rarely less than 6 feet thick.

The ore consists of bornite and chalcopyrite, the latter locally intergrown with pyrite, disseminated through an andradite-diopside tremolite gangue. Malachite, azurite, cuprite, and native copper also occur in small quantities. Magnetite is common as disseminated grains. A small veinlet of quartz carrying specks of native gold was cut in the shaft. Other gangue minerals include actinolite, cancrinite, and epidote. The copper minerals are generally most abundant close to the unaltered limestone, and the grade of the ore decreases away from it. Before 1907, about 2,000 tons of practically unsorted ore had been shipped, averaging 6 to 8 per cent copper.

The Best Chance (35)

Reference: McConnell, 1909, pp. 40-42.

The Best Chance property lies about 1,000 feet east-northeast of the Grafter, from which it can be reached by a trail. It has the largest surface showing of cupriferous magnetite so far discovered in the district. The outcroppings of ore measure 360 feet in length, with a maximum width of 65 feet, and an average width of about 30 feet.

The geology of the Best Chance showing is similar to that of the Arctic Chief, in that the ore lies along a quartz diorite-limestone contact and both rocks are intensely altered near the contact. The zone of skarn is barely 50 feet thick. It is composed principally of andradite, diopside, actinolite, epidote, chalcopyrite, and magnetite. The copper minerals, which are associated with the magnetite, consist mostly of bornite and chalcopyrite, and minor copper carbonates and oxides. Small clots of chalcocite have also been discovered.

Claims in the Northern Part of the Belt

The Pueblo (36)

References: McConnell, 1909, pp. 43-46. Cockfield, 1928, pp. 14-18.

The Pueblo mine is in the valley of Porter Creek near the northern end of the copper belt, at an elevation of 2,660 feet above sea-level. It is accessible from Whitehorse—about 6 miles along a good road.

The Pueblo orebody is in limestone close to its contact with granodiorite. The limestone replaced by the orebody was originally cut by some granitic dykes, and partly altered sections of these are visible. A porphyry dyke 2 to 4 feet wide cuts the orebody. The limestone near the lobe is thoroughly recrystallized. It contains a few garnets but otherwise secondary minerals are scarce. The granitic rocks near the contact are only slightly mineralized.

The workings consist of a 70-foot shaft from the bottom of which one drift extends 120 feet at N19°W and another southwest for 35 feet. A second shaft was sunk for 30 feet from a point 90 feet along the larger drift. The long drift and both shafts were reported to be entirely in ore, whereas the short drift is entirely in limestone.

The workings and surface outcrops indicate that the orebody is an irregular mass 300 feet long, 170 feet wide near the centre, and at least 100 feet deep.

The ore is essentially cupriferous hematite. It grades in texture from a fine compact variety to a coarse glistening specularite which is everywhere slightly oxidized. The copper sulphides are more altered than the hematite and the copper is present chiefly as carbonates, oxides, and silicates. Bornite is apparently absent and chalcopyrite is preserved only in a few limited areas. The alteration of most of the original copper sulphides into various secondary minerals was accompanied by an impoverishment of certain parts of the lode and an enrichment of others, especially near the periphery. The grade on this account varies, ranging from 1 to 10 per cent copper. Smelter returns from a shipment of 700 tons of ore from different parts of the lode gave 5½ per cent copper and 1¼ ounces a ton silver. Gold and silver values in the Pueblo ores are small.

In 1927, drilling by the Richmond Yukon Company, Limited, indicated an orebody west of the old workings, and another north of them. The latter appeared to trend at right angles to the former Pueblo lode, and was in a skarn gangue.

War Eagle (37)

References: McConnell, 1909, pp. 52-53. Cockfield, 1928, p. 17.

This showing, one of the most northerly in the copper belt, is about 1½ miles north of the Pueblo. Outcrops are scarce around the showing, and the few visible ones indicate that the eastern part of the claim is underlain by granodiorite and the western part by greywacke (formerly described by McConnell as porphyrite) containing lenses of limestone. The limestone is altered to skarn containing sulphides along its contact with the granodiorite. The skarn covers an area 1,000 feet long and 250 feet wide.

The orebody lies close to the granodiorite and consists of copper sulphides in alternating bands of tremolite-garnet and dark feldspar-augite rock, each 10 to 25 feet wide. The tremolite bands carry bornite and chalcopyrite in grains and small masses, and constitute the principal ores. The copper content of the feldspar-augite bands is considerably less than that of the tremolite bands. Magnetite and molybdenite locally accompany the copper sulphides.

Further work by the Richmond Yukon Company, Limited, consisting of a shaft and drifts at three levels, established the main orebody to be about 125 feet long by 45 to 55 feet wide. Samples indicated that the copper content was from 1.5 to 9 per cent and the silver content from 1 ounce to 3 ounces a ton.

A hematite-magnetite body was discovered north of the main orebody.

The Anaconda (38)

Reference: McConnell, 1909, pp. 50-51.

This claim lies west of Porter Creek at the northern end of the copper belt. The workings consist of a long westerly trending tunnel that did not intersect shipping ore, and several pits and trenches.

The Anaconda is in limestone near its contact with granodiorite to the east. The ore is contained in steeply-east-dipping tremolitic bands about 10 to 15 feet wide alternating with layers of marble and layers rich in garnet. The sulphides, bornite and chalcopyrite, are most abundant in the tremolite bands farthest from the granodiorite. Some of the garnet-rich skarn bands are also rich in sulphides.

The Copper King (39)

Reference: McConnell, 1909, pp. 46-49.

The Copper King showing was the first claim located in the belt. It is on the east bank of McIntyre Creek about 4 miles northwest of Whitehorse. The claim is in a wedge-shaped limestone inclusion about 1,200 feet long and 600 feet wide, entirely within granodiorite. The limestone strikes in an easterly direction into the adjoining Carlisle claim. The limestone is everywhere profoundly altered to an andradite-augite-tremolite-actinolite skarn. The copper sulphides, bornite and chalcopyrite, are most commonly found near the cores of unaltered limestone. Magnetite, molybdenite, and locally free gold, occur in the ore.

The workings consist of an inclined shaft 130 feet long following an ore shoot, and two drifts: one, at 63 feet from the collar of the shaft, extends west mainly through altered granodiorite and limestone for 230 feet; the other, at 91 feet, extends for 65 feet east. Two other shafts were sunk on mineralized rock away from the main workings.

The workable ores occur in irregularly shaped lenses, mainly in unaltered limestone. Shipments of high-grade copper ore, totalling about 500 tons, are stated to have averaged more than 15 per cent copper, 1 ounce to 3 ounces a ton silver, and a trace of gold.

In 1927, the Richmond Yukon Company, Limited did considerable development work on the adjoining Tamarack-Carlisle claims. Shafts were deepened, and from them tunnels were driven and diamond-drilling was carried out; all outlined more ore of the type on the Copper King property.

Claims in the Southern Part of the Belt

The Valerie (40)

Reference: McConnell, 1909, pp. 53-55.

The Valerie is the only claim in the southern part of the belt upon which much development work has been done. It lies west of the head of Miles Canyon, about 3 miles south of the Arctic Chief.

The western part of the Valerie is underlain by limestone, and the eastern part by hornblende granodiorite, passing locally into diorite. The orebodies have developed along the ragged contact between the sedimentary and plutonic rocks. The limestone is partly replaced by diopside, garnet, chalcopyrite, and magnetite, whereas the adjoining granodiorite has been altered principally to garnet and epidote.

The workings consist of a 92-foot shaft from which exploratory drifts totalling 270 feet in length have been driven in various directions. In addition, two shafts, each 20 feet deep, have been sunk on promising outcrops of ore.

Copper minerals are irregularly distributed along the limestone-granodiorite contact and occur as massive lenses separated by lean stretches. The ores resemble those of the Pueblo by having no bornite but consisting of chalcopyrite and derived carbonates and oxides. Other minerals are arsenopyrite, magnetite, diopside, garnet, and calcite. About 40 tons of selected ore, obtained from surface workings, is said to have averaged 18 per cent copper.

Other Copper Occurrences

Contact Metamorphic Deposits

Fleming Group (41)

References: Cairnes, 1912, pp. 140-145. Cockfield and Bell, 1926, p. 49; 1944, pp. 19-20.

The Fleming group lies on the northeast spur of Carbon Hill at the contact of Yukon group rocks with granodiorite. The Yukon group gneisses and schists strike northwest at an angle to the granodiorite contact. Trenches have exposed two bands of skarn developed from lime-rich layers. The skarn bands contain discontinuous, 3- to 10-inch-wide lenses of massive chalcopyrite, bornite, and specularite.

Miscellaneous Occurrences

College Green (42)

Reference: Cairnes, 1908, p. 18.

The College Green is one of four claims along a band of limestone 50 feet wide at the south end of Gray Ridge. The copper minerals, chiefly chalcopyrite, occur in the associated andesitic volcanic rocks in irregular bunches and veins.

Jubilee Mountain

North of Jubilee Mountain in the southeast corner of the map-area, a lens of limestone in greenstone lies next to a body of serpentinized dunite. The contact is concealed by vegetation and talus, but for about 30 feet between the limestone and the talus there is exposed a dark green rock composed of actinolite, epidote, and garnet. Along its contact with limestone, this rock carries disseminated bornite, chalcopyrite, specularite, and hematite.

Other Showings

Small showings of chalcopyrite, bornite, and pyrite occur in greenstone 1¼ miles north of Marsh Lake and 2 miles northeast of Dundalk.

NON-METALLIC DEPOSITS

Fluorite

Small showings of fluorite were found at the head of the south fork of Wheaton River. Cubes and octahedra of fluorite, about 1 inch to 1½ inches across, occur with pyramidal crystals of quartz in several 2- or 3-foot cavities in a leucogranite characterized by smoky quartz. Most of the showings are within a few hundred feet of the contact of the leucogranite body.

Coal

Whitehorse Coal (43)

References: Cairnes, 1908, p. 20. Cockfield and Bell, 1926, p. 52; 1944, p. 20.

Several claims known as the Whitehorse coal claims have been located in rocks of the Tantalus formation on Mount Granger west of Coal Lake. In 1906 a tunnel about 60 feet long was driven on one of the seams and several trenches were dug. When visited in 1948 the tunnel and all the trenches had caved. The following description is from Cairnes (1908, p. 20).

The seams in the tunnel strike N63°W and dip 42°NE. Those measured were 9 feet 8 inches, 10 feet 8 inches, and 2 feet 6 inches thick. The coal is anthracitic in character and no seam of coking coal was found. Proximate analyses follow:

Sample	A (%)	B (%)	C (%)	D (%)
Water	2.15	3.78	3.76	2.35
Volatile combustible matter	6.10	10.06	8.34	6.65
Fixed carbon	69.86	38.38	62.50	42.27
Ash	21.98	47.48	25.40	48.73
Total	100.00	100.00	100.00	100.00

Sample A is from the 9-foot-8-inch seam.
" B is from the 2-foot-6-inch seam.
" C is from the 10-foot-8-inch seam.
" D is from a seam found in the creek below the workings.

Mount Bush Coal (44)

References: Cairnes, 1908, p. 32; 1912, pp. 145-147. Cockfield and Bell, 1926, p. 52; 1944, p. 20.

Cairnes (1912, p. 145) partly stripped three seams of coal in the Tantalus formation west of the summit of Mount Bush. The seams strike about north and dip 60 to 80°W. They were 18 inches, 6 feet or more, and 3 feet or more thick. West of the coal exposures the Tantalus formation is terminated by a fault which would cut off the seams about 2,000 feet down their dip.

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A proximate analysis of a sample from the outcrop of the 6-foot seam is as follows:

	Per cent
Moisture	4.78
Volatile combustible matter	8.62
Fixed carbon	56.50
Ash	30.10

The high ash-content of this semi-anthracite coal is probably partly due to contamination by sand from the stripping of the frozen outcrop.

HOTSPRINGS

Takhini Hotspring

Reference: Fyles, 1950, p. 160.

The hotspring is about 1½ miles north of Takhini River and about 4 miles east of the old bridge crossing the river. The spring comes up in a flat, wooded, drift-covered area about half a mile south of a group of low, rocky hills. It forms a pool about 15 feet across and 6 feet deep that overflows to form a small creek. When the spring was visited in July 1946, the overflow amounted to a few tens of gallons per minute. The water was about the right temperature for a hot bath (ca. 110°F). Large bubbles of gas rise from the bottom of the pool. Particles of yellow iron oxide collect in a green algal growth floating on the pool. About an acre of ground below the spring is covered by a rusty, calcareous deposit. In 1956 the water was being piped to a swimming pool serving as a local tourist attraction.

The following analysis was made by the Mines Branch, Ottawa, from about a gallon of water collected from the spring in July, 1946.

pH	7.4
	Parts per Million
Residue on evaporation	2,800.0
Alkalinity as $CaCO_3$	113.0
SiO_2	35.0
Fe	0.53
Cu	nil
Ca	594.0
Mg	86.5
Alkalis as Na	40.0
Li	Neg. (spectroscopic)
SO_4	1,684.0
Cl	4.0
NO_2	nil
NO_3	nil
PO_4	nil
HCO_3	137.9
Ca hardness as $CaCO_3$	1,482.0
Mg hardness as $CaCO_3$	356.0
Total hardness as $CaCO_3$	1,838.0

NOTES FOR PROSPECTORS

None of the metalliferous deposits of the area, whether within granitic rocks or in rocks that they invade, is far from a granitic contact.

Copper mineralization appears to have favoured contact zones of granitic rocks with limestones or lime-rich rocks of any age. These deposits are irregular and difficult to explore. In this connection it might be noted that Fyles (1950) established that the intrusive "porphyrites" mapped by McConnell (1909) were in reality somewhat altered clastic sediments and tuffaceous rocks of the Lewes River group. Hence the "porphyrites" are interbedded with the limestones with which the mineral deposits are associated, rather than intrusive into them. Accordingly, detailed mapping may be rewarding in working out the structure of the limestone beds and hence in tracing or locating mineralized zones.

In the gold-silver and antimony-silver deposits, the fault-fractures or fracture systems that permitted the formation of quartz veins are extensive, but the sulphide content of the veins is irregular and the showings are difficult to evaluate.

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