CANADA

DEPARTMENT OF MINES AND RESOURCES

MINES, FORESTS AND SCIENTIFIC SERVICES BRANCH

GEOLOGICAL SURVEY OF CANADA

MEMOIR 252

FORT ST. JAMES MAP-AREA, CASSIAR AND COAST DISTRICTS, BRITISH COLUMBIA

BY

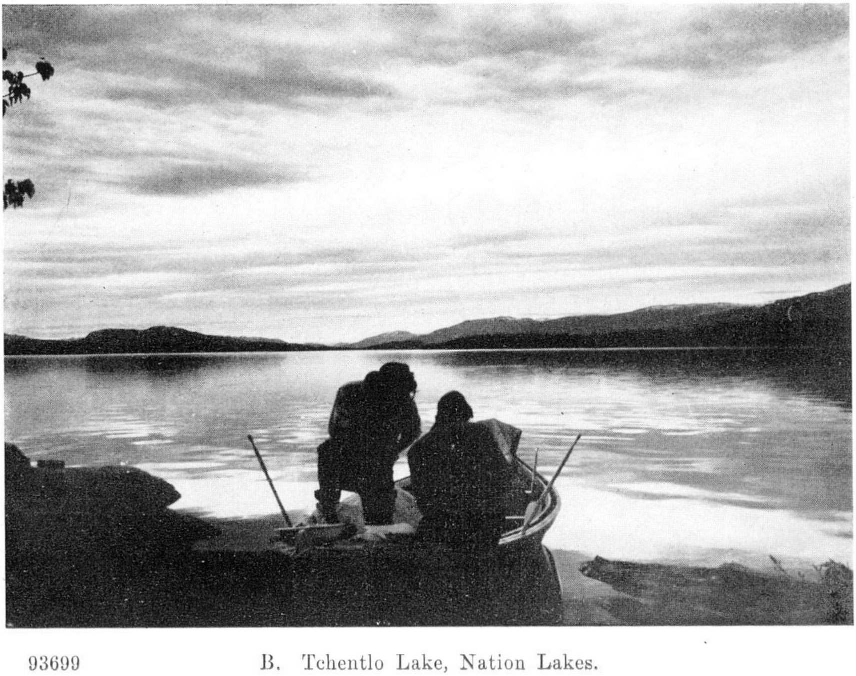
J. E. Armstrong

OTTAWA
EDMOND CLOUTIER, C.M.G., B.A., L.Ph.,
KING'S PRINTER AND CONTROLLER OF STATIONERY
1949

Price, 75 cents

No. 2490

89929 A. Stuart Lake from Fort St. James.



93699 B. Tchentlo Lake, Nation Lakes.

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PREFACE

This report deals with the geology and mineral deposits of an area of some 11,000 square miles in east-central British Columbia, within the Interior mountain and plateau system of the Canadian Cordillera. The area is readily accessible only in the south, where it is crossed by the Canadian National Railways transcontinental line to Prince Rupert, and by the Prince George to Prince Rupert highway. Elsewhere, access is by aircraft, by motor boats on the several large lakes, by widely spaced roads connecting some of these lakes, and by pack-horse trails. Though known to the fur trade since the earliest years of the last century, the mining history of the area did not commence until 1868, when placer gold was discovered on Silver Creek, a southern tributary of Omineca River. The succeeding few years witnessed much activity in placer mining, particularly along Manson and Germansen Rivers, and though overall production has latterly been small, some interest has been maintained in these placer fields to the present. Lode prospecting, on the other hand, received almost no attention until after the construction of the railway in 1914, and only in recent years, since the commencement of systematic geological mapping, and with it the discovery of a variety of metalliferous deposits, has interest in it exceeded that formerly applied to placer operations. The greatest single impetus arose through the discovery and successful operation of the Pinchi Lake mercury mine, which, between 1940 and 1944, produced more than 4,000,000 pounds of mercury, more than any other on the continent. Concurrent prospecting has disclosed other promising mercury deposits, as well as many showings of gold, copper, silver-lead-zinc, chromium, and non-metallic minerals.

Geological mapping of the Fort St. James area commenced in 1936. Except for 1938 and 1939, it continued to 1944, and has been identified principally with the work of the present author. Many of the names applied to the various map-units are new to the formational nomenclature of British Columbia, and others previously known have been redefined and their positions clarified in the light of new information. Among the many problems considered by Dr. Armstrong in this memoir are: those of the Wolverine metamorphic complex and their relation to the Shuswap rocks of southern British Columbia; the redefinition of the late Palæozoic Cache Creek group; the age, petrography, and mode of formation of the large ultrabasic bodies of the Trembleur intrusions; the probable pre-Jurassic age of the Topley granitic rocks; the relations of the dominantly marine Takla formations to the widespread and mainly continental Hazelton group of northwestern British Columbia, and of the Omineca batholithic rocks to the Coast intrusions of the province. Structurally, too, the area has provided evidence for more than one period of orogenic disturbance, and has disclosed the occurrence of great, northwesterly trending fault zones of which the Pinchi fault zone, along which the principal mercury deposits occur, has an overall length of at least 150 miles.

The accompanying geological map, on a scale of 1 inch to 6 miles, is, essentially, a compilation of the Fort Fraser (East Half), Fort Fraser (West Half), Takla, and Manson Creek 4-mile maps, Nos. 630A, 631A, 844A, and 876A, respectively, previously issued over a period of years, which have required some revision as field work proceeded.

GEORGE HANSON,
Chief Geologist, Geological Survey of Canada

OTTAWA, August 4, 1948

Fort St. James Map-Area, Cassiar and Coast Districts, British Columbia

CHAPTER I

INTRODUCTION

GENERAL STATEMENT

Fort St. James map-area lies in east-central British Columbia between longitudes 124 and 126 degrees and latitudes 54 and 56 degrees, and includes an area of about 11,200 square miles. The villages of Fort St. James, Vanderhoof, and Burns Lake lie within the area, which also includes smaller settlements and Indian villages.

ACCESSIBILITY

The Canadian National railway and the Prince George to Prince Rupert highway cross the southern part of the map-area, following Nechako and Endako Valleys. Vanderhoof, on the railway in the southeastern corner of the area, connects with Fort St. James at the outlet of Stuart Lake, 41 miles to the north, by regular, year-round bus and truck service operating over an excellent gravelled road. Fort St. James is connected with Germansen Landing, 125 miles to the north, by a good gravel road over which regular trucking service is maintained except in winter months. An excellent road extends southward from Burns Lake 14½ miles to François Lake. A good road also leads north from Burns Lake for 21 miles to Babine Lake. A motor road skirts the north shore of François Lake from François Lake post office to Colleymount, and another extends southward 6 miles from the village of Endako to the east end of François Lake. A fair truck road connects Takla Landing on Takla Lake with Old Hogem on Omineca River, 40 miles to the northeast, and a branch from this road reaches the Bralorne Takla mercury mine. The Aiken Lake tractor road leads from Old Hogem up Discovery Creek Valley to the northern boundary of the area, a distance of about 30 miles, and a branch tractor road, 23 miles long, extends from this point to Germansen Landing.

During the summer season, May 15 to October 30 approximately, motor launches tow 20-ton scows from Fort St. James to Takla Landing, a distance of 120 miles. Stuart and Babine Lakes are much travelled by small boats, and an 8-mile portage connects them. To facilitate the transportation of supplies over this portage, wagons and teams may be hired at the Indian villages at either end. Nation Lakes and River, and Omineca River below Old Hogem, are navigable for small boats.

Much of the area that cannot be reached by road or water is provided with good trails over which pack-horses can be taken, and an aeroplane base is maintained at Fort St. James by Central British Columbia Airways.

FIELD WORK AND ACKNOWLEDGMENTS

FIELD WORK

Geological mapping of the Fort St. James area, on the scale of 1 inch to 4 miles, was commenced in 1936 by the Geological Survey. Between 1936 and 1944 (except in 1938 and 1939) one or more field parties have operated each year. In 1936 and 1937, J. G. Gray (16, 63)[1] and J. E. Armstrong (3, 4, 6) mapped the east and west halves of the Fort Fraser map-area respectively. J. E. Armstrong (8, 9, 12, 14) commenced the mapping of the Takla map-area in 1940, and completed it in 1944. Geological mapping of the Manson Creek map-area was begun by A. H. Lang (92, 94) in 1940, continued by him in 1941, and completed in 1944 by J. E. Armstrong and J. B. Thurber (18, 20). In 1941 and 1943 J. E. Armstrong (8, 9) studied the Pinchi Lake mercury belt from southeast of Fort St. James to Omineca River. In 1942 search for chromite deposits was undertaken in the Middle River Range by J. E. Armstrong and H. W. Little, and in Mitchell Mountains by C. S. Lord.

Previous Geological Work

The first geological mapping in northern British Columbia was by A. R. C. Selwyn (114, pp. 29-87) of the Geological Survey, in 1875. He examined the country along a route between Quesnel and Peace River by way of Prince George, Fort St. James, and McLeod Lake. In 1876, G. M. Dawson (48, pp. 17-94) made a geological reconnaissance in the basins of Blackwater, Salmon, and Nechako Rivers and on François Lake.

In 1879, Dawson (52) made a long trip from Port Simpson, near Prince Rupert, to Edmonton, Alberta, by way of Skeena River, Babine trail, Babine and Stuart Lakes, Fort McLeod trail, Parsnip River, Pine Pass, and Peace River.

R. G. McConnell (102) made a geological reconnaissance of the territory drained by Finlay and Omineca Rivers in 1893, and visited the Germansen-Manson placer field. In 1915, Charles Camsell (39) made a rapid reconnaissance from Fort St. James via water to Takla Landing and thence overland to Germansen Landing and Manson Creek and from there south to Fort St. James. Burns and François Lakes were briefly visited by George Hanson (67) in 1924. A study of the Manson Creek placer deposits and of the local bedrock geology was made by F. A. Kerr (86) in 1933, and in the following year (87) he examined important mineral deposits along the Canadian National railway. Other examinations of mineral deposits and placer creeks have been made by Douglas Lay (95) and published in the Annual Reports of the Minister of Mines for British Columbia.

ACKNOWLEDGMENTS

The writer acknowledges the co-operation of Messrs. E. Bronlund, G. Mason, D. C. Malcolm, and G. Ogilvie of the Consolidated Mining and Smelting Company of Canada; Dr. C. E. Cleveland of Bralorne Mines, Limited; Mr. Frank Joubin of Pioneer Gold Mines, Limited; Dr. D. F. Kidd of Leta Exploration, Limited; and the many prospectors and residents

1 Numbers in parentheses are those of bibliographic references in Chapter VII.

of the area. In the field work he was ably assisted in 1936 by P. J. MacMillan; in 1937 by H. W. Little, B. I. Nesbitt, and O. R. Fulton; in 1940 by B. I. Nesbitt, E. J. W. Irish, and E. W. Johnson; in 1941 by S. A. Kerr, J. H. Abrams, and G. R. Hilchey; in 1942 by H. W. Little, J. H. Abrams, and D. J. Carlisle; in 1943 by G. W. Sinclair, K. A. Matheson, and E. F. Roots; and in 1944 by J. B. Thurber, E. F. Roots, A. G. Hodgson, R. P. Jordan, A. R. Thompson, R. L. Christie, and O. W. Feniak.

HISTORY

FUR TRADE PERIOD: 1793-1861

Sir Alexander MacKenzie, the first white man to cross the Canadian Rockies in charge of an expedition, was the discoverer of the interior of British Columbia, or, as it was known at that time, "New Caledonia". This term was applied to that part of the province lying between the Coast and Rocky Mountains and latitudes 51°30′ and 57°00′ approximately. In October 1792, MacKenzie left Fort Chipewyan, Lake Athabaska, on his voyage of discovery to the Pacific Ocean. He ascended Peace River, through the Rocky Mountains, to the junction of Parsnip and Finlay Rivers, and established winter quarters a short distance farther west. In May 1793, he continued his journey, ascending the Parsnip to its head, where he portaged across to MacGregor River and descended that stream to the Fraser. He then followed Fraser River to the mouth of the Blackwater, where he left his canoe and proceeded overland west to the Pacific Ocean, arriving at Bentinck Arm on July 22, 1793.

Simon Fraser established the first trading posts west of the Rocky Mountains. In 1805 he was sent to Lake Athabaska for the North-West Company with orders to extend the activities of that company west of the Rockies. In the spring of 1805, one of Fraser's subordinates, James McDougall, had visited McLeod Lake, and proceeded farther west to Carrier Lake, 15 miles east of Fort St. James. Fort McLeod, at the outlet of McLeod Lake, was founded by Fraser in the autumn of the same year (1805). This was the first permanent post erected within British Columbia, and it has existed, much the same, until this day. In 1806, Fraser proceeded from Lake Athabaska west up Peace and Parsnip Rivers, across to MacGregor River, and down to the Fraser, the great river that now bears his name. He descended this stream to Nechako River, which he ascended to Stuart River, and followed this to Stuart Lake, arriving on July 26, 1806. Here, near the outlet, he established Fort St. James, the second fort established west of the Rockies. Later in the same year Fraser proceeded up Nechako River to Fraser Lake, where he founded Fort Fraser. Fort George was established in 1807. In May 1808, Fraser commenced, probably from Fort St. James, his great expedition down Fraser River, and reached the Gulf of Georgia about the beginning of July 1808.

Between 1809 and 1821 John Stuart and D. W. Harmon were in charge of the activities of the North-West Company in the interior of British Columbia. In 1821 this company united with the Hudson's Bay Company, an organization that was to play a leading rôle in the later development of the province. During the next 40 years, that is until 1861, the residents of this region were concerned primarily with the fur trade, and several men famous in the history of the province served at Fort St. James with the Hudson's Bay Company, among them Sir James Douglas, W. Connolly, P. W. Dease, Peter Skene Ogden, and Donald Manson.

MINING PERIOD: 1861-1947

In 1857 placer gold was discovered on lower Fraser and Thompson Rivers. The news of the discovery spread rapidly, and by the end of October 1858 some ten thousand miners were working on Fraser River from Fort Langley to Lytton. By 1859 the more adventuresome of these had reached Quesnel, and by 1861 the rich deposits on Williams and Lightning Creeks were discovered. In the following year most of the other rich creeks in the Cariboo became known. The first recoveries from the Cariboo placers were remarkable; apparently more than $2,000,000 in gold was recovered before the end of 1861. In consequence, a second great migration of miners to British Columbia commenced in 1861 and continued undiminished until 1864. The easily worked bonanza deposits of the Cariboo quickly yielded their wealth, and from 1863 a progressive decline in the yearly output ensued. As interest diminished in the Cariboo, prospecting for placer gold spread farther north. In 1868 the Omineca placer field came into prominence with the discovery of gold on Silver Creek, and by 1871 all the important creeks were known.

The succeeding few years witnessed a large migration of placer miners into the Fort St. James area, more than a thousand men in 1871 alone. They came either north from Quesnel or east from Hazelton, the trip in both instances involving a long and arduous journey by pack-train. Supplies were brought in by the same routes at a cost of about 20 cents a pound. Gold valued at more than $400,000 is reported to have been produced in the Omineca district in 1871, most of it coming from Germansen and Manson Rivers. Much of the gold was recovered by comparatively few men, and existing high costs of living forced most of the miners to leave the district. In 1874, sixty claims worked by eighty miners yielded gold to the value of $80,000, and in 1875 the production was valued at $32,000. The succeeding 3 years saw little activity, but was followed by 2 years of renewed interest in the area, and in 1880 about eighty miners recovered gold valued at $45,000. From 1880 to 1897 production gradually diminished, averaging only a few thousand dollars a year. Total production up to 1897 was estimated by McConnell to amount to $1,000,000, more than half of it recovered prior to 1874. The years from 1897 on saw the entry of many companies with much capital; large expenditures were incurred for machinery, and several costly flumes were constructed. One company alone in a period of about 7 years spent more than $250,000. Between 1897 and 1912 the annual production of gold amounted to only about $20,000, and it is more than probable that the money expended during these years exceeded the value of all the gold recovered since the original discoveries in 1870. Between 1913 and 1932 activity was at a low ebb, and the value of the annual placer gold production dwindled to between $3,000 and $5,000. From 1933 to 1941 the area experienced a revival of interest on the part of companies, and several brought in equipment capable of handling comparatively large quantities of gravel. Hydraulicking, ground sluicing, steam shovelling, and dragline methods were put to use, and several costly flumes were built. During the period between the completion of the railway to Vanderhoof, in 1914, and the construction of the Germansen-Fort St. James road, in 1937, the cost of freighting supplies into the area averaged more than 10 cents a pound. Since 1938 these costs have dropped to about 2 cents. Due to world war conditions all the major companies had ceased operations by 1943, and since then only individual miners have worked the creeks. The overall production of placer gold from the Manson area probably exceeds $1,500,000.

Until the completion of the Prince Rupert Branch of the Canadian National Railways in 1914, the Fort St. James area witnessed almost no lode prospecting. Before 1914, the nearest railhead was at Ashcroft, a distance of more than 350 miles by wagon road and pack-trail. From 1914 to 1936, the area was prospected intermittently, and about twenty-five gold, silver-lead-zinc, copper, and molybdenum showings were discovered.

Prior to 1935, the only geological mapping in the area consisted of reconnaissance surveys along the main routes of travel. Since 1935 officers of the Geological Survey of Canada have been engaged in geological mapping of the area on the scale of 1 inch to 4 miles, and in the course of this work have discovered many deposits of mercury, gold, copper, silver-lead-zinc, and chromium minerals. Included in these is the now famous Pinchi Lake mercury mine, which was brought into production by the Consolidated Mining and Smelting Company of Canada, Limited, in 1940. Between 1940 and 1944, this mine produced more than 4,000,000 pounds of mercury, becoming, thereby, one of the largest mercury producers in the world and the largest on this continent. Between 1937 and 1943 most of the prospectors in the area were searching for mercury, and numerous additional showings were found, including those of the Bralorne Takla mercury mine.

CLIMATE

Winters in the Fort St. James area are cold and summers mild, with rather abrupt seasonal changes. Annual temperatures range from a maximum of about 100 degrees Fahrenheit to a minimum of 60 degrees below zero. However, it is only rarely that summer temperatures exceed 80 degrees, and in the winter sub-zero temperatures seldom persist for more than a week at a time. Winter weather generally commences about the first week in November, although snow may be expected in the mountains at any time from September on, and generally remains after the first of October. The accumulated snowfall in the vicinity of Vanderhoof seldom exceeds a depth of 3 feet, but in the Omineca Mountains may attain a depth of from 6 to 20 feet. Spring breakup comes around the middle of April at Vanderhoof, about the end of April on the large lakes, and about the middle of May in the Omineca Mountains, but snow does not leave the higher areas until early in June. Summer frosts are common in the mountains. In the farming areas along the railway the frost-free period averages from 80 to 90 days, and the growing season is about half a year long.

Precipitation varies considerably from south to north across the map-area. The average annual precipitation at Vanderhoof, during a 23-year period ending in 1945, was 13·34 inches; at Fort St. James, during a 52-year period ending in 1945, it was 15·61 inches; and at the west end of François Lake during a 12-year period ending in 1945 it amounted to 18·84 inches. The precipitation in the Omineca Mountains probably exceeds 30 inches.

FLORA AND FAUNA

The abundant trees are white spruce, black spruce, lodgepole pine, alpine fir, and aspen. Less common are Douglas fir, balsam, poplar, and birch. Douglas fir is not found north of Stuart Lake. Willow and ground birch are widespread, especially in mountain valleys, and in many places make travel difficult. Mountain ash, alder, juniper, devil's club, wild rose, and soopoo-lalia (soapberry) are common. Timber-line is about 5,000 feet above sea-level. Lodgepole pine predominates in the sandy and gravelly flat areas, particularly in the Nechako Plain; spruce predominates in the wet stream bottoms and on the mountain slopes; and alpine fir is generally found above an elevation of 3,500 feet. Large expanses of forest have been burnt over, and are now a tangle of fallen trees. In other places the forest is over mature, with resultant windfalls.

Edible wild fruits include huckleberries, blueberries, dewberries, raspberries, strawberries, gooseberries, black and red currants, and high and low bush cranberries.

Moose and black bear are general throughout the area. Deer are found mainly in the southern part, and mountain goat, cariboo, and grizzly bear were observed in the Omineca Mountains. An occasional cougar has been reported south of Fort St. James and wolves have reduced the number of deer and moose in recent years. Smaller animals present in important numbers include the marten, fisher, weasel, mink, wolverine, otter, muskrat, red, silver, and cross fox, coyote, beaver, lynx, marmot, porcupine, and rabbit.

Franklin's grouse is the most abundant gamebird, and blue and ruffed grouse are also represented. Ptarmigan are plentiful above timber-line. Several species of ducks, including mallard, are common on the rivers and smaller lakes, and Canada geese are found in the early autumn on the larger rivers and lakes.

Sockeye salmon ascend the larger streams draining into Fraser and Skeena Rivers, to spawn in August and September. Spring and cohoe salmon also ascend the Skeena waters into Babine Lake. Char, lake trout, and rainbow trout are common in the lakes, and grayling are found in the waters draining into Parsnip River.

INDUSTRIES

The principal areas of settlement are in Nechako and Endako Valleys, at the southeastern end of Stuart Lake, and along François Lake. The prosperity of the district is mainly dependent on agriculture, lumbering, trapping, and mining.

The main agricultural development has been in Nechako and Endako Valleys and along François Lake. The best farm lands are in glacial-lake basins. Most of the farms are small, with clearings of 5 to 20 acres, except in the vicinity of Vanderhoof where some of the farmers have several hundred acres under cultivation. The main cash crops suitable for export are timothy and clover seed. Spring and Fall wheat, oats, and barley are also grown, as well as a wide variety of vegetables. A few beef cattle are raised on some of the farms.

Small sawmills are built at several places along the Canadian National railway and at Fort St. James, Pinchi Lake, Babine Lake, and François Lake. Some lumber for local use is cut from spruce and to a lesser extent from Douglas fir. The main lumbering operations, however, are concerned with making railway ties and coal-mine pit-props for export. The ties are cut mainly from spruce and the pit-props from lodgepole pine.

Trapping is done throughout the area by both white men and Indians. The main fur-bearing animals are beaver, red, silver, and cross fox, mink, muskrat, marten, fisher, weasel, wolverine, otter, lynx, wolf, and coyote. Mink ranching is featured at several places.

Mining operations are dealt with fully in other pages of this report.

CHAPTER II

PHYSIOGRAPHY AND GLACIATION

PHYSIOGRAPHY

Fort St. James map-area lies wholly within the Interior system of the Canadian Cordillera, and for convenience may be divided into the following parts: Neckako Plateau, Omineca Mountains, and Rocky Mountain Trench (Figure 1).

That part of the area south of Nation Lakes and the Northwest Arm of Takla Lake lies within the Nechako Plateau. The boundary between this plateau and Omineca Mountains to the north is drawn arbitrarily, as parts of the areas included in each are transitional. Within the Fort St. James area, the Nechako Plateau may be subdivided into plateau proper, the Nechako Plain, and the Middle River Range. In the plateau proper the valleys are broad, and the divides are rounded hills that rise 1,500 to 2,500 feet above the valley floors. Toward the north boundary of the plateau the hills are somewhat higher, and distinct areas of upland occur at elevations of 4,000 to 5,000 feet. The valleys, however, occupy the wider areas. They have fairly flat bottoms, and an average elevation of 2,000 to 2,800 feet above sea-level.

The Nechako Plain occupies an area of several thousand square miles on both sides of the Canadian National railway between longitudes 122 and 125 degrees, and includes about 1,000 square miles in the southeast quarter of the Fort St. James area. The plain has a maximum relief of only a few hundred feet, and consists of rolling ground moraine interspersed with flat, glacial-lake basins. The main rivers have cut great post-Glacial channels as much as 400 feet deep into this plain, and in places bedrock has been exposed. Elsewhere the plain is devoid of outcrop except for widely scattered rock knolls that rise above the drift, which in most places is from 100 to 400 feet thick.

The Middle River Range comprises several high peaks, with an average elevation of 6,500 feet, separated by broad creek valleys. Intrusive rocks form the core of these mountains.

All of the Fort St. James area north of the Nation Lakes and the south end of Takla Lake, except the northeast corner of the area, lies within Omineca Mountains. These comprise the southern ranges of a continuous belt of mountains, 50 to 75 miles wide, that stretches along the southwest side of the Rocky Mountain Trench from Nation River 400 miles northwest to the Yukon. The great Omineca-Cassiar batholith forms the backbone of these mountains. Omineca Mountains themselves comprise Finlay, Swannell, and Hogem Ranges, parts of each of which fall within the Fort St. James area (*See* Figure 1).

Finlay Ranges are represented by the Wolverine Mountains, which occupy a belt 35 miles long and 15 miles wide in the northeast corner of the map-area between the Manson Lakes-Omineca River Valley and the Rocky Mountain Trench. They are characterized by a single backbone ridge with projecting spurs, rising to elevations of 6,900 feet and approximately parallel with the Rocky Mountain Trench. Smooth profiles characterize their slopes and most of their summits in contrast with the

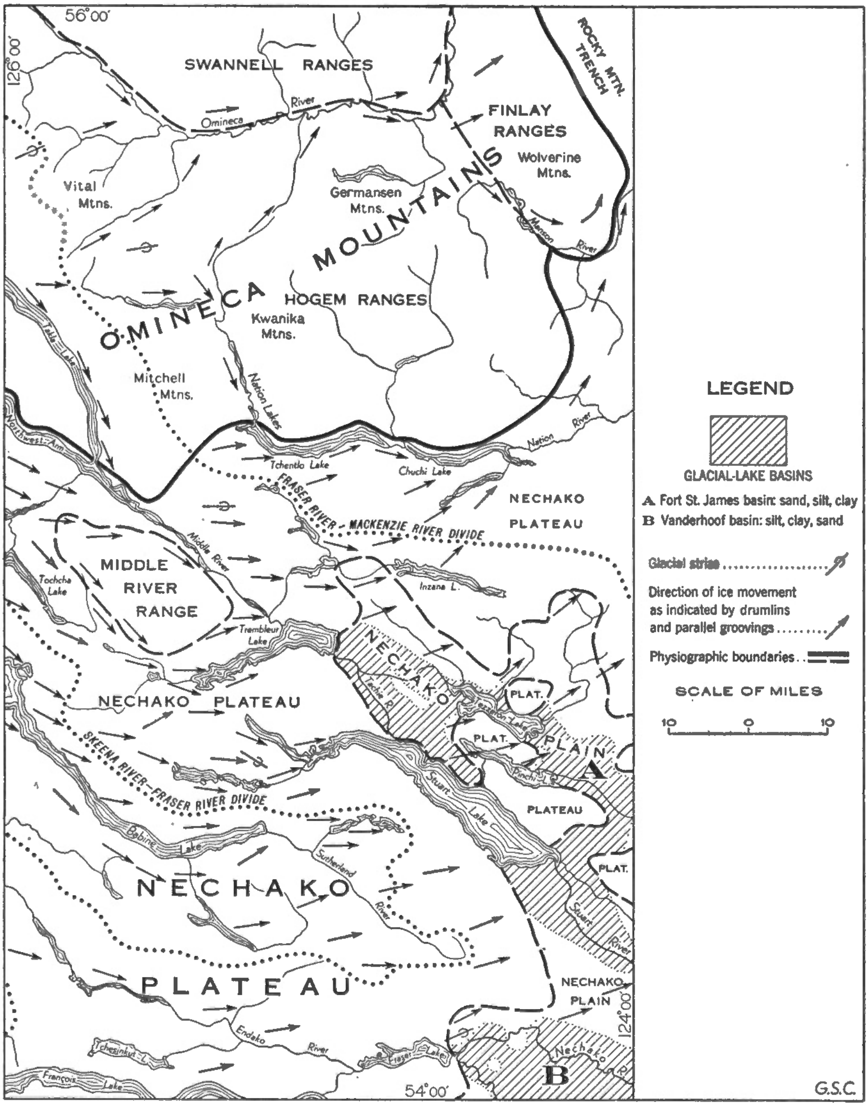


Figure 1. Physiographic divisions and glacial geology of Fort St. James area, British Columbia.

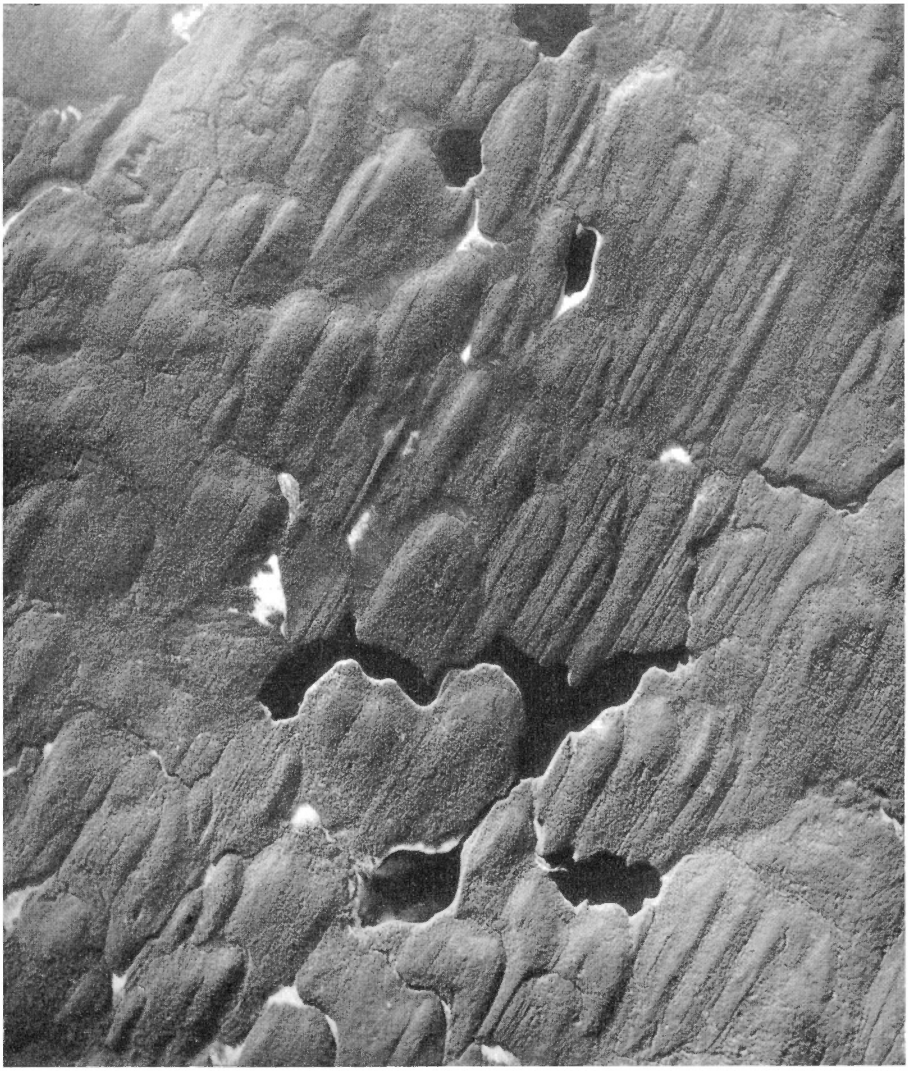
ruggedness of most of Swannell and Hogem Ranges. The Wolverine Mountains are underlain by relatively gently folded, granitized, sedimentary rocks of probable Late Precambrian and Lower Cambrian age.

The southern part of Swannell Ranges occupies the area north of Omineca River to the northern boundary of the map-area. The ranges are separated into two groups of mountains by the wide valley of Discovery Creek. The eastern group, which is dissected by several large creeks, consists of mountains underlain by steeply folded Palæozoic and Mesozoic sedimentary and volcanic rocks, and rises to elevations of about 6,700 feet. The western group is underlain mainly by granitic rocks, and is extremely rugged, with many pinnacles and knife-edge ridges. Several peaks more than 8,000 feet high occur in this range in the Aiken Lake area to the north, but the highest peak in the Fort St. James area is about 7,000 feet above sea-level.

All of that part of the Fort St. James area lying south of Omineca River, east of Manson Lakes, and north of the Nation Lakes and Northwest Arm of Takla Lake is occupied by the Hogem Ranges. These consist of many small ranges and individual mountain masses separated by wide, transverse and lateral valleys several thousand feet deep. The largest and the most rugged of these ranges is the Mitchell Mountains, between Takla Lake and Upper Nation Lakes, whose highest peaks range in elevation from 6,500 to 6,790 feet. A granitic batholith forms the core of these mountains. Another prominent range stretches from the headwaters of Gaffney Creek northwest to Germansen Lake, and includes Germansen Mountains, Baldy Mountain, and Mount Gillis. This range is also underlain by granitic rocks, but has smoother crest lines than those of the Mitchell Mountains. The remaining ranges and mountains comprising the Hogem Ranges in this map-area show considerable variation in ruggedness: some are composed of ridges with relatively smooth crest lines, whereas others are mainly a series of pinnacle-like peaks. This variation is due largely to the underlying bedrock, the more rugged ranges being composed of granitic and volcanic rocks and the smoother ranges of sedimentary strata. Along the southern edge of the Hogem Ranges, near Tchentlo and Chuchi Lakes, extensive areas of an old erosion surface are stepped above the general level of the bordering Nechako Plateau.

The northeast corner of the Fort St. James map-area is crossed by the Rocky Mountain Trench, a great depression that lies directly west of the Rocky Mountains and forms their west boundary throughout most of their length. The trench is a great, nearly flat-bottomed, parallel-sided trough, several thousand feet deep, and ranging from 2 to 15 miles wide, that extends from the Forty-ninth Parallel 450 miles northwestward to the Grand Canyon of Fraser River where it merges abruptly with the Nechako Plateau. However, it reappears as a distinct topographic feature 100 miles farther northwest at the junction of Pack and Parsnip Rivers, and continues northwestward another 325 miles in a straight line to Chee House on Kechika River. Both the southern and northern sections of the trench separate mountains formed wholly of sedimentary rocks on the northeast wall from those containing metamorphic and intrusive rocks on the southwest wall. It is the northern section of the trench that crosses the corner of the Fort St. James area, and there it has a width of about 12 miles and is about 4,000 feet deep.

The Fort St. James area is drained by the waters of three major river systems, namely the Fraser, Skeena, and Mackenzie. As a result, two main drainage divides, the Fraser-Skeena and the Fraser-Mackenzie, the latter



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Drumlinized till plain: illustrating drumlin-like ridges and intervening grooves. Ice moved in direction towards top of picture, parallel with grooves.

a continental divide, traverse the area. Consequently, the run-off in this area eventually reaches such widely separated places as Vancouver and Prince Rupert on the Pacific Ocean and Aklavik on the Arctic. François Lake, Fraser Lake, and Endako and Nechako Rivers in the southern part of the map-area drain east to Fraser River. Takla, Trembleur, Cunningham, Stuart, Inzana, Tezzeron, and Pinchi Lakes and Middle, Tachie, and Stuart Rivers drain southeast into Nechako River and thence east to Fraser River. Babine Lake and Sutherland River drain northwest into Skeena River. Nation Lakes and River, Manson Lakes and River, and Omineca River drain east into Finlay River and thence into the Mackenzie via Peace River. The western part of the Nechako Plateau is commonly called the "Lake District of British Columbia" and contains innumerable lakes ranging in size from mere ponds to Babine Lake, 110 miles long, which is the largest in the province.

GLACIATION

INTRODUCTORY STATEMENT

All of the Fort St. James area was extensively glaciated during Pleistocene time (*See* Figure 1). Except for a few widely scattered outcrops, glacial till, as much as 400 feet thick, covers much of the Nechako Plain, most of the valleys and lower hills, and extends up the mountain slopes to elevations of about 5,000 feet. In a few places till was observed on flat-topped mountains 6,000 feet high. The surface of much of this till consists of nearly parallel drumlins and intervening groovings[1] elongated in the direction of ice movement. In the Omineca Mountains erratics occur up to elevations of 7,600 feet.

Large areas in the Nechko Plain are occupied by glacial-lake deposits, consisting of white silt, clay, and sand, overlying the till ridges.

As indicated by the few striæ observed on the tops of hills and ridges and in the Nechako Plain, the main ice movement west of the Rocky Mountain Trench was easterly. Striæ also indicate, as would be expected, that wherever the ice was confined to valleys it moved along them but always in easterly, southeasterly, or northeasterly directions. The distribution of till and erratics and the elongation of the nearly parallel drumlins and intervening groovings substantiate this direction of ice movement. Erratics are generally found east or southeast of their place of origin. An excellent example of this is found near a large granitic batholith that crosses much of the area from southeast to northwest. On the east side of this batholith the till boulders and erratics consist predominantly of granite, whereas on the west side the till is devoid of granite boulders and no granite erratics were observed.

DRUMLINS AND PARALLEL GROOVINGS

Nearly parallel, drumlin-like ridges and intervening depressions or groovings are widespread in the Fort St. James area (*See* Plate II). They are generally confined to areas less than 5,000 feet high, and, consequently,

[1]The term 'groovings' has been used to distinguish the features described from normal glacial grooves.

are best developed in the major valleys and the low-lying Nechako Plain. Kelly and Farstad (81, p. 9), in a recent soil survey in that part of the Nechako Plain centring around Prince George, observed and described these ridges as drumlins, and referred to the area in which they predominated as a drumlinized till plain. For convenience the term will be applied to mountain valley areas as well as to the drumlinized part of the Nechako Plain, the writer realizing full well that the former do not constitute a plain. The shape and the size of the drumlins vary, and in places distinct ridges do not occur but only a poorly defined grooving is represented and cannot be recognized except with the aid of air photographs. The descriptions of the ridges that follow apply to those throughout the Nechako Plain, including that part in the Fort St. James area.

The drumlinized till plain consists essentially of parallel ridges of till and of gravel derived from the till. The till consists of well-rounded pebbles and boulders embedded in a grey to reddish brown clay and sandy clay. Much of the gravel associated with the till occurs at the tops of ridges, grades downward into till, and is evidently till from which the clay and sandy clay have been removed by post-Glacial run-off. This gravel is rarely stratified, but generally exhibits a rough sorting. Stratified gravels and sands were observed at a few places in the till plain. They occur commonly in lenticular beds, and probably represent interglacial outwash deposits.

The drumlins are most pronounced and best preserved in a large part of the Nechako Plain and along some of the major valleys in the Nechako Plateau and Omineca Mountains. They vary considerably in outline and size; some are nearly circular; others are oval; and still others are 5 to 10 times as long as they are wide. They are generally from ½ mile to 1½ miles long, although a few were observed to be more than 2 miles long. Most of them are ¼ mile or less wide, but a few reach widths of ½ mile or more. They vary considerably in height, probably averaging between 50 and 75 feet, although many are lower and a few range up to 150 feet. Their heights in any one place are uniform, but vary from one locality to another. In most places the stoss or upstream end of these drumlins is much steeper, higher, and wider than the lee or downstream end. The narrower the ridge the steeper its sides, and the narrowest ridges have steeper sides than ends. The surface of the individual ridges commonly shows shallow, well-defined, lengthwise grooves, which are rarely observed except in air photographs. In some photographs two sets of intersecting lengthwise grooves could be seen.

The drumlins seldom occur singly, and are for the most part alined in groups 5 to 6 miles long separated laterally by parallel, trough-like valleys. In such a group the stoss end of a ridge either rises abruptly from the lee end of the ridge in front of it, or the two ridges are separated by an intervening flat area that may have been modified by later drainage. As a rule the lowest elevation between the ends of two alined ridges is still higher than the floor of the trough-like valleys separating the ridges laterally. Less commonly the ridges are closely spaced, occasionally *en échelon*, and fused to one another laterally rather than separated by trough-like valleys. The ridges forming a group vary in size.

The intervening, trough-like valleys are 50 to 150 feet deep and in places are up to ½ mile wide. In many places valleys extend uninterrupted for as much as 6 miles, but not necessarily in a straight line. A valley may bend around the end of a drumlin, may split around a ridge and continue as two valleys, and may widen out into a flat area and then narrow again to a trough. The narrower, more trough-like valleys generally separate narrow, steep-sided ridges, and the wider valleys separate broader, rounded ridges.

Although in some parts of the Fort St. James area the general arrangement of drumlins and intervening valleys is maintained, the individual features are less sharply defined than elsewhere. The ridges are lower, wider, and have more gentle slopes and the valleys are wider and not as deep. However, the lengthwise grooving of the ridges is still pronounced.

In still other parts of the Fort St. James area, particularly in the higher valleys, at the tops of hills, and in the mountain passes, these groovings are shallow and discontinuous, and are separated by long, low mounds of till rarely more than 25 feet high. All three types of drumlinized till plain topography merge into one another from place to place.

Widely interspersed among the drumlins of unconsolidated material are ridges composed in part of bedrock. The stoss or front ends of these ridges are composed of bedrock that has been scoured, gouged, and rounded. These bedrock slopes vary from gentle to abrupt, and form the highest and widest part of the ridges. Behind each of them is a narrow ridge of till with steep sides. These ridges are from 25 to 200 yards wide, 200 to 700 yards long, and 100 feet or less high, and are separated by narrow, trough-like valleys. They exhibit a more marked parallelism in the direction of ice movement than the ordinary ridges, and are best developed near Carp Lake, east of the Fort St. James area, near the headwaters of Necoslie River, and near the south end of Babine Lake.

Wherever the slopes are gentle enough to prevent sliding, well-defined drumlins have been observed on hills up to elevations of 4,000 feet, 1,500 or more feet above the valley floors. Between elevations of 4,000 and 5,000 feet only a few poorly defined ridges occur, but shallow grooves are well marked in many places. Above 5,000 feet only the grooved type of topography has been observed.

The drumlins are elongated in the direction of ice movement, and in the Omineca Mountains, where most of the ice moved along the valleys, the drumlins are largely valley features curving around the higher hills. Generally the drumlins are most pronounced in areas where the ice apparently flowed uphill, and least pronounced in areas where the ice flowed downhill, parallel groovings forming instead.

The parallelism of the drumlins and groovings in the direction of ice movement, corroborating information provided by the glacial striæ, illustrates accurately the movement of the ice in Pleistocene time. As indicated by drumlins and groovings, the ice apparently moved eastward along Nechako Valley and south and southeast down the valleys of Babine and Takla Lakes, turning eastward through transverse gaps in the northeastern valley walls. When the ice flowing along the major valleys reached the Nechako Plain it moved easterly and northeasterly across the plain to the Rocky Mountains where it turned northwestward along the Rocky Mountain Trench. In the Omineca Mountains the ice moved easterly, southeasterly, and northeasterly along the valleys of the major rivers to the Rocky Mountain Trench.

Origin of Drumlins and Parallel Groovings

Although the writer was unable to distinguish two tills in the field, he believes that in view of other evidence and the observations of Lay (96, p. 16) and Johnston (78, p. 147) in the Cariboo region to the south, that there were at least two major advances of the Cordilleran ice-sheet in the Fort St. James area. The last advance was from southwest to northeast. Also, the origin of the parallel drumlins and intervening depressions is most readily explained by two major ice advances, the first one carrying a heavy load of debris, and the second a relatively light load. This conclusion is based on the following reasoning: it is believed that, following the last advance of the ice, the ice stagnated over a large area, as is evidenced by the lack of lateral and terminal moraines and the presence of kettles and eskers. In such an event the debris carried on, and in, the ice would be deposited haphazardly on the underlying surface, as in the case of a typical ground moraine. However, the till surface now exposed is arranged in the form of parallel drumlins and intervening depressions, and except for a few large erratics could not have been derived in such a manner. Therefore, the conclusion has been reached that the last ice-sheet was lightly loaded, in which case the great thickness of till constituting the drumlinized till plain must have been deposited by an earlier, heavily loaded ice-sheet.

During the first advance of the ice a heavy mantle of till was deposited in the lower mountain valleys and in the Nechako Plateau and Plain. Possibly as this ice-sheet retreated, or more probably as the second ice-sheet advanced, the till was grooved and reshaped into drumlins. Two sets of groovings intersecting at a considerable angle were observed at places in the Nechako Plain, and probably indicate local advances and retreats of the ice. The origin of the till drumlins was arrived at from a study of the rock drumlins interspersed among them in various places. These rock drumlins exhibit typical crag and tail characteristics, and it is quite evident that they were formed by the ice pushing up against a rock outcrop, riding up and over it, and depositing a tail of debris behind it, this tail fading away at the lee end. At the same time the ice moving on both sides of the outcrop gouged out depressions parallel with the ice movement. The till drumlins parallel these rock drumlins, and the two types never overlap one another. In the case of the till drumlins, it is believed that a knob of frozen till rather than a rock outcrop formed the buttress to the moving ice, and that the ice rode up and over it and around it, depositing a tail of material behind it, forming the drumlins. The intervening depressions would be gouged out by tongues of ice moving between two frozen hummocks and, as would be expected, these would be more regular and persistent than the drumlins. The shallow, lengthwise groovings observed on the sides and tops of many individual till drumlins were probably gouged out by large boulders that were embedded in the base of the ice, analogous to the formation of striæ on bedrock. Some of the erratics observed had a diameter of 15 to 20 feet.

GLACIAL-LAKE BASINS

(*See* Figure 1)

Widespread deposits of clay, silt, sand, and gravel formed in irregular-shaped, temporary, glacial-lake basins during the final stages of glaciation.

Parts of two such basins occur in the Fort St. James area. These are the Fort St. James basin, about 850 square miles in area, and the Vanderhoof basin, of about 450 square miles. The topography of these depositional basins varies from flat, in areas containing considerable thicknesses of glacial-lake sediments, to undulating or hilly, where only a thin mantle of sediments overlies the drumlinized till plain or bedrock. In many places areas of drumlins project through the lake deposits and apparently represent islands in the old glacial lakes. The main basins occupy natural depressions in the drumlinized till plain, and were not eroded from the plain; in most places the average elevation of the surrounding till plain is about 150 feet above that of the glacial-lake basins. However, in places the till plain rises abruptly as much as 300 feet above the lake basins, and at other places it grades imperceptibly into such basins. The approximate elevation of the Fort St. James basin ranges from 2,200 to 2,600 feet, and of the Vanderhoof basin from 2,200 to 2,500 feet.

The glacial-lake deposits consist of interbedded silt, clay, and sand, with all gradational types, and subordinate gravel. The fine sediments grade into one another both laterally and vertically. As good sections were observed in only a very few localities, it is difficult to measure the total thickness of the deposits. They are, however, at least 100 feet thick in the Fort St. James basin and 260 feet in the Vanderhoof basin, and their maximum thickness possibly exceeds 400 feet. Silt and sand predominate in the Fort St. James basin, and silt and clay in the Vanderhoof basin. Sand and gravel predominate along the margins of the basins, and probably represent beach deposits resulting from a modification of the adjoining till by melt water or wave action. Much of the sand and silt in the Fort St. James and Vanderhoof basins exhibits good crossbedding, and was probably laid down as deltaic beds at the mouths of glacial streams feeding the lakes. In most places the foreset beds range from 2 to 6 inches in length. Near the borders of the lake basins, pebbles up to 2 inches in diameter and occasional boulders up to a foot in diameter are found scattered throughout the clay and silt beds.

The silts, or 'white silts' as they were called by G. M. Dawson, are the most conspicuous of the glacial-lake deposits, although they are not as widespread as a casual examination would indicate. They are mainly cream-white to buff, and in a few places grey and brown. These silts, which are composed mainly of feldspathic rock flour, are finely stratified in parallel laminations a fraction of an inch to several inches, less commonly a foot or more, thick. They grade laterally and vertically into sand and clay. Ripple-marks are fairly common.

The clays are usually light grey to grey-brown, commonly in alternating bands. In places they are bluish grey. Varves up to a foot or more thick are common in the clays near Prince George.

The sands vary from very fine to coarse, and are widespread in the Fort St. James basin.

Origin of the Glacial Lakes

The glacial-lake deposits are found in the lowest parts of the Fort St. James area. These depressions, now occupied in part by the valleys of Nechako and Stuart Rivers, and Stuart, Pinchi, Tezzeron, and many smaller lakes, are believed to be pre-Glacial in origin, as outcrops of post-Paleocene sedimentary formations appear to be limited mainly to these low-lying areas. During glaciation a mantle of till was deposited in these depressions.

The last advance of the Cordilleran ice-sheet was probably followed by a period of stagnation and decay of the ice in the Nechako Plateau lakes were to a lesser extent confined by ice walls. Much ice floated in the drumlinized till plain acted as collecting basins for melt water forming largely on the top of the ice, but certainly at later stages the water rested on till. Much of the shoreline of these lake basins is composed of gravelly, wave-washed till, and island-like areas of similar till are common. The lakes were to a lesser extent confined by ice walls. Much ice floated in the lake waters, as is evidenced by the abundance of ice-rafted boulders and small patches of ice-rafted till.

These lake deposits are in many places crossbedded, and show rapid gradations from clay to silt to sand to gravel, suggesting that they are in large part deltaic in origin, deposited in the deltas of glacial streams that fed the lakes. As the ice dams that formed part of the shorelines of these lakes melted, the lake levels were lowered and their floors exposed. And at this time Nechako and Stuart Rivers began to excavate their post-Glacial channels and to build terraces along their banks. These channels are now several hundred feet deep.

A SUGGESTED GLACIAL HISTORY

Assuming that conditions of precipitation in Pleistocene time were relatively similar to those existing today, it is apparent that in central British Columbia much the greatest accumulation of ice was on the Coast Mountains. Ice also accumulated, although to a much lesser extent, on the Rocky Mountains, Omineca Mountains, and other ranges of the north-central interior of British Columbia. Relatively little, if any, glacier ice formed in the Nechako Plateau and Plain. As the mountain ice-fields grew the ice flowed out from them in all directions, at first largely confined to valleys. In the Coast and Rocky Mountains this movement was mainly easterly and westerly and in the Omineca and other interior ranges mainly northerly and southerly. These large valley glaciers coalesced in the low-lying Nechako Plateau and Plain. As glaciation continued, ice piled up until most of central British Columbia was covered by a single great sheet of varying thickness known as the Cordilleran ice-sheet. A few of the higher peaks and ridges either projected through the ice or were not far below the surface, and apparently at no time was the ice thick enough to flow indiscriminately over mountain and valley. In the mountainous areas the movement of the ice was confined largely to the main valleys, although some movement across the summits of the ranges forming the Omineca Mountains was observed. This movement was in general from west to east. However, during the maximum development of the Cordilleran glacier the ice moved across the low-lying Nechako Plateau and Plain in a general easterly and northeasterly direction. Apparently, as would be expected, the ice flowing easterly from the Coast Mountains, much the greatest source of ice, controlled the movement of the ice from the Coast Mountains to the Rocky Mountains. Even at the stages of maximum glaciation the amount of ice supplied by the Rocky Mountains and interior ranges was relatively small, and did not affect the movement of the ice-sheet.

At least two major advances of the Cordilleran ice-sheet have been postulated in the Nechako Plateau and Plain. The recession of the ice between these two major advances may have been limited to these areas. During the first advance of the ice most of the rock debris was eroded from the weathered outcrops and deposited in the low-lying areas, the greatest accumulation of till being in the Nechako Plain. Most of the till consists of material derived from the west, but near the western base of the Rocky Mountains some till composed of material from these mountains was observed. The first major advance of the ice was probably in the main from west to east, although most of the evidence for such a conclusion was obliterated by the last advance.

Following the first major advance of the Cordilleran ice-sheet, with its resultant scouring of bedrock, a recession of the ice-sheet occurred in the Nechako Plateau and Plain. This recession was followed by a re-advance of the ice across the Nechako Plateau and Plain. It is this later advance of the ice that may be traced by the trend of the drumlins, groovings, and striæ, and at the close of which the glacial lakes were formed. In contrast with the earlier ice advance the later or last one resulted, apparently, in the transportation of a relatively much lighter load of till, and the rearrangement of the earlier till into drumlins, as has already been suggested in the discussion of these drumlins and the associated parallel groovings. The ice in general moved from the Coast Mountains east to the Rocky Mountains. In detail the movement, particularly at the base of the ice, was much more variable, the underlying topography being the governing feature. In the Fort St. James area the ice flowed southeasterly down such valleys as those of Babine and Takla Lakes. Wherever possible the ice flowed easterly through gaps in the eastern walls of these valleys, apparently as a result of ice pressure from the west. The easterly flowing ice moved down the valleys of Omineca and Nation Rivers into the valley of Parsnip River. At the southern end of Babine and Takla Valleys the southeasterly moving ice met a great stream of ice moving easterly and northeasterly along Nechako Valley and across Nechako Plateau. The two streams of ice formed a great, confluent piedmont glacier that moved easterly and northeasterly across the Nechako Plain to the Rocky Mountain Trench. There it encountered the westerly moving glaciers from the Rocky Mountains, but, being much the larger, overrode these and moved upwards over the low western spurs of the Rockies. Farther east the main body of the Rocky Mountains acted as a barrier, and turned the ice-sheet northwesterly down the valley of Parsnip River.

This last advance of the ice was apparently followed by stagnation and decay of the ice-sheet in the Nechako Plain and Plateau, and the formation of glacial lakes.

CHAPTER III

GENERAL GEOLOGY

SUMMARY STATEMENT

Regional Geology

The Fort St. James area of central British Columbia lies wholly within the Interior physiographic system of the Canadian Cordillera[1]. This system, composed of dissected plateaux and scattered mountain ranges, occupies a belt more than 200 miles wide and extends southeast from the Alaska boundary at Yukon River to the southern boundary of British Columbia at Okanagan River.

The central British Columbia part of the Interior system is a region of great geological complexity, in which sedimentary and volcanic strata range in age from Late Proterozoic to Oligocene or younger. These strata record several periods of crustal disturbance accompanied or followed by uplift and erosion, and, south of latitude 56 degrees, central British Columbia was probably exposed to erosion from Lower Cambrian to Pennsylvanian time, from late Permian to Upper Triassic time, and also during most of Tertiary time. The writer believes that there have been four main periods of orogeny, namely: post-Lower Cambrian–pre-Pennsylvanian; post-Middle Permian–pre-Upper Triassic; Upper Jurassic or Lower Cretaceous; and post-Paleocene. Most of the observable faults and folds appear to have been formed during the last two periods, and if extensive faulting and folding took place during the earlier periods of crustal disturbance it has not been recognized. The post-Paleocene deposits include vast areas of only slightly disturbed volcanic rocks.

A rather remarkable feature in central British Columbia is that the Upper Palæozoic and Mesozoic strata are more closely folded than the adjoining, Late Proterozoic and Lower Cambrian formations. Several possible explanations might be advanced: (1) the Late Proterozoic and Lower Cambrian formations consisted largely of massive quartzites and limestones, competent rocks that did not yield as readily to pressure as the less competent argillites, ribbon cherts, and volcanic rocks that comprised much of the Palæozoic and Mesozoic strata; (2) during the Upper Jurassic or Lower Cretaceous period of orogeny the Late Proterozoic and Lower Cambrian strata may have been deeply buried under a thick cover of Palæozoic and Mesozoic rocks and, therefore, may have yielded in part by flowage rather than only by folding and faulting. The formation of schists would have resulted, a condition common throughout the older strata. These processes would not appear to have been as effective during the post-Paleocene disturbance, as the Late Proterozoic and Lower Cambrian strata near the Rocky Mountain Trench have been much folded and faulted in

1 Bostock, H. S.: Physiographic Subdivision of the Canadian Cordillera North of the fifty-fifth Parallel; Geol. Surv., Canada, Map 932A, 1948.

post-Paleocene time. Probably during most of the Cretaceous period the post-Cambrian rocks were undergoing erosion, and, consequently, by post-Paleocene time the underlying strata were not so deeply buried and hence not in the zone of flowage; and (3) another possibility that must be considered is that the Late Proterozoic and Lower Cambrian strata acted as a buttress against which the Palæozoic and Mesozoic strata were folded. If so, these older rocks probably formed a landmass on the east of the Palæozoic and Mesozoic geosyncline.

During the post-Middle Permian–pre-Upper Triassic and Upper Jurassic or Lower Cretaceous intervals, and probably during post-Paleocene time, the folded and faulted strata were invaded extensively by deep-seated igneous rocks, including the Trembleur and Topley intrusions in the post-Middle Permian–pre-Upper Triassic interval; the Omineca intrusions and part of the Coast Range intrusions in Upper Jurassic and Lower Cretaceous time; and the Kastberg and Bulkley intrusions and probably some of the Coast Range intrusions during the post-Paleocene disturbance.

The Late Proterozoic, Palæozoic, and Mesozoic formations of central British Columbia have a general northwesterly trend, but locally structures are quite irregular. The Coast Range and Omineca-Cassiar batholiths have a northwest elongation roughly parallel with the invaded strata. As a general rule, formations near batholiths are more intensely deformed and altered than those farther away. In the Manson Creek area all the pre-batholithic rocks lie near intrusions and have an average dip in excess of 60 degrees, whereas in the Cariboo district no large intrusive bodies are exposed and the strata generally dip at angles of less than 40 degrees.

Faults are widespread throughout the region, and both normal and reverse types have been recognized. They trend in many directions and in places appear to have broken the terrain into separate blocks, with unrelated structures. The great Pinchi and Manson fault zones and others along the Rocky Mountain Trench were partly or completely developed in post-Paleocene time.

Local Geology

Consolidated formations within the Fort St. James map-area range in age from Late Proterozoic to Oligocene or later, and comprise a great variety of sedimentary, volcanic, and intrusive types. The older formations have suffered repeated deformations but the common trend is northwesterly to westerly.

The oldest rocks in the area are represented in the Wolverine complex, which outcrops in the northeast corner of the area, and which consists of Late Proterozoic and Lower Cambrian sedimentary strata that were partly granitized in post-Lower Cambrian time. At the time the legend on the map accompanying this report was prepared for publication no evidence regarding the age of the Wolverine complex had been obtained other than that it included rocks of pre-Permian age that were probably of Precambrian age. However, in the Aiken Lake map-area to the northwest, Armstrong and Roots (17) in 1946 collected Lower Cambrian fossil sponges in Ingenika group rocks, which they believe to be in part non-granitized equivalents of those included in the Wolverine complex. Ruby group strata of Late Proterozoic age occur below the Ingenika group rocks of Lower Cambrian age. These Late Proterozoic and Lower Cambrian formations lie along the northwest extension of the belt of Wolverine complex exposed in the Fort St. James map-area, and they contain granitized equivalents similar to those in the complex.

Apparently the Fort St. James area was a landmass during most of Middle Cambrian to Pennsylvanian time, but, commencing probably in this latter period and extending into at least mid-Permian time, a thick succession of steeply folded and intensely faulted sedimentary and volcanic rocks was laid down, and outcrops along two wide belts that traverse the map-area from northwest to southeast. These rocks have been mapped as Cache Creek, and although separated from the Wolverine complex by a major fault, are believed to overlie the complex unconformably. In the Cariboo region to the southeast, Johnston and Uglow (80, p. 37) state that the Cariboo series of Late Precambrian age is overlain unconformably by the Slide Mountain group of Upper Palæozoic age.

No fossils later than Middle Permian age have been found in the Cache Creek group of the Fort St. James map-area. However, at places the fossiliferous Middle Permian strata are overlain by thick accumulations of volcanic flows, tuffs, breccias, and agglomerates, indicating that the close of the Palæozoic era was characterized by volcanic activity. This was accompanied or followed by a period of uplift and erosion extending, apparently, to Upper Triassic time. The writer also believes that the Trembleur ultrabasic intrusions and possibly the Topley acidic intrusions were emplaced during this Middle Permian to Upper Triassic interval. On the north shore of Pinchi Lake, pebbles of ultrabasic rocks constitute part of an Upper Triassic conglomerate. Also, at no place in the map-area were Trembleur intrusions observed cutting post-Permian strata. The Topley intrusions are unconformably overlain by the Tachek group, which contains fossil plants of probable Jurassic age.

Upper Triassic and Jurassic volcanic and sedimentary rocks of the Takla group occupy mainly a large belt that cuts diagonally across the map-area. They are much folded and faulted and probably overlie the Cache Creek group unconformably. Although this unconformity was not observed, its presence is based on the following evidence: Takla conglomerates contain abundant Cache Creek detritus, and no pre-Upper Triassic or late Permian rocks have been identified in the map-area. The writer also believes that the unconformity is angular, as it is difficult to believe that the Cache Creek group rocks could be uplifted and extensively invaded by batholithic intrusions without also being folded. However, this conclusion is purely speculative, as Cache Creek-Takla contacts, wherever observed, are along faults.

Volcanic rocks of the Tachek and Hazelton groups of Jurassic or Lower Cretaceous age, more probably the former, are found in the southwestern part of the map-area. They probably represent in part the same period of vulcanism as that of the Takla group, but as the three groups do not come in contact with one another their relations are not known.

In late Jurassic or early Cretaceous time, Takla group and older rocks were, apparently, subjected to a major crustal disturbance resulting in widespread folding, faulting, and uplift. No marine deposits of post-Jurassic age have been found in the Fort St. James map-area.

The Takla group strata are invaded by stocks and batholiths of the Omineca intrusions ranging in composition from pyroxenite to granite, with granodiorite predominating. The largest body is the Hogem batholith, with an area in excess of 1,200 square miles. The Omineca intrusions cut Middle Jurassic formations in the Fort St. James area and are overlain by probable Lower Cretaceous conglomerate in the Aiken Lake area (17).

A few small bodies of conglomerate of probable Lower Cretaceous age outcrop along Kwanika Creek and near the Aiken Lake road. They have each been mapped as Uslika formation, on the basis of lithology only.

Conglomerate and associated continental sedimentary strata of Upper Cretaceous and Paleocene age, including the Sustut group, are found at widely separate localities in the Fort St. James map-area; in the south they are interlayered with rhyolitic and related volcanic rocks. Within the map-area only Upper Cretaceous fossils have been found in the Sustut group, but in the McConnell Creek map-area to the northwest, Lord (99) found that beds containing Upper Cretaceous and Paleocene fossils form parts of a conformable succession, and that the Sustut group is structurally unconformable with underlying Takla and older strata.

Following the deposition of the Paleocene strata, these and older formations were subjected to widespread folding and faulting. Probably most of the major faults in the map-area and along the Rocky Mountain Trench were formed during this disturbance. Folding associated with this faulting has been observed along these major faults and near the Trench.

Several small areas of Eocene or Oligocene sedimentary and minor rhyolitic rocks are exposed in the southwestern part of the map-area. Their age with respect to the Upper Cretaceous-Paleocene rocks is not known. However, the younger rocks are found only in existing valleys, whereas the Upper Cretaceous-Paleocene strata occupy mountain tops in the McConnell Creek area.

Unconformable above the Eocene or Oligocene formations, particularly in the southern part of the map-area, are several thousand feet of nearly horizontal amygdaloidal and vesicular lava flows of Oligocene or later age, the Endako group.

A small patch of Pliocene or later conglomerate outcrops on the west slope of Mount Sydney Williams. Stream deposits were observed below Pleistocene till on Silver Creek.

A mantle of glacial debris covers much of the map-area.

TABLE OF FORMATIONS

Era	Period or epoch	Name	Lithology
Cenozoic	Recent		Stream deposits, talus, and soil
	Pleistocene		Silt, clay, sand, and gravel
			Gravel, till, boulder clay, sand clay, and erratics
	Pliocene or later		Stream deposits (conglomerate)
			Conglomerate
	Unconformity		
	Oligocene or later	Endako group	Andesitic and basaltic dykes
			Vesicular and amygdaloidal andesite, basalt, and dacite; flow breccia, agglomerate, and feldspar porphyry
			Trachytic, rhyolitic, and andesitic flows, dykes, and sills; may be older than Endako group
	Unconformity		
	Eocene or Oligocene		Rhyolitic flows, tuffs, and intrusions; minor dacite, andesite, and basalt
			Conglomerate, sandstone, and shale; minor tuff

TABLE OF FORMATIONS—*Con.*

Era	Period or epoch	Name	Lithology
Mesozoic and Cenozoic	The 'Upper Cretaceous or later' sedimentary and volcanic rocks may be in part the same age as the 'Eocene or Oligocene' rocks. No contacts between the two groups were observed.		
	Upper Cretaceous or later		Andesite, trachyte, and rhyolite; intercalated arkose and conglomerate
			Rhyolite, dacite, andesite, basalt, minor related tuffs, and breccias; may be partly or entirely equivalent to Eocene or Oligocene group
	The Sustut group occurs only in the northern part of the area, whereas the 'Upper Cretaceous or later' rocks are exposed only in the southern part; relations, therefore, are unknown, and the two groups may be in part of the same age.		
	Upper Cretaceous and Paleocene	Sustut group	Conglomerate, shale, greywacke, and tuff
	Contact relations not shown		
Mesozoic	Probable Lower Cretaceous	Uslika formation	Conglomerate; minor sandstone and shale
	Unconformity		
	Upper Jurassic or Lower Cretaceous	Omineca intrusions	Granodiorite, granite, syenodiorite, diorite; minor syenite, gabbro, and pyroxenite
	Omineca intrusions cut the Takla group, but are not in contact with the Tachek and Hazelton groups.		
	Jurassic and (?) Cretaceous	Tachek group	Andesite and andesite breccia; basalt and rhyolite

TABLE OF FORMATIONS—*Con.*

Era	Period or epoch	Name	Lithology
	The Tachek group overlies the Topley intrusions unconformably. It and the Hazelton and Takla groups may be in part equivalent, but are not in contact.		
	Jurassic and (?) Cretaceous	Hazelton group	Andesite, trachyte, basalt, and related breccias
	Contact relations not shown		
	Jurassic and Upper Triassic	Takla group	Andesitic and basaltic flows, tuffs, breccias, and agglomerate; interbedded conglomerate, shale, greywacke, limestone, and coal
	Upper Triassic		Shale, greywacke, conglomerate, tuff, and limestone
Palæozoic (?) and Mesozoic	The Takla group is separated from the Cache Creek group by an unconformity. Contact relations of the Takla group to the Topley and Trembleur intrustions are not shown.		
	Post-Middle Permian, pre-Jurassic(?)	Topley intrusions	Granite, diorite, syenite, and granodiorite
	Intrusive contact		
	Post-Middle Permian, pre-Upper Triassic (?)	Trembleur intrusions	Pyroxenite, serpentine, minor peridotite, and dunite; may be in part of same age as Omineca intrusions
			Peridotite, dunite, serpentinized and steatitized equivalents; minor pyroxenite and gabbro

TABLE OF FORMATIONS—*Conc.*

Era	Period or epoch	Name	Lithology
	Intrusive contact		
Palæozoic	Pennsylvanian(?) and Permian	Cache Creek group	Greenstone division: andesitic flows, tuffs, and breccias, with minor basic intrusions; chlorite and hornblende schists; minor argillite, slate, ribbon chert, and limestone
			Ribbon chert division: ribbon chert, argillaceous quartzite, argillite, slate, and greenstone; minor greywacke, conglomerate, and limestone; metamorphosed equivalents. In part older than limestone division; relation to slate division not known
			Slate division: slate, argillite, and greenstone; minor quartzite, limestone, and conglomerate
			Limestone division: massive limestone; minor argillite, slate, ribbon chert, and greenstone
Unconformity			
Late Precambrian, Lower Cambrian, and later intrusive rocks	Wolverine complex		Granitic gneiss, pegmatite, granite, or granodiorite
			Micaceous, chloritic, and garnetiferous schists; quartzite and crystalline limestone

UNDIFFERENTIATED ROCKS

Wolverine Complex

The rocks of the Wolverine complex have been named from their widespread occurrence in the Wolverine Range in the northeast corner of the Fort St. James map-area, where they occupy an area of about 425 square miles. Elsewhere a small body of similar rocks has been exposed at the head of Boulder Creek. The complex consists of granitic gneiss, 'granodiorite', pegmatite, quartzite, micaceous, chloritic, and garnetiferous schists, and crystalline limestone. Interbedded quartzite, schist, and limestone predominate along the western front of the Wolverine Range, and quartzite and micaceous schist at the head of the south fork of Boulder Creek. Granitic gneiss, 'granodiorite', quartz-mica schist, and pegmatite are the principal rocks exposed in the centre of the Wolverine Range. The eastern front of the range was not examined.

LITHOLOGY

The quartzites and quartz-mica schists are golden-brown to grey rocks consisting chiefly of quartz and muscovite, with more or less plentiful biotite. All gradations from quartz-mica schist through micaceous quartzite to relatively pure quartzite are represented. For the most part these rocks probably represent metamorphosed sandstone. With the addition of garnet the quartz-mica schists grade into garnetiferous schists. The chloritic schists are generally thinly bedded, fine-grained, green rocks composed largely of quartz and chlorite. They probably represent metamorphosed argillaceous rocks. The typical limestones are blue-grey to creamy, coarsely crystalline, poorly bedded rocks commonly containing much sericite.

The term granitic gneiss has been applied to banded gneisses, quartz-mica feldspar schists, feldspathized quartzites, and, most common of all, slightly foliated quartz-mica feldspar rocks, a group that has an overall mineral composition similar to granitic rocks, but with a wider variety of textures. The most characteristic types are white to grey, medium-grained rocks composed of quartz, white feldspar, muscovite, biotite, and an occasional garnet. They exhibit only a poorly developed foliation, due to the alinement of the mica flakes, and, with a reduction in mica, grade into feldspathized quartzite. They also grade into coarse-grained, quartz-mica-feldspar schists and banded gneisses, the latter consisting of bands of white feldspar and quartz separated by foliæ of mica, mainly biotite. Garnet is present in all types in conspicuous amounts, and occurs as bright red, rounded, and embayed grains, many of which contain particles of quartz. The granitic gneisses reveal a remarkable similarity in constitutent minerals for rocks of varied texture. In the Rosiwal analyses tabled below the locations are not given, but the samples were chosen as representative (*See also* Figure 2)[1].

[1] All analyses total 100 per cent. No other minerals have been recognized.

TABLE I

Modes of Granitic Gneisses

Number of specimen	Type	Quartz	Oligoclase or andesine	Orthoclase or microcline	Muscovite	Biotite	Garnet
		%	%	%	%	%	%
1	Slightly foliated, medium-grained, quartz-mica-feldspar rock....................	62·3	17·5	12·5	4·5	3·2	—
2	Fine-grained, feldspathized quartzite..................	28·8	20·8	49·4	—	1·0	—
3	Medium-grained quartz-biotite-feldspar schist..........	34·1	31·8	29·8	—	4·3	—
4	Coarse-grained, banded gneiss	32·7	22·9	42·0	2·0	—	0·4
5	Coarse-grained quartz-biotite-feldspar schist.............	56·5	27·0	12·8	1·5	1·7	0·5
6	Slightly foliated, medium-grained quartz-mica-feldspar rock....................	66·7	10·0	13·3	—	9·0	1·0
7	Slightly foliated, medium-grained quartz-mica-feldspar rock........................	65·2	11·5	15·3	—	7·5	0·5
8	Slightly foliated, medium-grained quartz-mica-feldspar rock........................	63·4	23·3	6·7	3·3	3·3	—
9	Slightly foliated, medium-grained quartz-mica-feldspar rock........................	62·0	22·1	9·3	2·1	3·5	1·0
10	Coarse-grained quartz-muscovite-feldspar schist......	40·0	10·0	40·0	10·0	—	—

The quartz grains vary in size up to 4 millimetres, and have extremely irregular edges by which adjoining grains are interlocked, forming a quartz mosaic. All the quartz grains show undulatory extinction. The plagioclase, which is chiefly andesine or oligoclase, is generally very fresh and in the form of smoothly rounded or angular grains quite different from the quartz. It is commonly twinned according to the albite and pericline laws, but twinning is not universal, and some of the feldspar identified as orthoclase may be untwinned plagioclase. The orthoclase exhibits many of the same features as the plagioclase. It is generally untwinned, although some typical grating-structure, characteristic of microcline, was observed. The mica occurs as thin, parallel films and shreds curving around and between other minerals.

The term 'granodiorite' has been applied to rocks that have a composition and texture similar to those of normal granodiorite, but which are believed to have been formed in situ by the progressive injection of granitic material and the gradual replacement of the injected rock. The largest observed body of these 'granodiorites' has an area of about 10 square miles; the smallest bodies are a few feet wide only. In most places their contacts are not sharply defined, but a few sill-like bodies of similar composition were observed in areas of quartz-mica schist. These 'granodiorites' are medium- to coarse-grained equigranular rocks. Stringers and dykes of similar composition have been intruded along bedding and foliation planes of the associated schists but do not cut the 'granodiorite' bodies.

A microscopic examination of typical specimens of 'granodiorite' reveals that they consist of quartz, plagioclase, orthoclase, biotite, and muscovite. These minerals exhibit the same general characteristics as those comprising the granitic gneisses. Rosiwal analyses of four specimens follow (*See also* Figure 2):

TABLE II

Modes of Typical 'Granodiorites'

Number of specimen	Quartz	Plagioclase: oligoclase or andesine	Orthoclase or microcline	Biotite	Muscovite
	%	%	%	%	%
1.	25·5	40·0	31·4	3·1	—
2.	37·6	36·9	18·9	—	6·6
3.	29·1	25·4	41·7	2·9	—
4.	31·0	35·6	28·6	4·8	—

These 'granodiorites' differ from the nearby Omineca granodiorites in several particulars. They have a more granulose texture, the quartz generally forming a mosaic; they contain no accessory minerals such as apatite and sphene; and they have a uniform composition, showing no differentiation. As will be seen from a study of the modes, the 'granodiorites' and granitic gneisses have the same general composition and the minerals have the same characteristics, features suggestive of a common origin.

The pegmatites are generally coarse-grained rocks consisting of quartz, plagioclase, and orthoclase feldspar, muscovite, biotite, and garnet in about this order of abundance. Books of mica up to 3 inches in diameter were observed in places. Many of the pegmatite bodies, especially the smaller ones, are dyke shaped and apparently intrusive. Some are fine grained, and are probably better called aplites. The more tabular bodies commonly parallel the gneissosity or schistosity of the invaded rock, but many of the larger pegmatite bodies are very irregular in size and shape. Few exceed 100 feet in thickness. Every gradation of grain size was commonly observed at the contact of these pegmatite bodies with the adjoining bodies of granitic gneiss and 'granodiorite', although, as already stated, in places the pegmatite is definitely intrusive. Except in grain size there is a striking similarity in appearance and mineral composition between the pegmatites and the 'granodiorites', and the similarity in mineral composition also applies to the granitic gneisses. There seems little doubt that the bulk of the material comprising the pegmatites, 'granodiorites', and granitic gneisses had a common source.

STRUCTURAL RELATIONS

Internal Structural Relations

The writer made only a very cursory examination of the Wolverine rocks in the Fort St. James map-area and obtained very little information on their structural arrangement. As contrasted with the adjoining Cache Creek formations they appear to occupy relatively gentle structures, though, in detail, frequent close sigmoid folds may be observed. However, relatively gentle folding seems to be characteristic of the Late Precambrian and Lower Cambrian formations of the Omineca and Cariboo districts of central British Columbia and is not a feature limited to their granitized equivalents, the Wolverine complex. In studying similar granitized rocks in the Aiken Lake map-area (17) to the northwest it was found that the Late Precambrian and Lower Cambrian formations could be traced along their strike into their granitized equivalents, and that the foliation in the granitized rocks is parallel with the original bedding.

External Structural Relations

As outlined in the section on age and correlation, the Wolverine complex is composed in large part of Late Precambrian and Lower Cambrian formations. In the Fort St. James map-area the contact of the Wolverine complex with the younger Cache Creek group lies along a major fault; in the Aiken Lake (17) map-area to the northwest the only observed contact is along a fault; in the Carp Lake (22) map-area to the southeast the contacts are drift covered; but in the Cariboo region farther to the southeast Johnston and Uglow (80, pp. 37-38) state that the Slide Mountain series of Late Palæozoic age occurs structurally unconformably above the Cariboo series of Precambrian age. The evidence for this unconformity in the Cariboo district may be summarized as follows: (1) there is some discordance of strike and dip between the two series; (2) the basal conglomerate of the Slide Mountain series rests on an erosion surface of the Cariboo series, and contains pebbles and boulders of the underlying formations of that series; (3) pebbles of folded, crenulated, slaty and schistose rocks in the Slide Mountain basal conglomerate are proof of the metamorphism of the Cariboo series before the deposition of the Slide Mountain series; (4) there is a decided difference in the degree of metamorphism to which the rocks of the two series have been subjected; and (5) felsite and quartz porphyry dykes were observed only in the Cariboo series.

In the Aiken Lake (17) map-area the general structure of the Late Precambrian and Lower Cambrian formations lends support to the view that they are separated by a structural unconformity from succeeding Cache Creek formations. The average dip of the Late Precambrian and Lower Cambrian strata is low as compared with that of Cache Creek beds, and their strike does not everywhere conform with the northwesterly trend of deformation of the younger rocks. In the southeast part of the Aiken Lake map-area the younger rocks trend about north 5 degrees west and the older rocks about north 70 degrees west. Also the Late Precambrian and Lower Cambrian rocks are much more metamorphosed than the Cache Creek rocks.

ORIGIN

As outlined in the following section on age and correlation, the writer believes that the rocks comprising the Wolverine complex consisted in large part, prior to granitization, of interbedded quartzities, argillites, limestones, and derived schists of Late Precambrian and Lower Cambrian ages.

The present quartzites, schists, and sericitic limestones included in the Wolverine complex have been formed from normal sedimentary rocks as a result of heat and pressure. The origin of the granitic gneisses, 'granodiorites', and pegmatites, however, is complicated by large-scale replacement effects whereby rocks of widely varying composition have acquired a granitic composition. The writer believes that the granitic gneisses, most of the 'granodiorites', and possibly some of the pegmatitic rocks are granitized sedimentary rocks similar originally to those from which the schists, quartzites, and sericitic limestones were derived. They were probably formed in situ by the progressive injection of granitic material, and the gradual replacement of sedimentary rocks of both argillaceous and siliceous compositions. The nature of these processes is not entirely clear, though certain probable conditions may be postulated. It is quite apparent that there has been no forcible emplacement of a granitic magma accompanied by pronounced deformation as with the Omineca intrusions. Instead, some process such as a gradual soaking of the overlying sedimentary rocks with emanations (granitizing solutions) rising from an underlying source (possibly a granite magma) must have taken place. In his study of the Shuswap complex, the equivalent of the Wolverine complex in southern British Columbia, Cairnes (32, pp. 269-270) has suggested that these emanations were essentially of the nature of pegmatitic and aplitic differentiates, high in volatile constituents and extremely mobile. He bases this conclusion on the facts: that pegmatites are abundant throughout the Shuswap complex; that aplitic injection material is an important constituent of the Shuswap gneisses; and that large areas of massive Shuswap granite contain bodies of pegmatitic granite of the same mineral composition. Cairnes states "that the principal processes have seemed to involve a gradual upward seepage of this pegmatitic and aplitic material, infiltration along bedding and schistosity planes, replacement or partial replacement of the intervening rock matter, and the growth, in situ, of probably much of the pegmatitic granite. In places the continued supply of magmatic material resulted in the complete conversion of large bodies of the original strata into massive granitoid rocks, which under conditions of transformation became partly plastic or molten, and where subjected to local stresses behaved much as a normal intrusive rock in its contact relations with adjoining rock masses." The writer believes that some process similar to that quoted above is applicable to the Wolverine complex. As previously pointed out, the granitic gneisses, 'granodiorites' (in part equivalent to Cairnes' granites and in part equivalent to his aplites), and the pegmatites exhibit a remarkable similarity of mineral composition and in the textures of the individual minerals, suggesting a common source. All the conditions general to the Shuswap complex are duplicated in the Wolverine complex.

From a field study of the Wolverine complex in the Fort St. James map-area, in the Aiken Lake map-area (17) on the northwest, and in the Carp Lake map-area (22) on the southeast, the writer has concluded that only the Late Precambrian and Lower Cambrian formations have been granitized. In all three areas Cache Creek formations of Permian and probable Pennsylvanian age come in contact with the Wolverine complex and, although no actual contacts have been observed, outcrops of the Cache Creek rocks were observed within 100 feet of outcrops of the Wolverine complex. In several places the Wolverine complex was 'granodiorite' or granitic gneiss and the nearby Cache Creek rocks showed no evidence of granitization.

In all places where the contact could be closely located, this contact relation is due to faulting, and it is quite possible that this is the explanation everywhere; however, is it not possible that the granitization of the Late Precambrian and Lower Cambrian sedimentary formations took place in post-Lower Cambrian and pre-Cache Creek time, that is, in pre-Pennsylvanian time, and that it was, consequently, entirely unrelated to the emplacement of any known granite intrusions?

AGE AND CORRELATION

The Wolverine rocks were first examined by McConnell in 1893 (102, p. 33). He reported that they resembled the Shuswap series of southern British Columbia, which at that time was regarded as of Archæan age and not unlike the Grenville series of eastern Canada. In 1927, Dolmage (56, p. 26) examined a similar series of schists and gneisses along Finlay River, north of the Manson Creek area. He states that the age of the series is not known, but is presumably Precambrian. Kerr (86, p. 11) accepted McConnell's and Dolmage's Precambrian age for the rocks in the Wolverine Range.

When the legend of the map accompanying this report was prepared the writer had no information on the age of the rocks included in the Wolverine complex except that they were probably pre-Cache Creek and possibly Precambrian. Since completing field work in the Fort St. James map-area the writer has had an opportunity to investigate similar rocks in the Aiken Lake map-area to the northwest, and has obtained evidence that rocks similar to those of the Wolverine complex are granitized equivalents of Late Precambrian and Lower Cambrian strata (17). Fossil sponges were collected from the Lower Cambrian rocks. The main area of the Wolverine complex in the Fort St. James map-area lies along a northwesterly projection of the belt of Late Precambrian rocks of the Cariboo district, and, presumably, may be in part of the same age. In the Cariboo, Lang (91, p. 14) collected Lower Cambrian trilobites from beds conformable with the Late Precambrian rocks.

SEDIMENTARY AND VOLCANIC ROCKS

Cache Creek Group

GENERAL STATEMENT

The Cache Creek group as exposed in the Fort St. James area consists of a very thick assemblage of interbedded sedimentary and volcanic rocks, mainly of Permian age but also probably in part of Pennsylvanian age. Foraminiferal limestones and ribbon cherts are characteristic of the group. Most of the rocks referable to the Cache Creek in the map-area occupy two northwesterly trending belts: one of these extends from south of Fort St. James northwest 160 miles to the upper part of Omineca River, has an area of 2,500 square miles, and will be referred to as the Stuart Lake belt; the other underlies an area of 600 square miles, stretches from Gaffney Creek 60 miles northwest to Nina Creek, and will be referred to as the Manson Creek belt. The latter belt contains no ribbon cherts, and although limestones are abundant no foraminifera have as yet been found in them. However, they are in part lithologically similar to typical Cache Creek rocks, and are in part at least of the same age. Smaller areas of rocks also mapped at Cache Creek occur near Babine Lake, Sutherland River, and Nechako River east of Fort Fraser. Although no fossils were found in these rocks they are lithologically similar to the Cache Creek group as exposed in the Stuart Lake belt.

Included in the Cache Creek group is a great assemblage of sedimentary, extrusive, and, to a minor extent, intrusive rocks, and their metamorphosed equivalents. The sequence of formations has been established in only a very general way. Lithological similarities in formations occurring at different horizons, scarcity of fossiliferous beds, great thicknesses of structureless volcanic flows, extensive younger intrusions with resultant metamorphism of the intruded rocks, widespread major and minor faulting, repeated folding resulting in steep, partly overturned beds, regional metamorphism, and paucity of outcrops below timber-line have each and all presented difficulties in the matter of stratigraphic interpretation that can only be solved by more detailed studies than were possible on the present mapping scale. Therefore, it is not possible to make more than a rough approximation of the stratigraphic sequence and the total thickness of the Cache Creek group. It appears to represent a conformable succession of 20,000 feet or more of interbedded limestone, ribbon chert, argillite, slate, quartzite, tuff, breccia, andesite, and basalt (greenstone), and their derived schists.

Four main lithological divisions of the Cache Creek group are recognizable in the field, namely: (1) a limestone division consisting of 90 per cent or more massive limestone and 10 per cent or less non-calcareous sedimentary rocks and greenstones. Rocks of this division are abundant in both the Stuart Lake and Manson Creek belts; (2) a ribbon chert division comprising about 50 per cent ribbon chert and argillaceous quartzite, 30 per cent argillite and slate, 15 per cent greenstone, and 5 per cent limestone and conglomerate. Ribbon cherts do not occur in the Manson Creek belt; (3) a slate division consisting of about 50 per cent slate and argillite, 45 per cent greenstone, and 5 per cent limestone, chert, and conglomerate. This division is not represented in the Stuart Lake belt nor does it come in contact with the ribbon chert division elsewhere, so the relations of the two are not known; and (4) a greenstone division composed of 90 per cent or more of andesitic and basaltic flows, tuffs, breccias, and agglomerates, and 10 per cent or less of argillite, slate, chert, quartzite, and limestone. Greenstones are abundant throughout the Fort St. James area. These lithological divisions are stratigraphic only in the broad sense that the bulk of the limestone is in the lower part of the Cache Creek group and greenstones predominate in the upper part of the group. In the following incomplete sections all thicknesses are approximate; apparent recurrences of lithologic types in any section do not imply stratigraphic repetitions, though some such may be represented and not recognized.

Eastern End of Tsayta Lake (Stuart Lake belt): a synclinal structure; rocks at least 50 per cent exposed; no apparent faults; believed to be a continuous section:

	Feet (approx.)
Ribbon chert division	4,000
Limestone division	3,000
Ribbon chert division	1,000
	8,000

Kloch Lake (Stuart Lake belt): a synclinal structure; rocks at least one-third exposed; no apparent faults; may be repeated folding in lower ribbon chert division, but apparently one simple fold in limestone and upper ribbon chert divisions as based on fossil evidence:

	Feet (approx.)
Ribbon chert division	4,000
Limestone division	4,000
Ribbon chert division	10,000 ±
	18,000

Mount Ogden (Stuart Lake belt): all formations dip northeast at about 60 degrees; rocks at least two-thirds exposed; no apparent faults; possibly repeated folding overturned to southwest:

	Feet (approx.)
Ribbon chert division	4,000
Limestone division	10,000
Ribbon chert division	3,000
Limestone division	1,500
Ribbon chert division	1,500
Limestone division	1,500
Ribbon chert division	2,500
	24,000

West of Tsitsutl Mountain (Stuart Lake belt): all formations dip northeast; rocks about one-quarter exposed; no apparent faults or repeated folding, but such features may be represented and account for the great thickness:

	Feet (approx.)
Ribbon chert division	4,500
Greenstone division	4,500
Limestone division	1,500
Greenstone division	1,500
Limestone division	2,000
Ribbon chert division	4,000
	18,000

The two main belts of rocks of the greenstone division lie between formations of Mesozoic age and others of Middle Permian age or older, and in the main the greenstone division appears to represent the younger part of the Cache Creek group.

A hypothetical composite section for the whole of the Cache Creek group in Stuart Lake belt would probably be somewhat as follows:

	Feet (approx.)
Greenstone division	5,000 +
Ribbon chert division	1,000 +
Greenstone division	1,000 +
Ribbon chert division	2,000 +
Limestone division	1,000 +
Greenstone division	1,000 +
Ribbon chert division	1,000 +
Limestone division	1,000–5,000
Ribbon chert division	5,000 +
	18,000–22,000 +

No sections in the Manson belt containing the slate division have been measured. However, it is known that some members of the slate division are older and some are younger than members of the limestone division.

LIMESTONE LITHOLOGICAL DIVISION

The most persistent band of limestone occurs near the Pinchi fault zone, and has been traced from south of Fort St. James northwest 140 miles to Omineca River. It varies in width from ½ mile at its northern extremity to 5 miles near Mount Pope. This limestone band was first noted by Selwyn in 1875 (114, p. 78), who described it as follows:

"From the summit known as Pope's Cradle (Mount Pope) . . . . this great limestone can be traced by the eye, forming a broad belt of white rocky ridges, for a distance of not less than thirty-five or forty miles on a bearing E.S.E., and W.N.W. Looking down upon it from Pope's Cradle, it has the appearance of a hogged-back rugged and broken ridge, winding through the country."

A second prominent band of limestone about 1 mile wide underlies Mount Copley and extends 35 miles northwesterly to the southern end of Mitchell Mountains. It probably represents the same limestone strata as the main band, repeated by folding. South of Kuzkwa River the two bands have been mapped as one due to the scarcity of outcrops. North of the Mitchell Mountains the second band was not recognized. Numerous outcrops of limestone were observed at the west end of Trembleur Lake and west of Tsitsutl Mountain and Mount Sydney Williams. They probably form part of one continuous band that has been extensively faulted. Three bands of limestone are exposed in the vicinity of Mount Ogden, the largest being 10,000 feet wide and more than 15 miles long. Two northwesterly trending bands of limestone, each about 12 miles long and 1 mile wide, occur southwest of Gaffney Creek, and may represent the same beds repeated by folding. About 50 square miles of limestone were mapped north of Omineca River, including a crinoidal variety similar to that found elsewhere in the Cache Creek group. However, pre-Permian limestones may be included here, as the northwesterly extension of this belt into the Aiken Lake area was found to contain limestones of probably both Permian (Cache Creek) and Lower Cambrian ages. Smaller bands and lens-like bodies of limestone as much as 1,000 feet thick occur at intervals throughout the Permian section. All the bands, particularly the smaller ones, pinch and swell along their strike and at depth, and in places disappear. Several limestone lenses 2,500 to 3,000 feet thick but only 2 to 3 miles long were observed.

The normal limestone is blue-grey, grey weathering, medium grained to dense, and massively bedded. In places the beds grade from blue-grey to white or cream across widths of from 15 to 20 feet. On the ridge lying northwest of Kloch Lake stylolitic structures were observed along the bedding planes. In much of the area the limestones are completely recrystallized, so that all evidence of bedding is lost except in some of the more thinly bedded sections where preferential chertification has taken place. The chert occurs along original bedding planes and weathers out in ridges ½ inch to 2 inches wide separated by beds of limestone ½ inch to 6 inches thick. In the more massively bedded limestones, chert occurs in white weathering nodules, averaging 2 to 6 inches in diameter. Many of the bands of limestone are iron stained, and carry abundant minute stringers and specks of red and brown hematite and limonite. Most of the limestones are criss-crossed with calcite stringers a fraction of an inch wide, and some of them are grey and black and contain argillaceous material. In places near the Pinchi fault zone, grey weathering limestone has been hydrothermally altered to buff weathering dolomitic rocks.

The following are analyses of representative samples of these limestones:

TABLE III

Analyses[2] of Limestones from near the Pinchi Fault Zone

Sample	CaO	$CaCO_3$	MgO	$MgCO_3$	$(FeAl)_2O_3$	Insol.	SiO_2
1.	45·07	80·05	7·40	15·47	0·77	3·25	3·07
2.	55·60	99·28	1·62	3·38	0·81	0·87	—
3.	34·81	62·16	0·21	0·44	1·80	33·01	27·97
4.	26·90	48·04	12·01	25·29	0·99	24·64	22·75
5.	34·03	60·77	17·97	37·56	1·59	0·38	—
6.	55·41	98·95	0·31	0·63	0·15	0·07	—
7.	51·32	91·59	1·38	2·88	1·56	3·21	3·07
8.	55·14	98·41	0·07	1·46	0·14	0·55	0·22
9.	54·18	97·71	0·13	0·27	0·62	2·89	1·02
10.	56·05	100·30	0·05	0·10	0·10	0·19	nil
11.	50·06	89·35	0·05	0·10	0·41	4·21	3·04
12	55·29	98·69	0·10	0·21	0·42	1·41	1·00
13.	55·67	99·37	0·20	0·42	0·20	0·58	0·09
14.	55·46	99·00	0·27	0·56	0·20	0·41	0·11
15.	52·52	94·75	0·04	0·08	0·57	1·55	0·95

1. Buff limestone outcropping 5 feet from south fault at Pinchi Lake mercury mine.
2. Blue-grey limestone outcropping near office at Pinchi Lake mercury mine.
3. White, siliceous limestone containing cinnabar from glory hole at Pinchi Lake mercury mine.
4. Buff limestone containing cinnabar from glory hole at Pinchi Lake mercury mine.
5. Buff limestone outcropping near Pinchi fault zone on lower part of Kwanika Creek.
6. Buff limestone outcropping along ridge west of Kwanika Creek.
7. Buff limestone outcropping on east side of Indata Lake at south end.
8. Blue-grey limestone outcropping on ridge west of Indata Lake at south end.
9. Brecciated buff limestone from Bron group of claims, west fork of Kwanika Creek.
10. White limestone containing cinnabar from "A" showing, Bralorne Takla mercury mine.
11. Brecciated buff limestone from "A" showing, Bralorne Takla mercury mine.
12. Blue-grey limestone from "A" showing, Bralorne Takla mercury mine.
13. Blue-grey limestone outcropping on ridge to west of Bralorne Takla mercury mine.
14. Blue-grey limestone outcropping on BB group, Silver Creek.
15. Brecciated, buff limestone containing cinnabar, Bralorne Takla mercury mine.

The argillite, slate, ribbon chert, and greenstone included in the limestone lithological division are similar to those in the other Cache Creek divisions and are described elsewhere.

RIBBON CHERT LITHOLOGICAL DIVISION

The ribbon chert division is most abundant in the Stuart Lake belt of Cache Creek rocks, where it underlies an area of at least 1,500 square miles. The ribbon chert strata appear to be much more closely folded than those of the limestone lithological division, and their thicknesses are difficult to estimate but represent a minimum total of at least 5,000 feet.

The ribbon cherts, the most characteristic rocks of the division, are generally blue-grey, but range in shade from cream-grey to black, and in places are pale green. They consist of beds of chert, ½ inch to 6 inches thick, commonly minutely crumpled, and separated by thin partings of black, lustrous carbonaceous argillite.

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1 Analyses by R. J. C. Fabry, Mineralogical Section, Geological Survey, Ottawa.

In many places the partings have a slaty cleavage and have been partly metamorphosed to graphite or to mica. Usually the chert layers are much thicker than the intervening argillaceous partings, but in places the latter equal or exceed the chert ribbons in thickness. Along the shores of Stuart and Trembleur Lakes exposures occur in which hundreds of separate chert beds are visible in rhythmic alternation. Individual beds commonly pinch and swell, exhibiting a nodular character, and can rarely be traced more than 25 feet.

These thinly bedded cherts are characteristically veined by white crystalline quartz, which forms veinlets that are usually less than $\frac{1}{16}$ inch wide and $\frac{1}{4}$ inch apart and stand out in slight relief as a reticulate pattern on weathered surfaces of the chert. In thin section the cherts show an intricate pattern of interlocking cryptocrystalline quartz.

Typical ribbon cherts are most abundant in the area lying between the southern end of Takla Lake and Fort St. James. Farther north somewhat similar rocks of probably the same origin have been called argillaceous quartzites in the field. These exhibit the same thin bedding as the ribbon cherts, but are coarser grained, and contain more argillaceous material, in part disseminated throughout the quartzitic beds and in part separating the beds. In thin section the quartzitic beds show an intricate pattern of crystalline quartz with a minor amount of disseminated argillite, enough to colour the rock dark grey or black.

In addition to ribbon cherts and argillaceous quartzites, some beds of massive chert and others of quartzite were observed. Also argillite and slate comprise about 30 per cent of the rock included in this division, but are lithologically the same as those of the argillite and slate of the slate division and will be described later in dealing with that division. Interstratified with the argillites and cherts are beds of dark grey schistose greywacke and conglomerate from a few inches to 10 feet thick. Pebbles in the conglomerate are predominantly of chert and quartz and rarely exceed $\frac{1}{2}$ inch in diameter.

Bands of greenstone, up to 1,500 feet wide, and lenticular bodies of greenstone, as much as 3 square miles in area, are intercalated with the ribbon cherts. They consist mainly of grey-green to dark green, fine- to medium-grained, chloritic andesites, amphibolites, and chlorite schists. In places they cut across adjacent Permian strata; in other places they appear to be interbedded with them. They probably comprise flows, tuffs, and minor intrusive rocks.

The other rock types included in the ribbon chert division are similar to those in other divisions.

Origin of the Ribbon Cherts

The ribbon cherts of the Cache Creek group were first observed by Dawson (55, p. 41) who termed them 'cherty quartzites'. He proffered the following explanation as to their origin: "These rocks have evidently been silicified subsequent to their deposition, but perhaps very soon after, for it is pretty clear that they were very much in their present condition before the main period of disturbance by which the formation has been affected. Their microscopic structure throws very little light on their original character, but they have in all probability been laid down as argillites or silts. It is worthy of remark that they closely resemble in their character cherty or hornstone-like rocks found in different parts of the world in association with contemporaneous volcanic beds, affording ground for the belief their condition may be connected with circumstances of volcanic action." It is difficult to imagine the silicification of an argillite or silt along hundreds of parallel bands ½ inch to 6 inches wide, so that a parting of the original argillite or silt between each band would remain unsilicified. The assumption that the rocks were originally siliceous argillites or silts, particularly siliceous varieties, cannot be ignored, especially if only the argillaceous quartzites, as contrasted with the ribbon cherts, are studied. If they were laid down as thinly bedded argillites or silts and later underwent regional metamorphism, with resulting recrystallization of the quartz, a rock type similar to the argillaceous quartzites might have been derived. The rapid alternation of the beds and resultant distinctions in composition might possibly be due to climatic variations. However, such an origin for the ribbon cherts, especially as they are finer grained than the argillaceous quartzites, does not seem possible, nor is it quantitatively adequate.

The theory advanced by Davis (47) in explanation of the development of the Franciscan cherts of California has been suggested by Cairnes (29, p. 41) as the most probable for the origin of the Cache Creek ribbon cherts. He says: "The silica is regarded as having been derived from silicate solutions coming in part from the greenstones while the latter were being extruded or were in the process of consolidation beneath the sea, and in part from the submarine siliceous springs which derived their content from magma reservoirs beneath the sea-bottom. The reactions of these silicate solutions, which were probably alkaline, with salts of sea water, would precipitate gelatinous silicic acid contemporaneously with the normal deposition of argillaceous material obtained by erosion from the adjoining low-lying land areas. The rhythmic segregation of colloidal silica from these mechanical impurities—a phenomena that has been produced experimentally—would account for that characteristic banding of the cherts and slates which has already been referred to."

In the Fort St. James area the ribbon cherts are in many places interstratified with flows of altered andesite (greenstone), proof of the existence of volcanic activity during the period of formation of the ribbon cherts. The nodular character of the chert bands, the pinching and swelling of the beds of chert, not due to thickening and thinning produced by folding, and the wedging out of beds of chert, features observed in the thinly bedded cherts of the Fort St. James area, are difficult to explain on any other hypothesis than that which attributes the rhythmic alternation of the beds to colloidal segregation.

Another hypothesis explaining the rhythmic alternation of the chert beds as due to periodic supersaturation and resulting precipitation of silica may be refuted on the grounds that, although it is in accord with the wedge-like character of the chert beds, it does not explain this same character in the shale partings.

As has been previously stated, the thinly bedded ribbon cherts of the Fort St. James area are characterized by veinlets of quartz. Such veinlets are characteristic of cherts in many regions, and have been attributed to the filling of shrinkage cracks in an original gel-like substance, following its dehydration, with recrystallized quartz obtained from the cherts themselves. This explanation would fit in with the colloidal segregation hypothesis.

Cairnes (29, p. 37) states that the minute crumpling exhibited by the thinly bedded cherts was for the greater part induced during the accumulation and consolidation of these rocks prior to, or during, their elevation above the water to form land areas.

GREENSTONE LITHOLOGICAL DIVISION

Two large belts of greenstones have been mapped; one extends from the narrows on Takla Lake north to Ominicetia River[1], and the other stretches from south of Omineca River near Germansen Landing northwesterly to the head of Nina Creek. They occupy areas of approximately 200 and 125 square miles respectively, and probably attain a maximum thickness of at least 10,000 feet. As previously noted, greenstones are also fairly abundant in the slate and ribbon chert lithological divisions.

The Takla Lake greenstone assemblage consists largely of grey-green to dark green, fine- to medium-grained, chloritic andesites and basalts, amphibolites, and chlorite schists. In a few places greenstone rocks cut across adjacent Cache Creek strata, and probably represent minor intrusions, but in most places they probably represent lavas and tuffs. Minor beds of sheared breccia and agglomerate were observed in several localities. Also included in the Takla Lake greenstone assemblage and comprising about 10 per cent of the strata are interbedded ribbon cherts, argillaceous quartzites, argillite, slates, and limestone.

Examination of many thin sections of Takla Lake greenstones shows considerable variation in their composition. Most of them show little trace of original minerals, but are composed of a fine-grained aggregate of about 50 per cent fibrous green hornblende, apparently formed by uralitization of pyroxene, and 50 per cent saussuritized feldspar, secondary quartz, carbonate, chlorite, and epidote. These constituents usually show a parallel arrangement of the grains, with all traces of original texture obliterated. Some of the greenstones are composed of 80 per cent or more secondary hornblende and chlorite. In a few less altered slides it could be seen that the rocks were composed originally of lath-shaped crystals of calcic feldspar and crystals of augite with a residuum of glass. Several sections indicated a porphyritic texture, in which phenocrysts composed of an aggregate of chlorite, epidote, and iron oxides were embedded in a groundmass of laths of feldspar and saussuritic material.

Thin sections of greenstone believed to have been derived from tuffs show an aggregate of secondary minerals with chlorite and hornblende predominating. The fragmental character could be recognized in weathered outcrops.

The Nina Creek greenstones are much less altered and foliated than those of the Takla Lake belt. They include altered andesitic and basaltic flows, tuffs, breccias, and agglomerates. The flows are fine grained to dense, green rocks composed mainly of chlorite and amphibole with minor amounts of feldspar. In places they show pillow structures, and in part they are

[1] This river is spelled Ominicetla on the accompanying map.

spherulitic and amygdaloidal. The tuffs are dense, cherty, grey and green rocks that exhibit good bedding on weathered surfaces. Breccias and agglomerates consist mainly of fragments of the greenstone flows, up to 5 inches in diameter, embedded in a flow or tuffaceous matrix. Fragments of limestone up to 8 feet in diameter are contained in bodies of greenstone. Thin beds of pink, white, grey, and green chert are intercalated with the argillite and greenstones.

SLATE LITHOLOGICAL DIVISION

Formations of this division are best exposed in the vicinity of Manson Creek and Germansen River, where they strike approximately east and comprise bands ½ mile to 4 miles wide, averaging 1 mile, of slate and argillite, with minor greenstone alternating with bands of greenstone, minor slate, and argillite. South of Manson Lake similar formations strike more nearly northwest-southeast. The slate lithological division, as mapped, is limited to the Manson Creek belt of Cache Creek rocks.

The slates and argillites are grey to black, but where iron minerals are present they weather to shades of brown and red. They commonly contain much carbonaceous material, which gives them a lustrous appearance. The cleavage planes of the slates are either parallel with the bedding or at angles of less than 20 degrees to it. The argillites have a blocky appearance, due to jointing in three directions, two nearly vertical, and one nearly horizontal. Near fault and shear zones they have been altered to lustrous graphitic schists. Beds are rarely more than 6 inches thick.

The greenstone bands comprise altered andesitic and basaltic flows, tuffs, breccias, and agglomerates, similar to those described under the greenstone lithological division.

Thin beds of pink, white, grey, and green chert are intercalated with the slates and greenstones.

STRUCTURAL RELATIONS

Internal Structural Relations

Although local variations in strike are numerous, the regional trend of the formations of the Cache Creek group is northwesterly in conformity with the axes of deformation in this district.

In most places the Cache Creek rocks are closely folded, the limbs of the folds dipping steeply, generally in excess of 60 degrees. Some overturned folds were observed and a more detailed field examination may reveal many others. During folding the limestone beds acted as relatively competent strata, and are not deformed to nearly the same extent as other interbedded strata. Apparently, they yielded to stress by recrystallization and flowage rather than by close folding.

The folds in the Cache Creek rocks exposed along the Pinchi fault zone have been studied in more detail than those elsewhere in the Fort St. James area. One probable major synclinal fold was traced from Trembleur Lake 25 miles northwest to Takatoot Lake. It could not be traced southeast of Trembleur Lake due to the scarcity of outcrops. A synclinal fold observed crossing Tsayta Lake, about 20 miles northwest of Takatoot Lake, may be a northwesterly extension of the Trembleur Lake-Takatoot

Lake syncline, but the area between Takatoot and Tsayta Lakes was not mapped in sufficient detail to verify this. The syncline was best observed between Trembleur and Kazchek Lakes, where limestone beds several thousand feet thick outcrop on both limbs of the fold. Fusulinids collected from four horizons in the limestone, three on the eastern limb and one on the western limb, corroborate the synclinal structure, and indicate a thickness of at least 4,000 feet of limestone. The fold is about 4 miles wide, and the limbs dip at approximately 60 degrees. A major anticlinal fold occurs to the west of the syncline just described. It extends from Trembleur Lake northwest 20 miles to near Elliott Lake, and is apparently 6 miles wide. Only part of the southeast limb was observed, and it may be faulted off along Middle River Valley.

Four northwesterly trending folds, two anticlines and two synclines, were observed along the ridge west of the Bralorne Takla mercury mine. They average 1 mile to 1½ miles in width, and their limbs dip at approximately 60 degrees. Three similar folds were seen along the ridge north of Tsayta Lake, and it is quite probable they are southeastern extensions of some of the folds along Bralorne ridge, in which case these folds are at least 8 miles long. Folds averaging 1 to 2 miles in width were also seen along the ridge southwest of the west end of Tsayta Lake, in the Vital Mountains, northwest and southeast of Akus Lake, north of the west end of Cunningham Lake, west of Mount Sydney Williams, and at Boling Point on Babine Lake. Many minor folds from 100 to 700 feet wide were observed in the ribbon cherts and argillites, and their axes are approximately parallel with those of the larger folds. Drag-folds are also abundant in these rocks and generally plunge in the same direction as that part of the major fold on which they lie.

The Cache Creek formations outcropping on either side of Fall River have an average dip of less than 30 degrees and strike nearly east in contrast with the northwesterly trending, steeply dipping Cache Creek rocks to the northwest and southeast. Three possible explanations for this different attitude suggest themselves, though due to scarcity of outcrops none has been verified: (1) unobserved faults may separate these low-dipping beds from those of higher dip; (2) the gently dipping beds may represent recumbent folds; and (3) they may occupy the noses of the parallel, northwesterly trending folds observed in the Vital Mountains, in which case they would indicate that these folds plunge to the northwest.

On Mount Ogden, the Cache Creek strata strike northwest and dip, on the average, 60 degrees to the northeast across a width of 8 miles. As no strike faults were apparent, this structure suggests either a very great thickness of beds or repeated folding with overturning to the southwest.

The formations comprising the belt of Cache Creek rocks extending from the west side of Takla Lake southeast to Trembleur Lake and the north arm of Stuart Lake strike northwesterly and dip from 60 degrees to vertically. Wherever studied in detail, such as west of Tsitsutl Mountain, they are much faulted and apparently tightly folded. The limestones outcropping near Pinchi Lake and Pope Mountain are steeply dipping; recrystallization has obliterated the bedding, exposures are poor, and, consequently, the major folds in this area were not identified. Attitudes obtainable on the formations of the greenstone belt exposed between Takla Lake and Ominicetia Creek were insufficient to reveal the structure, except to emphasize the general northwesterly trends and to suggest that this belt of greenstones is near or at the top of the Cache Creek group by virtue of contact with Takla group rocks.

In the Manson Creek belt of Cache Creek rocks the regional trend of formations varies from north 30 degrees west to north 70 degrees west. From Omineca River south to Skunk Lake, 12 miles south of Manson River bridge, the strata dip from 45 degrees southwest to vertically. South of Skunk Lake many northeast dips were observed also, probably due to local folding. North of Omineca River, local variations in strike are numerous, especially near major fault zones, due to dragging of beds along thrust faults.

External Structural Relations

Although most of the rocks of the Cache Creek group in the Fort St. James area are separated by a major fault from those of the Wolverine complex, those at the head of Boulder Creek appear to lie with structural conformity above probable formations of the Wolverine complex. However, as the correlation with the Wolverine complex is problematical, and as the contact is drift covered, this conformable relation is doubtful in view of evidence outside the Fort St. James area. In the Aiken Lake area, to the northwest, non-granitized equivalents of the Wolverine complex of Late Precambrian and Lower Cambrian age underlie the Cache Creek group apparently with angular discordance. As indicated in the description of the Wolverine complex, the main area of these rocks lies along a northwesterly projection of Proterozoic rocks of the Cariboo district, and presumably may be in part of the same age. In that district the Slide Mountain series, which is at least in part correlative with the Cache Creek group, overlies the Proterozoic rocks discordantly.

Although no actual contacts between the Cache Creek and Takla groups were observed, and although the two groups are believed to be separated by major faults in most places, the writer believes that the Takla group lies unconformably above the Cache Creek group and that the period between Middle Permian and Upper Triassic was a time of igneous intrusion, uplift, erosion, and probable deformation. This conclusion is based on the following observations.

(1) The Cache Creek rocks have been subjected to widespread regional metamorphism. The character and degree of metamorphism in these rocks is in strong contrast with that found in the Takla group rocks, which exhibit almost no evidence of metamorphism other than normal induration. A period of regional metamorphism before the deposition of Takla rocks would seem to be necessary to account for this contrast.

(2) Although both Cache Creek and Takla formations are steeply folded, in general the Cache Creek rocks exhibit closer folds with steeper flanks, a condition suggesting pre-Takla folding.

(3) The Trembleur ultrabasic intrusions are believed to be partly or wholly of pre-Upper Triassic, that is, pre-Takla age. They are confined to, and cut, Cache Creek rocks of Permian age. At no place were they observed to intrude Upper Triassic or younger rocks, whereas, on the north shore of Pinchi Lake, an Upper Triassic, Takla group, conglomerate contains pebbles of serpentine and grains of chromite as well as pebbles of Cache Creek rocks,

suggesting a nearby landmass from which Cache Creek and Trembleur rocks were being eroded. As postulated in the description of the Trembleur ultrabasic rocks, intrusion may have taken place when the invaded Cache Creek strata were lying flat or nearly so, and the upthrust of these bodies may have been at least in part a cause of the folding.

(4) On the west side of Takla Lake, a Takla group conglomerate of Lower Jurassic age is composed mainly of pebbles of Cache Creek rocks, poorly rounded limestone pebbles being particularly abundant. This conglomeratic material must have been derived from a nearby landmass from which Cache Creek rocks were being eroded, especially as the limestone pebbles evidently had not moved far. Wherever conglomerates are found in the Takla group they always contain an abundance of Cache Creek detritus.

(5) The Topley acidic intrusions, which are pre-Tachek in age, that is, probably pre-Jurassic, are apparently confined to areas of Cache Creek rocks, and it is quite possible they are pre-Takla in age. Possibly the Topley intrusions represent a later, more acidic phase of the igneous activity responsible for the Trembleur ultrabasic intrusions. Recent field work in the Aiken Lake map-area, adjoining the Fort St. James area on the north, also yielded evidence of pre-Jurassic, post-Permian granitic intrusions (17, p. 17).

(6) The two largest belts of greenstone included in the Cache Creek group lie between typical Cache Creek rocks and Takla group rocks, and may be in part late Permian or Lower or Middle Triassic in age. In any case the field evidence indicates that vulcanism was widespread towards the close of Cache Creek time.

(7) No sedimentary rocks of Upper Permian, Lower Triassic, or Middle Triassic age have been identified in the Fort St. James area. This gap in the geological section certainly indicates a period of uplift and erosion.

METAMORPHISM

The strata of the Cache Creek group, as originally laid down, consisted apparently of limestones, ribbon cherts, shales, sandstones, conglomerates, and andesitic and basaltic flows, tuffs, breccias, and agglomerates. These rocks were subjected to widespread dynamo-thermal metamorphism, as a result of which the limestones were recrystallized, most of the original bedding being obliterated; the chert beds of the ribbon cherts were recrystallized, and their argillaceous partings changed to graphitic and carbonaceous schists, and in places to micaceous schists; and argillites and slates resulted from the induration and metamorphism of the shales. In places quartz-mica and quartz-chlorite schists are found, and probably are metamorphosed argillaceous strata. The original sandstones have become quartzites, and the conglomerates have been sheared so that the pebbles are elongated and flattened. The volcanic rocks have been most altered, and now consist largely of chlorite and hornblende schists and amphibolites. Near Tsitsutl Mountain, chlorite-hornblende-clinozoisite schists are common. These compositional and textural changes were accompanied by the development of well marked schistose structures in rocks of all types except the limestones and quartzites. In the ribbon cherts the schistose structures are limited to the argillaceous partings. The schistosity has a general northwesterly trend; in most places except on the noses of the folds it is about parallel with the bedding.

In addition to dynamo-thermal metamorphism the Cache Creek rocks exhibit contact metamorphism in their relations with the larger bodies of Omineca and Topley intrusions. These contact zones vary in width from a few hundred yards to 2 miles. In them the compositional changes are usually greater than those due to regional metamorphism, except that the limestones and cherts only tend to become more coarsely crystalline. The argillaceous rocks, including the partings in the ribbon cherts, have been changed to biotite, quartz-biotite, and chlorite hornfelses and schists, and the volcanic rocks have been altered to chlorite and amphibolitic schists. The metamorphic aureole around the quartz diorite body north of the northwest arm of Stuart Lake is representative of the contact effects. The sequence of changes observed on approaching this contact is as follows:

(1) Argillite and chert	Zone about 1 mile wide
(2) Slate and recrystallized chert	
(3) Graphite schist	
(4) Biotite schist	
(5) Quartz-biotite schist	
(6) Augen gneiss	
(7) Granodiorite, quartz diorite	

Intricately folded hornblende-feldspar gneisses are well exposed near the Radio Gold property. They are intruded by abundant diorite dykes, and probably have resulted from replacement and contact metamorphism. These gneisses consist in general of alternating bands, a fraction of an inch thick, of hornblende and feldspar, and differ from those of the Wolverine complex, which are not as well banded and contain very little hornblende.

Reaction zones along the contacts of the Trembleur ultrabasic intrusions with Cache Creek rocks consist mainly of carbonate, talc, and quartz, and are apparently due to hydrothermal alteration (*See* p. 91). No contact metamorphic effects were observed.

Near the Pinchi Lake mercury mine, glaucophane (soda amphibole) schists occur interbedded with limestone and quartz-carbonate and quartz-mica carbonate schists. They are composed of glaucophane, clinozoisite, carbonate, quartz, and chlorite in varying proportions, and probably originated by a process of soda-metasomatism, possibly during the same period the cinnabar was deposited (*See* pp. 129, 130).

FAUNA AND AGE

As previously noted, the Cache Creek rocks, as mapped, occur in two northwesterly trending belts, which have been called the Stuart Lake and Manson Creek belts. As these belts are separated by a wide area of Omineca intrusions and Takla group rocks, the age of the formations included in each belt will be considered separately.

Stuart Lake Belt of Cache Creek Group

The Cache Creek group as exposed in the Stuart Lake belt comprises an assemblage of interbedded members of the limestone, ribbon chert, and greenstone lithological divisions. The slate division is not represented.

Foraminifera collected from five localities in the limestones were submitted to Professor C. O. Dunbar, of Yale University, for examination. He made a preliminary report[1] on them, from which the following information is taken:

Collection 1, from approximately 1½ miles west and 1 mile north of east end of Trembleur Lake, includes the Oriental genus *Cancellina* and two species of *Parafusulina*. Age: Middle Permian.

Collection 2, obtained approximately ½ mile east of collection 1, includes *Verbeekina* and *Misellina* (formerly *Doliolina*). Age: Middle Permian, but younger than 1.

Collection 3, obtained approximately ¼ mile east of collection 2, includes typical *Neoschwagerina* as well as *Cancellina* and *Parafusulina*. Age: Middle Permian, but younger than 2.

Collection 4, from southeast slope of Kloch Mountain at an elevation of 3,200 feet, includes abundant specimens of *Neoschwagerina*. Age: Middle Permian, same as collection 3.

Collections 1, 2, and 3 occur on the west limb of a syncline, and collection 4 is from the east limb. Nos. 1, 2, and 3 represent at least 3,500 feet of limestone.

Collection 5, from southeast end of a ridge lying between Pinchi village, Stuart Lake, and Pinchi Lake, includes a single species of *Triticites*. Age: probably Upper Pennsylvanian.

G. M. Dawson (48, p. 56) also collected foraminifera from Pope Mountain, which Professor Dunbar assigns to the Lower Permian.

Collection 5 and Dawson's collection apparently occur in the same band of limestone as collections 1, 2, 3, and 4, but 30 miles to the southeast, much of the intervening area being drift covered. Assuming the limestones represent a period of continuous deposition it probably commenced in Upper Pennsylvanian time and continued through Lower Permian into Middle Permian time.

Crinoidal disks and columns have been observed at many places and are characteristic of these limestones. However, they have no diagnostic value. A blastoid mould was collected from the limestone ridge southeast of Fort St. James.

Corals were collected from three widely scattered localities in the limestones, and were examined by Alice E. Wilson of the Geological Survey, who reports on them as follows:

"Collection 6, from limestone band north of Elliott Lake, contains *Diphyphyllum*-like sp.

"Collection 7, from same locality as 6, contains a coral of *Diphyphyllum* group, but too imperfectly preserved for identification.

"The corals present in collections 6 and 7 are of late Palæozoic age. They might occur either in Devonian or Carboniferous rocks.

"Collection 8, from south side Mount Pope, contains a *Lonsdaleia*-like coral and crinoid disks and stems. A coral fragment is slight evidence, but this one is certainly suggestive of a form limited to Carboniferous rocks."

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[1] Personal communication, 1942.

Alice E. Wilson reports on other fossil collections as follows:

"Collection 9, from northwest end of Kazchek Mountain, contains:

cf. *Stenopora*[1] n.sp.
Meekella-like brachiopod fragment
Bellerophon sp. close to *B. sublaevis* Hall
Euomphalus sp.
cf. *Aclisina* sp.

"Collection 10, from first bend in Nation River below Indata Lake, contains:

cf. *Composita* sp.
cf. *Loxonema* sp.

"Collection 11, from east of Indata Lake, contains:

cf. *Composita* sp.
Bellerophon sp.
cf. *Loxonema*—very minute

"The number of minute forms and the fragmentary nature of the specimens in collections 9, 10, and 11 make identification difficult. But the minute *Composita*, the *Aclisina*-like gastropod with revolving ornamentation, and the *Meekella*-like brachiopod fragment are suggestive of a Carboniferous age. This is somewhat corroborated by Dr. Fritz' independent description of the one bryozoa specimen as being something between the *Eostenopora* of the Devonian and the typical stenoporoids of the Carboniferous and Permian.

"Collection 12, second collection from first bend in Nation River below Indata Lake, contains:

Dielasma n.sp.
Small unidentifiable brachiopod of the terebratuloid type.

The development of the *Dielasma* indicates that the horizon is probably late Carboniferous or Permian."

Summing up the fossil evidence, the conclusion is reached that the limestone lithological division includes strata in part of probable Upper Pennsylvanian age, in part of Lower Permian age, and in part of Middle Permian age. Possibly some undifferentiated pre-Pennsylvanian limestones may have been mapped with the Cache Creek group.

Fossils were collected from the ribbon chert lithological division only on the south shore of Tsayta Lake, about a mile west of the narrows. These were examined by Alice E. Wilson, who reported on them as follows:

"*Pustula* sp.
Large striated brachiopod suggestive of *Meekella kueichowensis* Huang

From the development of both species it is probable that the rocks are of Permian age."

North of the east end of Trembleur Lake, formations of the ribbon chert lithological division lie both stratigraphically above and below formations of the limestone lithological division containing Middle Permian foraminifera.

No fossiliferous beds have been found in the greenstone division, but typical Cache Creek sedimentary strata are intercalated with the volcanic rocks. Stratigraphically the greenstones appear to predominate in the

[1] Identified by Dr. M. A. Fritz, University of Toronto.

upper part of the Cache Creek group and are, therefore, probably of Middle Permian or later age. Possibly some undifferentiated Upper Triassic or younger volcanic rocks may have been mapped with the Cache Creek due to the lack of concrete evidence as to their age. The large belt of greenstone north of Takla Lake lies between typical Cache Creek rocks and Takla group rocks of Mesozoic age and may include formations of both groups, although it has been mapped as Cache Creek.

The rocks of the Stuart Lake belt have been mapped as Cache Creek group due to the fact that they are lithologically similar to, and of the same age as, the Cache Creek group of the type area near Ashcroft. In both areas massive limestones containing foraminifera are characteristic of the group, but they are apparently not of the same age, those of the Stuart Lake belt containing probable Upper Pennsylvanian, Lower Permian, and Middle Permian fossils, and those of the Ashcroft area containing fossils as late as Upper Permian. These limestones do not occupy the same stratigraphic position in their respective areas, occurring near the bottom of the section in the Stuart Lake belt and at the top of the section in the Ashcroft area. Possibly only part of the Cache Creek group is found in the Stuart Lake belt, but a more probable explanation is that all of the group is present and has not been identified due to lack of fossil evidence.

Manson Creek Belt of Cache Creek Group

The Manson Creek belt exposes an assemblage of interbedded members of the limestone, slate, and greenstone lithological divisions. The ribbon chert division is not represented, and as ribbon chert is characteristic of the Cache Creek group and as no foraminifera have yet been found in the limestones it is quite possible that the rocks exposed in the belt should not be included with the Cache Creek. However, these rocks are in part lithologically similar to the typical Cache Creek of the Stuart Lake belt, and are apparently in part of the same age.

Corals were collected from two localities in the limestone and were examined by Alice E. Wilson of the Geological Survey, who reported on them as follows:

"Collection 13, from limestone 4 miles northeast of Currie Lake, and collection 14, from limestone 1½ miles northeast of Jackpine Lake. Both collections include a coral with discrete corallites; it might be a *Lithostrotion* or *Diphyphyllum*. Age: suggestive of Carboniferous."

No fossils have been found in the rocks of the slate division, so their age is not fixed, but fossils of possible Carboniferous or Permian age were found in interbedded limestone.

HISTORY AND CORRELATION

The Cache Creek group was named by A. R. C. Selwyn (113, pp. 54, 60-62) from its typical occurrence in the vicinity of Cache Creek near Ashcroft. He separated the rocks into Lower and Upper groups. His Lower Cache Creek group comprised the rocks on Thompson River above Spences Bridge, consisting of an assemblage of massively bedded limestones, thinly bedded shales, volcanic rocks, schists, and minor serpentines and soapstones. The limestone in one place was found to contain brachiopods indicating an horizon between the base of the Devonian and the summit of the Permian. Selwyn designated the rocks between Clinton and Lillooet through the Marble Canyon as the Upper Cache Creek group. This group was composed mainly of limestones with minor shales and other rock types. Owing to the misidentification of a contained foraminifera as *Loftusia* by W. J. Dawson the rocks were assigned a probable Eocene or Cretaceous age, but Selwyn (113, p. 62) stated that "near Clinton the Lower Cache Creek group was overlaid on the west by strata of the Upper Cache Creek group, apparently in conformable succession."

The first correlation of similar strata elsewhere in British Columbia was made by Selwyn (114, p. 78) in 1875. That year he visited Stuart Lake, approximately 275 miles north of Cache Creek, and on Pope Mountain, near the southeast end of the lake, he observed a great belt of limestone extending many miles to the northwest and southeast. He stated that "these limestones apparently had a thickness of not much less than 6,000 feet, and that there was no reason to doubt that they represented some part of the Cache Creek series, but whether the lower or upper groups was uncertain". In 1876, G. M. Dawson (48, pp. 55-57) visited Stuart Lake with the special object of studying the Cache Creek limestones exposed there. He collected fusulinids of supposed Carboniferous age from them, and as a result he correlated the Stuart Lake limestones with Selwyn's Lower Cache Creek group. A re-examination of these fossils in recent years has shown that they are of Permian age.

G. M. Dawson (50, pp. 87-90; 51) re-examined Selwyn's type area of Cache Creek in 1877. He collected fusulinids and *'Loftusia'* from the upper Cache Creek limestones exposed in Marble Canyon, and on the basis of the contained fusulinids assigned these limestones a Carboniferous age. He accepted W. J. Dawson's identification of *'Loftusia'*, but concluded it was a Carboniferous form rather than Eocene or Cretaceous (51). It was not until 1932 that the *'Loftusia'* was correctly identified as a Permian fusulinid. Dawson also collected fusulinids from the lower Cache Creek group. In view of the re-dating of *'Loftusia'* and the apparent conformity of the upper and lower groups, Dawson (50, p. 2) concluded that "the progress of our knowledge of these rocks, however, renders it probable that the division established between these groups cannot be maintained". In 1878 Dawson (50, p. 169) summed up the knowledge of the Cache Creek group as follows: "In the region here reported on, however, characteristic fossils of Carboniferous age have now been obtained in the limestone in several additional localities, and the association of these with the peculiar cherty quartzites, and with contemporaneous volcanic products and serpentines clearly ascertained in a number of places. These rocks are, however, often much disturbed and highly altered, in consequence of which neither the actual summit nor the base of the portion representing the Carboniferous period has been fixed. It therefore remains uncertain whether any part of these rocks, which so far have been spoken of as Cache Creek group, may belong to horizons higher or lower than the true Carboniferous. The thickness of the entire series is unknown but must be very great."

Subsequent investigations by Dawson (55) in the Kamloops map-area between 1888 and 1890 served to confirm the consolidation of the Lower and Upper Cache Creek groups as suggested by him in 1878, and he then (55, p. 38) outlined his views as follows: "There can indeed now, I think, be no doubt that the Marble Canyon limestones, which constituted the greater part of the Upper Cache Creek group, are in fact the higher member of the formation, and between these and the underlying rocks it may eventually become convenient to draw a line of division. But important beds of limestone also occur in the lower part of the formation; there is a stratigraphical and lithological interlocking between both parts, and the palæontological evidence, so far as it goes, indicates the reference of both parts to the Carboniferous".

Dawson's definition of the Cache Creek group as set forth in 1896, and which is similar to that propounded by him in 1879, is as follows: "The Cache Creek formation . . . must therefore be regarded as including a very thick series of Palæozoic rocks of which the greater part is definitely referable to the Carboniferous period by means of fossils, but of which it is scarcely probable that the upper and lower limits agree precisely with those of the typical Carboniferous. It may vary possibly at the base, particularly, to transgress these limits and to include beds older than those of the system" (55, p. 39).

Dawson (55, p. 46) summarizes the Cache Creek section from top to bottom as follows:

1. Massive limestones (Marble Canyon limestone) with minor intercalations of volcanic rocks, argillites, and cherty quartzites. At least 1,000 feet seen in some single exposures. Total thickness probably at least . . . 3,000 feet.

2. Volcanic materials and limestones, with some argillites, cherty quartzites, etc. Minimum thickness about 2,000 feet.

3. Cherty quartzites, argillites, volcanic materials, and serpentines with some limestones. The thickness of these beds, or of part of them, was roughly estimated in two places as between 4,000 and 5,000 feet. Minimum total thickness 4,500 feet.

Dawson says that the above section is merely an attempt to indicate the general order of succession, and to some extent the importance of the group in the western part of the Kamloops map-area.

In 1932, C. O. Dunbar (57, pp. 45-48) restudied the original sections of the foraminifera collected by Dawson in Marble Canyon, and although none of the sections were well oriented or centred he concluded that Dawson's '*Loftusia columbiana*' was *Neoschwagerina columbiana*, a Permian form and more probably Lower or Middle Permian than Upper.

In 1933, H. E. Wheeler spent several days in Marble Canyon, the type locality of Dawson's '*Loftusia columbiana*', and obtained from the north shore of the middle of the three Pavilion Lakes numerous cobbles of limestone containing abundant fusulinids. These were described in a paper published in 1942 by M. L. Thompson and H. E. Wheeler (117, p. 702) as follows: "From a study of well oriented sections of '*Loftusia columbiana* Dawson' it becomes obvious that this form should be referred to the genus *Yabeina* Deprat. In addition to *Yabeina columbiana* we have obtained from the Marble Canyon samples, representatives of one new species of *Yabeina*, *Y. minuta*, one new species and one new variety of the genus *Schwagerina* Moller, *S. pavilionensis* and *S. pavilionensis* var. *acris*, poorly preserved specimens which we are referring with question to the genus *Nankinella* Lee, and poorly preserved specimens which we are referring with question to the genus *Stafella* Ozawa. This is the first time the genus *Yabeina* has been recognized in the Permian of North America. Wherever this genus is found it occurs stratigraphically in what is believed to be the youngest Permian fusulinid faunas known from Asia, Europe, and Africa.

Thompson and Wheeler (117, p. 705) conclude by saying: "It seems to us that the sea of late Cache Creek time was the last known Palæozoic marine invasion of North America."

In 1946, S. Duffell of the Geological Survey collected foraminifera from the limestones of Marble Canyon. R. T. D. Wickenden of the Geological Survey examined the specimens and identified them as *Yabeina*, of Upper Permian age.

As previously recorded in this report fusulinids contained in the Cache Creek limestones of the Fort St. James area have been assigned to probable Upper Pennsylvanian, Lower Permian, and Middle Permian epochs. Brachiopods of Permian age have also been found in Cache Creek quartzites of this area.

From the preceding historical account, the Cache Creek group may be defined as a very thick assemblage, 20,000 feet or more, of interbedded sedimentary and volcanic rocks, mainly of Permian age, but also probably in part of Pennsylvanian age. The whole of the Permian period may be represented. Foraminiferal limestones and ribbon cherts are characteristic of the group.

As redefined the Cache Creek group has an areal extent of about 3,500 square miles in the Fort St. James map-area and 500 square miles in the type Ashcroft map-area northwest from Cache Creek. These two map-areas form parts of a discontinuous belt of rocks that are lithologically similar to, and probably of the same age as, the Cache Creek, and that outcrop from the International Boundary at Skagit River northwest more than 550 miles to the headwaters of Omineca River. Areas totalling at least 2,000 square miles of lithologically similar, non-fossiliferous rocks are exposed between the Ashcroft map-area and the Fort St. James map-area. They form part of a belt broken only by the overlap of Tertiary volcanic rocks at two places between Soda Creek and Vanderhoof. South of the Ashcroft map-area, in the Hope map-area, rocks of the Hozameen group are exposed (35). They are lithologically similar to the Cache Creek and probably of the same age, although no fossils have been found in them. The Fergusson group (formerly in part Bridge River series) of the Bridge River area west of the Ashcroft area also comprises lithologically similar non-fossiliferous rocks (31, pp. 9-13).

Exposed on both sides of Thompson River east of Kamloops Lake, and in the vicinity of Shuswap and Okanagan Lakes, are large areas of rocks that may be in part at least correlated with the Cache Creek group (33). They comprise assemblages in part lithologically similar to that of the Cache Creek group and they usually contain, in addition to Permian fusulinids, other fossils thought to be probably of Mississippian age. Foraminiferal limestones are characteristic of these assemblages, but ribbon cherts are poorly represented. The fossiliferous beds of the Chilliwack group of southwestern British Columbia may be correlated with the Cache Creek group. Fossils were collected by Daly and examined by Girty (45, p. 515), who compared them with those of the Nosoni formation of northern California, which was originally considered to be of Carboniferous age but now regarded as Permian (118, pp. 1-11). Daly (45, pp. 514-515) states that the lower, non-fossiliferous members of the Chilliwack group may belong to one or more systems older than the one represented by the fossiliferous beds. The Chilliwack group contains no ribbon cherts.

The Slide Mountain group (80, pp. 18-21) of the Cariboo may be in part correlated with the Cache Creek group, but may be in part older. It has been divided into four members: the Guyet conglomerate, 900 feet thick at the base; the Greenberry limestone, 400 feet thick; the Waverley basic volcanic rocks, 2,000 or more feet thick; and, at the top, the Antler ribbon cherts and argillites, 3,500 or more feet thick. Except for the basal Guyet conglomerate this group is very similar to the Cache Creek. Fossils of doubtful Mississippian age were collected from the Greenberry formation, but as the collections were unsatisfactory it is quite probable the fauna is post-Mississippian in age. Johnston and Uglow believed the Slide Mountain group was equivalent to the lower part of the Cache Creek group.

The upper part of the Dease group of northern British Columbia is lithologically and palæontologically similar to the Cache Creek group (69, p. 5; 82, p. 81). It is composed of the typical ribbon cherts, foraminiferal limestones, argillites, and greenstones, and contains fossils of Permian age. The lower part of the Dease group may, however, be as old as Ordovocian.

The Asitka group of the McConnell Creek area (99), which joins the Fort St. James area on the northwest, contains limestones from which foraminifera of Lower Permian and possible Pennsylvanian age have been collected, indicating the same age for this group as that assigned to the Cache Creek group. However, the two groups are lithologically dissimilar, and are separated by a fault, so that their structural relations to one another are unknown.

The Braeburn foraminiferal limestones of northwestern British Columbia and southwestern Yukon may be correlated with the Cache Creek group (36, p. 29; 37, p. 53), and the Taku group of the same area contains an abundance of ribbon chert and may be of the same age (37, pp. 52, 53).

Clapp (40, pp. 43-44) correlated the Leech River formation of southern Vancouver Island with the Cache Creek group, although he found no fossils. Permian and probable Pennsylvanian fossils were collected by Gunning (64, p. 59) from limestone lenses in volcanic rocks in the Buttle Lake region of central Vancouver Island. These rocks may also be correlative with the Cache Creek group.

Permian limestones in Washington and Oregon, such as the Granite Falls limestone (2), contain a fusulinid fauna similar to that of the Marble Canyon limestones of the Cache Creek group.

Takla Group

GENERAL STATEMENT

The Takla group was named from its abundant occurrence in the vicinity of Takla Lake. It consists of an apparently conformable succession of interbedded volcanic and lesser sedimentary rocks ranging in age from Upper Triassic to Upper Jurassic. Most of the rocks referable to the Takla group in the Fort St. James area occupy two northwesterly trending belts. One extends from south of Fort St. James 150 miles northwest to the northern boundary of the map-area and has an area of at least 2,300 square miles. The other underlies an area of about 150 square miles and stretches from Tochchaw Lake 30 miles north to Takla Landing. Smaller areas of Takla group rocks lie along the northeastern side of the Pinchi fault zone between Tchentlo Lake and Omineca River.

Due to the great thickness of lithologically similar, structureless volcanic flows comprising much of the Takla group and to the scarcity of fossiliferous beds, the stratigraphic succession of the group has been established only in a very general way. Sedimentary rocks and volcanic tuffs apparently predominate in the lower part of the group and volcanic flows in the upper part. Limestone appears to be restricted to the Upper Triassic formations. In the vicinity of the Pinchi fault zone, where the most detailed study of the group was made, sedimentary rocks of Upper Triassic age have been recognized and mapped separately, but elsewhere in the area lithologically similar beds are undifferentiated, and are mapped with formations of Jurassic age.

As a result of widespread major and minor faulting and repeated folding it has not been possible, on the scale of the mapping, to determine accurately the total thickness of the Takla group. Sections at least 10,000 feet thick and consisting mainly of massive volcanic flows were observed in the mountains lying between Omineca River and Nation Lakes.

The minimum thickness of the Upper Triassic section is estimated at various localities as follows:

	Feet
East end of Pinchi Lake: argillite, slate, greywacke, tuff, conglomerate ..	400
North shore of Pinchi Lake: limestone, argillite, tuff, greywacke, andesite	500
Halobia Creek: argillite, greywacke, tuff, conglomerate	1,000
Rottacker Creek: argillite, greywacke, tuff, chert	1,200
Kwanika Creek: argillite, greywacke, tuff	1,500

The Upper Triassic rocks exposed on the north shore of Pinchi Lake represent a different part of the section than those found elsewhere. Hence the maximum thickness of the Upper Triassic series is probably well over 2,000 feet.

In the McConnell Creek area to the northwest Lord (99) estimates the Jurassic assemblage of the Takla group to be considerably more than 23,000 feet thick, consisting of at least 18,000 feet of volcanic rocks and 5,000 feet of sedimentary rocks.

LITHOLOGY

Upper Triassic Sedimentary Rocks

The Upper Triassic sedimentary rocks of the Takla group are exposed along Kwanika, Halobia, and Rottacker Creeks, and on the shores of Pinchi Lake near the east end. All these localities are on the northeast side of the Pinchi fault zone. Non-fossiliferous, lithologically similar rocks also outcrop between the arms of Takla Lake, where they form a narrow band lying between Cache Creek formations and volcanic members of the Takla group.

The Upper Triassic sedimentary rocks consist essentially of interbedded argillite, greywacke, and tuff, with here and there thick beds of conglomerate and limestone. The argillites are black, carbonaceous rocks in beds a fraction of an inch to 6 inches thick. At the east end of Pinchi Lake they exhibit a good slaty cleavage about parallel with the stratification. The tuffs and greywackes weather blue-grey to buff, are fine to medium grained, and form beds that vary from less than an inch to 10 feet in thickness. They consist largely of fragments of cherty and volcanic rocks, quartz, and feldspar in varying proportions. Intermediate types, best termed tuffaceous greywackes, are the most widely exposed. Many beds grade from coarse-grained, tuffaceous greywacke at the bottom to argillite at the top. These rocks also exhibit good crossbedding.

Two beds of conglomerate, each 25 to 50 feet thick, are exposed at the east end of Pinchi Lake. Thinner beds outcrop along Halobia Creek northeast of Indata Lake. Pebbles in the conglomerate are angular to rounded, and up to 3 inches in diameter. Most of them are of grey chert and black argillite; a few are of greywacke, limestone, serpentine, and volcanic rocks. The matrix is gritty, and includes a few lens-like beds of greywacke.

Two bands of brownish grey, medium-grained, crystalline limestone, at least 150 and 300 feet thick respectively, outcrop on the two long points on the north side and near the east end of Pinchi Lake. The limestone weathers light buff and is veined by white calcite stringers. It contains small lenses of conglomeratic material consisting largely of fragments of cherty and volcanic rocks. Interbedded with the limestone is a flow of fine-grained, green andesite. Beds of grey limestone 15 to 20 feet thick outcrop at the east end of Pinchi Lake and along Rottacker Creek.

Undivided Takla Rocks

The undivided Takla rocks comprise andesitic and basaltic flows, tuffs, breccias, and agglomerates, and interbedded shale, greywacke, conglomerate, and limestone.

Volcanic Rocks. The lava flows, which range from 25 to 100 feet or more thick, are best exposed in the mountains north and south of Nation Lakes, north of Germansen Lake, between the arms of Takla Lake, and north of Tochchaw Lake. They are mainly green, grey-green, grey, black, red, and purplish red, porphyritic and non-porphyritic andesites and basalts.

Most of the flows observed in the mountains north and south of Nation Lakes and north of Germansen Lake are massive types, although in places ellipsoidal and amygdaloidal structures were observed. The typical lava displays numerous white or buff, lath-shaped plagioclase phenocrysts and green pyroxene phenocrysts in a microcrystalline groundmass. Most phenocrysts are from $\frac{1}{16}$ to $\frac{1}{4}$ inch long, although some in excess of $\frac{1}{2}$ inch were observed.

A microscopic examination of numerous thin sections revealed that the most common feldspar is andesine, which occurs as phenocrysts exhibiting Carlsbad and albite twinning. Labradorite was observed in a few slides. The feldspar is never free from alteration, and in the slides examined is partly to completely saussuritized. The alteration proceeds along cleavage and twinning lines from the centre of the crystal outwards. Secondary epidote, zoisite, and carbonate are the principal alteration products, and around the edges of some of the crystals secondary albite is developed as a clear rim. The pyroxene was determined as augite. It generally is altered to massive, green, pleochroic hornblende, which in turn is altered to chlorite. Biotite was observed in a few specimens as a minor constituent. Other minor constituents are quartz, magnetite, ilmenite, sphene, apatite, and zircon. The groundmass is usually formed of minute feldspar laths, which may either show a fluxion arrangement or occur as a felted mass. The dominant flow is, therefore, an augite andesite or, when the feldspar is labradorite, a basalt.

The amygdaloidal and ellipsoidal flows are usually denser than the typical andesite, and their composition approaches that of basalt. The outer rims of the pillows generally consist of a 2-inch glassy margin containing original vesicles now filled with chlorite and calcite. The amygdaloidal types of similar composition form a zone near the top of the flow containing ovoid green and white amygdules of chlorite and calcite.

The lava flows exposed north of Natowite Lake are usually green and rather coarse textured, with large, pale phenocrysts of feldspar; in some instances the rock resembles gabbro. The lavas are entirely augite andesites and basalts, mostly porphyritic, with phenocrysts of labradorite and augite in a fine-grained groundmass.

Commonly the groundmass has a diabasic texture. North of Natowite Lake several exposures of an equigranular, medium-grained, olivine-rich rock, containing about 25 per cent olivine and 75 per cent augite and labradorite, were observed. It resembles an intrusive rock, but no contacts were seen.

Tuffs predominate north of Omineca River, along Discovery Creek, and along the Pinchi Lake fault zone, and are elsewhere abundant wherever the Takla group is exposed. They are generally thinly bedded, green and red, andesitic types, and vary from dense rocks to others consisting of subangular fragments up to ¼ inch long. The beds vary in thickness from a fraction of an inch to 5 feet or more, the thicker layers commonly consisting of coarser material. Microscopic examination showed that the medium- and coarse-grained tuffs consist essentially of fragments of feldspar and volcanic rocks.

A medium-grained, green, andesitic tuff extends from the east end of Pinchi Lake 80 miles northwest to east of Indata Lake. It consists of angular fragments of andesite, basalt, volcanic glass, pyroxene, amphibole, pink and white feldspar, chlorite, and quartz. Fragments of volcanic rocks normally make up more than half of the total fragments. In places the tuff grades into an andesitic breccia, in which the larger fragments range from ½ to 1 inch in diameter and include a few of limestone and chert. Wherever observed this tuff and breccia occur in beds 10 feet or more thick. Also widespread along the mercury belt are dense, grey to black, basaltic tuffs. Approximately 1,000 feet of them outcrop at the southeast side of Pinchi Lake, where they occur in massive beds 5 to 20 feet thick alternating with fissile beds 3 to 8 inches thick. Similar basaltic tuffs in beds 1 inch to 1 foot thick were observed at the east end of Tezzeron Lake, northeast of Kazchek Lake, east of Kloch Lake, and along Takatoot Creek. A few bands of red, andesitic tuffs occur interbedded with the grey and black, basaltic, and green, andesitic tuffs.

Agglomerate and flow breccia are common in the Takla group, being most abundant north of Germansen Lake, west of Discovery Creek, and west of Takla Lake. The fragments vary from ½ inch to 2 feet or more in diameter, and consist of red, green, and grey, porphyritic and non-porphyritic andesite and basalt. In the breccias the fragments are angular and the matrix is andesitic, whereas fragments in the agglomerate are subrounded to rounded and lie in a tuffaceous matrix.

Sedimentary Rocks. As previously stated, the sedimentary rocks of the Takla group are interbedded with the volcanic rocks, and at no place are more than a few hundred feet thick. They consist of conglomerate, greywacke, shale, argillite, sandstone, and limestone.

The conglomerates are best exposed near the head of Discovery Creek, between the arms of Takla Lake, north of Chuchi Lake, on the north side of Pinchi Lake, and west of Gloyazikut Creek. They form beds from a few feet to at least 100 feet thick; the thicker beds commonly containing lenses of greywacke. The pebbles are generally subangular to rounded and less than 2 inches in diameter, and are embedded in an arenaceous or tuffaceous matrix. Grey chert, black argillite, and greenstone, lithologically similar to Cache Creek rocks, and white quartz comprise most of the pebbles. The conglomerates near the head of Discovery Creek, west of Gloyazikut Creek, and between the arms of Takla Lake contain abundant pebbles of grey limestone similar to Cache Creek limestone. These limestone pebbles are subangular and range up to 10 inches in length.

The greywackes and sandstones are fine- to medium-grained, dark greyish green, grey, and buff rocks. The beds range in thickness from a few inches to several feet, and consist of subangular to partly rounded grains of quartz, chert, and volcanic rocks in varying proportions.

The argillites and shales are grey to black rocks occurring in beds from less than an inch to several feet thick. They are best exposed on Discovery Creek, where they occur in beds averaging 2 inches in thickness. They are interbedded with sandstone, greywacke, and tuff.

Intercalated with the lavas on the hill north of the Pinchi mercury mine are lenses of grey limestone 10 to 300 feet wide and 400 feet long. About 4 miles south of the mouth of Duckling Creek, a lens of Upper Triassic limestone, 2,200 feet long and 400 feet thick, is interbedded with lavas and tuffs.

The section of the Takla group exposed along Silver Creek was studied in some detail. It consists of at least 200 feet of limestone and shale overlain conformably by 1,000 feet or more of tuffs and lavas with intercalated sandstone, shale, and conglomerate. The basal limestone is a compact, lavender-grey rock in a bed 150 feet thick. Associated shales are black, carbonaceous rocks in beds 1 inch to 6 inches thick. These rocks may be of Upper Triassic age. The overlying volcanic rocks comprise buff, red, green, purple, grey, and black, compact tuffs and red and green porphyritic andesites. An aggregate of at least 300 feet of conglomerate, sandstone, and shale is interbedded with them. The conglomerate consists chiefly of subrounded to angular pebbles of argillite and quartzite in a pinkish grey siliceous matrix. Pebbles up to 4 inches across were observed. The sandstone and shales are grey and black in beds that average ½ inch to 4 inches in thickness, the sandy beds being the thicker.

Coal was observed on Discovery Creek approximately 4 miles up from the mouth. It occurs in sedimentary strata that are probably part of the Takla group, although no fossils were found in the coal measures and they are separated from fossiliferous Takla formations by drift. The section exposed consists of 140 feet of conglomerate, sandstone, shale, clay, and coal. The beds strike approximately east and dip about 75 degrees to the south. The conglomerate comprises boulders up to 1 foot in length, although most of them are less than 6 inches in diameter, in a sandy matrix. The boulders and pebbles consist of black cherty argillite, black argillite, greywacke, buff sandstone, grey quartzite, greenstone, and quartz. Most of them are lithologically similar to Cache Creek rocks.

Internal Structural Relations

STRUCTURAL RELATIONS

The Upper Triassic rocks exposed at the east end of Pinchi Lake have been folded into an anticline about half a mile wide and trending about 20 degrees north of west. Similar rocks outcropping along the lower part of Halobia Creek, the first creek northeast of Indata Lake, are folded into a northwest-plunging syncline about a mile wide.

The Takla strata north of Nation Lakes and south of the batholith that outcrops south of Germansen Lake are folded into an east-west anticline whose axis lies in the vicinity of Klawli Lake. South of Nation Lakes sedimentary members of the Takla group apparently strike east and dip steeply south, and may form part of the southern limb of the Klawli Lake anticline. North of Germansen Lake the Takla group rocks strike northwesterly and dip from 45 to 75 degrees southwest. North of the head of Discovery Creek they have been folded into a northerly plunging anticline.

The Takla strata along Silver Creek form a series of northwesterly trending folds, 500 to 1,200 feet wide.

The rocks exposed between the arms of Takla Lake, west of the Nalcus Mountain stock, are folded into two northwesterly trending anticlines with an intervening syncline. These folds are 4 to 5 miles wide. The strata east of the stock strike almost north and dip nearly vertically.

South of the east end of Pinchi Lake the Takla rocks, which are here of Jurassic age, have been folded into a northwesterly trending anticline at least 1½ miles wide.

External Structural Relations

Although no actual contacts between the Cache Creek and Takla groups were observed, and although the two groups are believed to be separated in most places by major faults, the writer believes, for reasons previously stated, that the Takla group lies unconformably above the Cache Creek group and that the period between Middle Permian and Upper Triassic was apparently one of igneous intrusion, uplift, erosion, and probably deformation.

Takla group, Hazelton group, and Tachek group rocks may be in part equivalent, but are not in contact.

Although the contacts of the Takla group with the Uslika formation and Sustut group are along faults, a marked angular unconformity probably separates them from the Takla group.

AGE

Fossils collected from several localities were identified by F. H. McLearn of the Geological Survey as follows:

"1. Sandstone outcropping 100 yards south of the Pinchi Lake road, near sawmill, about 3·8 miles east of Pinchi Lake mercury mine.

Trigonia (Clavellatae group)
Astarte?
Nerinea sp.

Age: Jurassic.

2. From tuff bed outcropping 5 miles south of east end of Tchentlo Lake.

    1 specimen, somewhat distorted and incomplete.
    Halobia?

    A tentative dating of Upper Triassic is suggested.

3. Ammonite from shale outcropping on Discovery Creek approximately 2 miles from mouth.

    'Harpoceras' sp.

    The ammonoid in this collection is merely a flattened impression of the shell. It appears to be an Hildoceratid and, therefore, of upper Liassic, that is, upper Lower Jurassic age.

4. Sandstone outcropping on Kwanika group of claims.

    Astarte
    'Belemnites'

    A tentative Jurassic age may be assumed.

5. Fossils from limestone interbedded with volcanic rocks about 4 miles south of Omineca River, opposite Duckling Creek.

    An obscure Hydromedusae of the order Tubulariae.

    The specimens in lot 5 have given much trouble in identification. They seem to be close to, but not identical with, the Triassic genus Heterastidium of the order Tubulariae of the Hydromedusae. They probably belong to a new genus of this order. A tentative Triassic age is suggested.

6. From greywacke outcropping on west shore of Takla Lake 1 mile northwest of Ferry Landing.

    This collection includes *Trigonia* n.sp? and very poorly preserved specimens of *Pecten, Astarte?,* and gastropods.

    The species of *Trigonia* is a rather unusual one. The body of the shell has the ornament of the costatae group of *Trigonia,* and the area has ornament resembling that of other groups of the genus. Somewhat similar ornament is found in the English early Middle Jurassic species *Trigonia costatula* and in a small species recorded by Lees as *Trigonia* aff. *costatula* from the Laberge series of the Yukon. It is a kind of ornament that could be derived with little modification from Triassic species like *Myophoria elegans* and *Myophoria urd.*

    We cannot place too much reliance on one species in correlation, and the one species evidently belongs to an obscure species group of *Trigonia,* but we are justified, I think, in provisionally assuming a Jurassic age.

7. From greywacke outcropping on west shore of Takla Lake, 1½ miles northwest of Ferry Landing. Specimens are not well enough preserved for accurate identification.

    Trigonia? n.sp.
    Astarte? sp.
    A brachiopod?

A tentative correlation of Jurassic and possibly Lower Jurassic is suggested.

8. From sandstone outcropping on the Snell group of claims at junction of Silver and Kenny Creeks.

    'Belemnites' sp.

    Although the preservation of the belemnitid in collection 8 is not very good, it appears to be without furrows. If this is so, it resembles some belemnitids of Lower Jurassic age. As it is, a tentative Jurassic age can be assumed.

9. From limestone outcropping on north shore of Pinchi Lake about 4 miles east of Pinchi Lake mercury mine.

    Monotis subcircularis Gabb

    Age: Upper Triassic.

10. From argillite outcropping along Halobia Creek about 3 miles above its mouth.

    Halobia sp.

    Age: Upper Triassic".

A summary of the fossil evidence leads to the conclusion that the Takla group of the Fort St. James map-area includes strata of Upper Triassic age, Lower Jurassic age, and undivided Jurassic age. Probably most of the Jurassic period is represented, as in the McConnell Creek map-area to the northwest numerous collections of early and late Lower, Middle, and middle Upper Jurassic shells have been collected from this group (99).

CORRELATION

Upper Triassic and Jurassic sedimentary and volcanic formations occur throughout British Columbia west of the Rocky Mountains. Marine sedimentary rocks, including limestone, predominate in Upper Triassic sections, and continental and marine strata alternate throughout the Jurassic. Local accumulations of volcanic rocks occur throughout the Upper Triassic and Jurassic, and in many places comprise most of the formations.

The Takla group consists of an apparently conformable succession of interbedded volcanic and lesser sedimentary rocks ranging in age from Upper Triassic to Upper Jurassic. The sedimentary rocks are largely marine in origin. The Vancouver group of Vancouver Island and Queen Charlotte Islands (40, p. 40; 41, p. 38; 100, pp. 40-54) may be correlated with the Takla group. Both contain marine formations of Upper Triassic and Jurassic ages, and both comprise great accumulations of volcanic rocks.

The Hazelton group of central British Columbia, which is exposed in part in the southwestern corner of the Fort St. James map-area, comprises a conformable succession, possibly 10,000 feet thick, of interbedded sedimentary and volcanic rocks that range in age from pre-lower Middle Jurassic to Lower Cretaceous or younger (10, 11). Faunal collections have been identified from beds of two ages: (1) early Middle Jurassic, and (2) late Upper Jurassic or early Lower Cretaceous. No fossil plants have been found in the Middle Jurassic beds, which are mainly marine; however, Lower Cretaceous plants have been collected from many localities in the younger beds, which consist of interbedded continental and marine strata. The Hazelton and Takla groups may be correlative in part. Although both contain volcanic and sedimentary rocks of Jurassic age they differ in several features. Upper Triassic and early and late Lower Jurassic shells are common in the Takla group but have not been found in the Hazelton group, and the writer believes that the Hazelton group probably does not include any marine strata older than early Middle Jurassic although it contains pre-early Middle Jurassic volcanic assemblages. The early Middle Jurassic fauna of the Hazelton group is not the same as the Middle Jurassic fauna of the Takla group. The youngest fossils found in the Takla group are middle Upper Jurassic shells, whereas the Hazelton group contains late Upper Jurassic or early Lower Cretaceous shells and plants of Neocomian-Barremian and Aptian (Lower Cretaceous) ages. The sedimentary rocks of the Takla group are chiefly marine, but those of the Hazelton group, especially those of Upper Jurassic and Lower Cretaceous ages, are largely continental. The Takla group volcanic rocks are characterized by greenstones and tuffs and those of the Hazelton group are predominantly red and green, porphyritic andesitic flows.

The Quesnel River group of the Cariboo district (120, p. 82) and the McLeod group of the Dease Lake area (82, pp. 86, 90) bear a general lithological resemblance to the Hazelton group and are probably of the same age, in which case they may be correlated in part with the Takla group.

The following table enumerates other groups of Mesozoic rocks west of the Rocky Mountains as well as those already described that may be in part correlative with the Takla group.

TABLE IV

Upper Triassic and Jurassic Rocks of British Columbia West of the Rocky Mountains that may be Correlated in part with the Takla Group

Name of group or formation	Area	Age	Lithology
Hazelton group (10, 11)	Hazelton Smithers Houston Fort St. James Portland Canal Terrace Whitesail Lake	Jurassic and Lower Cretaceous	Sedimentary and volcanic
Quesnel River group (120)	Cariboo	Jurassic and Lower Cretaceous	Volcanic, minor sedimentary rocks]
McLeod group (82)	Dease	Jurassic and probably Lower Cretaceous	Volcanic, minor sedimentary rocks

TABLE IV—*Con.*

Name of group or formation	Area	Age	Lithology
Vancouver group (40, 41, 100)	Vancouver Island Queen Charlotte Islands	Upper Triassic and Jurassic	Volcanic and sedimentary
Nicola group (42, 108)	Nicola Princeton Ashcroft	Upper Triassic	Volcanic, minor limestone
Tulameen group (35)	Hope	Upper Triassic	Schists and sedimentary rocks
Cultus formation (35)	Hope	Upper Triassic	Sedimentary
Slocan group (30, 106)	Slocan, Kaslo, Nelson	Triassic, probably Upper	Sedimentary
Kaslo group (30, 106)	Slocan, Kaslo, Nelson	Triassic, probably Upper	Volcanic, minor sedimentary rocks
Rossland group (119, 106)	Rossland, Nelson	Upper Triassic	Volcanic, minor sedimentary rocks
King Salmon group (90)	Taku River	Upper Triassic	Sedimentary, minor volcanic rocks
Stuhini group (90)	Taku River	Upper Triassic	Sedimentary and volcanic
Honakta formation (90)	Taku River	Upper Triassic	Limestone
Takwahoni group (90)	Taku River	Lower Jurassic	Sedimentary, minor volcanic rocks
Sinwa formation (90)	Taku River	Jurassic (?)	Sedimentary
Yonakina group (90)	Taku River	Jurassic (?)	Sedimentary, minor volcanic rocks
Hurley formation (31, 34)	Bridge River	Upper Triassic	Sedimentary and volcanic
Pioneer formation (31, 34)	Bridge River	Upper Triassic (?)	Volcanic
Noel formation (31, 34)	Bridge River	Upper Triassic (?)	Sedimentary and volcanic
Redtop formation (25)	Hedley	Triassic, probably Upper	Sedimentary

TABLE IV—*Con.*

Name of group or formation	Area	Age	Lithology
Sunnyside formation (25)	Hedley	Triassic, probably Upper	Limestone
Hedley formation (25)	Hedley	Triassic, probably Upper	Sedimentary
Henry formation (25)	Hedley	Triassic, probably Upper	Sedimentary
Wolfe Creek formation (25)	Hedley	Triassic (?)	Volcanic, minor sedimentary rocks
Tyaughton group (34)	Tyaughton	Upper Triassic	Sedimentary
Taylor group (34)	Tyaughton Lake	Middle or Upper Jurassic	Sedimentary, minor volcanic rocks
Parson Bay group (23)	Alert Bay	Upper Triassic	Sedimentary, minor volcanic rocks
Nitinat formation (40)	Southern Vancouver Island	Jurassic or Triassic (?)	Marble
Sutton formation (40)	Southern Vancouver Island	Upper Triassic	Limestone
Sicker group (40)	Southern Vancouver Island	Jurassic or Triassic	Volcanic, minor sedimentary rocks
Metchosin group (40)	Southern Vancouver Island	Jurassic (?)	Volcanic
Marble Bay formation (103)	Texada Island	Triassic or Jurassic	Limestone
Texada group (103)	Texada Island	Lower Jurassic (?)	Volcanic
Britannia group (77)	Britannia	Triassic or Jurassic	Volcanic, minor sedimentary rocks
Bonanza group (65)	Northern Vancouver Island	Upper Triassic and (?) Jurassic	Volcanic, minor sedimentary rocks

TABLE IV—*Conc.*

Name of group or formation	Area	Age	Lithology
Quatsino formation (65)	Northern Vancouver Island	Triassic, probably Upper	Limestone
Karmutsen group (65)	Northern Vancouver Island	Triassic, probably Upper	Volcanic, minor limestone
Yakoun formation (100)	Graham Island	Middle Jurassic	Volcanic
Maude formation (100)	Graham Island	Lower Jurassic and Triassic (?)	Sedimentary
Bitter Creek formation (68)	Portland Canal	Jurassic and (or) Triassic	Sedimentary and volcanic
Bear River formation (68)	Portland Canal	Jurassic	Volcanic and sedimentary
Nass formation (68)	Portland Canal	Jurassic	Sedimentary
Laberge group (37)	Atlin	Jurassic	Sedimentary
'Older volcanics' (37)	Atlin	Jurassic and later	Volcanic
Nazcha formation (121)	Teslin	Jurassic	Volcanic and sedimentary
Shonektaw formation (121)	Teslin	Jurassic	Volcanic
Chieftain Hill group (37)	Taku Lake	Jurassic	Volcanic

Hazelton Group

Rocks that have been mapped as Hazelton group occur along the western border of the Fort St. James area south of Decker Lake and in the vicinity of Wright Bay, Babine Lake. Altogether they occupy about 50 square miles in this area, but to the west are widespread as far as Portland Canal. The group comprises a conformable succession, possibly 10,000 feet thick, of interbedded greywacke, argillite, conglomerate, tuff, breccia, andesite, and basalt ranging in age from Lower Jurassic to Lower Cretaceous. However, in the Fort St. James area, only volcanic members of the group, about 2,000 feet in aggregate thickness, are exposed.

LITHOLOGY

These volcanic rocks consist of andesitic and, to a lesser extent, basaltic, dacitic, trachytic, and rhyolitic flows, and andesite breccias. They are usually massive and pale to dark green. Less commonly they are red, grey, purple, black, and, in the case of the rhyolites, salmon-pink.

The andesitic flows south of Decker Lake are generally dark greenish grey, rusty weathering, and massive, and exhibit little flow structure. In places they are porphyritic, and the phenocrysts, which are rarely more than $\frac{1}{8}$ inch long, consist of white feldspar or dark green pyroxene. Calcite amygdules up to several inches in diameter are fairly common. Thin sections of these green andesites are composed of saussuritized andesine and chloritized augite phenocrysts embedded in a groundmass consisting of feldspar, augite, devitrified glass, and alteration products, chlorite, epidote, and secondary quartz predominating.

Near Wright Bay flows of dark green to black porphyritic augite andesite and interbedded andesite breccias predominate. They strike approximately northeast and dip vertically. A thin section of typical augite andesite is composed of phenocrysts of augite and andesine up to $\frac{1}{8}$ inch long in a groundmass of saussurite, secondary quartz, carbonate, and chlorite. In many places the augite has been altered to secondary amphibole, chlorite, and epidote. Also exposed in the vicinity of Wright Bay are interbedded flows of purple and lavender trachyte and dacite, and salmon-pink flows of rhyolite.

The Hazelton group volcanic rocks have been largely altered to limonite, chlorite, and epidote. Epidote occurs in many places as numerous veinlets, usually less than 2 inches wide, irregularly distributed throughout the rock. These veinlets may have distinct boundaries, but normally they grade into the host rock. The veinlets also contain some quartz. Epidotization is most pronounced in the rocks of Boo Mountain.

Exposures of volcanic rocks lithologically similar to those just described outcrop in the canyon of Sheraton Creek from $\frac{1}{2}$ mile above the mouth to $4\frac{1}{2}$ miles upstream. These rocks have been provisionally classified with the Hazelton group.

STRUCTURAL RELATIONS

Near Boo Mountain and Gerow Creek the Hazelton group rocks dip steeply and strike about northeast. South of Decker Lake they are unconformably overlain by Endako lavas of Tertiary age.

AGE

No fossils were found in the Hazelton group rocks in this area and, consequently, their age is not definitely known. However, they are lithologically similar to, and appear to be an eastern extension of, rocks mapped as Hazelton, and are probably of Jurassic or Lower Cretaceous age. They do not come in contact with the Tachek group of probably Jurassic age, nor with the Takla group of Upper Triassic and Jurassic age. These two groups and the Hazelton group are all, apparently, in part of Jurassic age, a period of extensive vulcanism.

Tachek Group

GENERAL STATEMENT

The Tachek group has been named from its typical occurrence at Tachek Mountain, which lies about 10 miles west of the Fort St. James map-area at about latitude 54°37′. It consists of a basal series of sedimentary strata 300 feet thick overlain conformably by about 2,000 feet of andesite breccia, andesite, and rhyolite (93). The sedimentary strata, consisting mainly of tuff, shale, and conglomerate, and containing fossil plants of probable Jurassic age, overlie Topley granite unconformably.

In the Fort St. James area formations of the Tachek group comprise at least 1,000 feet of porphyritic and non-porphyritic andesite, andesite breccia, basalt, and rhyolite. They are exposed in two localities only, both along the western boundary of the area. One area of about 5 square miles lies between the Canadian National railway and Babine Lake and forms the eastern extension of the type area exposed at Tachek Mountain. The other area, 50 square miles, lies between Babine and Tochchaw Lakes. No sedimentary strata were observed at either locality.

LITHOLOGY

The most characteristic member of this group is a green or purple eruptive andesite breccia that weathers to a much lighter shade. Most of the fragments are andesite, but fragments of rhyolite, chert, granite, and feldspar also occur. The fragments vary in size from $\frac{1}{16}$ inch to 6 inches in diameter, and are embedded in a green or purple, glassy matrix. The eruptive andesite breccia lying between Wright Bay and Tochchaw Lake is interbedded with flows of dark green to black, porphyritic augite andesites. These andesite flows weather reddish brown, and contain phenocrysts of augite up to $\frac{1}{8}$ inch in length. Of lesser areal extent are interbedded flows of red, purple, and lavender, porphyritic trachytes and andesites. They contain phenocrysts of white feldspar as much as $\frac{1}{4}$ inch long in a hematitic groundmass.

STRUCTURAL RELATIONS AND AGE

No fossils were found in the Tachek group in the Fort St. James area. However, to the west of the area, near Tachek Mountain, fossil plants were collected by A. H. Lang (93) from the basal sedimentary strata. These were reported on by W. A. Bell of the Geological Survey as follows: "This lot provided a collection of fossil plants comprising the genus *Otozamites* and sterile specimens of an unidentified matoniaceous fern. Similar forms are characteristic of the Jurassic, but some species have a wide range extending from Triassic into Cretaceous time." From this it is apparent that the Tachek group is probably of Jurassic age, although possibly Cretaceous. However, a pre-Cretaceous age seems most probably due to the fact that although fossil plants have been collected from Cretaceous rocks at more than fifty localities in central British Columbia, in none of these collections has *Otozamites* been recognized, as might be expected if it were a Cretaceous genus, especially as most of the Cretaceous genera are widespread.

The Tachek group rocks bear some lithological resemblance to part of the Hazelton group but, in general, are fresher and less deformed.

Uslika Formation

The Uslika formation is named from its abundant occurrence in the vicinity of Uslika Lake in the Aiken Lake map-area (17) adjoining the Fort St. James area to the north, where it consists of 5,500 feet of conglomerate. In the Fort St. James area conglomeratic rocks of three small areas have been mapped as Uslika formation. One of these forms a southward extension from the Aiken Lake area. The other two occur along the Pinchi fault zone on Kwanika and Rottacker Creeks.

LITHOLOGY

The conglomerate exposed along the northern boundary of the map-area consists of well-rounded pebbles and boulders up to 10 inches in diameter embedded in a grey to brown, sandy matrix. Volcanic flows, tuffs, fine clastic sedimentary rocks, cherts, and schists make up the pebbles and boulders of some beds; other beds are composed largely of granitic pebbles much resembling various rock types found in the Omineca intrusions; still other beds consist chiefly of pebbles of white vein quartz and chert. In a few beds the pebbles and boulders are coated with shiny hematite.

The conglomerate exposed on Kwanika and Rottacker Creeks is made up of well-rounded pebbles and boulders ranging from a fraction of an inch to 18 inches in diameter and embedded in a rusty red, arkosic matrix. They consist of pink and green syenodiorite and diorite, dark grey chert, black argillite, grey and buff arkose and greywacke, and white quartz and feldspar. All pebbles and boulders are coated with hematite and have glistening, reddish brown surfaces. Beds of red-brown arkose a few feet thick occur with the conglomerate on Rottacker Creek. The total thickness there is unknown, but is more than 100 feet.

AGE

The Uslika conglomerate on Kwanika Creek overlies a syenodiorite body, and the other exposures contain pebbles and boulders of rocks resembling those of the Omineca intrusions; therefore, they are probably of Lower Cretaceous or later age. In the Aiken Lake map-area (17, p. 14) two collections of fossil plants of probable Lower Cretaceous age were made from an argillite bed that has been included with the Uslika formation.

Sustut Group

The Sustut group is named from its widespread occurrence in the vicinity of Sustut River in the McConnell Creek map-area, which lies to the northwest of the Fort St. James area (99). In the type area the group comprises more than 3,000 feet of conspicuously bedded and banded continental strata of relatively simple structure and of Upper Cretaceous and Paleocene ages. Part of the group is exposed only along the western border of the Fort St. James area, on both sides of Takla Lake near Takla Landing. There outcrops of interbedded conglomerate, shale, greywacke, and tuff, containing fossil plants of Upper Cretaceous age, occupy an area of about 15 square miles.

LITHOLOGY

The conglomerates are grey to buff rocks composed of well-rounded pebbles, up to 10 inches in diameter although generally less than 2 inches, embedded in a sandy textured matrix. The most conspicuous pebbles are of granitic rocks resembling the various rock types found in the Omineca intrusions. In some zones they comprise at least half the pebbles, whereas in others they are virtually absent. Also abundant are pebbles of white vein quartz; grey, black, and green cherty rocks; green, red, and purple andesitic and basaltic lavas; grey, green, and red tuffaceous rocks; and grey and black argillites and shales. The proportions of the various pebbles vary widely from place to place, and at different stratigraphic levels. The matrix is composed mainly of sand-like grains of rocks similar to those of the pebbles. The conglomerate forms lenses, thin beds, or bands up to 100 feet in thickness and commonly about 20 feet thick.

In the type McConnell Creek map-area, to the northwest, buff, greenish brown, and light grey, fine- to coarse-grained greywackes and arkoses are the dominant rock types of the Sustut group. In the Fort St. James area greywackes are common, but no true arkoses were observed. Superficially the greywackes resemble sandstones, but actually most of them are composed of minute rock fragments. Some phases are tuffaceous. Beds range in thickness from a fraction of an inch to a few feet.

In most places the greywackes are interbedded with grey, black, and buff shales in beds from a fraction of an inch to a few feet thick. Grey, green, and buff tuffs are interbedded with the shales and greywackes.

STRUCTURAL RELATIONS

The Sustut group, as exposed in the Fort St. James area, occupies an area lying between two northerly trending major faults; consequently, its stratigraphic relations to older formations could not be observed. However, a major erosion interval between the emplacement of the Omineca intrusions and the deposition of the Sustut group is postulated, based on the presence in Sustut conglomerates of pebbles derived from Omineca intrusions and all older formations. Lord (99) states that in the McConnell Creek map-area additional evidence of extensive erosion subsequent to the deposition of the Jurassic formations of the Takla group is afforded by the occurrence of Sustut strata resting on various horizons of this group. He notes further that the widespread, extremely gentle dips of the Sustut formations in the vicinity of Thutade Lake are not duplicated anywhere in the Takla group, and that a marked angular unconformity probably separates the two groups in places.

AGE AND CORRELATION

Fossil plants collected from the Sustut group exposed near Takla Lake were identified by W. A. Bell of the Geological Survey as follows:

"Locality 2A (Geol. Surv. Cat. No. 3350): west shore Takla Lake, 4 miles northwest of Ferry Landing.

Platanus sp.

Remarks. In itself not diagnostic of age, but resembles a number of Upper Cretaceous specimens of *Platanus* and it is probable that the age is about the same as that of the succeeding lots.

Locality 3A (Geol. Surv. Cat. No. 3345): west shore Takla Lake, 1½ miles southeast of Ferry Landing:

Conifers

Desmiophyllum sp.
Cyparissidium gracile Heer

Cycadeoids

Pseudocycas unjiga (Dawson)

Angiosperms

Sterculia sp. of *S. minima* Berry
Cinnamomum newberryi Berry
Sorbus ? sp.
Andromeda sp.

Remarks. The age is inferred to be Upper Cretaceous and most probably Cenomanian (basal Upper Cretaceous) or about the age of the Dunvegan formation of Alberta.

Locality 4A (Geol. Surv. Cat. No. 3347): west shore Takla Lake, 1½ miles southeast of Ferry Landing:

Ferns

Sphenopteria (Anemia?) sp.

Conifers

Cyparissidium gracile Heer

Angiosperms

Ficus sp. of *F. woolsoni* Newberry
Cinnamomum newberryi Berry
Sorbus? sp.

Remarks. An Upper Cretaceous age contemporaneous with that of preceding locality, 3A, is indicated.

Locality 1F (Geol. Surv. Cat. No. 3346): Takla Creek, 1½ miles from Takla Lake:

Conifers

Desmiophyllum sp.

Angiosperms

Ficus sp. of *F. woolsoni* Newberry
Sorbus ? sp.
Dalbergites sp.

Remarks. An Upper Cretaceous age, the same as for preceding lots, is indicated.

Locality 2F (Geol. Surv. Cat. No. 3349): Takla Creek, 1½ miles from Takla Lake:

Cycadeoids

Pseudocycas unjiga (Dawson)

Angiosperms

Ficus sp. of *F. stephensoni* Berry
Nelumbo sp.
Carpolithes sp.

Remarks. An Upper Cretaceous, probably Cenomanian, age is indicated.

Locality 1R (Geol. Surv. Cat. No. 3348): talus, 5½ miles south of Ferry Landing on west shore Takla Lake:

Conifers
Desmiophyllum sp.
Cyparissidium gracile Heer

Angiosperms
Magnolia sp.
Anisiphyllum ? sp.

Remarks. An Upper Cretaceous age, about the same as for preceding lots, is indicated."

Summing up the fossil evidence the conclusion is reached that the Sustut group in the Fort St. James map-area is partly or entirely of basal Upper Cretaceous age. However, in the McConnell Creek map-area to the northwest, fossil plants, of basal Upper Cretaceous age and also of Paleocene age are contained in the Sustut group at different stratigraphic levels (99). Possibly only the Upper Cretaceous part of the group is represented in the Fort St. James map-area, although unfossiliferous Paleocene beds may be present.

Sedimentary strata of continental origin and containing plants of Upper Cretaceous age that may be correlated in part with the Sustut group occur at several places in British Columbia west of the Rocky Mountains. Included here is the Beady formation of the Dease Lake area (82, p. 94), a conglomerate of late Cretaceous or early Tertiary age; the Honna and Haida formations of Upper Cretaceous age exposed on Graham Island (100, pp. 54-66), the former consisting of conglomerate and sandstone and the latter of sandstone, shale, and coal; and the Upper Cretaceous, Nanaimo group (41, pp. 79-80) of southern Vancouver Island, which is in part of marine origin.

Upper Cretaceous or Younger Rocks

Rocks of Upper Cretaceous or later age occupy an area of about 150 square miles between François Lake and the Canadian National railway and along the south shore of François Lake. They are divisible into two lithologic groups: (1) andesitic and related lavas and interbedded conglomerate and arkose outcropping between François, Tchesinkut, and Burns Lakes, and on the hill east of Tchesinkut Lake; and (2) acidic volcanic rocks exposed along the south shore of François Lake near Southbank.

ANDESITIC ROCKS

Included in the andesitic rocks are at least 2,000 feet of andesitic, trachytic, and rhyolitic flow and fragmental rocks with minor amounts of conglomerate and arkose. The flow rocks are mainly andesite, but range in composition from basalt to trachyte and rhyolite. The andesites and trachytes are usually grey, green, or purple, the basalts almost black, and the rhyolites buff. Under the microscope the andesites are seen to consist of phenocrysts of biotite, hornblende, and plagioclase feldspar up to ¼ inch in length, in a groundmass ranging from vitrophyric to cryptocrystalline. Where the groundmass is vitrophyric, it usually has a flow texture, but where the groundmass is cryptocrystalline no such texture is to be seen. The cryptocrystalline groundmass is composed of plagioclase feldspar, secondary quartz, paragonite, chlorite, epidote, and a little devitrified glass. The plagioclase ranges between sodic andesine and labradorite, and ordinarily shows a little alteration to paragonite. The biotite phenocrysts are reddish brown, corroded, and altered to penninite, epidote, and magnetite.

The microscope shows the trachytes to be composed of phenocrysts of albite, orthoclase, biotite, and hornblende up to ¼ inch in diameter embedded in a cryptocrystalline groundmass composed of small laths of albite and orthoclase and accessory grains of magnetite and apatite. The biotite shows some alteration to penninite and magnetite, and the hornblende is in many slides completely changed to penninite, epidote, and iron oxides. Under the microscope the basalt is seen to consist of phenocrysts of augite, usually altered to chlorite, embedded in a hyalopilitic groundmass made up of simple or one-twinned laths of labradorite in a residuum of glassy matter. The groundmass shows evidence of flow texture. A little magnetite and patches of carbonate are also present. The rhyolites are similar to those described below under the acidic volcanic group.

These andesitic and related flows are not vesicular, but in places contain amygdules that range up to 2 inches in diameter, and many of which contain a centre of white calcite surrounded by a ring of clear quartz crystals. The lavas contain spots of epidote and chlorite, but not to such an extent as the volcanic members of the Hazelton and Takla groups.

The main exposures of conglomerate and arkose are found in the areas lying north and south of the west end of Tchesinkut Lake. At the west end of the lake the beds strike north 25 degrees east, dip 45 degrees southeast, and form a band that extends north for 4 miles. The greatest thickness observed in any one exposure was 100 feet. The exposures usually occur on cliff faces, and commonly consist of beds of conglomerate, averaging 10 feet in thickness, interlayered with beds of arkose 3 feet thick.

The conglomerate consists of pebbles ranging in size from a fraction of an inch to boulders 8 or 10 inches in diameter, the common size being from ¼ to 1 inch. The pebbles are fairly well rounded and consist mainly of blue-black chert, grey cherty quartzite, white quartz, pink granite, red and green andesite and dacite, buff rhyolite, and greenstone. The matrix is hard and green, and consists mostly of interlocking fragments of the same material as the pebbles in a siliceous cement.

The arkose is a fine-grained, red, bedded rock, composed of fragments of quartz and feldspar in a hematite cement.

ACIDIC VOLCANIC ROCKS

The acidic volcanic rocks comprise rhyolitic, dacitic, and andesitic flows and related tuffs and breccias. Rhyolitic and dacitic rocks predominate. They are massive, hard, fine-textured rocks, generally buff or creamy white, although some are pink, grey, brown, and lavender. They are predominantly porphyritic, containing small phenocrysts of quartz and feldspar. In the rhyolites the feldspar is usually orthoclase or albite-oligoclase, and in the dacites andesine. The groundmass consists of feldspar, quartz, and partly devitrified glass. Associated with the rhyolitic and dacitic flows are flow breccias consisting of angular fragments of rhyolite, dacite, and related volcanic rocks embedded in a matrix of quartz, feldspar, and glass.

Along the south shore of François Lake, 1 mile west of Southbank, vitric tuffs outcrop for ½ mile. They are dense, bedded, grey and red rocks, which under the microscope are seen to be composed of partly devitrified glass, carbonate, hematite, limonite, and an occasional quartz shard.

The andesitic rocks included in this division are similar to those in the andesite group.

STRUCTURAL RELATIONS

The Upper Cretaceous or younger formations are only slightly deformed as compared with the older stratified formations of the area. Attitudes are not everywhere determinable, but the general strike appears to vary from north 10 to 40 degrees east and their dips from 30 degrees northwest to 30 degrees southeast, with an occasional dip as high as 50 degrees.

On the hill west of Tchesinkut Lake andesite flows overlie unconformably a body of Topley granite, and fragments of the granite, up to 6 inches in diameter, occur in the andesite.

The relation of the Upper Cretaceous or younger formations to those of Eocene or Oligocene age could not be determined conclusively due to the scarcity of outcrops. It is quite possible that the Eocene or Oligocene sedimentary formations and those intercalated with the Upper Cretaceous or younger volcanic rocks represent the same period of sedimentation. This conclusion is based on the folowing observations: (a) some of the conglomerates north of Tchesinkut Lake are indistinguishable from the Eocene or Oligocene conglomerates; (b) overlying conformably the Eocene or Oligocene rocks, and outcropping along the François Lake-Burns Lake road, are rhyolitic rocks lithologically identical with the rhyolites of the Upper Cretaceous or younger rocks; and (c) the fossils collected from the Upper Cretaceous or younger rocks were very fragmentary, and could readily be of Eocene or Oligocene age.

Representatives of the Upper Cretaceous or younger rocks and those of the Sustut group are widely separated in the map-area, and their structural relations are not known. They may be in part of the same age.

AGE

The only fossils collected from these rocks were a few fragments of dicotyledonous leaves from a tuff outcropping on the north shore of Tchesinkut Lake. According to W. A. Bell of the Geological Survey these indicate an Upper Cretaceous or later age.

Lithologically similar conglomerates are found in the Sustut group, the rocks of Upper Cretaceous or later age, and the Eocene or Oligocene formations. The fossil plants found in associated sedimentary beds in the Fort St. James map-area fall into two distinct groups, one of Upper Cretaceous age and the other of Eocene or Oligocene age. Other plant collections are too fragmentary to be of much value, and it is quite possible that these three groups of rocks should be included in two groups only, one of Upper Cretaceous and Paleocene age and the other of Eocene or Oligocene age. However, with two such groups it would be rather difficult to decide in which the rocks of Upper Cretaceous or later age should be included.

Eocene or Oligocene Sedimentary Rocks

GENERAL STATEMENT

Four small areas of Eocene or Oligocene sedimentary rocks have been mapped, and they have a total areal extent of about 35 square miles. These rocks outcrop along the north shore of François Lake near the western border of the map-area; along the Burns Lake-François Lake road about 2 miles north of François Lake; north and east of the village of Burns Lake; and along the base of the hills on the north side of Endako River Valley from a point north of Palling to the western border of the map-area.

These rocks comprise poorly consolidated conglomerate, sandstone, shale, and all intermediate types. The exposures along the Burns Lake-François Lake road are interbedded in the upper part with white rhyolitic tuffs. The following sections were measured:

(I) Section along the creek flowing south along the eastern border of the map-area, between latitudes 54°15′ and 54°30′, into Rose Lake:

		Thickness Feet
Top:	Small pebble conglomerate	10
	Sandstone with streaks of lignite	10
	Coarse pebble-conglomerate	15
Bottom:	Feldspathic sandstone and crumbly shale	20
	Total	55

(II) Section along creek bordered by trail from Palling to Babine Lake:

		Thickness Feet
Top:	Feldspathic sandstone	6
	Conglomerate with streaks of lignite; small pebbles at top, large pebbles at bottom	15
	Feldspathic sandstone and crumbly shale	40
	Shale	40
	Conglomerate	10
Bottom:	Shale	4
	Total	115

(III) Section along François Lake-Colleymount road:

		Thickness Feet
Top:	Crumbly shale and feldspathic sandstone	50
	Conglomerate	25
	Crumbly shale and feldspathic sandstone	35
	Feldspathic sandstone	20
	Shale and feldspathic sandstone	75
Bottom:	Conglomerate	10
	Total	215

LITHOLOGY

The conglomerate is composed of pebbles ranging in size from ¼ inch to boulders 6 or 8 inches in diameter, the common size being from ½ to 1 inch. They are well rounded, and consist mainly of blue-black chert, grey cherty quartzite, and white quartz. The matrix is grey or buff, and consists of smaller fragments of the same material in a siliceous cement. The sandstone, which grades into both conglomerate and shale, is usually a massive, buff-coloured rock composed of quartz and feldspar in a ferruginous cement. Sandstones exposed along the François Lake-Colleymount road about 1 mile east of Mourse Creek, and along the Burns Lake-François Lake road, are calcareous. The shale is blue-black and crumbly. Throughout all the sections observed are streaks of lignite and carbonized wood.

The interbedded tuffs observed along the François Lake-Burns Lake road are fine-grained, mottled, white rocks containing blebs of colourless quartz, and fragments of grey andesite and white rhyolite. In thin section they were observed to be crystal tuffs, composed of angular fragments of quartz, feldspar, rhyolite, and andesite in a partly devitrified glassy base. Some crystals of quartz were also observed.

STRUCTURAL RELATIONS

Beds outcropping along the north side of Endako Valley are nearly flat-lying, the dips seldom exceeding 5 degrees, whereas the strata along the François Lake-Colleymount and Burns Lake-François Lake roads have dips up to 70 degrees. The steeper dips are probably due to slumping.

AGE AND CORRELATION

Fossil plants collected by various workers from these rocks have been reported on by W. A. Bell of the Geological Survey as follows:

"Lot 519 (Geol. Surv. Cat. No. 3013). Lang, 1939. Rocks exposed along François Lake-Burns Lake Road, 2 miles north of François Lake:

Ferns

Cladophlebis sp. cf. *Osmumda arctica* Heer

Conifers

Glyptostrobus europaeus (Brongniart) Heer
Sequoia langsdorfii (Brongniart) Heer

Angiosperms

Ostrya oregoniana ? Chaney
Juglans sp.
Quercus sp.
Rhamnus sp.

The angiosperms are too fragmentary for specific identification. They indicate only a Tertiary age.

"Lot 44-1 (Geol. Surv. Cat. No. 4072). Armstrong, 1936. Locality same as Lot 519:

Conifers

Sequoia langsdorfii (Brongniart) Heer

Remarks. Not indicative of anything beyond a Tertiary age.

"Lot 576 (Geol. Surv. Cat. No. 1770). Hanson, 1924. Locality same as for Lot 519:

Conifers

Sequoia langsdorfii (Brongniart) Heer
Sequoia brevifolia Heer

Angiosperms
Ostrya oregoniana Chaney
Ulmus sp. (samaras)

Remarks. The presence of *Ostrya oregoniana* in this lot, and seemingly also in lot 519, suggests an age about the same as that of the Bridge Creek flora of Oregon, or at least an age not earlier than Eocene or later than Lower Miocene.

"Lot 1184 (Geol. Surv. Cat. No. 4084). Lang, 1938. Rocks exposed along east bank of T-Allin Creek, 1 mile above its mouth:

Conifers
Pinus sp.
Sequoia langsdorfii (Brongniart) Heer
Sequoia brevifolia Heer

Angiosperms
Alnus sp.

Remarks. Florule too meagre to indicate anything but a Tertiary age."

Small areas of rocks similar to those from which the plants were collected are widespread throughout British Columbia and probably represent isolated freshwater basins of sedimentation. Fossil flora have been collected from these beds at many localities and, according to Bell, they represent two distinct ages, the earlier probably Paleocene or Lower Eocene, and the latter commonly classed as Upper Eocene or Oligocene although it may be as late as Miocene. The beds of the Fort St. James map-area appear to belong to this latter group.

In several places elsewhere in British Columbia these continental sedimentary strata of Upper Eocene or later age have been named. Included here are the Coldwater beds and Tranquille beds of the Kamloops area (42); part of the Princeton group of the Princeton area (108); the Kitsilano formation of lower Fraser Valley (79, pp. 23-29); and the Sooke and Carmanah formations of southern Vancouver Island (40, pp. 136-141).

Eocene or Oligocene Volcanic Rocks

Rhyolitic flows and tuffs and, to a minor extent, dacitic, andesitic, and basaltic flows, of apparently Eocene or Oligocene age and at least 1,000 feet thick, occupy an area of about 50 square miles along the north shore of François Lake, 16 miles east from T-Allin Creek.

LITHOLOGY

The rhyolitic flows are massive, hard, fine-textured rocks, dominantly buff or creamy white, although many of them are mottled or banded showing shades of pink, grey, brown, and lavender. They are predominantly porphyritic, containing phenocrysts from $\frac{1}{8}$ to $\frac{1}{4}$ inch in diameter of colourless quartz and white feldspar. Under the microscope several varieties were identified: (1) rhyolite porphyry, (2) spherulitic rhyolite, and (3) oligoclase rhyolite. The rhyolite porphyry is composed of phenocrysts of quartz, orthoclase, and to a lesser extent albite and biotite in a cryptocrystalline groundmass composed of orthoclase, quartz, and partly devitrified glass. In the spherulitic rhyolite the phenocrysts are much less abundant and most of the groundmass is spherulitic. In the oligoclase rhyolite the phenocrysts are of oligoclase and chlorite and the groundmass of indeterminate feldspar, quartz, and devitrified glass. The chlorite appears to have replaced biotite.

Two miles north of Tchesinkut Lake and about 4 miles from the west end, a rhyolite tuff was observed to overlie an andesite porphyry. This tuff is a fine-grained, light grey, porous rock, which under the microscope was seen to be composed of angular fragments of quartz and glassy volcanic material in a glassy matrix.

Associated with the rhyolite flows are rhyolite flow breccias, consisting of angular fragments of porphyritic and non-porphyritic rhyolite and quartz in a matrix of similar composition, which shows flow lines bending around the fragments.

The dacitic, andesitic, and basaltic flows associated with the Eocene or Oligocene rhyolites are similar to those already described as being of Upper Cretaceous or later age, and it is quite possible that the Eocene or Oligocene rocks and the Upper Cretaceous or later rocks represent the same general period of volcanism and sedimentation.

STRUCTURAL RELATIONS AND AGE

The Eocene or Oligocene sedimentary rocks outcropping along the north shore of François Lake and along the François Lake-Burns Lake road are structurally conformable with the overlying rhyolitic flows and tuffs. Therefore, these rhyolitic rocks are probably of the same age.

Endako Group

The Endako group was named for its abundant occurrence in the area drained by Endako River. It consists of relatively flat-lying lava flows, as much as 2,000 feet thick, that were erupted during Oligocene or later time. South of Babine Lake and Sutherland River, areas totalling approximately 1,000 square miles are underlain by Endako lavas. Nearly flat-lying, fresh-looking volcanic rocks that form the mass of Hunitlin Mountain, about 25 miles north of Fort St. James, and the ridges northeast and southeast of the mountain have been included with the Endako lavas. Three small areas of volcanic rocks outcropping near the Manson Creek road between Sylvester Creek and Manson Lake have also been mapped provisionally as Endako group, although no evidence as to their age was obtained.

LITHOLOGY

Although the following detailed descriptions apply to the Endako group west of the 125th meridian, the rocks exposed east of this meridian, which were studied by Gray (63), are believed to be essentially the same. The Endako group comprises chiefly green, red, brown, and black, dacitic, andesitic, and basaltic, amygdaloidal and vesicular lava flows. The degree of vesicularity varies greatly, and in places the rocks resemble pumice. The larger vesicles show horizontal elongation and average an inch in length. Chalcedonic and opalescent quartz, cream-coloured calcite, chlorite, pectolite, prehnite, and zeolites form the amygdules. Pillows were observed in some of the lavas along the Palling-Babine Lake trail.

Examination of ten thin sections of the vesicular lavas shows considerable variation in their composition. Seven of the sections were of andesite, two of basalt, and one of dacite, which is an indication of the relative proportion of these three types. The andesites include both porphyritic and non-porphyritic types, and vary in composition from augite andesites to more acidic varieties containing no augite. The porphyritic andesites carry phenocrysts, up to ½ inch in length, of andesine feldspar, biotite, and, in the more basic varieties, of augite, embedded in a groundmass composed of feldspar laths, accessory and secondary minerals, and in the augite andesites, augite crystals and glassy material. The mineral composition of the non-porphyritic andesites is similar to that of the porphyritic rocks. The augite andesites grade into flows that are more properly termed basalts. These are usually dense, black rocks, and their composition is similar to that of the augite andesite except that the feldspar is more basic, normally about that of labradorite. In one thin section of basalt phenocrysts of olivine were observed. With addition of quartz the andesites grade into dacites.

Along the north shore of Babine Lake opposite Donald Landing and along the south shore of François Lake opposite Johns Island, columnar basalts are exposed. The columns of the Babine Lake basalts are nearly vertical, whereas those along François Lake lie horizontally. In both cases the columns are six-sided.

Flows of feldspar porphyry make up the greater part of the Endako group outcropping along Shovel Creek. These rocks contain phenocrysts of white and pink feldspar up to ½ inch in length, and some of biotite and hornblende in a greenish or lavender-grey, aphanitic groundmass. In many places the phenocrysts have weathered out, imparting to the rock a pseudo-vesicular appearance.

Interbedded with the vesicular lavas are breccias, which are of two distinct types: (1) andesitic flow breccias, and (2) acidic flow breccias. The andesite breccias are exposed on the hill north of the eastern end of Babine Lake, on Taltapin Mountain, and along the west side of Shovel Creek. Acidic breccias were observed south of Sutherland River, on Taltapin Mountain, and along the west side of Shovel Creek. The andesite breccias are green, brown, or purple, depending on the colour of the fragments. These usually range in size from ½ inch to 4 inches, although a few are larger. Most of the fragments are of andesite, but a few are of rhyolite, chert, granite, and feldspar. The matrix is partly devitrified glass. The acidic breccias are composed of small angular fragments, ranging from ⅛ to ½ inch in diameter, in a glassy green matrix. The fragments are of andesite, feldspar, quartz, chert, granite, and jasper. The base has a perlitic texture.

Along Mourse Creek and at the head of Sterns Creek agglomeratic flows were observed. Those along Mourse Creek are brown or black, and contain rounded masses of basalt and andesite up to 3 feet in diameter. The agglomeratic flows at the head of Sterns Creek contain numerous pebbles of granite. Andesitic and dioritic dykes, which are probably related to the Endako lavas, are common. They vary in width from a few inches to more than 30 feet, and are dark green, fine-grained, hard rocks, commonly impregnated with pyrite.

Under the microscope the andesite dykes were seen to be composed of primary hornblende or augite and andesine feldspar laths, secondary chlorite, epidote and calcite, and accessory apatite and sphene. The texture is crytocrystalline. Some dykes have a porphyritic texture, the phenocrysts being andesine feldspar and hornblende or augite. The diorite dykes are coarse-grained rocks composed of phenocrysts of andesine and hornblende up to ½ inch in size embedded in a groundmass of andesine feldspar and hornblende laths. The hornblende is partly chloritized.

Near the Manson Creek road north of Sylvester Creek white and lavender trachyte and rhyolite and green and brown andesite outcrop in several small areas. They consist of flows, dykes, and sills and have been included with the Endako group, although it is possible that they are more closely related to the Eocene or Oligocene volcanic rocks.

STRUCTURAL RELATIONS AND AGE

The Endako lavas are predominantly flat-lying, but dips up to 50 degrees were observed in some localities. When hills of these lavas are viewed from a distance of a few miles three or four members may be seen, but on closer examination no distinguishing features can be recognized.

Formations of the Endako group overlie Eocene or Oligocene formations unconformably, so that the group is of Oligocene or later age. No fossils were found in these rocks.

In 1876 G. M. Dawson (48, p. 75) examined outcrops of the Endako group along the shore of François Lake and Nechako River, and mapped them with rocks to the south of the Fort St. James area, which contained fossil plants corresponding to those of Miocene formations of Alaska.

Pliocene or Younger Conglomerate

A poorly consolidated conglomerate has been found in two localities. Five miles west of Mount Sydney Williams it occupies an area of ½ square mile, and 2 miles south of the west end of Trembleur Lake an area of 100 yards. In both areas the rock overlies Tertiary Endako lavas unconformably.

The conglomerate is composed of pebbles and boulders ranging in size from ¼ inch to 2 feet in diameter. They are fairly well rounded, and consist mainly of amygdaloidal and vesicular andesite, granite, greenstone, serpentine, and chert. The matrix, which is very crumbly, is siliceous. The conglomerate is not more than 200 feet thick.

Calcareous Tufa

Along the north shore of Trembleur Lake, calcareous tufa has been deposited by springs issuing from fissures in the argillites. Individual deposits are from 3 to 6 inches thick, and occupy areas of 10 to 25 square feet. The tufa is a white to buff, porous rock composed of calcium carbonate and fragments of argillite around which the carbonate has been deposited.

On the point on the south shore of the west arm of Tchentlo Lake calcareous tufa has been, and still is being, deposited by warm springs issuing from Permian limestone. The deposit is at least 100 feet in diameter and has a maximum thickness of about 25 feet. The tufa is a very porous, white travertine.

INTRUSIVE ROCKS

General Statement

Intrusive rocks are widespread in the Fort St. James area. They range in age from post-Middle Permian and pre-Upper Triassic to Tertiary, and in composition from ultrabasic to acidic, with rocks of granitic composition predominating. They vary in size from the Hogem batholith to small stocks, sills, and dykes. Also included here are the granitized rocks of the Wolverine complex, although in the magmatic sense of the word they are not intrusions. The four main epochs of intrusion and granitization were probably as follows:

(1) Post-Lower Cambrian, possibly pre-Pennsylvanian granitization, resulting in the formation of the Wolverine complex.

(2) Post-Middle Permian-pre-Upper Triassic: Trembleur intrusions—ultrabasic rocks; Topley intrusions—mainly granite and diorite. The Trembleur and Topley intrusions possibly represent differentiation at depth from a common source magma.

(3) Upper Jurassic or Lower Cretaceous: Omineca intrusions; mainly granodiorite and related types; minor pyroxenite; serpentine.

(4) Eocene or Oligocene: rhyolite, granophyre, and granite porphyries; possibly the Duckling Creek and Chuchi Lake syenites belong here.

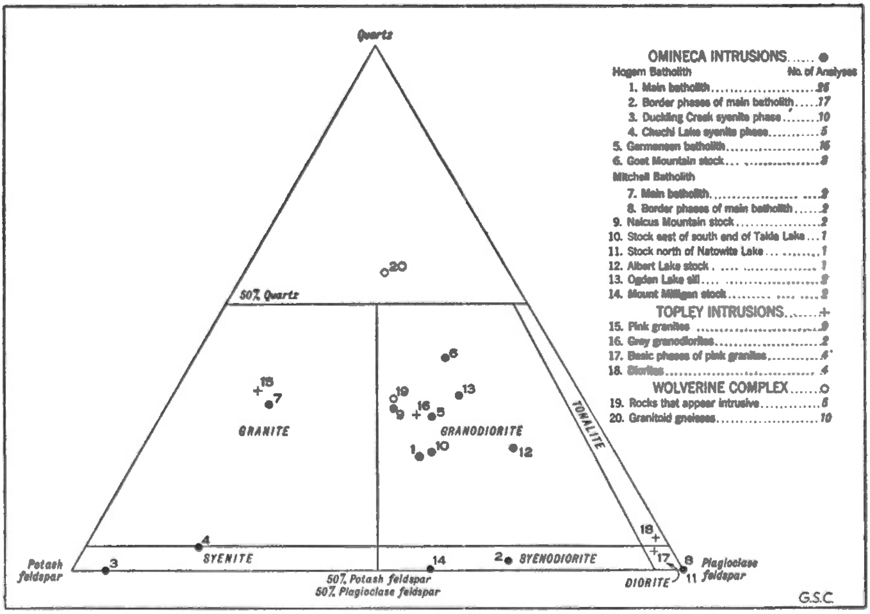

Figure 2. Modes of granitic rocks, Fort St. James area, British Columbia.

A detailed study of the rocks, particularly the granitic types, assigned to the various epochs have indicated the following similarities and differences. Johannsen's classification has been used throughout (*See* Figure 2).

TABLE V

Wolverine granitic rocks	Topley intrusions	Omineca intrusions	Eocene or Oligocene intrusions, including Duckling Creek and Chuchi Lake syenites
	Colour and Texture		
Grey and white equigranular rocks; granulose	Pink and green equigranular rocks	Grey, pink, and green equigranular rocks	Grey, pink, and green porphyritic rocks
	Composition (See Figure 2)		
Granodiorite, granite-gneiss	Granite and diorite predominate	Granodiorite forms main part of bodies; syenodiorite forms border phases	Granite and syenite porphyries; rhyolite porphyries
Modes on fifteen specimens of granodiorite and granite-gneiss: quartz, 49%, potash feldspar, 23%, plagioclase, 28%	Modes on nine specimens of pink granite: quartz, 34%, potash feldspar, 52%, plagioclase, 14% Modes on four specimens of diorite: quartz, 6%, potash feldspar, 1%, plagioclase, 93%	Modes on twenty-five specimens of granodiorite: quartz, 21%; potash feldspar, 32%, plagioclase, 47% Modes on seventeen specimens of syenodiorite border phases: quartz, 2%, potash feldspar, 27%, plagioclase, 71%	Modes on fourteen specimens of syenite: quartz, 2%, potash feldspar (including microperthite), 89%, plagioclase, 9%
In appearance and constituent minerals the Wolverine granitic rocks are very uniform	Uniformity of composition in individual bodies, but considerable variation in composition from one mass to another	Variable composition in individual bodies is marked	Uniform composition in individual bodies
Muscovite and biotite common	Biotite, hornblende, pyroxene, and chlorite are the common ferromagnesian minerals present; muscovite is characteristic of Germansen batholith.		
Minor amounts of magnetite only accessory mineral noted	Magnetite, apatite, and sphene common accessory minerals.		
	Microscopic Features		
Quartz forms a mosaic of small grains	Quartz mainly in individual grains		

TABLE V—*Conc.*

Feldspars fresh; plagioclase commonly untwinned; no intergrowths	Feldspars commonly much altered; plagioclase generally twinned, commonly zoned; micrographic intergrowths fairly general		Microperthite characteristic
	Differentiation		
	Differentiation into separate bodies of granite and diorite; main differentiation apparently took place before emplacement	Differentiation of individual masses marked: in many bodies all gradations from granite and granodiorite at centre to syenodiorite, diorite, gabbro, and pyroxenite at borders; main differentiation apparently took place after emplacement	Very little evidence of differentiation
	Structures		
Gneissic	Primary foliation common Bodies commonly equidimensional	Massive Bodies generally elongated in a northwest direction	Massive
	Other Features		
Confined to areas of Late Precambrian and Lower Cambrian strata	Deeply eroded; commonly form basement rocks on which younger formations were deposited	Only partly eroded; commonly form core of mountain ranges	

Trembleur Intrusions

GENERAL STATEMENT

The name Trembleur intrusions has been applied to many bodies of ultrabasic rocks of probable pre-Upper Triassic age in the Fort St. James map-area. They consist of sills, stocks, and batholiths of peridotite, dunite, and pyroxenite, and their serpentinized and steatitized equivalents. Some gabbro believed to be of the same age has been included with them.

The largest body of ultrabasic rocks is a batholithic mass about 80 square miles in area underlying Mount Sydney Williams and the area south to Trembleur Lake. North of Baptiste Creek, except for a contact zone of talcose and amphibolitic rocks, this batholith consists predominantly of peridotite and dunite, partly to completely serpentinized. The dunite forms irregular masses varying from a few square feet to many thousand square feet in area within the peridotite (Figure 3). These masses have no regular

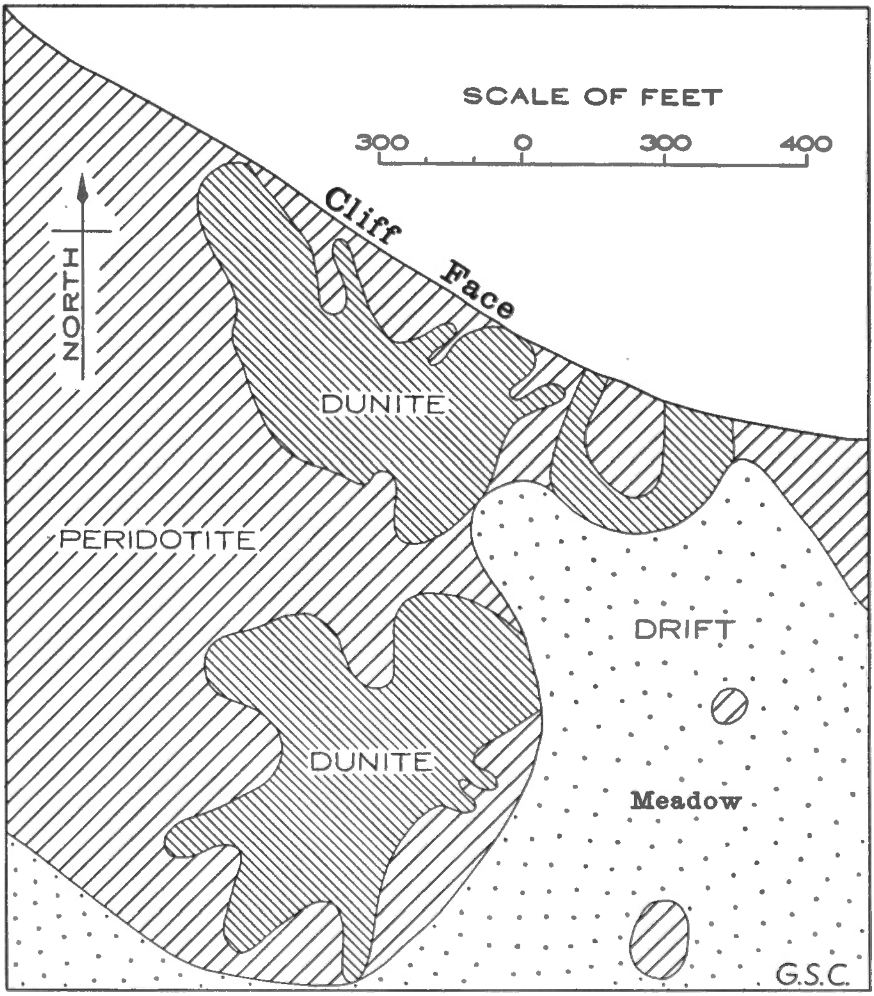

Figure 3. Irregular masses of dunite in peridotite, Mount Sydney Williams.

distribution, and are equally numerous near the borders as well as within the interior of the batholith. The peridotite-dunite contacts are gradational across 2 to 4 inches. These relations suggest that the dunite was segregated from the peridotite during cooling and consolidation, probably by the aggregation of masses of olivine crystals. In those parts of the batholith in which the original rock types are recognizable, dunite probably exceeds one-third the total mass.

Several small lenses of pyroxene-rich peridotite up to 500 square feet in area were observed in the peridotite. They also exhibit gradational contacts across a few inches with normal peridotite, again suggestive of crystal aggregation during cooling.

Branching dykes of coarse-grained, serpentinized, pyroxene-rich peridotite and pyroxenite, varying in width from a fraction of an inch to a foot, are fairly numerous in the peridotite and dunite. The smallest are the width of one or two crystals, which in places are perpendicular to the walls. All have definite but not sharp borders, and they do not exhibit chilled margins. As suggested by Cooke (43, p. 63), who studied similar dykes in eastern Quebec, they resemble the final pegmatitic crystallization of a magma rather than the result of injection after the peridotite was wholly solidified.

Between Baptiste Creek and Trembleur Lake the batholith consists mainly of carbonate-talc rocks believed to be altered ultrabasic rocks, as many exposures of serpentinized peridotite, dunite, and pyroxenite occur in the carbonate-talc area. The peridotite-dunite area north of Baptiste Creek also includes zones of carbonate-talc rock.

Two small stocks of serpentinized peridotite were observed northwest of Mount Sydney Williams. Each is at least $1\frac{1}{2}$ miles long and has a maximum width of about $\frac{3}{8}$ mile. Four, smaller, sill-like bodies of serpentinized peridotite and dunite are exposed in the same general area. The largest is about 6 miles long and 400 feet wide, and is composed of serpentinized dunite. The other three are each $\frac{1}{4}$ to $\frac{1}{2}$ mile long, about 100 feet wide, and are serpentinized. All are partly steatitized.

Several sills of serpentinized dunite, 100 to 300 feet wide and of unknown length, outcrop along the north shore of Trembleur Lake.

On Mount Sydney Williams several dykes of uralitized and saussuritized gabbro up to 30 feet wide were observed cutting peridotite. On the peak northwest of Mount Sydney Williams a stock of gabbro and pyroxenite, about 1 mile long and $\frac{1}{4}$ mile wide, is exposed. No sharp boundaries mark the contacts between the gabbroic and pyroxenitic phases, but each grades into the other through variation in the proportion of feldspar. The pyroxenite phases are partly serpentinized. Another small stock of altered gabbro was observed near Trembleur Lake. It is about $\frac{1}{4}$ mile in diameter and is surrounded by carbonate-talc rocks, no contacts being observed. These gabbroic and pyroxenitic bodies probably represent a later phase of the same magma from which the Mount Sydney Williams peridotite-dunite body originated.

Many scattered outcrops of partly to completely serpentinized peridotite and dunite occur in the area to the west of Tsitsutl Mountain and Mount Sydney Williams. Although extensively faulted they apparently represent two major sill-like bodies and several smaller sills and pipes. Most of the faults and contacts are marked by zones of talcose rocks. One of the larger masses has a maximum width of at least 1 mile and a length of more than 6 miles; the other is about $\frac{1}{3}$ mile wide and 8 miles long. The smaller sills vary in thickness from 25 to 400 feet, and in length from a few hundred feet to 4 miles. Two peridotite pipes, each about 30 feet in diameter, were observed in an area of amphibolitic greenstone. The contacts of these pipes are drift covered. Xenoliths of greenstone and argillite, varying from a few feet to 1,000 feet in diameter, occur in the larger bodies of ultrabasic rocks.

The two, large, sill-like bodies show a rough differentiation from peridotite at the top to dunite at the bottom. One of the smaller sills, about 400 feet thick, grades from pyroxenite at the top to dunite at the bottom. Small lenses of dunite and pyroxenite occur in the peridotite areas, the largest observed measuring 50 by 100 feet. The differentiation is probably due to the settling of olivine crystals during cooling, and the lenses of pyroxenite and dunite in the peridotite also suggest crystal segregation during cooling.

Many exposures of the two, large, sill-like masses also exhibit primary banding in the peridotite. The bands vary from 2 to 6 inches in width and consist of peridotite containing about 10 to 20 per cent pyroxene alternating with peridotite composed of 40 to 50 per cent pyroxene. The attitudes of these primary bands vary widely, suggesting later faulting. In a few places the bands are curved, indicating flowage prior to consolidation. North of the north fork of Tildesley Creek an irregular mass of serpentinized dunite about 20 feet wide and 50 feet long was observed cutting across primary bands in partly serpentinized peridotite. The dunite-peridotite contacts are gradational on a megascopic scale. Similar dunites have been described by Hess (75, pp. 334-340) in the Stillwater complex of Montana. He suggests that they represent a secondary formation of dunite by reheating of serpentinized peridotite, thereby generating a secondary magma.

Dyke-like bodies of coarse-grained, serpentinized pyroxenite and pyroxene-rich peridotite up to a few feet wide cut both peridotite and dunite. They are comparable to pyroxenites observed on Mount Sydney Williams.

An area of serpentinized ultrabasic rocks, 65 square miles in extent, lies between Stuart and Cunningham Lakes. This area is believed to be underlain by an ultrabasic batholith, but it is possible that several smaller bodies are represented, as only a reconnaissance survey has been made. The assumed batholith appears to consist of a central core of peridotite and dunite about 50 square miles in area. Bordering this core on the east, north, and west are areas of pyroxenite totalling about 12 square miles, and rimming the pyroxenite on the east and west are areas of gabbroic rocks of about 2 square miles each. The dunite forms irregular bodies in peridotite and grades into peridotite across a few inches simply by an increase in pyroxene. The pyroxenite-peridotite contacts are believed to be gradational, although serpentinization is everywhere so far advanced that an actual gradation from unaltered peridotite to pyroxenite was not observed. However, intermediate types containing about 50 per cent olivine and 50 per cent pyroxene were seen along these contacts. The contact between the pyroxenites and the border phase gabbros are gradational; pyroxenites containing no feldspar grade into gabbroic rocks containing about 25 per cent labradorite across intervals of 200 feet.

A small body of chloritized and saussuritized diorite, about a mile in diameter, outcrops south of Rubyrock Lake well within the ultrabasic area. No contacts were observed, and the diorite may have been derived from the same magma as the ultrabasic rocks.

A stock of serpentinized and steatitized peridotite and dunite, about 3 by 7 miles in surface area, is exposed in the southeastern part of Mitchell Mountains. The southern third of the body consists predominantly of talcose peridotite and dunite, partly serpentinized, whereas the northern two-thirds of the body is composed of almost completely serpentinized rocks. The talcose rocks consist in large part of elongated crystals of olivine in a talc matrix, a very unusual rock type. Dunite forms irregular areas in peridotite, but the relative proportions of the two could not be estimated in the field due to the widespread alteration to serpentine and talc. Several pendants of limestone, chert, and slate, up to 3,000 feet long and 800 feet wide, occur throughout the stock.

A small body of uralitized and saussuritized gabbro, about 500 feet in diameter, cuts the Mitchell Mountains ultrabasic stock near its western border. Two dykes of garnet-diopside-vesuvianite rock were also observed in this stock.

A body of ultrabasic rocks occupies about 2 square miles in the north part of Mitchell Mountains. Although only a cursory examination was made of this body, it apparently forms a pendant in the granodiorite batholith underlying these mountains, as it is bordered by granitic rocks and cut by granitic dykes. Serpentinized peridotite and dunite make up the bulk of the pendant, although a few lenses of pyroxenite were observed. The granodiorite-ultrabasic contacts are talus-covered, but exposures within 50 feet of the contact do not show excessive serpentinization.

Murray Ridge and Pinchi Mountain, both near Pinchi Lake, are formed of stocks of pyroxenite and pyroxene-rich peridotite, each at least 15 square miles in area. They are partly to completely serpentinized, and have been altered to quartz-carbonate-mariposite rocks along fault and shear zones.

Two serpentine sills, each about 1,500 feet thick and 8 miles long, outcrop between Ogden Creek and Ominicetia River, and are probably serpentinized peridotites.

At least ten small bodies of serpentine and altered serpentine, averaging half a square mile or less in area, are exposed along the Pinchi and Manson fault zones. All of them conform with the bedding of the intruded rocks, and are probably sills. Most of the serpentine is altered to carbonate, quartz, and mariposite. These sills are so completely serpentinized and otherwise altered that their original composition is uncertain.

LITHOLOGY

The various rock types encountered in the Trembleur intrusions are, in their order of relative abundance, peridotites, dunites, pyroxenites, and gabbros.

The peridotites, characteristically, are composed of olivine crystals with varying amounts of rhombic pyroxene, usually about 10 per cent, and a little accessory chromite, spinel, and magnetite. They are massive, fine- to medium-grained rocks, dark green on fresh surfaces, and weathering commonly to bright orange and reddish brown. Generally the olivine occurs in colourless anhedral crystals, averaging $\frac{1}{16}$ to $\frac{1}{4}$ inch in diameter, and the rhombic pyroxene, either enstatite or bronzite, in subhedral or euhedral crystals averaging $\frac{1}{4}$ to $\frac{1}{2}$ inch in diameter, imparting a porphyritic texture to the rock in many places. The peridotites are everywhere partly or wholly altered to serpentine. Even in the least altered specimens the olivine crystals are altered along their borders and lines of fracture to serpentine and grains of magnetite, and the pyroxenes are partly changed to bastite. In many partly altered specimens the olivine is much less altered than the pyroxene.

The southern third of the ultrabasic body exposed in the southern part of Mitchell Mountains consists, in large part, of a very unusual dark green, red, and orange weathering ultrabasic rock differing from a normal peridotite in texture. It is composed of elongated euhedral crystals of olivine in a matrix of talc. The olivine crystals, which are 3 to 6 times as long as they are wide, are only slightly serpentinized, veinlets of chrysotile serpentine filling cracks in the crystals and coating the faces. In the ultrabasic rocks of the Fort St. James area, talc is always a secondary mineral replacing olivine, pyroxene, and serpentine. This replacement is selective, serpentine being replaced first, pyroxene next, and olivine last. Assuming the relatively unaltered crystals of olivine in these olivine-talc rocks are of primary origin, it is evident that the matrix was either pyroxene or serpentine before replacement by talc. However, in similar olivine-talc rocks in Finland (66, pp. 66-67) a secondary origin has been suggested for the olivine, and, although for reasons that follow, the writer does not believe the olivine in the Mitchell Mountains rocks is secondary, such a possibility cannot be excluded. In most of the ultrabasic rocks in the Fort St. James area serpentine appears to form pseudomorphs after pyroxene or olivine, although it is possible some serpentine is deuteric. As the olivine in the olivine-talc rocks shows only a little serpentinization, the talc matrix probably was pyroxene originally, and was either replaced directly by talc or was serpentinized first and then replaced by talc. Therefore, assuming the olivine is primary, the original rock would be a peridotite consisting of olivine crystals in a pyroxene matrix, whereas elsewhere in the Fort St. James area the normal peridotite consists of either interlocking grains of olivine and pyroxene or pyroxene crystals in an olivine matrix.

The dunites are massive, fine- to medium-grained, dark green rocks that weather to orange and reddish brown shades. They are composed of partly to completely serpentinized olivine and minor amounts of chromite, spinel, and magnetite. The olivine occurs in colourless anhedral crystals, averaging $\frac{1}{16}$ to $\frac{1}{4}$ inch in diameter. The alteration of the olivine to serpentine is similar to that of the olivine comprising the peridotites, and the dunites, with the addition of pyroxene, grade into peridotites.

The pyroxenites are coarse-grained, dark green, reddish brown weathering rocks composed mainly of pyroxene, with small amounts of magnetite. Those associated with peridotites consist largely of enstatite or bronzite, and those associated with gabbroic rocks, or forming separate intrusions, of diallage, diopside, or augite. Most of the pyroxenites are partly to completely serpentinized.

The gabbros are medium- to coarse-grained, dark green rocks composed originally of one-third or less labradorite and two-thirds or more diallage or diopside. The pyroxene has been almost entirely altered to hornblende or actinolite and chlorite, and most of the feldspar has been saussuritized to sodic oligoclase, zoisite, carbonate, and paragonite. In some specimens perfect zoisite pseudomorphs after feldspar preserve Carlsbad twinning.

Completely serpentinized dunite, peridotite, and pyroxenite can rarely be distinguished from one another in hand specimens. They are typically dark green, massive, dense-textured rocks consisting of serpentine, with minor chromite and magnetite.

ORIGIN AND MODE OF INTRUSION

Previous to chemical investigations of silicate systems, magmas of the composition of any known igneous rocks were considered possible. However, on the basis of geochemical studies, especially by Bowen (26, pp. 89-108), conclusions were reached to indicate that liquids of essentially the same composition as ultrabasic rocks cannot exist, and, therefore, that ultrabasic rocks could not be derived from a magma of the same composition, but were in fact accumulations of early formed crystals from magmas of basaltic composition or their derivatives. Bowen pointed out that the temperatures necessary to melt olivine and pyroxene were so high that liquids of a corresponding composition should strongly metamorphose the country rock; whereas such effects have not been observed. He also drew attention to the non-occurrence of ultrabasic lavas, indicating that magmas of similar composition did not exist.

That certain ultrabasic rocks originated as suggested by Bowen is in all probability true; but in recent years, several workers, particularly Cooke (43, pp. 64-66) and Hess (75, pp. 321-344), have suggested that, in spite of geochemical evidence to the contrary, some ultrabasic bodies, especially those found in the strongly deformed zones of the earth's crust, were formed by the intrusion of a primary ultrabasic magma. Their conclusions are based on field evidence. In the Fort St. James area, also, field evidence suggesting such a primary origin has been obtained. The facts may be summarized as follows.

(1) The largest ultrabasic bodies in the Fort St. James area are about 65 and 80 square miles in area respectively. If they represent differentiates of a primary basaltic magma from which the much larger feldspathic complement had been separated, these more acidic components should be abundantly represented in areas neighbouring on, or adjoining, the ultrabasic masses, and gradational phases such as feldspathic peridotites should also be found. Such conditions, however, do not obtain in this area, unless the Topley granitic and dioritic intrusions may be of the same general age as the Trembleur intrusions, although they cut the ultrabasic rocks south of the northwest arm of Stuart Lake.

(2) The large ultrabasic bodies, as described, contain irregular masses of dunite and pyroxene-rich peridotite distributed throughout the normal peridotite. The contacts are gradational. The large sills outcropping west of Tsitsutl Mountain and Mount Sydney Williams show a rough gradation from dunite at the bottom to pyroxene-rich peridotite or pyroxenite at the top. These relations are characteristic of magmas that differentiate in place.

(3) The dyke-like bodies of pyroxenite and pyroxene-rich peridotite that cut the peridotite and dunite in the vicinity of Mount Sydney Williams and Tsitsutl Mountain indicate that pyroxene-forming magma remained fluid after consolidation of these rocks. Many of the dykes are only the width of one or two coarse crystals of pyroxene, ½ to 1 inch, and these crystals are in many places orientated at right angles to the walls, suggesting crystallization in place, and it is difficult to imagine how they could have been formed from material already largely crystalline, as Bowen's hypothesis would necessitate.

(4) The great length of many of the ultrabasic sills as compared with their thickness suggests a degree of fluidity comparable to that of less basic magmas. Included in some of the sills are numerous masses of country rock, also indicating relative high fluidity, the ultrabasic magma flowing around masses of invaded rock rather than pushing them aside.

(5) As already described, an irregular mass of serpentinized dunite was observed cutting across primary banding in partly serpentinized peridotite exposed north of Tildesley Creek. This dunite certainly suggests temperatures high enough to melt olivine and the creation of an olivine magma. Two peridotitic, pipe-like masses were also observed north of Tildesley Creek, and may represent feeders to some of the sills nearby.

Hess (75, pp. 327-334) suggests that the ultrabasic magma is a product of partial fusion of the peridotite substratum, and that this magma has roughly the composition $H_4Mg_3Si_2O_9$ (serpentine). He supposes the magma contains 5 to 15 per cent water. The presence of this quantity of water would greatly lower the melting point, thus accounting for the lack of contact metamorphic effects; and as the water, instead of escaping during consolidation, united with olivine and pyroxene to form serpentine no hydrothermal alteration of the country rock need be expected.

As previously described, the large sills outcropping in the area west of Mount Sydney Williams and Tsitsutl Mountain show a rough differentiation from pyroxenite at the top to dunite at the bottom, indicating crystal settling during cooling. However, the sills as now exposed dip nearly vertically whereas the differentiation suggests that intrusion took place when the invaded Permian strata were flat-lying or nearly so.

The conditions under which the ultrabasic stocks and batholithic bodies were intruded are not clear. They now occur in areas of steeply folded Permian strata, and it may be that their emplacement was at least in part a cause of the folding. All field evidence indicates a lack of power on the part of the ultrabasic rocks to assimilate the country rock. Large masses of unaltered limestone and other sedimentary rocks occur in some of the ultrabasic bodies. Analyses of a specimen from one limestone mass yielded more than 98 per cent calcium carbonate, indicating no assimilation or alteration by the ultrabasic intrusion. Some of the siliceous and argillaceous xenoliths, however, exhibit contact reaction zones.[1] The above evidence would suggest that the ultrabasic magmatic material thrust its way upward and outward by pushing aside the intruded rock.

SERPENTINIZATION

The peridotites, dunites, and pyroxenites of the Trembleur intrusions have all been partly to completely altered to serpentine, and in the aggregate are at least 60 per cent serpentinized. Most of the serpentine is olive- or emerald-green, and for purposes of further description may be divided into four main types, namely: (1) antigorite, a bladed serpentine, the atomic structure of which has not been identified; (2) chrysotile, a vein-mesh serpentine whether visibly fibrous or not; (3) bastite serpentine, pseudomorphic after pyroxene; and (4) isotropic serpentine, which in thin section appears isotropic or nearly so and has no discernible structure.

The origin of serpentine in ultrabasic rocks, particularly in peridotite, has for many years been a subject of controversy, and those who have

[1] See discussion of steatitization, pp. 89, 90.

studied this problem favour either one or other of two theories: (1) deuteric, in which serpentinization is brought about by solutions emanating from the cooling ultrabasic intrusion itself; or (2) hydrothermal, in which the serpentinizing solutions emanated from later intrusive rocks. The writer believes that both processes have been active, but that most of the serpentine resulted from deuteric processes, hydrothermal serpentine being formed mainly along zones of faulting, shearing, and fracturing.

Deuteric Serpentinization

A satisfactory theory to account for the bulk of the serpentine of the ultrabasic rocks in the Fort St. James area must account for the following facts: (1) Serpentinization is confined to the ultrabasic rocks. (2) The serpentine formed in the ultrabasic bodies has a haphazard arrangement, and is as intense at the centres of the masses as at the borders. (3) Except for zones of more intense serpentinization a few feet wide bordering granitic dykes, serpentinization is in no way related to the proximity of younger, acidic intrusions. If the solutions producing most of the serpentine came from such intrusions, the percentage of serpentine would be expected to increase toward the contacts, but no evidence of this was observed. For example, the ultrabasic body exposed in the northern part of Mitchell Mountains is surrounded by intrusive granitic rocks, but except for a zone of brownish, hydrothermal serpentine and amphibole within a few feet of the contact, this ultrabasic body is no more serpentinized than the Mount Sydney Williams ultrabasic batholith, which is nowhere near exposed granitic rocks. (4) Serpentine is not confined to, and most of it is not related to, fault, shear, or fracture zones, although as outlined in the discussion of hydrothermal serpentine these zones have apparently provided channelways for later solutions, resulting in some further serpentinization. In view of the above facts it is necessary to conclude, therefore, that the greater part of the serpentine of the ultrabasic rocks was not caused by emanations from later intrusions, and, therefore, must have been caused by solutions emanating from the ultrabasic intrusion itself. In all the larger ultrabasic bodies crystals of olivine, uniformly distributed and about equally serpentinized, were observed in partly serpentinized massive peridotites and dunites. From this it may be concluded the attack on the olivine crystals was brought about by a residual liquid present in the interstices between the grains rather than by solutions concentrated in more widely spaced channelways. If the original composition of the ultrabasic intrusion had roughly the composition of serpentine it is quite possible that some of the serpentine now found between grains of olivine crystallized directly from the residual liquid.

It is possible to study in thin section the progress of serpentinization from fresh peridotite and dunite to serpentine rocks. Alteration of the olivine and rhombic pyroxene to serpentine commenced at, and proceeded from, crystal, fracture, and cleavage faces. The process apparently began with incomplete alteration of the olivine crystals to chrysotile serpentine and pyroxene grains to bastite. In most thin sections complete replacement of pyroxene to bastite took place before the olivine was totally altered. The chyrsotile serpentine veinlets fill cracks in the olivine. In the centre of many veinlets is an isotropic strip flanked on each side by perpendicular fibres of serpentine. Very fine-grained magnetite occurs in the central strip. As alteration of the olivine proceeded, the chyrsotile serpentine appears to have been changed to antigorite, and no chrysotile serpentine was observed in the completely serpentinized rocks. At an early stage of complete serpentinization the original crystal boundaries are recognizable, and the mesh texture of antigorite derived from olivine, and the characteristic texture of bastite derived from pyroxene, are best defined. At a later stage the texture may indicate a gradual alteration to an aggregate of blade-like antigorite in which the crystal boundaries of the original minerals are completely obliterated, and in which the antigorite shows a lattice texture, with blades commonly crossing at right angles regardless of the original mineral. Brownish yellow, isotropic serpentine was observed in many thin sections, especially those of specimens from shear zones. This type of serpentine was observed only in completely serpentinized rocks. It may represent an end product in the deuteric process of serpentinization, or it may be hydrothermal serpentine.

Hydrothermal Serpentinization

Several granitic dykes were observed cutting serpentinized ultrabasic rocks in the vicinity of Tsitsutl Mountain and in the northern part of Mitchell Mountains. No apparent alteration of these serpentinized rocks was noted except at one place in each of two localities. In both places a zone, a few inches wide, of greenish brown serpentinized material borders the dykes. Under the microscope this material is seen to consist of chyrsotile serpentine, isotropic serpentine, carbonate veinlets, actinolitic amphibole, chlorite, talc, and chromite. Serpentine comprises about 60 per cent of the rock, and some is undoubtedly of deuteric origin; however, some of the serpentine appears later than the actinolite, talc, and carbonate, all minerals believed to have resulted from hydrothermal action. Similar alteration, but less intense, was effective for 30 feet on either side of the dykes.

Although the ultrabasic-granite contact of the serpentinized peridotite in the northern part of Mitchell Mountains is drift covered, specimens were obtained within 20 feet of the contact. Microscopic examination revealed that these specimens were composed of about 55 per cent olivine, 35 per cent pyroxene, 8 per cent tremolitic amphibole, and 2 per cent talc, the last two minerals believed to have resulted from hydrothermal solutions emanating from the granite. The pyroxene and olivine, which are partly serpentinized, are pierced by needles of amphibole; the talc replaces pyroxene along cleavage planes; and a few serpentine veinlets were observed cutting the amphibole.

Fault, shear, and fracture zones cut many of the large ultrabasic masses, and most of the small bodies lie along similar zones. They vary in length from a few hundred feet to several miles or more, and commonly are less than 300 feet wide. Most of them trend northwesterly. Along many of them the serpentinized rocks have been altered to an aggregate of carbonate, talc, quartz, chlorite, and mariposite, which replace serpentine, pyroxene, and olivine. However, in several thin sections, veinlets of serpentine appear to cut talc and carbonate, indicating possible hydrothermal serpentine. Some structural zones consist only of schistose serpentine; others are composed of massive, ellipsoidal, ultrabasic fragments up to 3 feet in diameter in a sheared serpentine matrix. In one such zone cutting a banded peridotite, the banding in the ellipsoids strikes at all angles, indicating considerable movement. Thin sections were cut from ellipsoids of various sizes and types, as well as from the sheared matrix and the schist of the non-ellipsoidal zones. The ellipsoids consist of peridotite and dunite partly to completely serpentinized, the type of serpentine apparently depending on the degree of serpentinization—chrysotile, mesh antigorite, blade-like antigorite, and isotropic serpentine all being represented in various ellipsoids. The sheared matrix, on the other hand, is always composed of blade-like antigorite, as is the schist of the non-fragmental shear zones. Here and there carbonate and talc occur in the matrix along with the antigorite. Some of these ellipsoidal zones consist of fragments of peridotite, less than 50 per cent serpentinized, in a matrix of antigorite, and many of the fragments have a rim of isotropic serpentine. The antigorite of the matrix and isotropic rims suggests an origin later than that of the deuteric serpentine, and may be due to later hydrothermal solutions. Most of the rock of the structural zones crossing large ultrabasic bodies and that of the smaller bodies along such zones appears more serpentinized than the massive parts of the large bodies.

STEATITIZATION

Hess (73, p. 635) defines steatitization as that process of hydrothermal alteration of an ultrabasic rock which in its final stages results in the formation of a talcose rock. It may be applied to the processes by which either soapstones or relatively pure concentrations of talc are formed. Soapstones are rocks containing talc, carbonate (generally present), and more or less chlorite as essential minerals.

Soapstones and related carbonate-quartz rocks are abundant in the Fort St. James area. Talc-carbonate rocks predominate in the southern half of the Mount Sydney Williams peridotitic batholith, underlying most of the area between Baptiste Creek and Trembleur Lake. As previously described, an area of about 8 square miles forming the southern third of the ultrabasic stock exposed in the southern part of Mitchell Mountains consists, in large part, of a rock composed of olivine in a talc matrix. In addition to these two large masses of soapstone, most of the ultrabasic bodies have been hydrothermally altered to talc-carbonate-quartz-chlorite-mariposite rocks along zones of shearing, faulting, and fracturing. These minerals occur in varying proportions, and two main rock types have been recognized, namely: carbonate-quartz-mariposite rocks, and talc-carbonate rocks. The zones of altered rocks vary in width from 10 to 500 feet or more, and in length from 25 feet to about a mile. Some of the smaller ultrabasic sills that lie along major fault zones, such as the Pinchi fault zone, have been completely altered to carbonate-quartz-mariposite rocks.

Wherever exposed the ultrabasic rocks exhibit zones of altered rock along their borders. Such zones consist of talc, chlorite, actinolite, and tremolite, and are especially pronounced along the contacts of serpentine and siliceous sedimentary rocks (*See* p. 91).

Carbonate-quartz-mariposite rocks predominate along fault, shear, and fracture zones, whereas most of the talc-carbonate rocks form large bodies of massive soapstone in which there is no apparent evidence of structural failure.

The carbonate-quartz-mariposite rocks are medium to coarsely crystalline and weather buff to yellow-brown. Buff-coloured carbonate, quartz, and bright apple-green mariposite[1] are distinguishable in hand specimens. On fresh surfaces the rock commonly is a vivid apple-green, due to the presence of mariposite, although this mineral in no place constitutes more than 5 per cent of the rock and usually amounts to less than 1 per cent. The great bulk of the rock, 80 to 90 per cent on the average, is an ankeritic carbonate, a variety with indices of refraction: $\omega = 1 \cdot 698$, $\varepsilon = 1 \cdot 539$. Mixed with the carbonate is 10 to 15 per cent of cherty quartz, probably formed in situ. A rough analysis of carbonate-quartz rock from the small body of altered serpentine near the Pinchi Lake mercury mine is as follows: $MgCO_3$, 56·4 per cent; $CaCO_3$, 16·1 per cent; $FeCO_3$, 16·2 per cent; and insoluble, largely silica, 12·0 per cent. These rocks are generally traversed by a network of magnesite veinlets and milky white quartz stringers that constitute 5 to 10 per cent of the whole. They vary in width from a fraction of an inch to 4 inches. On the south face of Pinchi Mountain a few veins of magnesite, 1 to 4 feet wide, were observed cutting carbonate-quartz rock along the Pinchi fault zone where it crosses a body of pyroxenite. Irregular masses of magnesitic carbonate up to 25 feet across and veined by cherty quartz were also observed here. In most thin sections carbonate was observed replacing serpentine, although in several late hydrothermal serpentine veinlets cut the carbonate.

The carbonate-quartz-mariposite type of alteration was presumably brought about by dilute carbonate solutions rising along channelways provided by fault, shear, and fracture zones. The following equation may represent in part the alteration of serpentine to carbonate:

$$H_4Mg_3Si_2O_9 + 3CO_2 = 3MgCO_3 + 2SiO_2 + 2H_2O$$

Serpentine + carbon dioxide = magnesite + silica + water

As most of the carbonate is ankeritic and not pure magnesite, the iron and calcium must be accounted for. The iron probably came from the serpentine, as iron protoxide in many cases replaces a small part of the magnesia in serpentine. The calcium may have been absorbed from rocks with which the solutions came in contact. The cherty quartz mixed with the ankeritic carbonate may be the silica released according to the equation.

The talc-carbonate rocks are greenish buff, have a greasy feel, and are composed on the average of 60 per cent talc and 40 per cent ankeritic carbonate. Specks of magnetite, chromite, and pyrite occur as accessory minerals. The high percentage of talc imparts a dense appearance to these rocks. This type of alteration was presumably brought about also by dilute carbonate solutions. The chemical reaction might be expressed as follows:

$$2H_4Mg_3Si_2O_9 + 3CO_2 = H_2Mg_3(SiO_3)_4 + 3MgCO_3 + 3H_2O$$

Serpentine + carbon dioxide = talc + magnesite + water

This equation, it will be noted, differs from the first only in the larger proportion of carbon dioxide to serpentine. The talc and carbonate replace serpentine, pyroxene, and olivine. In most instances this replacement is selective, serpentine being replaced first, pyroxene next, and olivine last. In some thin sections talc was observed as perfect pseudomorphs after pyroxene, the pyroxene twinning still preserved.

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[1] This mica is probably mariposite, and belongs to the mariposite-fuchsite-muscovite group, which forms part of a gradational series. 2V = approximately 0 degrees, indicating mariposite.

CONTACT REACTION ZONES

Hess[1] defines contact reaction zones as follows: "Where two solid rocks are in contact with each other, the one a serpentinite and the other a siliceous sediment or its metamorphosed equivalent, perhaps a quartz-mica schist, there is a strong contrast in chemical compositions. The permeation of hydrothermal solutions along such contacts results in an interchange of material between them as well as recrystallization of both rocks to form minerals stable under the conditions obtaining. The alterations thus formed on either side of the contact will be called contact reaction zones."

Contact reaction zones were observed along the contact of the Mount Sydney Williams peridotite batholith on the southwest face of the mountain, along the southwestern contact of the peridotite stock outcropping in the southern part of Mitchell Mountains, and along the borders of some of the sills outcropping between Mount Sydney Williams and Tsitsutl Mountain. The contact zone on the southwest face of Mount Sydney Williams is 50 to 100 feet wide, and comprises talc and some carbonate. On the argillite side of the contact the talc-carbonate zone grades into a chlorite zone, which in turn passes into a partly amphibolitized argillite. On the serpentinized peridotite side of the contact a gradation from talc-carbonate to serpentine, with carbonate veinlets, to serpentine was observed. In some places actinolite crystals occur in the talc-carbonate zone and in the serpentine-carbonate veinlet zone. The southern part of the Mitchell Mountains peridotite stock cuts cherty and argillaceous rocks. Wherever the contact was observed it forms a zone about 10 feet wide of tremolite schist. This zone grades into talc-carbonate-serpentine rock on one side and into chloritic cherty rock on the other. The contact zones observed along some of the sills outcropping between Mount Sydney Williams and Tsitsutl Mountain are similar to those just described. Most contacts are marked by trenches resulting from the rapid weathering of the talcose rocks.

Hess[2] states that the mineral succession series—hornblende, actinolite (tremolite), chlorite, talc, and carbonate—is characteristic of steatitization, and if the temperature is sufficiently high when alteration commences hornblende will be the first mineral to form, otherwise any lower temperature mineral may form first.

STRUCTURAL RELATIONS AND AGE

The Trembleur intrusions are believed to be partly or wholly of pre-Upper Triassic age. Except for the small peridotite mass forming a pendant in Omineca granodiorite in the northern part of Mitchell Mountains, they are confined to and cut Cache Creek rocks of Permian and probable Pennsylvanian ages. At no place were they observed intruding Upper Triassic or younger rocks, whereas, on the north shore of Pinchi Lake, an Upper Triassic conglomerate contains pebbles of serpentine and grains of chromite as well as pebbles of Cache Creek rocks, suggesting a nearby landmass from which both Cache Creek and ultrabasic rocks were being eroded. Near Pinchi Mountain and Murray Ridge ultrabasic intrusions apparently come in contact with post-Permian rocks, but in both places the actual contacts are concealed by glacial drift. The Trembleur intrusions are cut by dioritic rocks of the Topley intrusions of possible pre-Jurassic age and by granitic

[1] Hess, H. H.: Metamorphic Differentiation at Contacts Between Serpentinite and Siliceous Country Rocks; Am. Min., vol. 21, No. 6, June 1936, p. 334.

[2] Hess: op. cit., pp. 636-637.

members of the Omineca intrusions of Upper Jurassic or Lower Cretaceous age. As already referred to in discussing the Cache Creek group, the interval between Middle Permian and Upper Triassic time was apparently one of uplift, erosion, and probable intrusion of the ultrabasic rocks. The Topley intrusions were also probably emplaced during this interval.

Ultrabasic rocks of probable Upper Jurassic or Lower Cretaceous age are included with the Omineca intrusions in the Fort St. James and adjoining Aiken Lake and McConnell Creek map-areas on the north and northwest. These younger ultrabasic rocks are mainly hornblendite and pyroxenite, but include minor peridotite. Some of the rocks of the Fort St. James map-area mapped as Trembleur intrusions but whose age relations could not be determined may also be of the same age as these Omineca intrusions.

Topley Intrusions

The name Topley intrusions has been applied to a group of acidic intrusive rocks of probable pre-Jurassic age. They were first recognized in the Topley area, adjoining the Fort St. James area to the west immediately south of Babine Lake, and were then thought to be of pre-Jurassic age (70, pp. 56-59). More than 600 square miles of the southern part of the Fort St. James area are underlain by Topley or similar intrusions. The exposed masses range in size from stocks less than a mile in diameter to batholithic bodies occupying areas of as much as 250 square miles. Gently dipping volcanic strata of the Tachek and Endako groups overlie the Topley intrusions in many places, and it is probable that most of the exposed areas of Topley intrusions form parts of one batholith extending from Topley east to Vanderhoof and from Stuart and Babine Lakes south to François Lake. If so, it would have an area of at least 1,500 square miles. The Topley intrusions consist mainly of granite, diorite, and syenite.

LITHOLOGY

Granite. Granite is exposed over an area of about 250 square miles between Fraser Lake and Shovel Creek. Another large body of granite, 90 square miles in area, lies northeast of the village of Burns Lake. In the outcrop these granitic rocks vary considerably, and two distinct varieties may be distinguished: (1) pink granite, and (2) grey or grey-green granite and granodiorite. The pink granite, which is the most prevalent type, ranges from a very coarse pegmatitic rock to fine-grained granite. In most places it is coarse grained and either porphyritic or non-porphyritic, and consists of pink and white feldspar, quartz, biotite, and hornblende. In the porphyritic varieties the pink feldspar normally occurs in large, well-formed crystals up to 2 inches long, whereas the white feldspar and quartz form the matrix. The grey and grey-green, granitic rocks are porphyritic and non-porphyritic, medium- to fine-grained rocks consisting mainly of white feldspar. They range in composition from granite to granodiorite, and grade into one another.

Numerous thin sections of the pink granitic rocks were studied under the microscope, and analyses made by the Rosiwal method show that most of them are normal granites (*See* Figure 2 and Table VI). Border phases are dioritic in composition.

The following table gives the modes of specimens collected from Topley granite masses, as determined from Rosiwal analyses.

Table VI

Modes of Specimens from Topley Pink Granites

Specimen number	Location	Name	Quartz	Potash feldspar (orthoclase and microcline)	Plagioclase feldspar Al. albite Ol. oligo-clase An. ande-sine By. by-townite	Biotite	Horn-blende	Augite	Miscellaneous
				Main Intrusions					
			%	%	%	%	%	%	%
1	Molydenum property south of Endako.	Granite........	40·3	46·9	4·6, Ol.	6·5	....	....	Accessory minerals.. 1·3
2	Railway cut 2 miles west of Endako.	Granite........	32·3	32·6	15·7, Ol.	....	....	....	Chlorite............14·1 Accessory minerals.. 4·8
3	Head of Savory Creek.........	Granite.......	38·1	51·7	10·2, Ol.	....	....	....	Accessory minerals.. 0·4
4	Railway cut 3 miles east of Priestly.	Granite.......	27·6	59·6	9·5, Ol.	....	....	....	Chlorite............ 1·8 Accessory minerals.. 1·7
5	Two miles south of Hanson Lake.	Granite.......	26·6	48·0	11·4, Ol.	....	13·0	....	Accessory minerals.. 0·4
6	Taltapin property.............	Granite.......	37·0	56·0	5·0, Al.	....	....	....	Accessory minerals.. 2·0
7	Sunrise claim.................	Granite.......	35·6	42·0	20·7, Ol.	1·8	....	....	Accessory minerals.. 0·3
8	Fraser Lake railway cut.......	Granite.......	20·8	43·3	30·1, Ol.	3·8	....	....	Chlorite............ 1·9
11	South of Fraser Lake..........	Granite.......	32·4	56·2	11·4, Ol.	....	....	....	....
				Border Phases					
9	Fraser Lake railway cut.......	Granodiorite. .	7·1	10·5	61·0, An.	....	19·0	....	Magnetite.......... 2·4
10	Near Fraser Lake............	Diorite.......	....	....	65·0, An.	2·0	32·0	....	Magnetite.......... 1·0
12	South of Fraser Lake..........	Diorite.......	....	....	74·3, By.	....	....	25·7	....
13	Justine Lake..................	Tonalite.......	8·6	....	Altered 55·8	....	31·5	....	Chlorite............ 4·1

An examination of thin sections of the grey granitic rocks revealed that they contain more plagioclase feldspar and less orthoclase feldspar than the pink granites. They are composed, on the average, of about 20 per cent orthoclase and microline, 35 per cent oligoclase, and 20 per cent hornblende, biotite, and chlorite.

A granitic stock, 8 square miles in area, outcrops north of Wright Bay, Babine Lake. Normally it is a grey, medium-grained granite, but all gradations between grey, pink, and white varieties are found. Locally this granite is foliated, the strike of the foliation being north 50 degrees east.

Muscovite granite, probably of the same age as the Topley granites, occupies 27 square miles on the north side of Babine Lake opposite Donald Landing. It is a coarse-grained, white rock composed of approximately 40 per cent quartz, 55 per cent white feldspar, and 3 per cent muscovite.

On the west side of Taltapin Mountain, a small body of granodiorite and granite is exposed. Most of it is a light greenish grey granodiorite, but this grades into a pink granite lithologically similar to Topley granite. It cuts the Topley diorite outcropping nearby and may be much younger.

Diorite. The largest body of diorite, between Stuart Lake and Babine Lake and Sutherland River, is about 225 square miles in area. A second large body of diorite, about 75 square miles in area, extends from Taltapin Mountain to 5 miles south of Taltapin Lake. These diorites are green, medium- to coarse-grained rocks characterized by abundant hornblende. Rosiwal analyses show them to be mainly normal hornblende diorites (*See* Figure 2 and Table VII).

The following table gives the modes of specimens collected from Topley diorite masses, as determined from Rosiwal analyses.

TABLE VII

Modes of Specimens from Topley Diorites

Specimen number	Location	Name	Quartz	Potash feldspar (orthoclase and microcline)	Plagioclase feldspar (andesine)	Biotite	Horn-blende	Augite	Miscellaneous
			%	%	%	%	%	%	%
16	South slope Taltapin Mountain.	Diorite........	1·0	....	45·0	....	47·3	0·9	Accessory minerals.. 6·1
17	Radio Gold property..........	Diorite........	....	....	52·5	....	40·5	3·4	Accessory minerals.. 3·5
18	Grizzly (Shass) Mountain......	Diorite........	0·9	....	37·3	....	61·3	....	Magnetite........... 0·5
19	Grizzly (Shass) Mountain......	Granodiorite..	15·8	5·4	56·4	4·7	17·7	....	....

The diorite body north of Babine Lake shows well-developed foliation that strikes northwesterly conforming with the strike of the intruded Cache Creek rocks. The foliation is apparent over a large part of this body, but is not always equally well defined, and in places is absent. In a few places it assumes the character of alternating bands of hornblende with others of feldspar, but normally only a parallel orientation of the hornblende grains is shown, without segregation of light and dark minerals into distinct bands. Most hand specimens show less evidence of foliation than the exposures from which they were obtained. The diorite body south of Babine Lake is less well foliated than the Babine Lake intrusion.

Stocks of hornblende and augite diorite, probably of the same age as the Topley diorites, outcrop along the south shore of Rubyrock Lake and a mile west of Stuart Lake respectively. The hornblende diorite stock south of Rubyrock Lake is about a mile in diameter, and is a medium-grained, grey rock stained reddish brown at the surface. It is composed largely of chloritized hornblende and saussuritized feldspar. The augite diorite west of Stuart Lake is exposed over an area of about 3 square miles. It is a medium-grained, grey-green rock stained reddish brown, and is composed essentially of augite and plagioclase feldspar.

Syenite. Exposed along the ridge lying between Wright Bay, Babine Lake, and Tochcka Lake are two irregular areas of albite syenite totalling 12 square miles in area. This syenite is a medium-grained, grey-brown rock that weathers reddish brown, due to the presence of pyrite. It contains 90 to 95 per cent albite, 2 to 8 per cent hornblende, and less than 2 per cent quartz and accessory minerals.

STRUCTURAL RELATIONS AND AGE

It is possible that the various bodies of Topley intrusions here referred to were not all intruded during the same period of igneous activity, but no conclusive evidence of this has been obtained. Their relations to one another are known only in a few places. The granodiorite-granite stock exposed on the west slope of Taltapin Mountain intrudes the diorite body outcropping nearby. This stock is believed to be of the same age as the Topley granite batholiths, although it may possibly be younger. The muscovite granite outcropping north of Babine Lake opposite Donald Landing grades into diorite to the east. No other contacts between granite, diorite, and syenite were observed.

The Topley intrusions are probably of pre-Lower Cretaceous age and are possibly of post-Middle Permian, pre-Upper Triassic age. This conclusion is based on the following evidence.

(1) In the Topley map-area a thin group of sedimentary strata lies unconformably upon the granite and conformably below Tachek volcanic rocks. It provided a collection of fossil plants containing the genus *Otozamites*, which is characteristically a Jurassic genus although ranging from Triassic to Lower Cretaceous. In discussing the age of the Tachek group evidence was presented in support of a Jurassic age for these plants and the sedimentary strata in which they are found; therefore, the underlying granite would be Jurassic or older. If the slight possibility of a Lower Cretaceous age is not excluded the granite would be at least as old as Upper Jurassic.

(2) No contacts of the Topley granite and rocks of the Hazelton group are exposed, so it is not known whether the granite is pre-Hazelton or post-Hazelton, although the available evidence would suggest pre-Hazelton. The Hazelton group strata comprise a conformable succession ranging in age from Jurassic to Lower Cretaceous; therefore, if the Topley granite were post-Hazelton it would be post-Lower Cretaceous, which in view of the evidence already cited is most improbable. The Tachek volcanic rocks, which conformably overlie the fossiliferous sedimentary rocks referred to above, include a basal breccia containing many fragments of granite, and are lithologically similar to some of the volcanic rocks of the Hazelton group.

(3) The Topley intrusions cut Cache Creek rocks of Permian age and are, therefore, post-Middle Permian. They also cut the Trembleur intrusions of probable pre-Upper Triassic age. At no place do the Topley intrusions come in contact with Takla group rocks of Upper Triassic to Jurassic age, so their relations are unknown. However, as they are apparently confined to areas of Cache Creek rocks it is quite possible they are of pre-Takla age.

(4) As previously noted, the period between Middle Permian and Upper Triassic was, apparently, a time of uplift, erosion, and probable intrusion of the Trembleur ultrabasic rocks. Possibly the Topley intrusions represent a later, more acidic, phase of the igneous activity responsible for the Trembleur intrusions.

(5) The Topley intrusions are older than the Bulkley intrusions of post-Paleocene age to the west and the Omineca intrusions of Upper Jurassic or Lower Cretaceous age to the north. The Bulkley and Omineca intrusions are mainly of granodiorite and syenodiorite, whereas the Topley intrusions are characteristically granite and diorite.

(6) Recent field work in the Aiken Lake map-area (17) adjoining the Fort St. James area on the north has also yielded evidence of pre-Jurassic intrusions. Along Thane Creek and near the Vega mine a lower Lower Jurassic volcanic formation of the Takla group contains numerous pebbles and cobbles of granodiorite. Several outcrops of the same granodiorite outcrop along Thane Creek, but their contacts with Takla group rocks are drift covered. West of Uslika Lake a basal conglomerate of the Takla group contains well-rounded pebbles of diorite and granodiorite. This conglomerate is probably of Lower Jurassic or earlier age.

(7) Bodies of Topley intrusions are commonly equidimensional in outline, whereas bodies of Omineca intrusions are generally elongated in a northwest direction, parallel with the regional trend of deformation, suggesting that they were intruded at a later date than the Topley rocks.

(8) The Topley intrusions are deeply eroded and commonly form basement rocks on which younger formations were deposited, whereas the Omineca and younger intrusions are only partly eroded and generally form the cores of mountain ranges.

Omineca Intrusions

The name Omineca intrusions has been applied in this report to numerous bodies of intrusive rocks, believed to be of Upper Jurassic or Lower Cretaceous age, that are exposed in the Omineca Mountains. They range in size from small sills and dykes to batholiths, and in composition from granite to pyroxenite, with granodiorite predominating.

LITHOLOGY

Hogem Batholith

(*See* Figures 2 and 4)

The largest known body of Omineca intrusions is the Hogem batholith, which extends from Chuchi Lake northwest 75 miles across the Fort St. James map-area and beyond into the Aiken Lake and McConnell Creek map-areas. It underlies an area of at least 1,200 square miles, about one-half in the Fort St. James area, and varies in width from 4 to 25 miles. This batholith has apparently differentiated in place into a granodiorite-granite core with syenodiorite or more basic rock forming a border zone from a fraction of a mile to several miles wide. The various types grade imperceptibly into one another.

The main body of the batholith is composed of grey to pink granodiorites and granites. The granodiorites are generally grey and the granites pink, although this is not everywhere true. Both types range from medium-grained, equigranular rocks to coarse-grained, porphyritic types carrying pink feldspar phenocrysts, generally orthoclase or microcline, as much as an inch or more long. A detailed microscopic examination of twenty-five representative samples showed six of them to be granite and nineteen granodiorites, illustrating roughly the proportions of the two main types. No regular distribution of granodiorite or granite was observed. The average mode, as determined by Rosiwal analyses of the twenty-five sections studied, was that of a granodiorite containing 19·5 per cent quartz, 30·1 per cent orthoclase and microcline, 42·4 per cent oligoclase or andesine, 7 per cent hornblende, biotite, and chlorite, and 1 per cent accessory apatite, sphene, and magnetite (*See* Table VIII and Figure 2). In the porphyritic varieties, microcline generally forms the phenocrysts. Much of the plagioclase feldspar is zoned. In a few thin sections, especially of the granites, microperthitic intergrowths of plagioclase in microcline were observed. Alteration of the feldspars to sericite, zoisite, and saussurite is common. Green hornblende is the dominant ferromagnesian constituent, although in places it is replaced by dark brown biotite in ragged flakes. Some of the biotite has been derived from the hornblende. Both the biotite and hornblende have been altered in part to chlorite.

The border phases consist mainly of green, medium- to coarse-grained syenodiorites. A microscopic study of twelve thin sections shows these rocks to be composed of as much as 2·5 per cent quartz, 11·9 to 26·9 per cent orthoclase and microcline, 28·4 to 68·2 per cent plagioclase feldspar (mainly andesine), 6·7 to 42·7 per cent ferromagnesian minerals, 0·5 to 5·3 per cent magnetite, and 3·5 per cent apatite and sphene. The average mode of ten specimens, as determined by the Rosiwal method, is as follows: 0·5 per cent quartz, 22·4 per cent orthoclase and microcline, 51·0 per cent andesine, 23·5 per cent ferromagnesian minerals, 1·6 per cent magnetite, and 1·0 per cent apatite and sphene (*See* Table VIII and Figure 2). Augite is the common ferromagnesian mineral; it is normally partly altered to green uralite, dark brown biotite, and chlorite. The abundance of magnetite is characteristic. These syenodiorites are best exposed along the eastern border of the batholith east of Duckling Creek, where they grade into granodiorite and diorite.

Diorite is well exposed near the west end of Chuchi Lake. It is a coarse-grained, dark green rock consisting mainly of andesine feldspar (generally saussuritized), augite (in part chloritized and epidotized), a minor amount of quartz, and accessory magnetite, apatite, and sphene. The average mode of three specimens is: 3·3 per cent quartz, 58·9 per cent andesine, 36·7 per cent augite and alteration products, and 1 per cent accessory minerals.

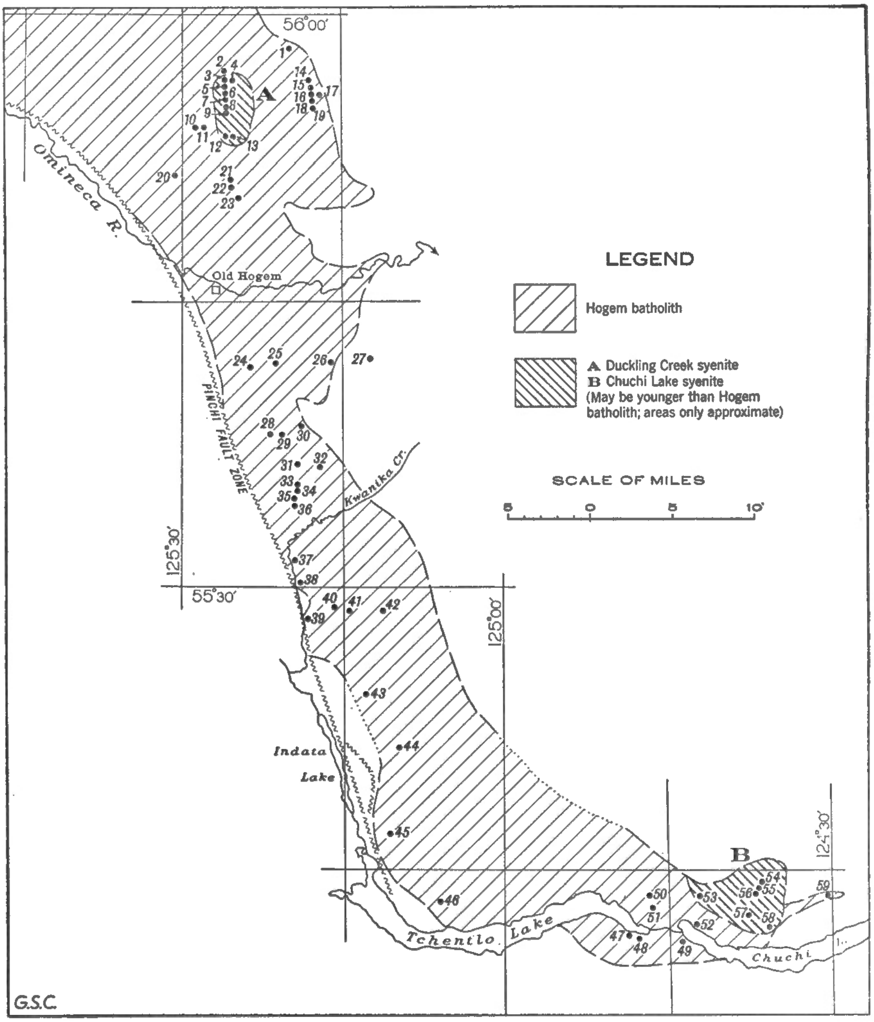

Figure 4. Diagram of Hogem batholith, showing location of specimens collected and studied.

Gabbroic rocks are exposed along the western border of the batholith east of Indata Lake and the upper end of Tchentlo Lake. They are coarse-grained, dark green rocks consisting mainly of bytownite feldspar and augite, with minor amounts of orthoclase feldspar and accessory minerals. Rosiwal analyses on two specimens yielded: 5·9 per cent orthoclase, 45·9 per cent bytownite, 38·4 per cent augite, 4·4 per cent chlorite, 5·5 per cent magnetite, and 0·8 per cent apatite and sphene. The chlorite is an alteration product of the augite. These gabbros grade into pyroxenites.

The contacts of the Hogem batholith are generally well defined, although the intruded rocks are cut by numerous granitic, aplitic, and lamprophyric dykes near the borders of the batholith. In places, however, the contacts of the batholith appear gradational.

The following table gives the modes of specimens collected from the Hogem batholith, as determined from Rosiwal analyses; specimen numbers correspond with those of locations shown on Figure 4.

Table VIII
Modes of Specimens from Hogem Batholith

Specimen number	Name	Quartz	Potash feldspar (orthoclase and microcline)	Plagioclase feldspar Al. albite Ol. oligoclase An. andesine By. bytownite Alt. plag. altered plagioclase	Horn-blende	Pyroxene	Biotite	Chlorite	Mag-netite	Apatite	Miscellaneous Alt. prod. alteration products
	Main Batholith										
		%	%	%	%	%	%	%	%	%	%
10	Granodiorite........	18·2	18·0	60·0, Ol.	2·5	—	—	—	0·9	—	0·4 sphene
11	Granite.............	9·7	50·6	35·6, Ol.	1·2	—	—	0·9	1·0	0·4	0·2 sphene
20	Granite (2 specimens)......	17·9	57·3	23·5, Ol.	1·0	—	—	—	—	—	—
21	Granodiorite........	23·7	7·2	58·1, An.	10·7	—	—	—	—	—	0·3 sphene
22	Granodiorite........	17·3	9·7	55·7, An.	15·3	—	—	—	—	—	2·0 sphene
23	Granodiorite........	18·3	37·0	37·4, An.	6·4	—	—	—	—	—	0·9 sphene
24	Granodiorite........	21·0	30·6	40·5, Ol.	1·0	—	—	4·5	1·2	—	1·2 sphene
25	Granodiorite........	17·9	29·8	42·3, Ol.	3·8	—	0·7	4·0	1·0	0·2	0·3 sphene
27	Granodiorite........	12·5	29·2	41·7, Alt. plag.	4·0	—	4·0	8·2	0·4	—	—
28	Granodiorite........	24·4	12·1	53·4, Ol. Alt. plag.	—	—	*—	5·4	0·9	—	3·8 epidote

TABLE VIII—*Conc.*

Specimen number	Name	Quartz	Potash feldspar (orthoclase and microcline)	Plagioclase feldspar Al. albite Ol. oligoclase An. andesine By. bytownite Alt. plag. altered plagioclase	Horn-blende	Pyroxene	Biotite	Chlorite	Mag-netite	Apatite	Miscellaneous Alt. prod. alteration products
29	Granite............	21·3	41·2	31·3, Ol. Alt. plag.	—	—	—	1·8	—	—	4·4 Alt. prod.
30	Granodiorite........	27·1	18·9	46·4, Ol. Alt. plag.	—	—	—	—	1·3	—	6·3 Alt. prod.
31	Granite............	20·5	40·4	35·2, Ol. Alt. plag.	—	—	—	—	0·9	—	3·0 Alt. prod.
32	Granodiorite........	18·0	22·6	48·3, Ol.	—	—	—	9·0	1·1	1·0	—
33	Granodiorite........	32·4	30·3	36·6, Ol.	—	—	0·7	—	—	—	—
34	Granodiorite........	20·7	33·0	46·3, Ol.	—	—	—	—	—	—	—
35	Granite............	36·5	32·9	29·8, Al.	—	—	0·5	0·3	—	—	—
36	Granodiorite........	20·3	13·3	59·0, Ol. Alt. plag.	5·3	—	—	—	—	1·0	1·1 sphene
39	Granodiorite........	12·5	29·4	41·6, Ol.	—	—	—	—	—	—	16·4 Alt. prod.
40	Granodiorite........	6·9	35·7	43·9, Al.	12·9	—	—	—	—	—	0·6 sphene
41	Granite............	34·1	41·9	18·1, Ol.	—	—	5·6	—	0·2	—	0·1 sphene
42	Syenodiorite.........	3·6	23·3	60·3, An.	10·6	—	—	—	1·2	—	1·0 sphene
43	Granodiorite........	8·8	22·1	64·8, An.	2·9	—	—	—	1·4	—	—
50	Granodiorite........	19·5	22·8	44·9, Ol.	6·7	—	—	6·1	—	—	—
51	Granodiorite........	10·0	27·5	47·3, Ol.	11·4	—	—	3·0	0·8	—	—

Border Phases of Main Batholith

1	Syenodiorite.......	—	26·9	46·6, An.	—	18·2	3·0	—	5·3	—	—
2	Syenodiorite.....	—	22·1	28·4, An.	—	30·5	12·6	—	2·5	1·4	2·1 sphene
14	Syenodiorite.....	—	24·6	40·6, An.	—	31·4	—	—	2·4	1·0	—
15	Syenodiorite.....	—	20·1	54·7, An.	—	21·3	—	—	2·2	1·0	—
16	Syenodiorite.........	1·6	11·9	54·5, An.	22·6	—	5·3	—	2·2	1·9	—
17	Syenodiorite.........	2·5	23·2	59·0, An.	—	13·5	0·7	—	0·6	0·5	—
18	Granite.............	7·0	49·0	21·0, An.	—	23·0	—	—	—	—	—
19	Syenodiorite.........	2·1	24·6	50·5, An.	—	20·5	—	—	2·3	—	—
26	Syenodiorite.........	—	25·6	68·2, An.	1·2	—	—	4·5	0·5	—	—
37	Syenodiorite.........	3·5	29·5	59·0, An. Alt. plag.	4·5	—	—	—	—	—	3·3 alt. prod.
38	Syenodiorite.........	—	18·4	53·8, An.	3·2	20·1	3·9	—	0·6	—	—
44	Gabbro............	—	3·0	27·4, By.	—	60·7	—	2·9	5·9	—	—
45	Gabbro............	—	8·8	62·5, By.	—	16·1	—	5·9	5·0	1·7	—
46	Diorite......	—	—	62·5, An.	37·5	—	—	—	—	—	—
47	Diorite.............	3·1	?	45·4 Alt. plag.	15·3	—	—	—	—	—	18·3 epidote 12·7 alt. prod. 2·1 sphene
48	Diorite.............	7·0	?	68·8 Alt. plag.	23·2	—	—	—	1·0	—	—
49	Syenite....	—	56·3	19·6, An.	—	12·9	—	5·2	2·4	1·6	—
52	Syenodiorite.........	—	26·5	53·2, An.	—	6·1	—	13·5	0·7	0·3	—
55	Syenodiorite.........	—	75·0	Altered feldspar	14·0	—	9·0	—	2·0	—	—
59	Syenodiorite.........	—	17·4	64·1 Alt. plag.	4·8	—	—	13·7	—	—	—

Germansen Batholith

(*See* Figures 2 and 3)

The Germansen batholith outcrops between Tsaydaychi and Germansen Lakes, and occupies an area of about 300 square miles. It consists mainly of grey to pink, medium- to coarse-grained, equigranular granodiorite and granite. In places it grades into a coarse-grained porphyritic rock with pink orthoclase and microcline feldspar phenocrysts up to an inch or more long. Rosiwal analyses made on thin sections of fourteen selected samples indicate a batholith of fairly uniform composition, and in which the border facies are much the same in mode as the core. Of the fourteen samples analysed nine were granodiorites, four granites, and one a syenitic rock on the border between a syenite and granite. The average mode of the fourteen specimens is as follows: 29·4 per cent quartz, 23·2 per cent orthoclase and microcline, 37·8 per cent oligoclase, 3·1 per cent microperthite, 4·7 per cent biotite, and 2 per cent hornblende, muscovite, chlorite, apatite, and sphene (*See* Table XI and Figure 2). The quartz generally forms a mosaic and is characterized by strain shadows.

A small stock of coarse-grained, pink, porphyritic granodiorite exposed near Klawli Lake has been included with the Germansen batholith. A Rosiwal analyses of one thin section gave 17·7 per cent quartz, 5·9 per cent microline and orthoclase, 70·5 per cent oligoclase, 2·9 per cent chlorite, and 2·9 per cent magnetite.

Comparison of Germansen and Hogem Batholiths

Germansen Batholith	*Hogem Batholith*
Uniform composition with no basic border phases	Basic border phases
Higher in quartz; quartz in mosaic, and many strain shadows	Quartz in fairly large grains and relatively unstrained
Biotite only ferromagnesium mineral in any quantity	Hornblende and pyroxene common ferromagnesium minerals
Muscovite characteristic	No muscovite
Very little magnetite	Magnetite abundant
Sugary appearance	

The following table gives the modes of specimens collected from the Germansen batholith, as determined from Rosiwal analyses; specimen numbers correspond with those of locations shown on Figure 5.

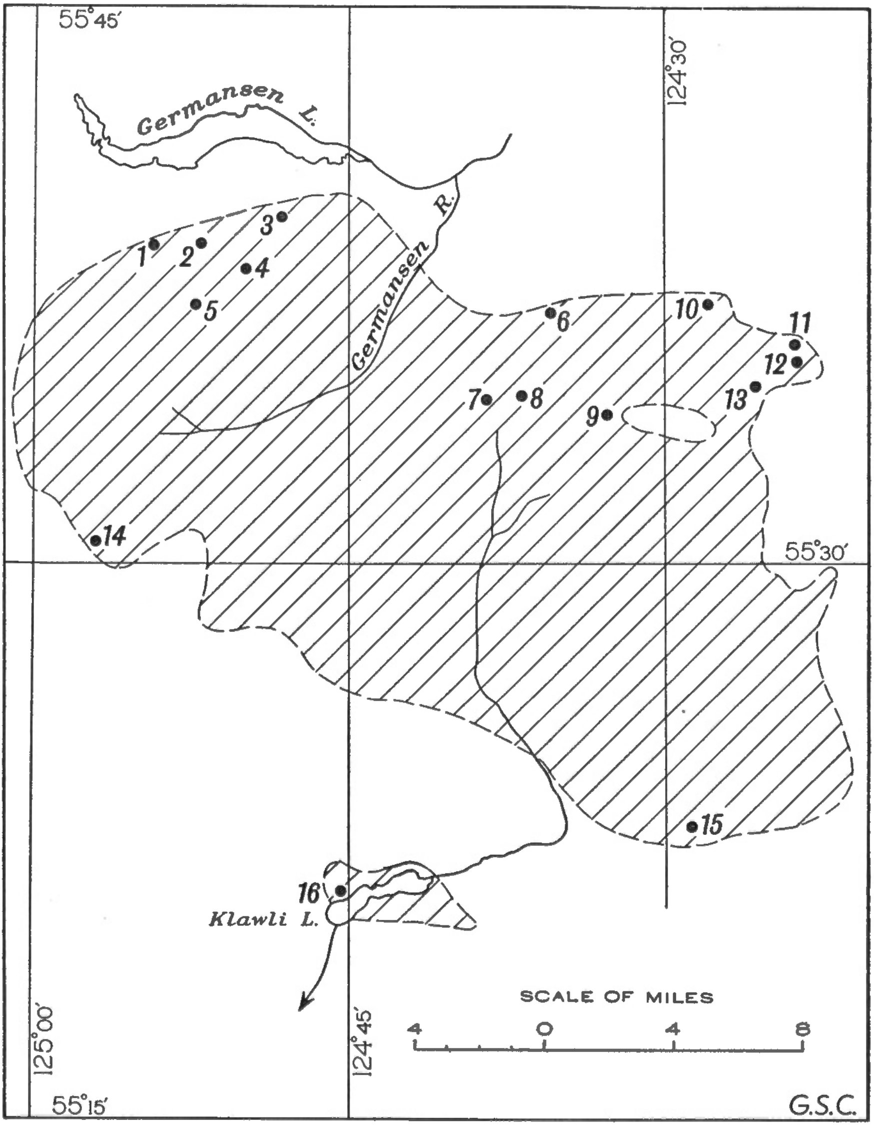

Figure 5. Diagram of Germansen batholith, showing location of specimens collected and studied.

Table IX

Modes of Specimens from Germansen Batholith

Specimen number	Name	Quartz	Potash feldspar (orthoclase and microcline)	Plagioclase feldspar (oligoclase)	Micro-perthite	Biotite	Miscellaneous
		%	%	%	%	%	%
1	Granodiorite	27·5	13·3	46·2	—	12·3	0·7 apatite
2	Granodiorite	50·3	12·6	28·5	—	6·8	1·0 epidote 0·8 sphene
3	Granodiorite	28·8	23·3	38·6	0·7	4·6	3·5 hornblende 0·5 apatite
4	Granodiorite	23·7	17·8	47·6	—	1·8	9·1 chlorite
5	Granodiorite	34·7	5·9	45·8	—	10·9	2·1 hornblende 0·7 apatite
6	Granodiorite	36·8	11·9	47·5	—	3·8	Minor accessory minerals
8	Granite	37·3	24·8	27·9	4·7	5·3	Minor accessory minerals
9	Granodiorite	31·6	9·3	43·0	10·3	4·6	1·2 muscovite
10	Granite	24·2	52·8	12·2	4·4	4·4	2·0 muscovite
11	Syenite	4·7	45·5	37·4	6·5	—	5·9 muscovite
12	Granite	24·2	27·6	30·0	12·8	3·7	1·7 muscovite
13	Granite	36·3	31·8	27·3	—	2·3	2·3 muscovite
14	Granodiorite	23·8	17·3	54·6	4·3	—	Minor accessory minerals
15	Granodiorite	20·4	31·2	42·6	—	5·8	Minor accessory minerals
16	Granodiorite	17·7	5·9	70·5	—	—	2·9 chlorite 2·9 magnetite

Mitchell Batholith

The Mitchell batholith forms the backbone of Mitchell Mountains on the east side of Takla Lake. It intrudes Cache Creek rocks, occupies an area of about 160 square miles, and consists mainly of coarse-grained pink granite, in part porphyritic, with a border phase of grey, medium-grained, equigranular diorite. The granite is composed of quartz, orthoclase and microcline, oligoclase, microperthitic intergrowths, biotite, and minor accessory minerals. The orthoclase and microperthite generally form pink crystals up to an inch long. Rosiwal analyses on two thin sections indicated the following average composition: quartz, 28·5 per cent; orthoclase, microcline, and microperthite, 49·5 per cent; oligoclase, 16·5 per cent; biotite, 5·5 per cent; and minor accessory minerals (*See* Figure 2). Only a very rapid field examination was made of this batholith, and although it appeared to be mainly pink granite, in places it was a grey granodiorite, and a more complete study might reveal much more granodiorite as in the case of the other larger Omineca intrusions.

The border phase, which varies in width from a fraction of a mile to several miles, is a normal diorite. A Rosiwal analysis on one specimen indicated the following mode: 43·5 per cent andesine, 51·6 per cent hornblende, 1·3 per cent biotite, 2·4 per cent magnetite, and 1·1 per cent apatite (*See* Figure 2). Pink granitic stringers 1 inch to 1 foot wide cut the diorite. The differentiation exhibited in this batholith seems to be more complete than in the Hogem batholith; in this respect and in its granitic composition the Mitchell batholith is more similar to the Topley than to the Omineca intrusions, and it may be that it belongs with them. However, in general appearance it more nearly resembles the Omineca intrusions, with which it has been mapped.

Goat Mountain Stock

The northern part of the Middle River Range is underlain by a granitic stock, which is exposed over an area of about 45 square miles. The central part of the stock consists of medium-grained, equigranular, grey soda granite. The border phase consists mainly of normal pink granite, with some syenite. Rosiwal analyses of two specimens of the grey soda granite yielded the following average mode: 41·6 per cent quartz, 44·3 per cent albite, 11·0 per cent microperthite, 2·7 per cent biotite, and 0·3 per cent accessory minerals (*See* Figure 2). The albite is commonly zoned. The accessory minerals are magnetite, apatite, and sphene. In thin section the pink border phase is porphyritic, with phenocrysts of albite, microperthite, and quartz in a groundmass consisting of a micrographic intergrowth of quartz and orthoclase. Biotite is the only ferromagnesian mineral present. The composition of the rock by the Rosiwal method and based on one analysis is as follows: 23·6 per cent albite, 37·2 per cent quartz, 10·7 per cent microperthite, 27·4 per cent orthoclase, 0·9 per cent biotite, and 0·2 per cent accessory minerals.

Acidic and basic dykes related to this stock are fairly common. One basic dyke cutting the soda granite consists largely of zoned andesine, pale green hypersthene, and biotite. The acidic dykes are almost invariably porphyritic with phenocrysts of quartz and feldspar.

Nalcus Mountain Stock

The Nalcus Mountain stock is a very irregular-shaped body cutting Takla group rocks on both sides of the Northwest Arm of Takla Lake. It has a surface area of about 60 square miles, and consists mainly of medium- to coarse-grained, equigranular, pink soda granite. Rosiwal analyses of two specimens yielded the following composition: 30·5 per cent quartz, 31·2 per cent orthoclase and microperthite, 36·2 per cent albite, 2·1 per cent chlorite and biotite, and minor accessory minerals (*See* Figure 2). The border phases are normally coarse grained and porphyritic, with phenocrysts of red orthoclase up to 1 inch long. Granitic and aplitic dykes are numerous near the contacts. This stock is similar to the Goat Mountain stock, and the two of them probably formed at the same time.

Stock North of Natowite Lake

Scattered outcrops of diorite are exposed within an area of about 15 square miles north of Natowite Lake. The diorite is a fine- to medium-grained, equigranular, green rock. A Rosiwal analysis of a typical specimen indicated the following mineral composition: 68·4 per cent andesine, 28·8 per cent hornblende, and 2·8 per cent magnetite, sphene, and apatite (*See* Figure 2). On the south slope of the mountain on the south side of the Northwest Arm of Takla Lake similar diorite is cut by pink granite.

Stock East of South End of Takla Lake

A stock of grey to pink granodiorite, with a granite core and grey-green diorite border zone underlies an area of about 50 square miles east of the south end of Takla Lake. The central part is a medium- to coarse-grained, equigranular to porphyritic rock, whose mineral composition, by Rosiwal analysis of a selected sample of the grey variety, is: 18·9 per cent quartz, 25·8 per cent orthoclase, 42·4 per cent oligoclase, 9·6 per cent biotite, 2·7 per cent chlorite, 0·6 per cent hornblende, and minor accessory minerals (*See* Figure 2). The pink varieties, which are generally coarse grained, are probably normal granites, the colouring due to a preponderance of orthoclase. The border phase diorite is medium grained, and is composed mainly of hornblende and andesine. These rocks exhibit a slight foliation striking nearly east-west.

Stock East of Takla Landing

A stock, exposed over an area of about 25 square miles, cuts the Cache Creek rocks east of Takla Landing. It consists of medium-grained, grey, equigranular granodiorite in the centre, grading into grey-green diorite at its borders.

Albert Lake Stock

A stock, consisting mainly of light green and pink, medium- to coarse-grained, equigranular granodiorite is exposed over an area of 7 square miles east of Albert Lake. A Rosiwal analysis of a specimen indicated 21·8 per cent quartz, 59·0 per cent zoned plagioclase (oligoclase-andesine), 15·9 per cent orthoclase, 1·5 per cent biotite, and 1·7 per cent hornblende and chlorite (*See* Figure 2). This granodiorite grades into coarse-grained, darker green diorite, gabbro, and pyroxenite near the centre of the stock.

Ogden Lake Sill

A sill outcrops on the east side of Ogden Lake. It is about 9 miles long, 4,000 feet wide, strikes northwesterly, and has an area of 7 square miles. It consists of medium-grained, grey to pink, equigranular granodiorite bordered on both sides by serpentine sills. The average mode, as determined from two specimens by the Rosiwal method, is as follows: 29·6 per cent quartz, 20·4 per cent orthoclase, 41·1 per cent oligoclase-andesine, 6·7 per cent chlorite, and minor sphene and apatite (*See* Figure 2).

Mount Milligan Stock

A stock 2 square miles in surface area cuts the Takla group on Mount Milligan. It consists of a medium-grained, grey-green, equigranular syenodiorite. Rosiwal analyses of two specimens yielded the following average mode: 43·2 per cent andesine, 31·0 per cent orthoclase, 18·5 per cent hornblende, 6·2 per cent augite, and minor sphene, apatite, and magnetite (*See* Figure 2).

Stock Between Northwest Arm of Stuart Lake and Trembleur Lake

A body of tonalite (quartz diorite) occupies 16 square miles north of Stuart Lake, and is a medium-grained white rock composed of white feldspar, quartz, and biotite. It has not been completely unroofed, and roof pendants and inclusions of metamorphosed Cache Creek rocks are common. A Rosiwal analysis of a specimen of this rock gave the following mineral composition: 15·5 per cent quartz, 73·1 per cent andesine, and 11·3 per cent biotite (*See* Figure 2). The andesine shows beautiful zoning.

Stock North of Pinchi Lake

A small stock of fine- to medium-grained, green diorite intrudes Takla group rocks north of Pinchi Lake. It is composed essentially of andesine and hornblende.

CHUCHI LAKE AND DUCKLING CREEK SYENITES

(*See* Figure 4)

Associated with the Hogem batholith are two areas of syenite. One, north of Chuchi Lake, about 40 square miles in area, definitely intrudes the main batholith; the other, north of the west fork of Duckling Creek, and about 15 square miles in surface area, appears to grade into the main batholith, although no well-exposed contacts were seen. The writer has assumed for mapping purposes that these syenites represent a late phase of the Hogem batholith, but they may be much younger, as lithologically similar intrusions in southern British Columbia are of Late Upper Cretaceous or Tertiary age. On the map accompanying this report the writer has not indicated the areal extent of these syenites, but on Figure 4 an attempt has been made to delimit them.

The Chuchi Lake syenite is a medium- to coarse-grained, pink rock, in part porphyritic. A study of five thin sections by the Rosiwal method indicates that the syenite contains as much as 16·9 per cent quartz, 5·0 to 27·3 per cent orthoclase, 7·4 to 24·0 per cent oligoclase, 36·0 to 68·8 per cent microperthite, 0 to 14·0 per cent hornblende, 0 to 13·0 per cent biotite, and minor magnetite, apatite, and sphene. The average mode of these five specimens is: 4·8 per cent quartz, 14·1 per cent orthoclase, 15·6 per cent oligoclase, 51·5 per cent microperthite, 12·4 per cent ferromagnesian minerals, and 1·6 per cent magnetite, apatite, and sphene (*See* Table IX and Figure 2). The microperthite occurs generally as large pink crystals up to 1½ inches long. The hornblende, which also occurs in long crystals, is partly altered to brown biotite and magnetite.

The typical Duckling Creek syenites are coarse-grained, porphyritic, pink and green rocks composed mainly of pink orthoclase and microcline and green, altered augite. Some finer grained, equigranular phases were observed. The orthoclase generally occurs in large phenocrysts, up to 2½ inches long. Microscopic examination of six thin sections shows these rocks to contain 46·7 to 91·0 per cent orthoclase and microcline and 6 to 51·5 per cent altered augite (*See* Table X and Figure 2). The augite alters to ragged flakes of brown biotite and dark green chlorite. These rocks, which are actually orthosyenites, grade into normal syenites to the south, consisting of orthoclase and microcline, andesine, and microperthitic intergrowths of plagioclase in microcline, hornblende, and biotite. Nearly all these syenites are foliated in a north-south direction, with the dip vertical. Garnets are found associated with them in several localities, and may constitute up to 15 per cent of the rock.

The following table gives the modes of specimens collected from the Chuchi Lake syenite, as determined from Rosiwal analyses; specimen numbers correspond with those of locations shown on Figure 4.

TABLE X

Modes of Specimens from Chuchi Lake Syenite

Specimen number	Name	Quartz	Potash feldspar (orthoclase)	Plagioclase feldspar (oligoclase)	Micro-perthitic inter-growths	Horn-blende	Pyroxene	Biotite	Chlorite	Mag-netite	Apatite	Miscellaneous
		%	%	%	%	%	%	%	%	%	%	%
53	Syenite..	—	20·3	24·0	36·0	13·3	—	5·0	—	1·4	—	—
54	Granite..	7·1	8·6	15·7	57·0	9·2	—	—	—	2·3	—	—
56	Granite..	16·9	5·0	7·4	68·8	—	—	—	—	—	—	0·5
57	Syenite..	—	9·1	18·2	50·6	9·1	—	13·0	—	—	—	—
58	Syenite..	—	27·3	12·7	45·3	—	1·7	12·0	—	1·0	—	—

The following table gives the modes of specimens collected from the Duckling Creek syenite, as determined from Rosiwal analyses; specimen numbers correspond with those locations shown on Figure 4.

TABLE XI

Modes of Specimens from Duckling Creek Syenite

Specimen number	Name	Potash feldspar (orthoclase and microcline)	Plagioclase feldspar (andesine)	Micro-perthitic inter-growths	Horn-blende	Pyroxene	Biotite	Chlorite	Mag-netite	Apatite	Miscellaneous
		%	%	%	%	%	%	%	%	%	%
3	Syenite..........	46·7	—	—	—	35·0	8·3	5·0	1·0	—	1·6 sericite 2·4 sphene
4	Syenite..........	46·8	—	—	—	40·6	10·9	—	1·6	—	—
5	Syenite..........	90·4	—	—	—	—	2·7	3·3	—	—	3·6 sericite
6	Syenite..........	66·7	—	—	6·1	17·8	—	9·4	—	—	—
7	Syenite..........	80·8	—	—	—	—	3·9	11·5	—	—	3·8 copper ore
8	Syenite..........	91·0	—	—	—	8·0	—	—	—	—	1·0 copper ore
9	Syenite..........	64·5	20·5	—	5·0	—	—	—	—	—	20·0 alt. prod.
12	Syenite..........	3·0	5·0	68·1	10·0	—	—	—	—	—	13·8 alt. prod.
13	Syenite..........	11·8	11·9	29·8	9·8	—	4·7	—	—	—	13·2 garnet 19·7 alt. prod.

STRUCTURAL RELATIONS AND AGE

The Omineca intrusions, as mapped, are probably of more than one age. However, the main bodies are believed to have been intruded in very late Jurassic or Lower Cretaceous time. They cut Upper Triassic and Lower Jurassic formations of the Takla group in the Fort St. James map-area. They were not observed cutting the Middle and Upper Jurassic formations of the Takla group in the McConnell Creek map-area, but as these formations occur conformably above Lower Jurassic formations the assumption has been made that the Omineca intrusions probably are post-Upper Jurassic. They had been deeply eroded by Albian (late Lower Cretaceous) time, as is evidenced by the abundant granitic boulders and pebbles found in the Uslika formation conglomerates. However, some of the intrusions such as, particularly, the Mitchell batholith bear a considerable resemblance to the older Topley intrusions, and may belong with them. The Chuchi and Duckling Creek syenites have been mapped with Omineca intrusions although they may be much younger, as lithologically similar intrusions in southern British Columbia are believed to be of late Upper Cretaceous or Tertiary age.

Structural features serving to distinguish the Omineca intrusions from the Topley intrusions have been discussed elsewhere in this report.

CORRELATION

Granitic intrusions of late Jurassic or early Cretaceous age are common throughout British Columbia west of the Rocky Mountains. Although the Coast intrusions of the Coast Mountains range in age from Upper Triassic to Upper Cretaceous and possibly later, they were in large part intruded in late Jurassic or early Cretaceous time and are thus in part of the same age as the Omineca intrusions.

The Omineca and Coast intrusions have many features in common: both consist mainly of granodiorite and granite with minor basic phases; the larger bodies of both are elongated in a northwest direction; the intrusions of both are massive; and mineral deposits are common to each.

Eocene or Oligocene Intrusions

GENERAL STATEMENT

Bodies of rhyolite, rhyolite porphyry, granophyre, and to a minor extent of trachyte porphyry and granite porphyry vary in size within the map-area from dykes 3 to 10 feet wide to stocks ¼ to 1 mile in diameter. These are believed to have been intruded at a late stage in the Eocene or Oligocene period of volcanism.

Many of these bodies are intimately associated with rhyolitic flows and are difficult to distinguish from them, or to recognize as dykes, sills, or stocks. Other bodies of similar composition throughout the map-area may be correlated with the flows on a lithological basis only, and it is quite probable that intrusions of more than one age have been grouped here.

LITHOLOGY

A large body of rhyolite porphyry outcrops immediately west of Sheraton (Poison) Creek. It is at least a mile in diameter, and apparently cuts the nearby Topley granite, although no actual contact was observed. Under the microscope the rock is seen to be composed of phenocrysts of colourless quartz and pink albite up to ¼ inch in diameter, in a buff-coloured, cryptocrystalline groundmass of orthoclase (?) and quartz. Two other bodies of rhyolite and rhyolite porphyry are exposed on Silver Island, Babine Lake, and Tsitsutl Mountain, Middle River Range. They are about 500 feet and ¼ mile in diameter respectively. Dykes of rhyolite are especially abundant near Taltapin Mountain, Sheraton (Poison) Creek, and east of Priestly. A study of five thin sections of rhyolitic dykes showed them to have the same composition and texture as the Eocene or Oligocene rhyolitic flows.

Along the shores of Trembleur Lake and the eastern part of Babine Lake, numerous grey to buff, fine- to medium-grained, porphyritic and non-porphyritic, granophyric dykes, ranging in width from 6 inches to 100 feet, can be seen cutting the Cache Creek strata. Granophyric dykes were also observed cutting the Topley granite near Boer Mountain. Under the microscope they were observed to represent two distinct types: (1) those in which the phenocrysts are of orthoclase, albite, and quartz, and (2) those containing, in addition, phenocrysts of a mafic mineral now represented by penninite. The phenocrysts are about ⅛ inch in diameter. In both types the groundmass is composed of a cryptocrystalline micrographic intergrowth of quartz and orthoclase.

In the railway cuts east of Priestly and south of the Burns Lake-Endako highway near Ross Creek, dykes of trachyte porphyry were observed cutting the granite. They are light buff rocks containing phenocrysts of pink and white albite and orthoclase, and green chloritized hornblende embedded in a white to grey, cryptocrystalline, feldspathic groundmass.

North of Burns Lake, near Boer and Bald Mountains, dykes of granite porphyry cut the granite. A thin section of granite porphyry from the Hiyou claim is composed of phenocrysts of biotite and plagioclase feldspar in a medium-grained groundmass of quartz and orthoclase. The feldspar phenocrysts are too altered to permit accurate identification but are probably oligoclase.

STRUCTURAL RELATIONS AND AGE

Some of these intrusions cut the Eocene or Oligocene flows, but none was observed cutting the Endako group volcanic rocks. Therefore, they are probably of Eocene or Oligocene age.

CHAPTER IV

STRUCTURAL AND HISTORICAL GEOLOGY

STRUCTURAL GEOLOGY

General Statement

The Wolverine, Cache Creek, and Takla strata have a general northwesterly trend, but structures are quite irregular locally. Most of the larger bodies of the Omineca intrusions have a northwest elongation roughly parallel with the invaded strata.

The structures in the Fort St. James map-area probably owe their origin to several periods of deformation, although positive evidence for more than one major orogeny has not been observed. However, in the adjoining McConnell Creek (99) and Aiken Lake (17) map-areas, to the northwest and north, evidence has been obtained indicating two major orogenies, one in late Jurassic or early Cretaceous time, and the other in post-Paleocene, probably early Eocene, time. In the McConnell Creek area, Sustut group rocks of Upper Cretaceous and Paleocene ages, which are nearly flat-lying in most places and overlie steeply folded Takla and Cache Creek strata unconformably, are themselves extensively faulted and tilted along the Pinchi fault zone. In the northeast corner of the Aiken Lake map-area, Sifton conglomerate of Upper Cretaceous or Paleocene age outcrops along the Rocky Mountain Trench and has, apparently, been downfaulted into its present position. Ruby and Ingenika strata of Late Proterozoic and Lower Cambrian ages exposed within 20 miles of the trench have been much folded and faulted. The folds strike north 30 degrees west and are overturned to the southwest. In places these overturned folds have developed into overthrust faults, the northeast side moving up with respect to the southwest side. These folds and faults parallel the Rocky Mountain Trench and probably were formed at the same time as the trench, that is in post-Paleocene time. The Late Proterozoic and Lower Cambrian rocks exposed elsewhere in the Aiken Lake map-area have been folded into fairly open symmetrical folds striking north 60 degrees west. These are believed to have been formed previous to the overturned folds along the trench, and Roots (17) believes he can recognize the later overturned folds superimposed on the earlier folds east of Pelly Creek.

The late Jurassic or early Cretaceous and post-Paleocene, probably early Eocene, orogenies that deformed the rocks of the McConnell Creek and Aiken Lake map-areas probably also deformed the rocks of the Fort St. James map-area. Other periods of possible deformation represented in the Fort St. James map-area occurred in post-Lower Cambrian and pre-Pennsylvanian, post-Middle Permian and pre-Upper Triassic, and post-Oligocene times.

Evidence has been obtained in the Aiken Lake map-area and in the Cariboo district to indicate that the Late Proterozoic and Lower Cambrian formations are separated by a structural unconformity from succeeding

Cache Creek formations of Permian and possible Pennsylvanian age (*See* pp. 29, 30). Although no actual contacts between the Cache Creek and Takla groups were observed, the Takla group probably lies unconformably above the Cache Creek group, and for reasons previously given (pp. 42, 43), the period between Middle Permian and Upper Triassic time was apparently one of uplift, erosion, and probable igneous intrusion and deformation. The close of Oligocene time was marked by local orogenic movements that folded or tilted and probably uplifted the Eocene or Oligocene and older rocks.

Folding

Much of the Wolverine complex consists of granitized rocks, and no attempt was made to separate it into formations. The general trend of the Wolverine schists exposed along the western front of Wolverine Mountains is about north 75 degrees west. In the Aiken Lake map-area to the north, except near the Rocky Mountain Trench, the Late Precambrian and Lower Cambrian strata, non-granitized equivalents of the Wolverine complex, have been folded into fairly open, northwesterly trending folds (17). These are, on the average, 15 miles wide, and the limbs dip at less than 45 degrees. Several possible explanations have been offered (pp. 18, 19) to account for the fact that in central British Columbia the Upper Palæozoic and Mesozoic strata are more intricately folded than those adjoining, much older, Late Proterozoic and Lower Cambrian formations.

In most places the Cache Creek rocks are closely folded in a northwesterly direction, the limbs of the folds dipping steeply, generally in excess of 60 degrees. Some overturned folds were observed, and a more detailed field examination may reveal many others. During the folding the limestone beds acted as relatively competent strata, and are not deformed to nearly the same extent as interbedded argillaceous and cherty strata. Apparently the limestones yielded to stress by recrystallization and flowage rather than by close folding.

Folds in the Takla rocks were observed only in a few localities where sedimentary formations predominate. Most of them strike from west to northwest and the limbs dip at about 45 degrees. Locally the Takla group rocks do not appear to be as closely folded as those of the Cache Creek group. Also, most of the Cache Creek rocks are schistose, whereas the Takla group rocks, though partly altered, generally retain their original textures.

Most of the Hazelton and Tachek group rocks exposed in the Fort St. James area are massive, structureless, volcanic flows, and their general trend could not be determined. The occasional attitude observed indicated variable strikes and dips, and most dips exceed 30 degrees.

The Upper Cretaceous, Paleocene, and Eocene or Oligocene sedimentary formations are exposed only in small isolated patches. They are predominantly gently dipping, although locally, due to slumping and faulting, dips may be steep.

The Endako group of volcanic rocks of Oligocene or later age is nearly flat-lying.

Faulting

Several, major, northwesterly and northerly trending fault zones have been mapped. The most important of these is the Pinchi fault zone, with an overall length of at least 150 miles. This fault zone follows the western border of the Hogem batholith for at least 100 miles, and it is quite probable that the batholith, because of its relative rigidity, acted as a buffer against later regional stresses, thereby localizing the fault zone along the border.

PINCHI FAULT ZONE

(*See* Plate V)

The Pinchi fault zone, the main structural feature of the Pinchi mercury belt, extends from southeast of Fort St. James, 150 miles northwest to Omineca River. Lord (99) has mapped the northwestern continuation of this fault zone in the McConnell Creek map-area, and has named it the Omineca fault. The Pinchi fault zone varies in width from 200 to 5,000 feet, but in most places does not exceed 1,000 feet. It forms the northeastern edge of a northwesterly trending fault belt that is as much as 10 miles or more wide in places. In general the northeastern margin of this zone represents the contact between closely folded, stratified Permian rocks on the southwest and Mesozoic formations and Omineca intrusions on the northeast. Although the fault contact between Permian and Mesozoic strata was nowhere observed, it seems probable that the Pinchi fault zone marks the site of major thrust faulting from the west, and that Permian rocks have moved up with respect to Mesozoic formations. Many subsidiary faults were, however, observed in the Cache Creek rocks within the fault zone. Their attitudes are quite variable, but the more pronounced faults strike from northwest to northeast and dip steeply to the west. Along the faults the Permian rocks, which in most observed places were limestones, have been brecciated across zones 1 foot to 20 feet or more wide, and where the faults are closely spaced the limestones are completely brecciated. Gouge seams up to 2 feet wide and slickensided surfaces mark many of these subsidiary faults. They were best observed in the underground workings at the Pinchi Lake and Bralorne Takla mercury mines.

At the Pinchi Lake mercury mine three major faults have been exposed on the southwest side of the contact between Permian and Jurassic rocks. The most important of these faults strikes about north 60 degrees west and dips 60 degrees southwest. This fault has been observed in the glory hole and on all the levels of the mine. Along the fault the rocks are brecciated and silicified across a zone 4 to 30 feet wide. The brecciated zone is bounded by slickensided, slip-wall surfaces. It is a reverse fault, and the hanging-wall has moved up at least 75 feet with respect to the foot-wall. A second fault, striking nearly east and dipping about 50 degrees south, is exposed in the underground workings 100 to 200 feet northeast of the first fault. This is also a reverse fault. A third fault is exposed on the surface about 600 feet northeast of the first fault. It trends northwesterly, and is marked by a brecciated zone 50 feet or more wide.

At the Bralorne Takla mercury mine, two major parallel faults, approximately 120 feet apart, were intersected by underground workings on the "B" showing. Both strike north 15 degrees east; one of these dips 65 degrees northwest, and the other dips nearly vertically. On both faults the hanging-walls have apparently moved north and downward. Many branch faults and fractures subsidiary to these two were observed underground. The more pronounced of these branch faults strike about north 15 degrees west.

Movement along the Pinchi fault zone has undoubtedly occurred at different times. The last movements are believed to have taken place in post-Paleocene time, a conclusion based mainly on observations made by Lord (99) along the Omineca fault in the McConnell Creek map-area, which has offset Paleocene beds of the Sustut group.

The Pinchi fault zone is characterized by the carbonatization of the rocks along it, as described elsewhere in this report (pp. 136-138).

MANSON FAULT ZONE

A major fault zone, here named the Manson, has been traced from Gaffney Creek 40 miles northwest of Nina Creek, and is the main structural feature of the Manson Creek gold belt. From Omineca River north it forms the contact between stratified Cache Creek rocks on the east and Takla rocks on the west, and possibly marks the site of major thrust faulting from the east. Drag-folding of the beds along Manson River and Nina Creek indicates that the east wall of the fault zone moved north, and possibly up, relative to the west wall. The fault zone was observed in Gaffney Creek, on Gillis Creek, along the road on the east side of the second Manson Lake, southwest of Skeleton Mountain, at the head of Lost Creek, on Manson River and Slate Creek near the settlement of Manson Creek, at the big bend on Germansen River, and along Nina Creek. At all these localities the wall-rocks across an average width of 200 feet are partly to completely altered to a buff-coloured aggregate of carbonate, quartz, chlorite, and mariposite, an alteration that has obliterated all evidence of the fault plane or planes along which the pre-carbonate movements took place. All fault surfaces now observable along the Manson fault zone appear to be the result of more recent movements. In places the carbonate rocks are brecciated and silicified. Many of the numerous branch faults along the main fault zone are also marked by carbonatized wall-rocks.

SOWCHEA SHEAR ZONE

A zone of altered rocks consisting mainly of cream-coloured, buff weathering aggregates of ankeritic carbonate, quartz, mariposite, and serpentine crosses the property of the Stuart Lake antimony mine near Sowchea Bay, Stuart Lake. This zone is about 150 feet wide, strikes northwesterly approximately parallel with the bedding of the Cache Creek formations it traverses, and dips 40 to 50 degrees northeast. Drill-holes indicate considerable brecciation along this zone. Although the writer made only a very brief examination of this showing he believes this band of carbonate rocks lies along a zone of major shearing or faulting.

Twelve miles southeast of the antimony property on Tsah Creek, along a projection of the assumed shear zone described above, another band of quartz-carbonate-mariposite rocks is exposed. The intervening area is drift covered.

The northwest extension of the Sowchea shear zone probably lies beneath Stuart Lake, and possibly continues north along Tachie and Middle Rivers. The ultrabasic rocks along the west side of Middle River are sheared and altered.

WOLVERINE FAULT

The large fault indicated for 50 miles along the western front of the Wolverine Range was not observed, but is inferred from a marked discordance of the strata on either side. The Cache Creek formations, west of the fault, strike nearly east and dip vertically, whereas the Wolverine strata on the east side of the fault strike about north 75 degrees west and dip steeply southwest.

TAKLA FAULT

A major fault extends from near the head of the Northwest Arm of Takla Lake 40 miles north to about latitude 55°45′. Although drift-covered along most of its length, this fault may be easily identified in air photographs. North and south of Takla Lake, near Takla Landing, it forms the contact between Sustut group rocks of Upper Cretaceous age on the west and Takla group rocks of Upper Triassic and Jurassic ages on the east. The west side has apparently moved down with respect to the east side. The dip was not observed, so it could not be determined whether the faulting was normal or reverse.

FAULT OR SHEAR ZONES IN VICINITY OF UPPER FALL RIVER

Several, northwesterly trending zones of carbonate-quartz-mariposite rocks were observed on both sides of upper Fall River. They traverse Cache Creek formations, and are believed to mark former zones of shearing. Pyritization is also general along these zones. In addition to the northwesterly zones, several northeasterly trending faults have been inferred in this district in order to explain abrupt changes in the attitude of the strata.

FAULTS IN WESTERN PART OF MOUNTAINOUS AREA WEST OF MIDDLE RIVER

The Cache Creek strata and the Trembleur ultramafic sills outcropping on the western slopes of the mountainous area west of Middle River have apparently undergone block faulting. A major, northwesterly trending fault is believed to lie along the valley of Gloyazikut Creek. Farther east, several northerly trending faults were observed; others in this area trend northeasterly; and both sets of faults have displaced the ultrabasic sills as much as 6,000 feet.

HISTORICAL GEOLOGY

The following is a brief statement of the geological history of Fort St. James area as interpreted from available data.

Late Precambrian and Lower Cambrian Time

The oldest known rocks exposed in east-central British Columbia are of Late Precambrian and Lower Cambrian age. They are predominantly sedimentary rocks, and include a maximum thickness of at least 30,000 feet of quartzite, argillite, limestone, and derived schists and gneisses. The Lower Cambrian formations overlie the Late Proterozoic formations with apparent conformity, and both series were deposited in a basin extending from south of the Cariboo district northwesterly into the Aiken Lake area and from the Rocky Mountains for an unknown distance west of their present exposures. This basin crosses the northeast corner of the Fort St. James map-area. Where exposed in this area, these formations have been altered to granitic gneisses and to various types of metamorphic rocks, and constitute the Wolverine complex.

From the bottom to the top of the Late Precambrian-Lower Cambrian section, the general change, from quartzite through slate and argillite to limestone, possibly indicates that the Late Precambrian rocks were laid down in a land-locked, sinking area, whereas the Lower Cambrian rocks, with their fossil sponges, were laid down in an arm of the sea.

Middle Cambrian to Mississippian Time

Apparently, the region extending south of Ingenika River to the Cariboo district and from the Rocky Mountain Trench to the Coast Range was a landmass during most of Middle Cambrian to, and including, Mississippian time, and would include all of the Fort St. James map-area. In Lower Cambrian time the area was uplifted and marine waters withdrawn until Pennsylvanian time.

In the Cariboo district the Slide Mountain series of Late Palæozoic age is believed by Johnston and Uglow (80, pp. 37-38) to lie with angular unconformity above the Cariboo series of Late Proterozoic age (*See* pp. 29, 30), and in the Aiken Lake map-area the general structure of the Late Proterozoic and Lower Cambrian formations also lends support to the belief that they are structurally unconformable with the Late Palæozoic formations.

In view of the evidence obtained in nearby areas the writer has also concluded that in the Fort St. James map-area the Cache Creek rocks, of Permian and probable Pennsylvanian ages, overlie the Late Proterozoic and Lower Cambrian formations of the Wolverine complex with structural unconformity. Perhaps this unconformity is mainly due to uplift and erosion, but the possibility of some orogenic disturbance is not precluded.

In dealing with the origin of the Wolverine rocks, the writer stated (pp. 30, 31) that the granitization of the Late Proterozoic and Lower Cambrian rocks took place in post-Lower Cambrian time, but raised the question as to whether it may not have antedated the deposition of the Cache Creek group.

Pennsylvanian to Middle Permian Time

During Pennsylvanian to and including Middle Permian time the Fort St. James area again subsided and was in a large part flooded by the sea. In these waters the Cache Creek formations were laid down. They now occupy two northwesterly trending belts separated by a belt of Takla group rocks and Omineca intrusions. However, at the time of deposition the two belts possibly formed part of one basin of deposition, at least 60 miles wide, extending from Wolverine Mountains in the northeast to

Takla Lake in the southwest. The Cache Creek group appears to represent a conformable succession of 20,000 feet or more of interbedded limestone, ribbon chert, argillite, slate, quartzite, tuff, breccia, andesite, and basalt, and their derived schists. The volcanic rocks predominate in the upper part of the group. As previously stated (pp. 37-39), the writer believes that the ribbon chert was derived by chemical precipitation of colloidal silica from juvenile silicate solutions accompanying submarine extrusions of lavas. The presence of marine fossils indicates that the basin of deposition probably formed an arm of the sea.

No fossils younger than Middle Permian have been identified in the Cache Creek group of the Fort St. James or nearby map-areas. However, at most places the Middle Permian strata are overlain conformably by thick accumulations of volcanic flows, breccias, agglomerates, and tuffs, suggesting that volcanic activity may have continued into Upper Permian or even later time.

Upper Permian to Middle Triassic Time

Fossiliferous strata of Upper Permian and Lower and Middle Triassic ages are not known in east-central British Columbia, although these periods may be represented in places by volcanic rocks. The writer believes, for reasons already given (*See* pp. 42, 43), that this interval was a time of uplift, erosion, igneous intrusion, and probable deformation.

Upper Triassic and Jurassic Time

Following the late Palæozoic-early Mesozoic period of uplift and erosion, a large part of the Fort St. James map-area was once more inundated by the sea, commencing in Upper Triassic time, and until the close of the Jurassic period conditions must have been extremely chaotic and widely fluctuating. Sedimentation during this period was continually interrupted by vulcanism and of very indefinite duration. The Takla group rocks were deposited at this time. They consist of at least 10,000 feet of interbedded volcanic and sedimentary formations. Volcanic rocks, both lavas and pyroclastic material, predominate throughout; local accumulations in many places comprise most of the formations and are many thousands of feet thick. Sedimentary rocks of Upper Triassic age attain a maximum thickness of 2,000 feet, but at no place were more than a few hundred feet of sedimentary rocks observed in the Jurassic sections. Limestones are common in the Upper Triassic formations and conglomerates in the Jurassic; well-bedded tuffs are common in the volcanic rocks of Triassic age, but flows and breccias are more widely represented in Jurassic time. It seems probable that marine conditions prevailed in Upper Triassic time and fluctuating marine, near-shore, and possibly continental conditions in the Jurassic period.

Available evidence suggests that the sea finally withdrew from the Fort St. James area near the end of Jurassic time. The Tachek group of volcanic rocks exposed in the southwestern part of the Fort St. James map-area and in the Houston map-area on the west were probably laid down during Jurassic time, but the only associated sedimentary strata are of continental origin and may indicate that most of the southwestern part of the Fort St. James map-area, now occupied by the Topley intrusions and Tertiary volcanic rocks, was a landmass during Upper Triassic and Jurassic time.

Upper Jurassic and/or Lower Cretaceous Time

For reasons already outlined in the section on structural geology (pp. 115, 116), the writer believes that the Jurassic period was closed by a great orogenic disturbance accompanied or immediately followed by the Omineca batholithic intrusions. The main forces producing the disturbance probably acted laterally from the southwest, and compressed the Jurassic and older formations into great folds, with axes striking northwest, which rose above the sea-forming ranges of mountains. Deep within these ranges, vast quantities of acidic magma were emplaced, forming the Omineca intrusions. Following this period of orogeny and intrusion, active erosion commenced, and by late Lower Cretaceous (Albian) time had exposed Upper Triassic and Jurassic strata and parts of the Omineca batholithic intrusions. No Lower Cretaceous strata have been recognized in the Fort St. James map-area except along its northern border, but to the west, in the vicinity of Hazelton and east of the Rocky Mountains, Lower Cretaceous strata are abundant, and the Lower Cretaceous landmass in a large part of the Fort St. James map-area may have been a main source of the materials for these Lower Cretaceous rocks.

Upper Cretaceous and Paleocene Time

Sedimentary formations of Upper Cretaceous and Paleocene age, named the Sustut group, are found only in a few, small, isolated patches in the northern part of the Fort St. James area, but are well exposed in the McConnell Creek map-area to the northwest. They are continental in origin, and are characterized by conglomerates consisting in large part of pebbles of Omineca intrusions. Their part in the geological history is described by Lord (99) as follows: "More than 3,000 feet of sedimentary strata were accumulated in a shallow, sinking continental basin during the Upper Cretaceous and Paleocene epochs. Initial deposition, from a bordering mountainous area that probably included that of the Omineca batholith, was everywhere rapid, as attested by the widespread deposits of coarse greywackes, and at times by very rapid erosion as evidenced by recurrent conglomerate sheets. Sedimentation continued without recognized interruption into Paleocene time".

In the southern part of the Fort St. James map-area extensive areas of volcanic rocks may be of Upper Cretaceous or later age. Intercalated with them are conglomerate and arkose.

Tertiary Time

In early Tertiary, probably pre-Upper Eocene, time orogenic movements of great importance affected the whole of the Cordilleran region (*See* pp. 115, 116). The evidence for this belief has been discussed previously. It resulted in the uplift of the peneplaned surface of the Jurasside mountains and in the formation of new mountains. In the Fort St. James and McConnell Creek areas the Eocene and younger sedimentary rocks occupy the major valleys only, whereas the Paleocene and older rocks form the mountain ranges except where they have been downfaulted. Some intrusions are probably associated with this orogeny, such as the Chuchi Lake and Duckling Creek syenites and those classed as Eocene or Oligocene.

During Upper Eocene or Oligocene time deposits of sandstone, shale, conglomerate, and lignite accumulated in freshwater basins along some of the major valleys in the southern part of the Fort St. James map-area. These sedimentary strata are interlayered with volcanic rocks, indicating vulcanism of the same general age.

The close of the Oligocene epoch was marked by orogenic movements that folded or tilted and probably uplifted the earlier Tertiary rocks. This orogeny was followed by a period of widespread vulcanism, probably during Miocene time, when the Endako group of basaltic and andesitic flows, several thousand feet thick, was laid down in the southern part of the Fort St. James area. Pliocene erosion cut valleys several thousand feet deep through the Miocene lavas.

Quaternary Time

All of the Fort St. James area underwent extensive glaciation during Pleistocene time. At least two major advances of the Cordilleran ice-sheet have been postulated in the Nechako Plateau and Plain. Large quantities of till were deposited throughout the Fort St. James area during these two advances of ice and succeeding retreats. The last advance of the ice-sheet was followed by stagnation and decay of the ice, resulting in the formation of glacial lakes in which silt, clay, and sand were deposited. Deposits of recent stream gravel, alluvium, and sand have formed by the reworking of glacial material and the erosion of bedrock.

CHAPTER V

ECONOMIC GEOLOGY

INTRODUCTION

Mineral deposits are widespread throughout the map-area, but only a few have been productive. The several types are classified as follows:

- Metalliferous deposits
  - Placer deposits
    - Placer deposits in old stream channels
    - Placer deposits in present stream channels
  - Lode deposits
    - Deposits related to major fault or shear zones
      - Pinchi fault zone
      - Manson fault zone
      - Other major fault or shear zones
    - Deposits related to minor fault, shear, and fracture zones
    - Deposits occurring within intrusive masses
    - Other metallic deposits
- Non-metallic deposits
  - Coal
  - Magnesite
  - Asbestos
  - Asphaltum
  - Perlite

METALLIFEROUS DEPOSITS

Placer Deposits

The gold placer deposits of the Fort St. James area may be broadly classified as: (1) deposits in old stream channels, and (2) deposits in present stream channels.

Placer Deposits in Old Stream Channels

Most of the auriferous gravels found in old stream channels lie beneath glacial drift and are probably of pre-Glacial (Late Tertiary) age, although some may have been reworked by streams in Pleistocene time. The gold-bearing gravels commonly rest on bedrock, and the placer gold is concentrated in the lower few feet of gravels and in bedrock cracks and crevices.

Most of these ancient channels occur above the beds of the present streams, as along Germansen River, although, as on Vital Creek, they may occur below such levels. Buried channels have been worked on Tom, Harrison, Vital, Quartz, Silver, and Slate Creeks, and on Germansen and Manson Rivers and their tributaries. As these old channels are filled with as much as 150 feet of glacial debris, they may be mined successfully only on a relatively large scale, and by hydraulic, steam-shovel, dragline, ground-sluice, and underground methods.

The preservation of these buried gravels is remarkable when the effects of glaciation are considered. As will be seen from a study of the glacial map (*See* Figure 1), some of them lie in valleys that, presumably, lay across the course of ice erosion, although others occur in valleys that lie along the direction of ice movement. The general movement of the ice was easterly, and no buried placer deposits have been found in creeks draining the westerly slopes of mountains, that is the slopes on which the ice was moving uphill and apparently eroded deeply. In the areas where buried channels have been preserved the ice was either moving downhill or on the level, and, in general, depositing its load rather than excavating fresh material.

Placer Deposits in Present Stream Channels

Present stream channel deposits occur in post-Glacial or surface gravels in the beds and on the low benches of the present streams. In places the gold-bearing gravels rest on bedrock, and in other places on false bedrock, generally boulder clay. The best of such deposits occur downstream from where buried placer deposits have been eroded by present streams. Discovery Bar on Manson River is believed to have originated in this manner. The gold on Sowchea and Dog Creeks, which is concentrated on false bedrock, is believed to have been derived from the concentration of the gold in the overlying glacial drift. Much of the placer gold on Twentymile, Kwanika, and other creeks is concentrated on the upstream side of large boulders.

These recent deposits are generally shallow, easily worked by hand miners, and undoubtedly supplied much of the gold mined prior to 1900. In recent years deposits of this type on Twentymile Creek have been worked.

Source of Placer Gold

Harrison, Tom, Quartz, and Kelly Creeks

Harrison, Tom, Quartz, and Kelly Creeks all drain mountains underlain by Cache Creek formations in which numerous quartz veins and mineralized shear zones were observed. The principal sulphide is pyrite, and only low gold values have been obtained on assaying the quartz veins. However, the writer believes that these or similar but richer deposits, either eroded away or as yet undiscovered, were the source of the placer gold in the creeks, which is generally coarse and angular and apparently has not moved far.

Kwanika, Silver, Kenny, and Vital Creeks

Kwanika, Silver, Kenny, and Vital Creeks all lie along or near the Pinchi fault zone. Arquerite ($Ag_{12}Hg$), the natural amalgam of mercury with silver, and cinnabar are found in the auriferous gravels. The gold is usually coarse and angular, and apparently has not travelled far. For these reasons the writer believes that much of the placer gold along these creeks probably resulted from the erosion of mineral deposits related to the Pinchi fault zone.

Twentymile Creek

The source of the placer gold along Twentymile Creek is not known. The gold is coarse and flaky. Tributaries from the west drain an area in which quartz veins are reported to be common.

Manson-Germansen Rivers and Tributaries

As a result of the study of the bedrock geology and mineral deposits of the Manson-Germansen Rivers placer area it has been concluded that most of the placer gold probably resulted from the erosion of carbonate-quartz-mariposite-chlorite rocks, less altered rocks, and quartz veins along the Manson fault zone and associated branch faults. This conclusion is based on the following observations: (1) The placer deposits exhibit a linear arrangement along the Manson fault zone in a belt about 25 miles long by 3 miles wide. None of the deposits is more than 2 miles from an observed or projected major fault zone, and all are probably much nearer minor fault, shear, and fracture zones. (2) Much of the gold in the placers is coarse and angular, indicating that it has not been transported far. One nugget weighed 24 ounces, and many others up to 2 and 3 ounces. Many of the deposits occur on the downstream side of outcrops of carbonate-quartz-chlorite-mariposite rocks. For example, Discovery Bar on Manson River, reported to have been one of the richest deposits in the area, is directly below a wide carbonate zone. Unexposed fault zones containing mineralized veins probably occur above other known deposits. (3) Assays on specimens of carbonate-quartz-chlorite-mariposite rocks yield a trace to 0·01 ounce of gold a ton. These rocks could be the source of much of the fine gold. (4) The most productive placers lie near fault zones containing quartz veins with a valuable gold content. Many of the larger nuggets contain vein quartz attached to the gold, and this quartz appears to be identical with that in the veins.

Sowchea and Dog Creeks

The gold on Sowchea and Dog Creeks is fine, and has evidently been transported far. It is believed to have been derived from the concentration of the gold in the overlying glacial drift.

Lode Deposits

Deposits Related to Major Fault or Shear Zones

Pinchi Fault Zone

MERCURY DEPOSITS

About fifteen cinnabar (sulphide of mercury) deposits have been found along the Pinchi fault zone, including those of Pinchi Lake and Bralorne Takla mercury mines. During the field season of 1937, cinnabar was discovered by J. G. Gray of the Geological Survey in Cache Creek limestone on the north shore of Pinchi Lake where the main showings of the Pinchi Lake mercury mine were later developed. The property was optioned to the Consolidated Mining and Smelting Company of Canada, Limited, and in June 1940 a reduction plant with a rated capacity of 50 tons a day was brought into operation. In 1943 the plant had a capacity of more than 1,000 tons a day. The grade of the ore treated is reported to average 10 to 15 pounds of mercury a ton, and production during the years 1940 to 1944 inclusive exceeded 4,000,000 pounds. The Bralorne Takla mercury mine was brought into production in November 1943, with the completion of a 50-ton mill. Production of mercury from these two properties was far in excess of Canadian requirements, and Canada was able to supply the United Kingdom and the United States with part of their war needs. Both properties ceased operations during the summer of 1944, due to an over supply of mercury.

Although the cinnabar deposits occur in rocks of quite different character, all have been found in crushed rocks of, or related to, the Pinchi fault zone. Cinnabar deposits have been found along this fault zone for more than 100 miles. The mercury deposits may be grouped on the basis of associated rocks, as follows: (1) deposits in limestone; (2) deposits in serpentine; and (3) deposits in other rocks.

Deposits in Limestone

The principal cinnabar deposits are found in brecciated fault zones in Cache Creek limestone. Solution cavities, ranging in size from mere pits to openings several feet across and partly filled with calcite, are common in the limestone. The cinnabar occurs as veinlets, blebs, and individual grains filling pre-existing openings such as fissures, solution cavities, and interstices between grains and breccia fragments. Most of the cinnabar is the red, massive variety that weathers purplish red. Some bright red, earthy, "paint" variety films fracture surfaces in the orebodies, and occur mainly near the surface. Scattered grains of pyrite are found in most deposits. The common gangue minerals are quartz and calcite. Quartz and cinnabar seem to have been deposited contemporaneously, and the calcite both earlier and later. Most of the quartz is fine grained, but crystals have also formed in open cavities. The amount of quartz varies greatly from one deposit to another; in the deposits of the Bralorne Takla mercury mine it is only a minor constituent. Limestone has been replaced to some extent by cinnabar, especially along minute fractures in the rock. In solution cavities, on the other hand, cinnabar forms on the faces and cleavage planes of calcite crystals, and shows no evidence of replacement. In general the relative amount of limestone replacement by cinnabar varies indirectly with the size of pre-existing openings, the smaller the openings the greater the proportion of replaced wall-rock. Replacement, however, is not an important factor in the grade of the ore, and the best ore occurs in limestone that contains the greatest percentage of openings available for cinnabar deposition. Included in this group are the main deposits at the Pinchi Lake mercury mine, the deposits of the Bralorne Takla mercury mine, and the Lil, Bron, and Snell showings. The orebodies at the two productive mines vary greatly in size and shape. Many of them have no definite boundaries with the wall-rock but depend on assay values only. Others are bounded or partly bounded by faults. Although no figures are available, the larger orebodies at the Pinchi Lake mercury mine probably were in excess of 100,000 tons averaging 5 to 15 pounds of mercury a ton. The largest orebody mined at the Bralorne Takla mercury mine contained about 6,800 tons of 7-pound ore.

Deposits in Serpentine

Cinnabar deposits are commonly associated with small, sill-like bodies of serpentinized rock. Zones of shearing and brecciation along the contacts of many of these bodies have provided channelways for hydrothermal solutions. At an early stage this has resulted in extensive carbonatization of the fractured rocks, in which process much of the serpentine has been replaced by quartz and chalcedony, ankeritic carbonate, and mariposite, in widely varying proportions. This alteration has resulted in forming a brittle rock and, consequently, a favourable host rock for cinnabar deposits. At a later stage, following further brecciation, mineralizing solutions deposited cinnabar and chalcedonic quartz in the carbonatized and fractured rocks. The cinnabar and chalcedony occur in minute veinlets filling the fractures and coating the breccia fragments. No replacement of the wall-rock is evident, and no other metallic minerals were observed. The cinnabar-chalcedony veinlets are cut by calcite stringers, and in many places it is difficult to distinguish carbonates and silica formed at various stages. Included in this group are minor deposits at the Pinchi Lake mercury mine, and the Dan and Indata Lake showings.

Deposits in Other Rocks

A few, small, non-commercial deposits of cinnabar were observed in relatively massive, non-calcareous, sedimentary rocks. In these the cinnabar occurs in stringers of dolomite at or near the contacts of sills or dykes, these contacts acting as channelways for the mineralizing solutions. The Indata and Kwanika showings are of this type.

Mineralogy of the Mercury Deposits

The principal metallic mineral in all mercury deposits is cinnabar. It occurs as veinlets, blebs, and individual grains, and mostly as the red, massive, and crystalline varieties that weather a purplish red. Some of the cinnabar is sufficiently coarse grained for crystal faces to be visible. Some bright red, earthy, "paint" variety of cinnabar films fracture surfaces in the upper parts of the Pinchi Lake and Bralorne Takla mercury mines. Ross (109, p. 447) states that although some paint cinnabar is undoubtedly hypogene, some may be supergene.

Stibnite is fairly abundant at the lower levels in the Pinchi Lake mercury mine. A few specks of realgar and native arsenic were observed in a small dolomite stringer along Kwanika Creek. Scattered grains of pyrite are found in all deposits.

Arquerite, a natural amalgam of mercury and silver containing 86·6 per cent silver, has been panned on Silver, Vital, Kenny, and Kwanika Creeks, and has provided nuggets up to several ounces in weight. As yet this mineral has not been found in place.

The common gangue minerals in all types of mercury deposits are calcitic, ankeritic, and dolomitic carbonates. Quartz, generally fine grained, is abundant in some deposits, especially at Pinchi Lake mercury mine, but almost none occurs in the Bralorne Takla mercury mine. Chalcedony is common in the serpentine type deposits. Minor amounts of alunite (basic hydrous sulphate of aluminium and potassium) occurs in some of the ore-bodies at the Pinchi Lake mercury mine. A few grains of barite were observed in the serpentine type deposit at the Pinchi Lake mercury mine.

Structure and Origin of the Mercury Deposits

All the mercury deposits occur within the Pinchi fault zone, but most of them are along what appear to be faults subsidiary to the main break. It is quite obvious that at the time of mineralization these structures permitted easy passage of solutions that lacked the power to make openings for themselves or to move appreciably through the pores of unfractured rocks. All of the major orebodies at the Pinchi Lake and Bralorne Takla mercury mines consist of aggregates of numerous fillings of openings existing at the time of mineralization. Replacement of the host rocks has taken place only to a limited extent. These openings were most prevalent in the crush zones along subsidiary faults of the Pinchi fault zone and along complementary tension fractures. Ross (109, p. 455) describes similar conditions in many of the mercury deposits in the United States.

Schuette (110, p. 49) has pointed out that mercury deposits are usually found under a cap rock of gouge more dense than the receptacle rock in which the ore forms. In many places along the Pinchi fault zone relatively impervious cap rock and fault gouge have acted as traps to rising mercury-bearing solutions, and have induced concentrations of cinnabar. At the Pinchi Lake mercury mine the large orebodies are in limestone overlain by schists. More detailed underground study may reveal similar conditions in other deposits. Although "trapping" is undoubtedly an important factor in localizing ore, the relative permeability of solution channels is of equal or greater importance.

No genetic relationship is apparent between the mercury deposits and any nearby volcanic or intrusive rocks. The source of the ore-forming solutions is not known, but is probably connected with some deep-seated intrusion. The Pinchi fault zone provided abundant channelways for mineralizing solutions, and deposition occurred wherever other conditions were favourable. In many mercury deposits there is evidence to indicate that cinnabar is precipitated at temperatures varying between 100 and 150 degrees centigrade; at nearly atmospheric pressures; and from mineral-bearing alkaline solutions. Chemical analyses of the Pinchi Lake mercury mine limestones show a considerable increase in sodium and potassium where they have been mineralized with cinnabar. Also, the occurrence of alunite and glaucophane in the mineralized rocks of the Pinchi Lake mercury mine supports the belief that the ore-bearing solutions were alkaline at one stage during the formation of the mercury deposits.

In discussing the formation of cinnabar deposits, Ross (109, p. 464) came to the following conclusions: "that mercury deposits of the types mined in the United States are formed at geologically shallow depths and at relatively low temperatures and pressures. Dilute hydrothermal solutions of relatively simple composition commonly are modified by mingling with ground water before precipitation occurs. The fact that few other metals are associated with cinnabar deposits and that such deposits tend to be remote from those of other metals suggests that cinnabar lodes may be end-products formed after any other constituents that may have been in the hydrothermal solutions, when they left their magmatic source, had been precipitated in the course of earlier reactions. Precipitation of cinnabar is caused by any changes that decrease the temperature and alkalinity. The factors dominant in precipitation differ with the local conditions, but decrease in alkalinity may be one of the principal factors in most deposits. In some places, at least, precipitation is aided by encounter with cool water descending from above the water table. Such water even where not actually acid, is so low in alkalinity that dilution by it promotes precipitation."

Presumably the mercury deposits of the Pinchi Lake belt formed in Tertiary time as they are later than the faulting, and faulting has involved all the rocks in the area except those of Pleistocene and Recent age.

GOLD-SILVER DEPOSITS

The only deposit found along the Pinchi fault zone that is not a mercury deposit is the Kay gold-silver showing west of the Bralorne Takla mercury mine. The deposit consists of sulphide lenses lying along a fault zone in Cache Creek argillite and limestone. The largest lens is several feet wide and 20 feet long. The ore minerals comprise stibnite, jamesonite, arsenopyrite, sphalerite, pyrite, andorite, freibergite, native silver, and realgar. Andorite is a rare, argentiferous, antimony-lead sulphide.

The fault zone crossing this property probably forms part of the Pinchi fault zone, and the showings possibly originated from solutions ascending along channelways in it.

Manson Fault Zone

As previously pointed out, the Manson fault zone consists of buff-coloured carbonate-quartz-chlorite-mariposite rocks across a width of about 200 feet. These carbonate rocks have been formed by hydrothermal alteration of the wall-rocks, resulting in the replacement of all the original minerals, except quartz, by ankeritic carbonate. Similar carbonate rocks occur along some of the subsidiary fault and shear zones, whereas along others the alteration is much less complete and the wall-rocks have retained much of their original appearance. These carbonatized rocks formed relatively rigid bands along which later fault movements developed open fractures and breccia zones, rather than closed shears. Subsequent mineralizing solutions traversing these fractures and breccia zones resulted in further carbonatization and the deposition of sulphides. Many of the mineral deposits are along subsidiary faults.

Assays on carbonate-quartz-chlorite-mariposite rocks from eight places along the Manson fault zone yielded a trace to 0·01 ounce of gold and 0·03 to 0·69 ounce of silver a ton. None of these samples was from quartz veins, and the only metallic mineral apparent in them was pyrite in scattered grains. Quartz veins and stringers were observed at many places along the fault zone and in subsidiary faults. In the carbonate rocks they occur commonly as stock-works of intersecting stringers and veins of milky, comb, and sugary white quartz. They vary in width from a fraction of an inch to 12 feet or more, most of them being less than 6 inches. Some are mineralized with sulphides and free gold, and contain values in gold, silver, lead, and zinc. On the basis of mineral association they may be classified as: (a) deposits containing tetrahedrite; (b) deposits containing galena and sphalerite; and (c) deposits containing pyrite and galena.

Deposits Containing Tetrahedrite

The veins containing tetrahedrite consist of grey, vitreous, and white sugary quartz sparingly mineralized with tetrahedrite, chalcopyrite, and minor pyrite, malachite, azurite, and native gold. Principal values are in gold and silver. Some of the more promising prospects in the area, including the Fairview, Farrell, and Flag properties, are of this type. The most persistent vein on the Fairview property averages 1·5 feet in width for a length of about 200 feet, and is in carbonate rock. A selected sample assayed 0·28 ounce of gold and 22·3 ounces of silver a ton. The best vein on the Farrell property is in sheared andesite, is 2 feet wide, and may be more than 100 feet long. Picked samples have assayed 0·3 to 0·8 ounce of gold a ton. The veins on the Flag group vary in width from 2 inches to 5 feet and have a maximum length of 35 feet. Selected samples from the best showing assayed up to 0·19 ounce of gold and 37·1 ounces of silver a ton.

Deposits Containing Galena and Sphalerite

The galena-sphalerite deposits consist of quartz veins and quartz-rich zones mineralized with patches of galena, sphalerite, and minor pyrite, averaging half an inch or less in diameter. A quartz zone on Manson River near Discovery Bar is 12 feet wide, and occurs in sheared andesite along a subsidiary fault. It consists of parallel stringers of quartz ¼ to ½ inch wide, separated from one another by ¼- to 1-inch layers of wall-rock. The sulphides are in the quartz stringers. A grab sample assayed 1·58 per cent lead, 0·49 per cent zinc, and 1·32 ounces of silver and 0·005 ounce of gold a ton. A 4-foot vein sparsely mineralized with galena and pyrite occurs in carbonate rock near this quartz zone. Several other minor occurrences were observed elsewhere along the Manson fault zone.

Deposits Containing Pyrite and Galena

The Berthold property affords the only example of pyrite and galena deposit, which consists of a silicified fracture zone, 10 feet wide, in argillaceous quartzites near a probable branch of the Manson fault zone. The fractured zone is mineralized with fine-grained pyrite and minor amounts of galena. Assays indicate 0·01 to 0·06 ounce of gold and 6 to 13 ounces of silver a ton across 10 feet.

ORIGIN OF DEPOSITS ALONG MANSON FAULT ZONE

No genetic relationship is apparent between the mineral deposits of the Manson fault zone and any nearby volcanic or intrusive rocks. The source of the ore-bearing solutions is not known, but is possibly some deep-seated phase of the Omineca or later Tertiary intrusions. The Manson fault zone provided abundant channelways for mineralization, and deposition occurred wherever conditions were favourable; carbonatization preceded mineralization in many places along it.

Other Major Fault or Shear Zones

In addition to the zones of carbonatized rocks occurring along the Pinchi and Manson fault zones, many exposures of similar rocks have been observed elsewhere in the Fort St. James area. All of them are believed to mark zones of shearing. One such carbonate-quartz-mariposite zone crosses the Stuart Lake antimony property from northwest to southeast and probably extends 12 miles southeast to Tsah Creek, where a low-grade gold deposit has been found in similar rocks. The Nina copper deposit lies along a similar carbonate zone cutting Cache Creek rocks northeast of Nina Lake.

Stuart Lake Antimony Showing

The main showings on the Stuart Lake antimony property consist of three northwesterly trending veins in a carbonate zone believed to lie along a zone of faulting and shearing, and one northeasterly trending vein in Cache Creek argillites. The carbonate zone is about 150 feet wide, consists of ankeritic carbonate, quartz, serpentine, and mariposite intersected by a network of quartz veins and lenses, and grades into argillite and greenstone. The main vein in the carbonate zone varies in width from 2 to 5 feet and is 280 feet long. Stibnite is the only mineral to occur in any amount, and is generally in bands and lenses. In places good assays in gold have been obtained from the vein. The northeasterly trending vein in the argillite lies along a northeasterly trending fracture. It carried a shoot of almost solid stibnite 30 feet long and 41 inches wide.

Nina Copper Showing

The Nina copper showing, which consists of a mineralized zone at least 8 feet wide containing malachite and pyrite with minor azurite, lies in a 200-foot band of sheared, carbonatized, silicified, and pyritized interbedded argillite and andesite of the Cache Creek group.

DEPOSITS RELATED TO MINOR FAULT, SHEAR, OR FRACTURE ZONES

Included here is a great variety of mineral deposits, which, on the basis of mineral occurrence, may be grouped as follows: (1) deposits containing one or more of the metals, silver, lead, and zinc; (2) copper deposits; (3) tungsten deposits; and (4) tin-vanadium deposits.

Silver-Lead-Zinc Deposits

The silver-lead-zinc deposits occur in small, irregular veins, 2 inches to 5 feet wide, filling shear and fracture zones. In many of the deposits that occur in the Cache Creek greenstones these rocks have been much carbonatized and silicified. The deposits may be divided into several distinct types according to the minerals present. These are: (a) deposits in which the chief ore minerals are galena, sphalerite, and chalcopyrite, and the gangue is quartz; (b) deposits in which the chief ore minerals are galena, sphalerite, pyrrhotite, and pyrite, and the gangue is quartz; (c) deposits in which the chief ore mineral is tetrahedrite, and the gangue is ankeritic carbonate with quartz and barite; and (d) deposits in which the ore minerals are galena and chalcopyrite, and the gangue is quartz, barite, and fluorite.

(a) Deposits of this type contain, besides galena, sphalerite, and chalcopyrite, minor amounts of pyrite and tetrahedrite. They are valuable for their gold, silver, lead, and zinc content. The Taltapin and Anderson groups and the Golden Glory and Silver Glance properties contain such deposits.

Those of the first two occur in fracture zones in Cache Creek greenstones near the contact of a Topley granite and granodiorite body and in roof pendants in that body, whereas the Golden Glory and Silver Glance deposits are along shear and fracture zones in Hazelton group andesitic flows and breccias. From a study of polished sections of Taltapin ore the following mineral sequence was determined: of the ore minerals, pyrite is earliest, followed by sphalerite, chalcopyrite and tetrahedrite, and galena. Quartz crystallized during a lengthy period. Much of it preceded the deposition of the sulphides, but some crystallized during the closing stages of mineralization.

(b) The only deposits of this type are those exposed on the Black Hawk group. On this property at least nine quartz veins, ranging in width from 15 inches to 5 feet, occur within a belt of fractured Cache Creek andesite 650 feet wide. The veins are mineralized with galena, sphalerite, pyrrhotite, and pyrite, and the wall-rocks are silicified and pyritized. The Germansen granodiorite batholith outcrops 1½ miles south of the showings.

(c) Deposits of this type contain, besides tetrahedrite, minor amounts of argentite, native silver, galena, chalcopyrite, pyrite, sphalerite, malachite, and azurite. The only valuable metal is silver, and the only deposit of this type is on the Silver Island property. The veins on this property lie at the contact of a Tertiary rhyolite stock with a Topley diorite body.

(d) The Mona property contains the only occurrence of this type. It occurs in andesite.

In all four types of silver-lead-zinc-deposits the ore shoots occur irregularly in the veins, which may be composed in part or entirely of sulphides. Very little surface oxidation is in evidence. It is represented by malachite and azurite, which occur only in negligible amounts.

Those deposits on the west side of Taltapin Mountain probably owe their origin to the intrusion of the nearby Topley granodiorite and granite. The Black Hawk showings appear to be related to the intrusion of the Germansen batholith. The mineralization on the Silver Island property is probably related to the Tertiary rhyolite stock outcropping on the island, and the rhyolite dykes exposed near the Silver Glance and Golden Glory deposits south of Decker Lake may bear some genetic relation to this mineralization. In all deposits, fault, shear, or fracture zones have provided channelways for mineralizing solutions.

Copper Deposits

Copper deposits are represented on two properties, namely, the Three Star group on Boo Mountain and the Klawli copper showing. The Three Star deposit occurs in a zone of fracturing, 20 feet wide, in sheared Hazelton group andesite of Jurassic (?) age. The chief ore minerals are chalcopyrite, pyrite, and specularite. These occur in a quartz gangue, either as bands from $\frac{1}{16}$ inch to several inches wide or as vugs in the volcanic rocks. The origin of this deposit has not been established.

The Klawli copper deposit comprises several mineralized zones in sheared andesite, the widest being 55 feet. These consist of quartz-carbonate veins up to 12 inches wide and averaging 4 inches, each separated by 3 to 4 feet of altered and mineralized andesite. The veins carry abundant chalcopyrite and pyrite, and minor azurite and malachite, and the same minerals are disseminated throughout the intervening altered andesite. The Hogem batholith outcrops about 1½ miles south of the showing, and probably is the source of the mineralizing solutions.

Tungsten Deposits

Nine miles south of the east end of Chuchi Lake, a disseminated deposit of scheelite, powellite, molybdenite, and chalcopyrite occurs in a fracture zone at the contact of a granite stock with silicified Takla group andesite. The mineralized zone is at least 12 feet wide. The deposit contains less than 0·1 per cent tungsten.

Tin-Vanadium Deposits

On Tsitsutl Mountain a rhodonite vein in Cache Creek sedimentary rocks consists of 70 per cent rhodonite, 2 to 3 per cent arsenopyrite, and a variable amount of calcite, garnet (spessarite), and ilmenite. Samples yielded a little tin, vanadium, nickel, cobalt, and manganese. The ilmenite is probably the source of the vanadium, cobalt, and nickel. The tin mineral was not identified.

Deposits Within Intrusive Masses

Included here are three types of deposits, namely: (1) molybdenum deposits; (2) copper deposits; and (3) chromite deposits. All are believed to have formed from emanations given off by the magmas from which the intrusive rocks, in which they occur, crystallized.

Molybdenum Deposits

Molybdenum deposits are represented by the Stella and adjoining molybdenite properties southwest of Endako. The Stella deposit consists of several quartz veins, up to 2 feet wide, containing scattered molybdenite, which is also disseminated through the adjoining Topley granite. The mineral occurs mostly in microscopic scales. Pyrite and hematite are sparsely distributed in the deposits. Some oxidation is evident, with the formation of the yellow oxide, molybdic ochre.

According to Kerr (87, p. 164) the Stella molybdenite quartz veins were clearly derived from the granite in which they occur, and were formed during a late stage in the cooling in a manner similar to pegmatites. The writer agrees that such an origin is the one most probable for this deposit.

Three miles south of Ling Lake, in a granite body, a pegmatite dyke 1 foot wide was observed to contain large flakes of molybdenite.

Copper Deposits

The Duckling Creek copper showing consists of a large, disseminated, copper deposit in syenite forming part of the Hogem batholith. Mineralization is represented by specks and small stringers (¼ inch by 6 inches) of malachite, chalcopyrite, bornite, and pyrite. Most of the stringers lie along fractures or planes of gneissosity.

Chromite Deposits

During the field season of 1942 nine chromite deposits were found in the dunites and peridotites exposed in the Middle River Range and the southern end of Mitchell Mountains. The largest chromite body discovered in the Middle River Range has a surface area of about 5 by 25 feet, and contains at least 50 per cent chromite. The largest lens observed in Mitchell Mountains was 8·8 by 32·5 feet, and contains 38·0 per cent chromite. In addition to lenses of chromite, many zones containing disseminated chromite were observed. The disseminated chromite is interstitial to grains of olivine and appears to be of early magmatic origin. In other places chromite forms very small veinlets in serpentinized dunite. The lenses of chromite are generally in sharp contact with the host rock, but in places the contact is gradational. The writer believes the larger, lens-like deposits are probably of early magmatic origin, the solutions depositing chromite originating in the ultrabasic magma that provided the dunitic and peridotitic host rocks.

Other Metalliferous Deposits

Manganese Deposits

Several small deposits containing manganese minerals have been staked near Fort Fraser. The manganese oxides, pyrolusite and psilomelane, occur along fractures in Cache Creek quartzites. The largest showing is approximately 4 by 10 feet, and consists of pyrolusite and psilomelane with thin seams of sandy, yellow clay.

A small vein of braunite and psilomelane occurs in Cache Creek limestone west of the south end of Indata Lake.

Contact Metamorphic Deposits

The only deposits of this type are on the Radio Gold property, where the showings occur at the contact of metamorphosed Cache Creek rocks (gneisses, schists, and banded foliated sediments) and a body of Topley diorite, which is intimately intruded by granodiorite. The mineral showings are of several types: (a) pyrite, magnetite, epidote, and glassy quartz, disseminated throughout the metamorphosed Cache Creek rocks and the diorite; (b) large, irregular lenses of glassy quartz, up to 20 to 30 feet thick and 100 to 200 feet long, carrying minor amounts of pyrite, chalcopyrite, and molybdenite; and (c) quartz veins carrying minor amounts of the same sulphides as the lenses. Available assays show a low content of gold and silver. The disseminated deposits have all the features of typical contact metamorphic deposits, but the quartz veins and lenses contain minerals usually associated with hydrothermal deposits.

NON-METALLIC DEPOSITS

Coal

Coal has tbeen found in two localities in the Fort St. James area, namely, Discovery Creek and Fraser Lake.

The coal along Discovery Creek is probably of Mesozoic age. The best seam is 2·5 feet thick, and dips almost vertically. The coal is very impure and lensy.

At the east end of Fraser Lake several narrow seams of Tertiary lignite coal are exposed. The widest seam does not exceed 12 inches.

Magnesite

A few veins of magnesite, 1 to 4 feet wide, were observed along the south face of Pinchi Mountain. Irregular masses of magnesitic carbonates up to 25 feet across and veined by cherty quartz were also observed there. These showings lie along the Pinchi fault zone, and the magnesite probably originated as a result of hydrothermal alteration of serpentine along the fault zone.

Asbestos

One showing of chrysotile asbestos and one of tremolite asbestos were observed in the peridotite exposed on Mount Sydney Williams. Neither deposit is large enough nor the grade of asbestos high enough to be of commercial interest.

Asphaltum

A small deposit of asphaltum and phosphate minerals occurs 2 miles north of François Lake post office. The minerals occur in an irregular vein, 4 to 12 inches wide, that outcrops at intervals for 100 feet. The vein consists of botryoidal phosphates, associated with some asphaltum and brecciated andesite. It occurs in a Tertiary andesitic flow. The phosphates are collinsite and quercyite. The showing is of mineralogical interest only.

Perlite

Perlite, a rhyolitic volcanic glass containing water, outcrops along the north shore of François Lake about 2 miles east of the ferry landing. It is in the form of a lava flow 30 feet thick and is overlain and underlain by normal rhyolite flows of probably Eocene or Oligocene age.

CARBONATIZATION

Carbonatization is widespread throughout the Fort St. James area, particularly along zones of faulting, shearing, and fracturing. It is most marked along the Pinchi and Manson fault zones, and along other major fault or shear zones such as those crossing the Stuart Lake antimony property and the Nina copper showing; the shear zones north of Fall River; and the numerous fault, shear, and fracture zones traversing the Trembleur ultrabasic masses in the mountainous area west of Middle River. Considerable carbonatization was also noted in the vicinity of the Taltapin and nearby properties, and near the Klawli copper showing.

Carbonatization Along Pinchi, Manson, and Other Major Fault or Shear Zones

(*See* Plate IV)

Undoubtedly more than one period of movement has affected the Pinchi and Manson fault zones, and other major fault and shear zones. In early stages of faulting the wall-rocks were sheared and brecciated, andesites were changed to chlorite schists, serpentines to serpentine schists, argillites to graphitic schists, cherts to quartz-mica schists, and limestones to carbonate-sericite schists. These shear and breccia zones acted as channelways for later carbonated solutions that attacked the wall-rocks and replaced them with ankeritic carbonates. Greenstones and serpentines were partly to completely altered to buff-coloured aggregates of ankeritic carbonate, quartz, chlorite, and mariposite (green mica); argillites and cherts to quartz-carbonate-mica schists; and grey limestones to buff dolomites.

Most of the serpentine outcropping along these fault zones has been altered to a buff carbonate rock, which in most places is composed of a network of magnesite veinlets and quartz stringers, from a fraction of an inch to 4 inches wide, cutting an aggregate of ankeritic carbonate, cherty quartz, and mariposite. A few veins of magnesite, 1 foot to 4 feet wide, were observed along the south face of Pinchi Mountain, as were also irregular masses of magnesitic carbonate as much at 25 feet wide and veined by cherty quartz. The following is a proximate analysis of the ankeritic carbonate: $MgCO_3$, 56·4 per cent; $CaCO_3$, 16·1 per cent; $FeCO_3$, 16·2 per cent; insol. (largely silica), 12·0 per cent.

The alteration products of the greenstones are very similar except that ankeritic carbonate and not magnesite is formed, and chlorite is a common constituent.

The Cache Creek ribbon cherts appear to have suffered least alteration, the main change being a replacement of some of the argillaceous material by ankeritic carbonate.

Dolomitization of the Cache Creek limestones is most conspicuous in the vicinity of the Pinchi Lake mercury mine and along Kwanika Creek. In both places blue-grey and white limestone have been partly to completely replaced by cream and buff dolomite. A study of the chemical analysis shows that the alteration consisted mainly in the substitution of magnesium for calcium. The large increase in insoluble material, mainly silica, in ore specimens from Pinchi Lake mercury mine is related to the later period of mineralization and not to the dolomitization. Silica may be observed replacing dolomite in many ore specimens.

TABLE XII

Analyses[1] of Pinchi Mercury Belt Limestones and Dolomites

Sample	CaO	$CaCO_3$	MgO	$MgCO_3$	$(FeAl)_2O_3$	Insol.	SiO_2	Alkalis
	%	%	%	%	%	%	%	%
33A	45·07	80·05	7·40	15·47	0·77	3·25	3·07	0·20
69A	55·60	99·28	1·62	3·38	0·81	0·87	–	0·07
110A	34·81	62·16	0·21	0·44	1·80	33·01	27·97	1·23 1·08 (Na_2O)
140A	26·90	48·04	12·01	25·29	0·99	24·64	22·75	
192A	34·03	60·77	17·97	37·56	1·59	0·38	–	–
200A	55·41	98·95	0·31	0·63	0·15	0·07	–	–
Pure dolomite	30·40	54·35	21·70	45·65	–	–	–	–

[1] Analyses by R. J. C. Fabry, Mineralogical Section, Geological Survey of Canada, Ottawa.

33A. Buff, dolomitic limestone outcropping 5 feet from 'south fault' at Pinchi Lake mercury mine.
69A. Blue-grey limestone outcropping near office at Pinchi Lake mercury mine.
110A. White, siliceous limestone containing cinnabar, from Pinchi Lake mercury mine.
140A. Buff, dolomitic limestone containing cinnabar, from glory hole at Pinchi Lake mercury mine.
192A. Buff dolomite outcropping 10 feet from east fault on Kwanika Creek.
200A. Buff limestone outcropping along ridge west of Kwanika Creek.

These carbonatized rocks formed relatively rigid bands along which later fault movements developed open fractures and breccia zones rather than closed shears. Subsequent mineralizing solutions traversing these fractures and breccia zones resulted in further carbonatization and silicification, together with deposition of cinnabar along the Pinchi fault zone, gold and accompanying sulphides along the Manson fault zone, stibnite along the shear zone south of Stuart Lake, copper sulphides along the shear zone northeast of Nina Lake, and copper sulphides along the shear zone northeast of Nina Lake. Post-mineral movements along the fault zones have offset some of the orebodies. Carbonatization is more pronounced along the main fault zones than the subsidiary faults, and the latter still preserve evidence of the early shearing. Many of the mineral deposits are along subsidiary faults.

Carbonatization near Taltapin and other Properties

In the vicinity of the Taltapin, Radio Gold, Anderson, and Boling properties, medium- to fine-grained, grey and grey-green carbonate-quartz rocks are found. They have resulted from the alteration of greenstones and chlorite schists, and possibly of chloritized and schistose sedimentary rocks of the Cache Creek group. The greenstones and chlorite schists were originally andesitic flows. In some localities the carbonate-quartz rocks exhibit well-developed banding, and in others good schistosity. They occur in roof pendants and at the contact of the Cache Creek rocks with nearby Topley intrusions. The writer believes the carbonatization and silicification was brought about by the same ascending hydrothermal solutions that formed the veins of the district, as both processes are more intense near the veins.

Under the microscope the carbonate-quartz rocks are seen to be composed of approximately 50 per cent calcite, in coarse and fine grains; 35 per cent quartz; 10 per cent feldspar; and 5 per cent chlorite, hornblende, sericite, and accessory minerals. The feldspar is of about the composition of andesine. The quartz, which occurs in fine grains, is in part introduced and in part original. Pyrite, ilmenite, titanite, and apatite are the accessory minerals. In most thin sections the grains show a parallel orientation, and, in part, a segregation into chloritic and non-chloritic bands. Quartz and calcite also occur in minute stringers, and in one thin section the calcite stringers were observed traversing the quartz stringers.

Carbonatization similar to that described above was observed in the vicinity of the Klawli copper showing and along the west fork of Klawli River.

CHAPTER VI

DESCRIPTION OF PROPERTIES[1]

PLACER GOLD CREEKS

Tom Creek

References: Galloway, J. D.: Northeastern Mineral Survey District No. 2; Ann. Rept., Minister of Mines, B.C., 1924, p. 109 (1925). Lay, Douglas: Northeastern Mineral Survey District No. 2; Ann. Repts. Minister of Mines, B.C.: 1927, p. 160 (1928); 1933, pp. 106-107 (1934).

Tom Creek flows northwesterly into Kenny Creek at a point 18 miles east of Takla Landing, from where it may be reached by truck road.

Placer gold was not discovered on Tom Creek until 1889, 20 years after the initial discovery of placer gold in this district on Vital Creek. The creek was worked extensively and with success for the next few years, the workings extending from 1 mile to 2½ miles above its mouth. The Mayflower Mining Company operated on Tom Creek from 1899 to 1904 or later, and are reported to have made a profit. They developed their ground by means of a deep, bedrock flume 200 feet long and 12 to 16 feet deep. Since about 1920, most of the mining has been at the lower end of the ground worked in earlier years. This part of the stream was first worked by W. McCormick, and from 1935 on by Tom Creek Placers, Limited. McCormick developed his leases by means of a bedrock tunnel, and this system was employed at first by Tom Creek Placers, Limited, who later changed to a surface operation using a steam shovel.

Tom Creek cuts across interbedded argillites, ribbon cherts, and schists of the ribbon chert division of the Cache Creek group. As the writer did not examine the placer workings the following information is taken from Lay's reports. The ground originally mined was from 10 to 20 feet deep and relatively free of large boulders. Lay (1934, p. 107) describes the area worked by McCormick and later Tom Creek Placers, Limited, as follows: "At the point where the Manson Trail crosses Tom Creek (approximately at lower end of old workings) it makes a sharp turn to the west, continuing its course through a canyon. A glacial deposit at this point strongly suggests that the older course of the creek was under this glacial deposit and more in line with the upper portion of the creek. This buried channel-segment is on the east side of the creek. A shaft 250 feet down stream from the head of the canyon, at which point the creek diverges from its former channel, reached bedrock at a depth of 73 feet. From 75 cubic yards of bedrock gravels mined from this working, it is stated 25 ounces of gold were recovered."

The recorded production from Tom Creek is 1,624 ounces of gold.

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[1] For each type of deposit, properties are described in geographic order, roughly from northwest to southeast. This is thought to have some advantage over an alphabetical sequence in that the relationship of adjoining or nearby occurrences of similar type may be more readily apparent.

Harrison Creek

Reference: Lay, Douglas: Northeastern Mineral Survey District No. 2; Ann. Rept., Minister of Mines, B.C., 1935, pp. C28-C29 (1936).

Harrison Creek, which flows southerly into Kenny Creek between Humphrey and Tom Lakes, may be reached by a truck road about 22 miles long from Takla Landing. The main workings are about ¾ mile above the mouth of the creek. The creek was worked intermittently between 1870 and the present (1947). In 1935 leases on it were acquired by Harrison Creek Ventures, Limited (Venture Exploration Company of East Africa), who undertook large-scale hydraulic operations for the next few years. Some of the earlier work consisted of underground mining.

The bedrock along Harrison Creek consists of northwesterly striking, steeply dipping, interbedded argillites, slates, ribbon cherts, and greenstones of the Cache Creek group of Permian or probable Pennsylvanian age, which contain numerous quartz stringers and veins.

In the part of the valley containing the workings the creek follows a canyon about ½ mile long. The east wall of the canyon forms the main rock-rim of the valley, rising steeply above the creek for many hundreds of feet. On the west side of the canyon are extensive flats 25 to 75 feet above the creek in the upstream part. Above and below the canyon just described the flats terminate. According to Lay (1936, p. C281) "the mode of the placer occurrence exemplified is a buried pre-Glacial channel remnant about one mile in length, which is plainly indicated topographically as lying buried in the right bank of the creek". The gravels in the old channel are free from large boulders, and are overlain by boulder clay. Encouraging amounts of coarse gold are reported.

The recorded production from Harrison Creek is 232 ounces of gold.

Kelly Creek

Reference: Lay, Douglas: Northeastern Mineral Survey District No. 2; Ann. Rept., Minister of Mines, B.C., 1933, p. 107 (1934).

Kelly Creek flows southerly into Byrnes Lake, a wide part of Kenny Creek, about 25 miles by truck road from Takla Landing. About 1931, placer gold was discovered on this creek, 1½ miles above its mouth, by an Indian, and several claims were staked and worked intermittently until 1940. The creek traverses an area underlain by interbedded sedimentary and greenstone formations of the Cache Creek group.

The placer deposits were not investigated by the writer, but according to Lay (1934, p. 107): "the post-Glacial waters of the creek have cut down through a glacial filling on the west side of the valley to or close to bedrock, and in doing so have made a concentration of placer on either true or false bedrock. The placer gold is fairly coarse, one nugget being obtained. All the diggings are shallow".

Silver and Kenny Creeks

Silver Creek flows northerly into Omineca River at Old Hogem, and Kenny Creek drains easterly into Silver Creek at a point 12 miles south of Omineca River and 28 miles east of Takla Landing, the truck road from the Landing to Omineca River at Old Hogem following along the north side of Kenny Creek and the west side of Silver Creek.

These creeks have fairly wide valleys with high gravel banks on both sides. In places these deposits are several hundred feet thick, and include both boulder clay and stream gravels. The present stream channels have cut into bedrock along parts of their courses, forming rock canyons. Along Kenny Creek the bedrock consists mainly of interbedded argillites, ribbon cherts, and greenstones of the Cache Creek group. Silver Creek below the junction flows almost along the Pinchi fault zone, traversing alternately Cache Creek and Takla formations.

Only sporadic attempts have been made to mine these creeks in recent years, and at the time (1943) the writer visited the area no placer deposits were being worked. However, fairly extensive old workings were observed on Silver Creek near the mouth of Vital Creek and near its junction with Kenny Creek. Workings on Kenny Creek were observed for about half a mile above the junction, and it is reported that earlier miners found concentrations of placer gold in shallow gravels overlying rock benches. Nuggets of arquerite, a natural amalgam of silver and mercury, have been found in Silver Creek. The recorded production from the two creeks is 642 ounces of placer gold.

In 1943, the Consolidated Mining and Smelting Company of Canada, Limited, actively developed a group of mercury claims near the junction of Silver and Kenny Creeks. At the north end of a stripping along Silver Creek a bed of Tertiary(?) gravel, 10 feet thick, was uncovered. This gravel rests on bedrock and is overlain by boulder clay. Boulders of rich cinnabar ore occur in the gravel, some as much as 2 feet in diameter. This probably represents an old channel of Snell Creek, a small tributary entering Silver Creek from the east.

Vital Creek

References: Galloway, J. D.: Northeastern Mineral Survey District No. 2; Ann. Rept., Minister of Mines, B.C., 1924, p. 108 (1925). Lay, Douglas: Northeastern Mineral Survey District No. 2; Ann. Repts., Minister of Mines, B.C.: 1933, pp. 105-106 (1934); 1936, p. 39 (1937).

Vital Creek flows northeast into Silver Creek from its source in Vital Mountains. It may be reached by 35 miles of truck road from Takla Landing. The first placer gold found in the Fort St. James area was obtained from Vital Creek in 1869, and the creek was worked for some years by the old-timers, first as drift-diggings and later by ground-sluicing and hydraulicking. Later, the creek was worked intermittently by several companies until 1922, when Lee Tong and associates took over and continued the old workings upstream. Between 1922 and 1934 they developed the property successfully by means of underground operations, following an old channel by driving a tunnel along bedrock for 935 feet. In 1935 Northérn Ventures, Limited (Venture Exploration Company of East Africa), acquired five claims and twelve leases on Vital Creek, covering the entire section of the creek that had been worked. They decided to abandon the drift mining, as carried out by Lee Tong and associates, in favour of hydraulicking. Hydraulic operations commenced in the late spring of 1936, but were abandoned during the summer as dumping facilities were insufficient to handle the great thickness of overburden. A shaft 90 feet deep was then sunk to bedrock. However, the company withdrew a year or so later without any production. The recorded production from Vital Creek is 3,986 ounces of placer gold.

The creek traverses, nearly at right angles, a belt of northerly trending, steeply dipping, interbedded Cache Creek argillites, ribbon cherts, quartz-mica schists, and greenstones. The present creek cuts into bedrock in most places along the lower 2 miles of its course. At a point about 2 miles above its mouth the creek drops over a falls about 80 feet high, and from there to its source only an occasional outcrop is found. Most of the earlier workings were below the falls, but the more recent workings commence just below the falls and continue upstream following a pre-Glacial bedrock channel. This old channel, which emerges into the present channel just below the falls, lies to the north and 80 feet below the present channel, and is buried beneath 200 feet of compact boulder clay and glacial gravel. Lee Tong and associates drifted along this channel for 935 feet. The gold recovered was in the form of extremely coarse, well-worn flakes, and almost all of it lay either on bedrock or in crevices in the rock. Of the overlying gravel only the bottom foot carried gold in paying quantities. The pay-streak was only a few feet wide.

Much of the first gold recovered came from the present day channel below the falls. This gold was probably concentrated in post-Glacial times as a result of erosion of the pre-Glacial channel.

Arquerite, a native amalgam of silver and mercury, is fairly abundant in the gold-bearing gravels along Vital Creek.

Quartz Creek

References: Lay, Douglas: Northeastern Mineral Survey District No. 2; Ann. Repts., Minister of Mines, B.C.: 1933, pp. 107-108 (1934); 1935, p. 39 (1936).

Quartz Creek rises in Vital Mountains and flows northerly into Fall River. The placer workings, which extend upstream for 1½ miles from the mouth of the creek, may be reached from the Takla Landing-Old Hogem truck road either by trail up Harrison Creek across the divide and down Quartz Creek or by trail up Teegee Creek and Fall River. The first route comprises 18 miles of road and 9 miles of trail, and the second, 38 miles of road and 7 miles of trail. It is not known when gold was first discovered on this creek, but it has been worked intermittently since the early thirties. The recorded production is 435 ounces of placer gold.

The bedrock along Quartz Creek consists of interbedded sedimentary and volcanic formations, in part schistose, of the Cache Creek group. Numerous quartz veins varying in width from a few inches to a few feet were observed along the creek and in Vital Mountains at the head of the creek.

The placer deposits were not examined by the writer and the following information is from Lay's reports. Near the workings the creek occupies a deep, wide valley, flows on bedrock, and is in part contained in a canyon, with steep walls about 100 feet in height composed of glacial boulder clay and gravels. Lay states that this is a post-Glacial channel, and that the pre-Glacial channel is buried in the right bank except at a point about ¾ mile above the canyon, where a segment is exposed in the left bank of the present creek. Placer mining efforts have been directed both to post-Glacial concentrations of gold-bearing gravels on rock benches and immediately overlying bedrock in the creek, and to the buried channel.

Kwanika Creek

Kwanika Creek is a large stream that flows southerly into Tsayta Lake. In recent years placer gold was found along a 2-mile stretch of this creek, commencing at the sharp northerly bend 2 miles above its mouth and continuing upstream. This part of the creek may be reached by a trail about 3 miles long from Tsayta Lake, which is 55 miles by water and 75 miles by road from Fort St. James.

A belt of northwesterly trending Cache Creek limestone crosses Kwanika Creek at the sharp northerly bend 2 miles above its mouth, and diverges to the west upstream. Thinly bedded, Upper Triassic greywacke, argillite, and tuff of the Takla group are exposed for several miles along Kwanika Creek above the bend, and tongues of the Hogem granodiorite-diorite batholith reach the creek and intrude both Takla and Cache Creek rocks. The Pinchi fault zone crosses the creek at the bend.

Kwanika Creek flows in what appears to be a post-Glacial channel, which has cut through 25 feet or more of glacial debris into bedrock. Where its present channel is not constricted by rock walls, the creek is bordered by low-lying gravel flats, 5 to 10 feet above low water. Fairly coarse placer gold has been found in the creek bed and on the gravel flats. The best concentrations of gold are around large boulders. Two men are reported to have obtained $3,500 worth of gold from Kwanika Creek in 1940 as a result of 3 months labour. Arquerite (natural amalgam) and cinnabar are obtained on panning.

Placer gold has also been found on some of the southerly flowing tributaries along the east fork of Kwanika Creek.

Twentymile Creek[1]

The head of Twentymile Creek lies about 6 miles west of the west end of Germansen Lake. The creek flows north into Omineca River. It may be reached by road from Manson Creek to the east end of Germansen Lake, and thence by boat or pack-trail to the west end of the lake, from where a good trail 6 miles long leads to the workings. During recent years several men have been engaged in ground-sluicing along Twentymile Creek and one of its easterly tributaries; individual annual recoveries are reported to have reached several thousand dollars.

Twentymile Creek flows through an area of Takla volcanic rocks. The placer workings are in extensive gravel flats, and the gold is found within a few feet of the surface. Many large boulders occur along the creek, and the best recovery is commonly made around these boulders. The gold is coarse and flaky, is generally found lying on boulder clay, and has evidently been concentrated in post-Glacial time.

[1] Examined by J. B. Thurber, Geological Survey, 1944.

West Fork of Klawli River

Klawli River is a fairly large stream entering Chuchi Lake (Lower Nation Lake) from the north. Several of the small tributaries at the head of the west fork have been worked for placer gold in past years, but no records are available to indicate the success met with in these operations. Workings were observed along two small tributaries, both of which have cut down to bedrock, which is mainly sheared andesitic greenstones of the Takla group. Small quartz veins cut these andesites.

The placer workings are in the beds of the present streams, which are evidently post-Glacial in origin.

Germansen River[1]

(*See* Figure 6)

References: Lay, Douglas: Northeastern Mineral Survey District No. 2; Ann. Repts., Minister of Mines, B.C.: 1927, p. 158 (1928); 1936, pp. 3-12 (1937). The Miner: The Germansen Operations; vol. 12, May 1939, p. 44 (1939).

Only a brief examination was made of the placer workings on Germansen River, and much of the information contained herein is from published accounts.

Germansen River may be reached by a fair truck road from Fort St. James, about 135 miles to the south. The river drains the lake of the same name, and flows 16 miles to Omineca River at Germansen Landing. For the first 2 miles of its course it occupies a wide valley and flows southeasterly. It then turns sharply northeast to enter a rock canyon some $\frac{3}{4}$ mile long, with walls rising some hundreds of feet above the river. Continuing for $4\frac{1}{2}$ miles, the river makes a right-angle turn and flows northwesterly to its confluence with the Omineca. The upper part of the valley in its northwesterly trending course is wide, the relief is mature, and numerous gravel-covered rock benches are exposed. Near Mill Creek the valley narrows, and the river below this point is confined to a canyon about $2\frac{1}{2}$ miles long, from which it emerges to enter the wide valley of Omineca River. For the most part, the river valley is incised to a depth of about 250 feet, but in places it is featured by low-lying benches and bars with no overlying boulder clay, and in other places by bedrock benches overlain by upwards of 10 feet of auriferous gravels, which in turn are overlain by as much as 75 feet or more of boulder clay.

Bedrock exposed along Germansen River consists mainly of interbedded slates, argillites, and greenstones of the Cache Creek group. These formations trend from westerly to northwesterly and dip nearly vertically. Several small bodies of serpentine were observed cutting these Cache Creek rocks. Quartz veins are fairly numerous, particularly in the greenstone bands. The Manson fault zone lies along part of the creek, and the rocks along it have been hydrothermally altered to buff-coloured aggregates of ankeritic carbonate, quartz, chlorite, and mariposite.

Placer gold was first discovered in Germansen River in 1870. The northwesterly trending part of the river has been worked almost continuously since then by individuals, and at times by companies. Two major

[1] Examined by J. B. Thurber, Geological Survey, 1944.

companies, Germansen Mines, Limited, and Germansen Ventures, Limited, commenced operations in 1931 and 1936 respectively. Both ceased operations in 1943 due to war-time difficulties. The 'old timers' generally confined

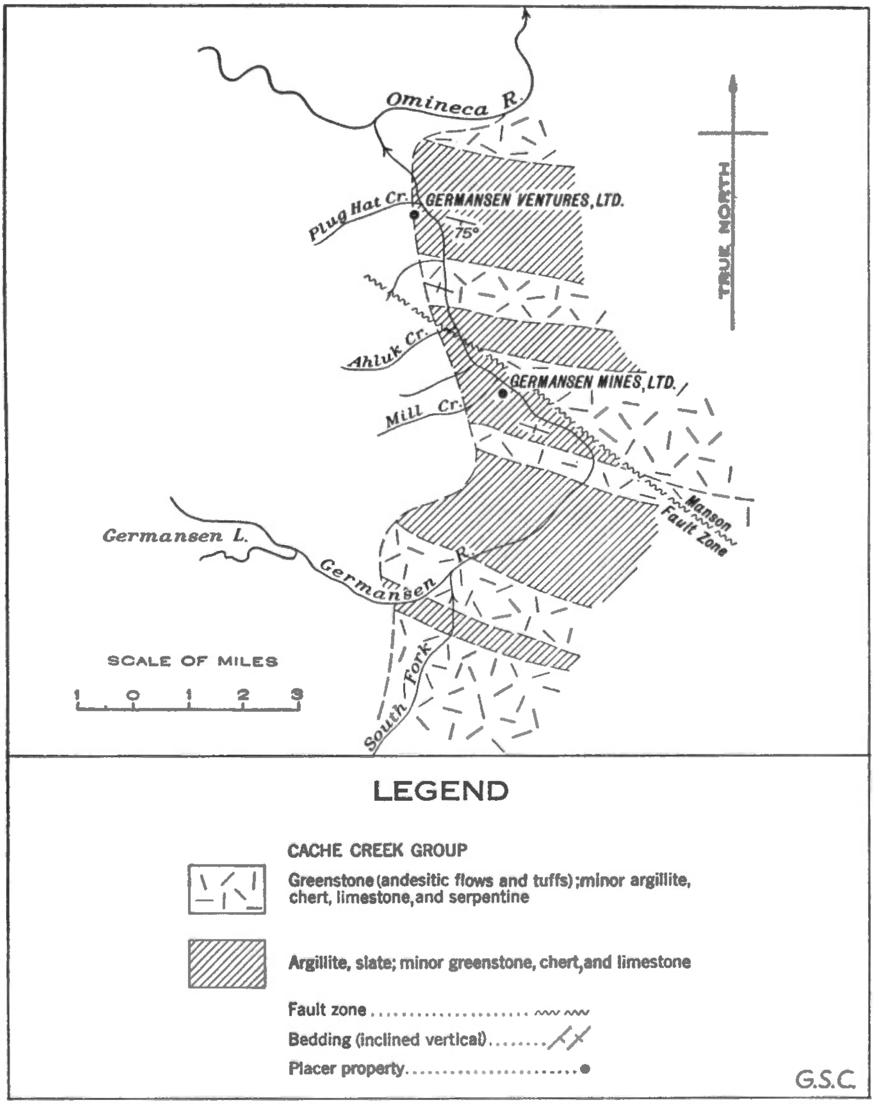


Figure 6. Geological plan of Germansen River placer area.

their operations to the low-lying benches and bars with little or no overburden, Holloway's bar being probably the most productive of these. The recorded production from Germansen River is 24,138 ounces of placer gold.

According to Lay the placer deposits along Germansen River may be classified as follows:

"(1) Deposits on low-lying gravel or rock benches and in the bed of the river. Most of these, if not all, are of post-Glacial age, and form the type of deposit extensively worked by the earliest miners.

(2) Deposits on rock benches lying at an elevation of about 35 feet above the river, and overlain by much glacial debris.

(3) Deposits in deeply-buried channels above the level of the river.

(4) Deposits in a channel system, deeply buried, below the level of the river."

It is evident that the river occupies, almost throughout the length in which placer gold has been discovered, a post-Glacial channel. Concentrations of placer gold in the bed of the river and on adjacent low-lying gravel or rock benches are apparently due to post-Glacial waters cutting across a former channel. Lay (1937, p. 8) describes the old channel as follows: "Rock benches at and above 20 feet above the river are overlain, usually quite heavily, with glacial material. Immediately overlying bedrock there is usually a more or less cemented layer of pieces of shattered bedrock, and fine gravel, overlain by imbricated gravels, some very coarse, derived almost entirely, save for boulders of granodiorite, from local rocks. Resting on the gravels is more or less silt, which is capped by up to 50 feet of boulder clay, on top of which there is usually a post-Glacial run of gravel."

GERMANSEN MINES, LIMITED

Germansen Mines, Limited, is reported to hold leases on Germansen River from Mill Creek to Little Slate Creek. The company was incorporated in 1931 to develop the ground, after an examination, prior to 1931, by R. C. and A. A. McCorkell.

In 1934 the company acquired the property, and operated it until 1943. This was an hydraulic operation, in which the water supply was obtained by ditch and flume from the south fork of Germansen River.

According to Lay (1937, p. 9), the following types of placer deposits are found on the property: (1) placer deposits on low-lying benches and in the bed of the river; (2) placer deposits lying on rock benches that form an extensive system at an elevation of about 35 feet above the river; and (3) placer deposits in a deeply buried channel system below river level.

The main workings are of the second type. When, in 1936, Lay examined the pit that had been opened he described the section of strata exposed on the faces as follows:

"The maximum height of the pit face was somewhat over 80 feet, and the following succession of strata was exposed from the top downwards; several feet of post-glacial gravels; about 50 feet of blue and red boulder clay; 2 feet of indurated silt; about 25 of imbricated gravels; and cemented large pieces of shattered bedrock and fine gravel immediately overlying hummocky bedrock of argillite. Gold is contained in the gravels overlying the cemented material, more especially in the coarser gravels; in the cemented material overlying bedrock; and in the cracks and crevices of the latter. The gold is in the main coarse, both nuggety and somewhat flat." He suggests the auriferous gravels are of pre-Glacial or early Glacial age.

98779 A. Hydraulic pit on Germansen River.

98784 B. Hydraulic pit on Germansen River.

GERMANSEN VENTURES, LIMITED

A placer mining operation of major proportions was commenced in 1936 by Ventures Exploration Company (East Africa), Limited, on Germansen River. Between 1936 and 1943, when operations were discontinued, the company spent more than $1,000,000 on the construction of roads, camps, flumes, and development work. This company held leases on the lower part of Germansen River and on Plug Hat Creek, the main camp being on Plug Hat Creek, which enters Germansen River about 2 miles from its mouth. A ditch and flume extended 15 miles from Germansen Lake to the workings. This was an hydraulic operation. Two main pits were worked, and for several years about 1,000,000 yards of gravel were moved each season. Since 1943 the property has been operated by local interests (*See* Plate III).

The main workings are on the west bank of Germansen River. The auriferous gravels, about 15 feet thick, lie on rock benches 50 feet or more above the river. These gravels are buried beneath more than 100 feet of boulder clay, silt, and gravel, forming a section similar to that in the pit on the property of Germansen Mines, Limited. The gold is in the main coarse and nuggety, and is concentrated on bedrock and in the cracks and crevices of bedrock.

Slate Creek[1]

(*See* Figure 7)

References: Galloway, J. D.: Northeastern Mineral Survey District No. 2; Ann. Rept., Minister of Mines, B.C., 1924, p. 109 (1925); Placer Mining in British Columbia; Bull. 1, 1931, B.C. Dept. of Mines, p. 80 (1932). Kerr, F. A.: Manson River and Slate Creek Placer Deposits, Omineca District, B.C.; Geol. Surv., Canada, Sum. Rept. 1933, pt. A, pp. 9-29 (1934). Lay, Douglas: Northeastern Mineral Survey District No. 2; Ann. Rept., Minister of Mines, B.C., 1933, p. 111 (1934).

Only a brief examination of the placer workings along Slate Creek was made by J. B. Thurber, and much of the information contained herein is taken from published reports. The region is reached by a fair motor road from Fort St. James.

Slate Creek is a small, easterly flowing stream that enters Manson River near the settlement of Manson Creek. The valley of the creek above the Consolidated Mining and Smelting Company camp is wide and flat, and is heavily mantled with glacial debris. Below the camp the creek cuts down to bedrock along much of its course.

Bedrock exposed along Slate Creek consists mainly of westerly striking, vertically dipping slates and argillites of the Cache Creek group. Minor beds of greenstone and schist were also observed. The Manson fault zone crosses Slate Creek, and along this fault zone the slates and argillites have been altered to a buff-coloured aggregate of ankeritic carbonate, quartz, and mariposite.

Slate Creek has been worked for placer gold from the Consolidated Mining and Smelting camp down to its mouth. Gold was first discovered on the creek in 1871, and from then until 1900 the creek was worked extensively by individuals. Most of these workings were not in the bed of the stream but on the bedrock benches bordering the stream. About 1896,

[1] Examined by J. B. Thurber, Geological Survey, 1944.

a group of leases on the creek about 3 miles upstream were acquired by the 43rd Mining Company with the object of working the deeper ground; later this company was organized into Kildare Mines, Limited, whose titles to the leases lapsed in 1922. These companies built a 4½-mile ditch and flume to Manson Creek. They opened up three pits, reported to be 30 to 60 feet deep, which were worked by hydraulic elevators. It is reported that $120,000 was spent on the property by the Kildare Mines, Limited. Apparently considerable gold was found at and near bedrock, but due to the system employed the operation did not pay. The material excavated held a high percentage of boulders about 1 foot in diameter, with some measuring 4 feet. Later work was conducted on this ground by the Consolidated Mining and Smelting Company of Canada, Limited. The recorded aggregate production from Slate Creek is 4,776 ounces of placer gold.

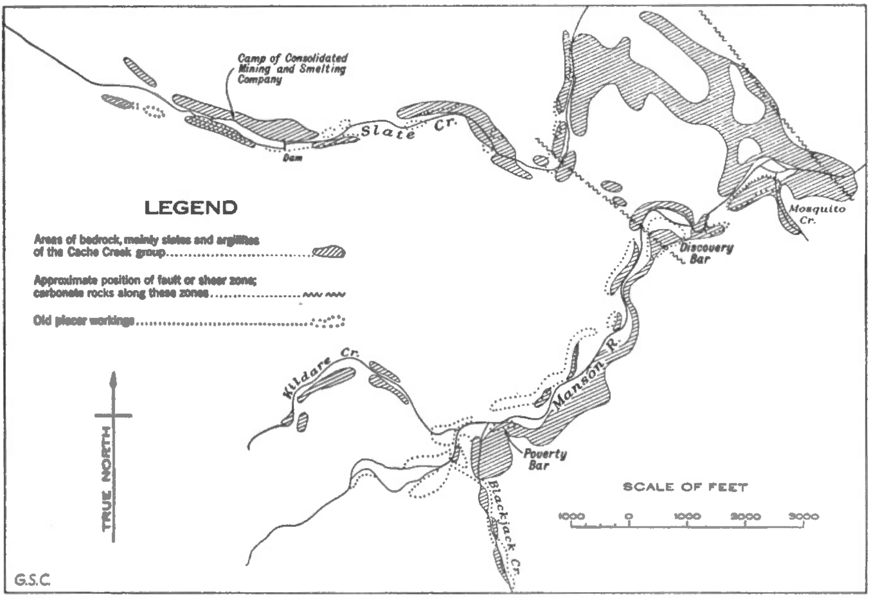


Figure 7. Geological plan of Manson River—Slate Creek placer area.

CONSOLIDATED MINING AND SMELTING COMPANY OF CANADA, LIMITED

About 1929 the Consolidated Mining and Smelting Company of Canada, Limited, leased a group of claims about 3 miles above the mouth of Slate Creek. Between 1929 and 1943 they tested and prospected the ground and conducted intermittent operations with a dragline-scraper plant using a 2-yard bucket. Operations were impeded by the tightly packed glacial gravels overlying bedrock.

Evidence obtained by drilling indicated the existence of five old channels on the right bank and one on the left bank of Slate Creek. Two seem to be clearly defined, their widths being 150 to 200 feet respectively. Pay gravel occurs on bedrock, beneath 30 to 60 feet of glacial till.

Kildare Creek, Blackjack Creek, and Manson River Between Kildare and Slate Creeks[1]

(*See* Figure 7)

References: Galloway, J. D.: Northeastern Mineral Survey District No. 2; Ann. Rept., Minister of Mines, B.C., 1924, p. 109 (1925). Kerr, F. A.: Manson River and Slate Creek Placer Deposits, Omineca District, B.C.; Geol. Surv., Canada, Sum. Rept. 1933, pt. A, pp. 9-29 (1934). Lay, Douglas: Northeastern Mineral Survey District No. 2; Ann. Rept., Minister of Mines, B.C., 1933, p. 111 (1934).

Only a brief examination of the placer workings in this region was made by J. B. Thurber, and much of the following information is taken from published reports. The region is reached by a fair motor road from Fort St. James.

Manson River between Kildare and Slate Creeks is a fairly wide, northeasterly flowing stream, bordered by rock benches along its southeast bank and by low-lying gravel benches and intermittent rock benches on its northwest bank. Kildare and Blackjack Creeks are small tributaries to Manson River entering from the northwest and south respectively, the former in a wide flat, and Blackjack Creek, near its mouth, in a rock canyon. Above the rock canyon the stream is confined to a drift canyon for 2,000 feet.

Bedrock exposed along this section of Manson River and along Blackjack and Kildare Creeks consists of westerly striking, steeply dipping, interbedded slates, argillites, schists, and greenstones of the Cache Creek group. Bands of buff-coloured aggregates of ankeritic carbonate, quartz, and mariposite cross the river above and below Discovery Bar, and are believed to represent a part of the Manson fault zone.

Manson River, from 2,000 feet above the mouth of Kildare Creek down to Mosquito Creek, has been thoroughly worked for placer gold, the lower reaches of Kildare Creek and most of Blackjack Creek having been mined. Gold was first discovered on Manson River in 1871, and for the next few years the bars proved exceedingly productive, but unfortunately no records were kept. F. A. Kerr examined most of the old workings, and the following is a synopsis of his report. No evidence of extensive workings was observed on Manson River above the canyon, situated 2,000 feet west of Kildare Creek. Below the canyon, on the south side of the stream, a wide bench lies slightly above the river flats. Bedrock is close to the surface over most of this bench, and gold in paying amounts is reported to have been obtained on the rock bench but none in the creek. The large flat on the south side of the river above Kildare Creek has been worked extensively and much of it probably paid well. The large flat across the mouth of Kildare Creek is reasonably shallow. It has been thoroughly worked, and probably also paid well. A company operated an hydraulic lift on Kildare Creek, but not profitably.

The entire length of the canyon on Blackjack Creek is reported to have been worked with fair results. In this section the workings are continuous along a narrow zone that weaves in and out of the present channel, and appears to indicate the presence of a continuous paystreak.

On the south side of Manson River below Blackjack Creek the lower end of a rock bench has been thoroughly worked, and is reported to have

[1] Examined by J. B. Thurber, Geological Survey, 1944.

yielded $100 a man each day for a short period. From this point downstream to Discovery Bar most of the river has been worked. Reports are at variance as to the extent and value of workings in the main channel of Manson River above Discovery Bar, some saying it has been all worked out at least once, others that it was only partly worked; some reporting good recoveries at most places, others stating it did not pay well except at Poverty Bar. It is reported that virtually all the workings along Manson River, whether in the present channel or above it, went to bedrock or were on bedrock.

The recorded placer gold production from Manson River and tributaries, except Slate Creek, is 8,039 ounces.

Lost Creek and Manson River Near Lost Creek[1]

(*See* Figure 8)

Reference: Lay, Douglas: Northeastern Mineral Survey District No. 2; Ann. Rept., Minister of Mines, B.C., 1936, pp. 12-16 (1937).

Only a brief examination of the placer workings in this area was made by J. B. Thurber, and much of the information that follows is taken from Lay's report. The workings are reached by a fair motor road from Fort St. James.

Lost Creek is a small tributary of Manson River, which it enters from the south about 5 miles below the settlement of Manson Creek. Near Lost Creek, Manson River flows almost due east, and rock benches flank both banks. The one on the south bank is quite long and some hundreds of feet wide near Lost Creek, and is as much as 50 feet above the river. This rock bench ends about opposite Dry Gulch (a draw on the north side of Manson River), and downstream from this point the rock rim of Manson River Valley rises almost vertically at the back of extensive bars for 30 feet, and then flattens abruptly to ground that slopes gently upwards but is underlain by rock at shallow depth. This slope merges farther downstream into extensive gravel flats.

Lost Creek has its source on the north slope of Skeleton Mountain, and is confined to a rocky gorge on the higher mountain slopes. It emerges from this gorge into a wide depression about 335 feet above Manson River and about parallel with Manson River Valley. It is crossed by Lost Creek, which, on the north side of the depression, enters a narrow, deep, rocky gorge that trends northeasterly to where it ends abruptly at the back of the rock bench flanking the south side of Manson River.

The bedrock exposed in the vicinity of Lost Creek and nearby parts of Manson River consists of interbedded argillite, slate, and greenstone of the Cache Creek group. The Manson fault zone crosses Lost Creek, and along it the wall-rocks have been altered to buff-coloured aggregates of carbonate, quartz, and mariposite.

Early mining operations, between 1871 and 1897, in this region were concerned mainly with the extensive deposits on Lost Creek, and on the rock benches flanking Manson River. Those between 1898 and 1916 included the hydraulic operations of G. W. Otterson on the north bank of Manson River; those of McKinnon on the upper part of Lost Creek, above the large depression described; and the driving of adits on the east bank of

[1] Examined by J. B. Thurber, Geological Survey. 1944

the lower part of Lost Creek by W. B. Steele and J. Mullen, who worked this creek intermittently until 1924. Dragline operations were conducted on Manson River opposite Dry Gulch in 1931.

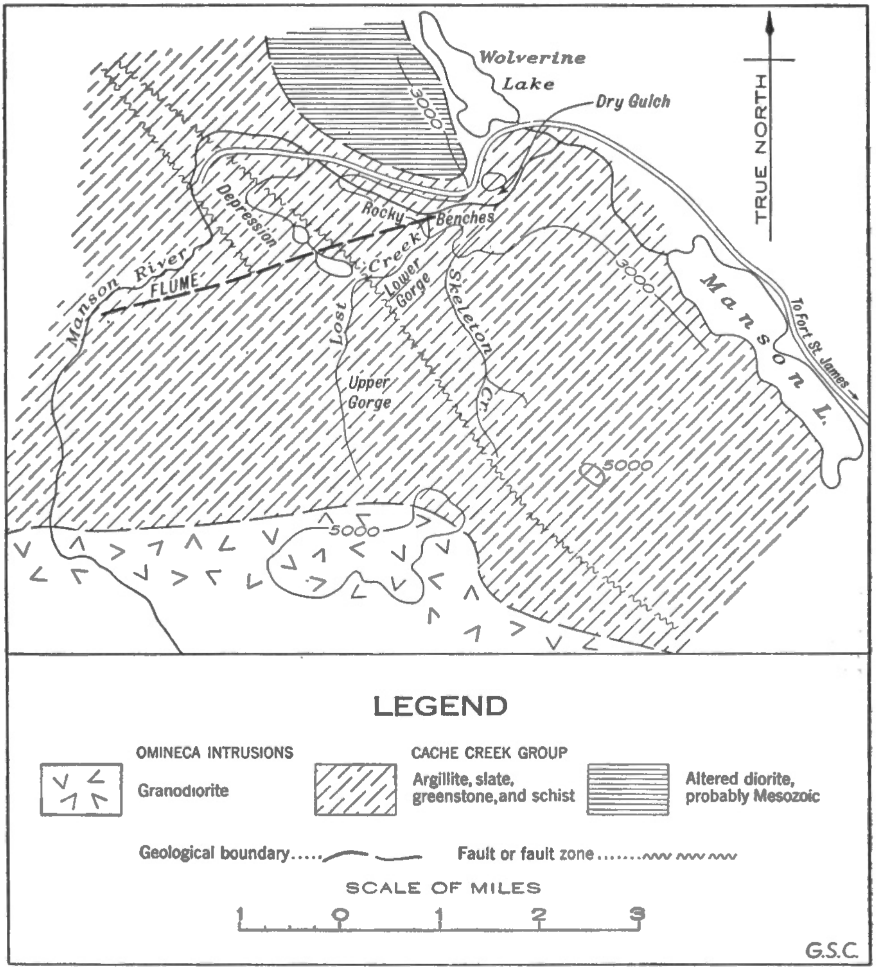


Figure 8. Geological plan of Lost Creek placer area.

In 1936, two companies, Lost Creek Placer Gold, Limited, and Dunsmore Gold Mines, Limited, were incorporated to develop placer deposits in this region. The former operated until forced to close during the war period, and the latter closed in 1939. Several individuals have, however, continued work in this vicinity.

The rock benches on the south bank of Manson River are overlain, near the river, by shallow stream gravels, apparently post-Glacial, and were worked thoroughly in the early years. Back from the stream, however, these post-Glacial gravels rest on glacial deposits, which in turn rest on bedrock. Lay says that these rock benches clearly represent former channels of the river.

Lay also suggests that the pre-Glacial channel of Lost Creek lies buried beneath glacial debris on its east bank. At several points the lower gorge on Lost Creek, which is about 6,000 feet long, has cut into this channel, resulting in the accumulation of post-Glacial placer deposits in the gorge. These were almost completely exhausted by early miners. Adits have been driven into the east bank of the creek at several points in search of this lost channel. One such adit, about 4,000 feet up the gorge, was driven 550 feet to bedrock, and at this point, which is 118 feet below the surface, pay gravels are reported to have been struck and several thousand dollars in gold recovered. The placer workings in the upper gorge of Lost Creek also indicated a pre-Glacial channel on the east side of the creek. The recorded placer gold production from Manson River and tributaries, except Slate Creek, is 8,039 ounces.

LOST CREEK PLACER GOLD, LIMITED

Lost Creek Placer Gold, Limited, was incorporated in 1936, with Bert McDonald as president. It holds leases for 1½ miles along the south side of Manson River near Lost Creek and covering the lower half mile of this creek. It also holds some ground on the north side of Manson River, including Dry Gulch. The company did surface work, first using a combination shovel and dragline. In 1939, a ditch and flume, about 6 miles long, were built to tap Manson River, and for the next few years the company used two monitors. In the last few years no large scale operations have been attempted, but Mr. McDonald did some hand sluicing in Dry Gulch.

According to Lay, three separate types of placer gold occurrences are found on this property: (1) the lower part of the pre-Glacial channel of Lost Creek; (2) the unworked parts of the rock bench on the south side of Manson River; and (3) post-Glacial concentrations on the floor of Big Wolverine Valley.

Only the rock benches have been worked by the company. As previously stated, the post-Glacial gravels on the rock benches on the south side of Manson River were worked extensively by the early miners, but not the gravels back from the river where they rest on glacial material. When Lay examined the property in 1936, a pit revealed 3 to 8 feet of post-Glacial gravels overlying 12 to 17 feet of boulder clay and glacial material, which rested on bedrock. Gold was obtained not only in the post-Glacial gravels but on bedrock.

DUNSMORE GOLD MINES, LIMITED

Dunsmore Gold Mines, Limited, was incorporated in 1936, and operated until 1939 on the lower gorge of Lost Creek, about 4,000 feet above the mouth. The operation was by adit and shaft on the east side of Lost Creek in search of the lost pre-Glacial channel.

Van Decar Creek

Van Decar Creek flows from the west into Middle River. It drains the long eastern ridge of Mount Sydney Williams, and is about 60 miles by water from Fort St. James. In the thirties a little placer gold was found near the fork of the creek about 2 miles above the mouth. Bedrock exposed upstream from the workings is serpentinized peridotite. As the gold seldom exceeded more than four to five colours a pan, little work was done, but a few nuggets valued at from 50 cents to $2 have been found.

Gold colours have been obtained on panning several other creeks flowing out of the Middle River Range, but as yet not in sufficient amount to encourage further work.

Dog Creek[1]

References: Gray, J. G.: East Half, Fort Fraser Map-Area, British Columbia; Paper 38-14, pp. 12-13 (1938). Lay, Douglas: Northeastern Mineral Survey District No. 2; Ann. Rept., Minister of Mines, B.C., 1931, p. 80 (1932).

Dog Creek flows southeasterly into Stuart River, and crosses the Fort St. James highway at a point 11 miles south of the Stuart River bridge. Placer workings are located 5 miles upstream from the highway crossing, and are accessible by wagon road. Gold was discovered along Dog Creek in 1931, and the recorded production since then is 111 ounces.

No outcrops of bedrock occur within the area of the placer workings, the creek having cut to a depth of 100 feet in glacial gravels. The valley has an average width of about 300 feet, and is bordered by low, gravel terraces. The placer gold, which occurs on false bedrock, is medium to fine and flaky. It occurs in a layer of gravel overlying a clay seam 12 to 18 inches thick, and is slightly above present creek level. A little gold also occurs in rudely stratified glacial gravels that form low terraces along the creek valley. Only the gravels above the clay seam are mined, as gold has not been found to occur below it in paying quantities. Most of the gold is obtained from around large boulders lying on the clay. A test made by Lay (1932, p. 80), on $\frac{1}{10}$ cubic yard of gravel from a shallow pit overlying false bedrock on an extensive bench near the creek, indicated gold to the value of $2.58 a yard.

The claim on which the most gold was found is on a small, flat area a short distance downstream from where the creek has cut through 100 feet of glacial drift. This drift section extends for about a mile upstream, and the gold recovered was probably concentrated from the glacial drift through which Dog Creek is cutting its channel.

Sowchea Creek[2]

Reference: Gray, J. G.: East Half, Fort Fraser Map-Area, British Columbia; Geol. Surv., Canada, Paper 38-14, pp. 13-14 (1938).

Sowchea Creek flows into Sowchea Bay, at the southeast corner of Stuart Lake. Placer gold has been recovered from gravels on three claims, but no important production has been reported. One claim lies 4½ miles upstream from the creek mouth. At this point a prospector was working (1937) on a small, flat area through which the creek flows. He reported that the gold concentration is greatest in the lower 3 to 4 feet of gravel, below which a clay seam is encountered that has acted as a false bedrock. Some gold is present in the gravel below this seam, but considerably less

[1] Examined by J. G. Gray, Geological Survey, 1936.
[2] Examined by J. G. Gray, Geological Survey, 1937.

than above it. The gold is fine, and is associated with considerable black sand. Similar conditions exist on the other two claims on the creek. Only the gravels overlying the clay seam are worked.

The gold is probably being concentrated from the glacial drift through which Sowchea Creek has cut its channel. Gravel terraces occur 100 to 150 feet above present creek level, and much gravel has been worked over by the creek in establishing its present course. The creek and its tributaries drain an area underlain by Topley diorite.

The recorded placer gold production from Sowchea Creek is 226 ounces.

Other Placer Creeks

In addition to those of the streams described, old placer workings were observed on the following creeks: (1) Ogden Creek, a medium-sized stream flowing into Omineca River from the southwest, about 6 miles above Old Hogem; (2) Dream Creek, a small stream flowing east into Silver Creek about 5 miles above the junction of Silver and Kenny Creeks; (3) Twin Creek, a small stream flowing into Kwanika Creek from the north, about 8 miles east of the Bralorne Takla mercury mine; (4) Boulder Creek, a small stream flowing easterly into lower Manson Lake; (5) bars on Omineca River below Germansen Landing; and (6) headwaters of Rainbow Creek, a medium sized stream flowing north into Nation River about 2 miles east of the map-area.

MERCURY DEPOSITS

Bralorne BB and Adjoining Groups

Reference: Armstrong, J. E.: Northern Part of Pinchi Lake Mercury Belt; Geol. Surv., Canada, Paper 44-5, p. 14 (1944).

Claims of the Bralorne BB and adjoining groups are along Silver Creek, near the mouth of Vital Creek, 30 miles by road from Takla Landing. The claims were staked in the autumn of 1940 by Mr. W. A. Prout of the exploration department of Bralorne Mines, Limited.

The Pinchi fault zone strikes north 25 degrees east through the property, the Permian-Mesozoic fault contact crossing Silver Creek at the Snell placer camp about ½ mile below the mouth of Vital Creek. A carbonatized serpentine sill, about 75 feet wide, follows this fault contact. Many subsidiary faults, striking and dipping in various directions, intersect the Permian limestone and along them the rock has been brecciated and dolomitized. Traces of cinnabar have been found in the limestone and altered serpentine, but extensive surface work has not uncovered deposits of economic significance.

Snell Mercury Property

(*See* Figure 9)

Reference: Armstrong, J. E.: Northern Part of Pinchi Lake Mercury Belt; Geol. Surv., Canada, Paper 44-5, pp. 9-10 (1944).

The Snell property is at the junction of Silver and Kenny Creeks, 26 miles by road from Takla Landing and 10 miles north of the Bralorne Takla mercury mine. The claims were staked in the summer of 1941 by Mr. G.

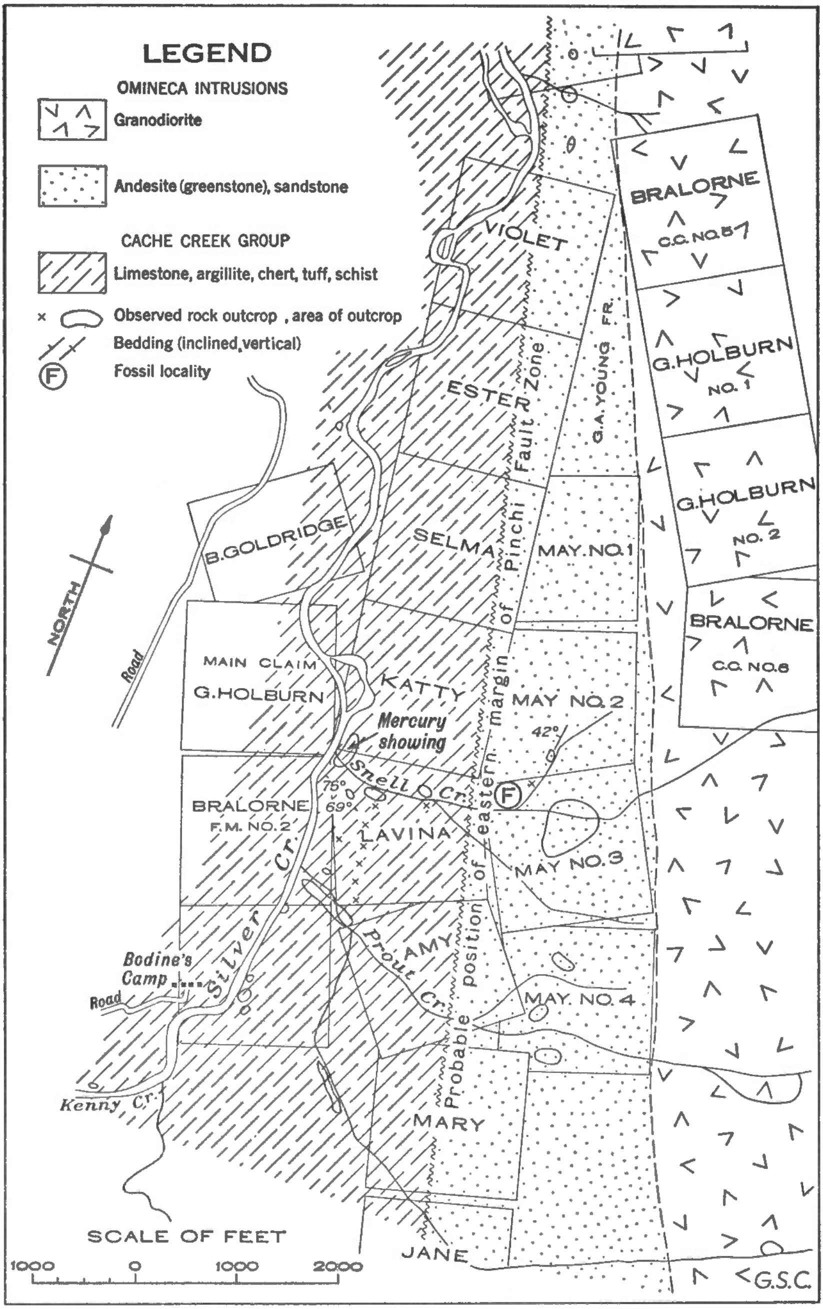


Figure 9. Geology of Snell mercury property.

Snell and associates. Bralorne Mines, Limited, acquired an option on the property in the autumn of 1941 but, following some surface exploration, allowed it to expire later in the year. Consolidated Mining and Smelting Company of Canada, Limited, held the property under option until 1944 and undertook extensive surface development and diamond drilling.

Outcrops are scarce except along the creeks, as most of the property is overlain by a heavy mantle of drift. About 1,000 feet south of Snell Creek the drift deposits include at least 120 feet of stratified sand and gravel. Interbedded limestone, argillaceous quartzite, tuff, slate, and schist of the Cache Creek group are exposed along Silver Creek and on the lower part of Snell and Prout Creeks. The beds strike northerly and dip steeply to the east. The various lithologic units occur in lenses up to 50 feet thick and several hundred feet long. The limestone and argillaceous rocks are the normal Permian types. The tuffs are cream and purple schistose rocks.

About 1,000 feet up Snell and Prout Creeks, green andesites and brownish sandstones of the Takla group are exposed. They appear to trend northerly and dip about 45 degrees to the west. Near the lower forks of Snell Creek interbedded, red, hematitic tuff and stratified limestone outcrop. These rocks are thought to be part of the Cache Creek group, although they may possibly be of Upper Triassic age.

The Pinchi fault zone crosses the property from north to south, and the fault contact between Permian and Mesozoic strata probably lies just east of the lower forks of Snell Creek. However, if the rocks outcropping at the lower forks of Snell Creek are Upper Triassic, and not Permian as mapped, this fault contact would probably lie just west of the forks of Snell Creek.

Many subsidiary faults, striking and dipping in various directions, cut the Permian strata. The more important of these strike north to northwesterly and dip 45 to 75 degrees south to southwest. They are well exposed at the mouth of Snell Creek. The crush zones along the faults are generally less than 6 feet wide.

Cinnabar, the only mineral of economic importance on the property, is associated with minor amounts of stibnite. An orebody about 40 feet long by 6 feet wide, and carrying 4 to 6 pounds of mercury a ton, occurs in limestone outcropping along Silver Creek at the mouth of Snell Creek. This body ends at a depth of 12 feet against a fault that strikes north 10 degrees east and dips 45 degrees northwest. Most of the ore in this deposit is contained in a siliceous paystreak 4 to 6 inches wide that follows a slip plane.

One good width of low-grade ore has been intersected in a diamond-drill hole on Silver Creek. The cinnabar is in cherty limestone and carbonate-quartz-mariposite rock at the contact of limestone with altered serpentine.

At the north end of a stripping along Silver Creek, a bed, 10 feet thick, of rusty Tertiary gravel has been uncovered. This gravel rests on bedrock and is overlain by boulder clay. Boulders of rich cinnabar ore occur in the gravel, some of them as much as 2 feet in diameter. The source of this float is unknown, but if the Tertiary gravel represents on old channel of Snell Creek the source is farther up this channel.

PLATE IV

96426 Bralorne Takla mercury mine.

Bralorne Takla Mercury Mine

(*See* Figure 10)

Reference: Armstrong, J. E.: Northern Part of the Pinchi Lake Mercury Belt, British Columbia; Geol. Surv., Canada, Paper 44-5, pp. 8-9 (1944).

INTRODUCTION

The Bralorne Takla mercury mine (*See* Figure 10) is on the divide between Silver and Kwanika Creeks at an elevation of about 3,600 feet. The property consists of twenty-seven claims and four fractions as follows: S.B., 1 to 8; B.C., 1 to 6; B.P., 1 and 2; Hope, 1 to 7, and Bra., 1 to 4. They were staked in September 1941 by Mr. W. A. Prout of the exploration department of Bralorne Mines, Limited. Cinnabar was discovered on the claims in July 1942. A program of development work was commenced in August of that year, and during the following winter 6,000 feet of diamond drilling was completed and a shaft started. Considerable ore was thereby blocked out, and by November 1943 a small mill was in operation (*See* Plate IV).

Production continued until September 1944, at which time mining ceased as there was no longer a market available for mercury. The plant was salvaged in 1945. During the 9 months of operation, 132,088 pounds of mercury were recovered from 11,249 tons of ore.

Freighting from the railway at Vanderhoof to the property was slow and expensive. Supplies were trucked from Vanderhoof to Fort St. James over 41 miles of good gravel road. At Fort St. James they were transferred to scows and hauled by water 110 miles to Takla Landing. During seasonal periods of high water the scows could carry as much as 20 tons, but in low water freight had to be transferred to small boats in order to navigate the rapids of Tachie River. At Takla Landing the freight was once again loaded on trucks and hauled 36 miles to the mine over a secondary road. The cost of freighting from Vanderhoof to the property was approximately 3 cents a pound. During the winter some supplies were flown from Fort St. James to the property at a cost of 7 cents a pound. The planes landed on skis in a meadow near the mine.

GENERAL GEOLOGY

(*See* Figure 10)

A mantle of drift, up to 100 feet or more thick, blankets much of the property, and there are few outcrops. Most of these have been found on claims S.B. 1, 3, 4, 6, and 8, and the cinnabar showings themselves are on claims S.B. 3 and 4. These claims are underlain by interbedded limestone, argillite, slate, chert, and derived schists of the Cache Creek group, the strata striking about north 30 degrees west and dipping 60 to 80 degrees southwest. The argillaceous and siliceous strata occur mainly in a band 600 feet wide, cutting across claims S.B. 1, 4, 6, and 8, and B.C. 5. Other bands of similar rocks also outcrop, but are less than 100 feet wide. The chert occurs in beds, ½ inch to 2 inches thick, commonly minutely crumpled, and separated by thin partings of argillite. The argillites and slates are grey to black, carbonaceous, and schistose rocks. The limestone is the normal blue-grey variety. Along and near faults it has been brecciated, and the breccia fragments are cemented with buff-coloured, ankeritic carbonate.

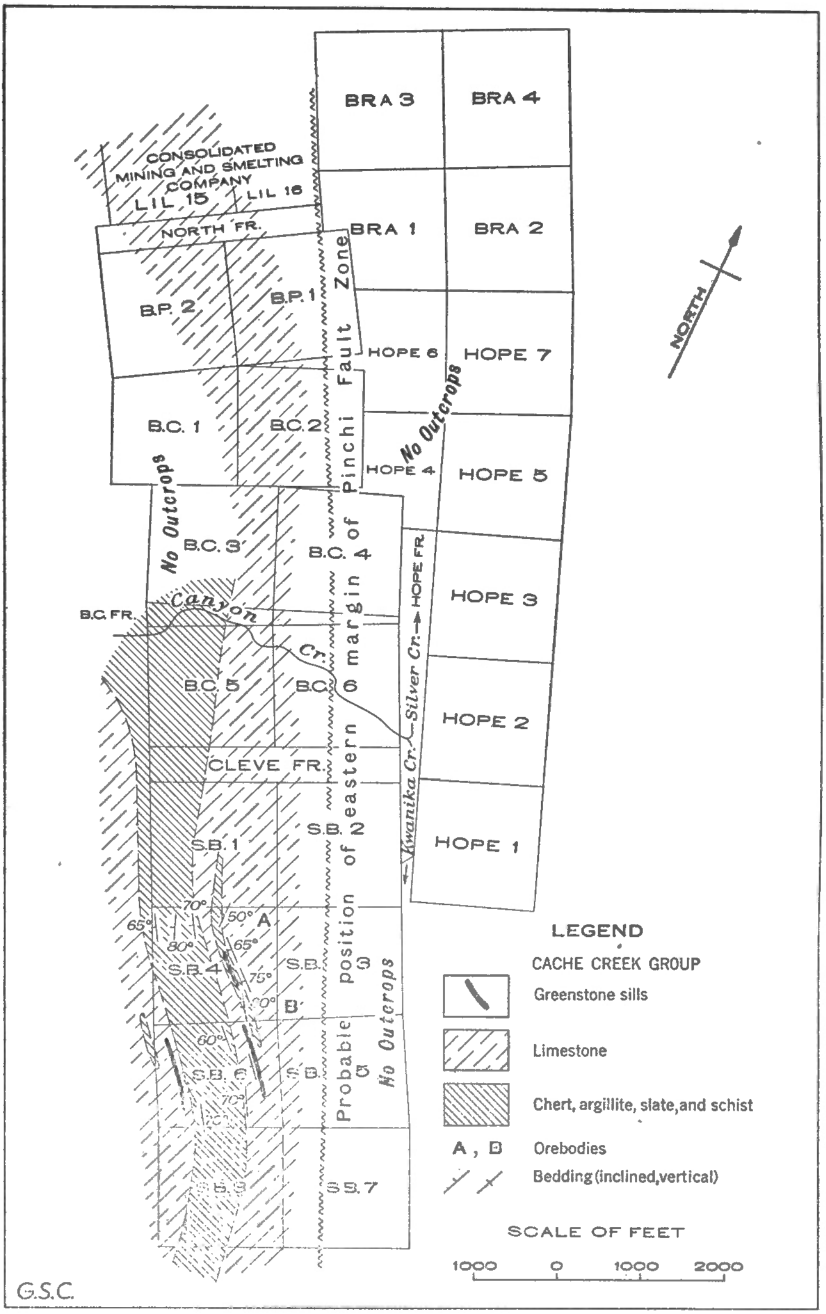


Figure 10. Geology in the vicinity of Bralorne Takla mercury mine.

Solution cavities, up to several feet across, are common in the limestone and are partly to completely filled with coarsely crystalline, cream-coloured calcite.

STRUCTURAL GEOLOGY

The Pinchi fault zone traverses the property from north to south, and its eastern margin, which represents a fault contact between Cache Creek rocks of late Palæozoic age and Takla rocks of Mesozoic age, probably underlies the mantle of drift east of the limestone ridge containing the cinnabar deposits (*See* Figure 10). Many subsidiary faults have been encountered in the limestone in the vicinity of the "A" and "B" cinnabar showings, both on the surface and underground. Their attitudes are quite variable, but the more pronounced faults strike from northwesterly to northeasterly and dip steeply to the west. The displacements effected are not known, as no horizon markers could be found. Along the faults the limestone has been brecciated across zones 1 foot to 20 feet or more wide, and where the faults are closely spaced the limestone is completely brecciated. Gouge seams up to 2 feet wide and slickensided surfaces mark many of the faults. More than one period of movement is in evidence, and some of the faults carry veinlets of calcite.

Two major parallel faults, approximately 120 feet apart, were intersected by the underground workings on the "B" showings. Both strike north 15 degrees east; one dips 65 degrees northwest and the other nearly vertically. These faults are marked by as much as 10 feet of gouge, clay, and breccia. On both faults the hanging-walls have, apparently, moved north and down relative to the foot-wall rocks. Many branch faults and fractures subsidiary to these two were observed underground, the more pronounced of which strike about north 15 degrees west. All the orebodies mined from the "B" showing occurred along or in the vicinity of the two main faults and their branches.

Two sets of faults were observed at the "A" showings. These strike approximately north 30 degrees east and north 60 degrees west. The northwesterly striking faults dip about 55 degrees southwest, appear to be the more important, and carry the principal deposits. All the faults are marked by intense brecciation of the limestone.

ECONOMIC GEOLOGY

Two groups of showings, the "A" and "B", approximately 1,000 feet apart (*See* Figure 10), are known, and both are in brecciated limestone. The intervening area is mostly drift covered. Only the "B" showings were developed by underground workings, and all the mercury recovered was from them, being confined to a body about 20 feet wide by 500 feet long by 250 feet deep.

Cinnabar is the only mineral of economic importance, and the best ore is found in the breccia nearest the fault planes. Much of the cinnabar occurs as veinlets, blebs, and individual grains filling minute fissures, and in places the cinnabar forms the breccia cement. Cinnabar also occurs in solution cavities and as coatings on the cleavage planes and faces of the calcite crystals. Limestone wall-rock has also been partly replaced by cinnabar, especially where it is finely fractured. The resultant orebodies are quite irregular in outline. The cinnabar is of the massive red variety.

Pyrite was the only other metallic mineral observed, and the gangue minerals are calcite and quartz. Coarsely crystalline, pre-cinnabar calcite occurs along fault planes and fills solution cavities, and veinlets of post-cinnabar calcite intersect the ore. Very little quartz was observed in the ore; most of it is fine grained, but a few crystals were observed in open cavities. Quartz and cinnabar were deposited contemporaneously.

The two largest orebodies mined in the "B" showings contained about 6,811 tons of 7-pound ore and 2,091 tons of 23·6-pound ore respectively. Both lay near the two major faults described. The cinnabar occurred in the crush zones along these faults and along subsidiary tension fractures. These fractures control the orebodies; as they disappear, away from the main faults, so do the ore minerals. It is quite evident that the mineralizing solutions ascended along the faults and spread out along the subsidiary fractures, depositing cinnabar mainly in open spaces.

Lil Group

Reference: Armstrong, J. E.: Northern Part of Pinchi Lake Mercury Belt; Geol. Surv., Canada, Paper 44-5, p. 13 (1944).

The Lil group, owned by the Consolidated Mining and Smelting Company of Canada, Limited, joins the Bralorne Takla holdings on the north and is crossed by the road to that property. The group consists of sixteen claims, but work has been confined to the Lil No. 15, immediately north of the Bralorne property.

The only rock outcropping on the group is Cache Creek limestone and at most places it is brecciated. This limestone lies in the Pinchi fault zone, which crosses the property from north to south. The eastern margin of the zone is drift covered, and one drill-hole penetrated more than 60 feet of overburden.

The discovery is reported to have yielded high-grade cinnabar ore from an outcrop, 10 feet in diameter, of brecciated limestone. When visited, this ore had been removed, and diamond drilling had revealed that the deposit pinched out at a depth of 15 feet. Further extensive drilling failed to discover more than an occasional speck of cinnabar.

Bron Group

Reference: Armstrong, J. E.: Northern Part of the Pinchi Lake Mercury Belt, British Columbia; Geol. Surv., Canada, Paper 44-5, p. 10 (1944).

The Bron group lies between the west fork of Kwanika Creek and the Bralorne Takla mercury mine, and may be reached by trail from this mine. It is owned by the Consolidated Mining and Smelting Company of Canada, Limited.

Except for one small sill of greenstone, the only bedrock exposed on the claims is Cache Creek limestone. This is the normal grey variety containing numerous solution cavities, up to 3 feet across, and patches of coarsely crystalline calcite. In most places it has been brecciated along fault planes and partly altered to dolomite. Commonly the fragments of the breccia are grey limestone, and the cement is buff dolomite. On the west fork of Kwanika Creek the breccia zone is 125 feet wide.

The Pinchi fault zone traverses the group from north to south and includes all the exposed limestone. The eastern border of the limestone outcrops forms a scarp, and probably marks the eastern margin of the Pinchi fault zone.

Cinnabar is exposed in a mineralized zone 10 feet wide on the west fork of Kwanika Creek. It occurs as minute crystals in brecciated limestone and as films on slip surfaces. Diamond drilling failed to reveal any cinnabar at depth.

Dan Group

Reference: Armstrong, J. E.: Northern Part of the Pinchi Lake Mercury Belt, British Columbia; Geol. Surv., Canada, Paper 44-5, pp. 11-12 (1944).

The Dan group lies south of the west fork of Kwanika Creek. It is about 4 miles by trail from the Bralorne Takla mercury mine, or 6 miles by trail from Tsayta Lake. The group is owned by the Consolidated Mining and Smelting Company of Canada, Limited.

When visited in 1943 very little exploratory work had been done, and only a few scattered outcrops could be seen. These indicated that the claims are underlain by a sill-like body of serpentine intruding blue-grey Cache Creek Permian limestone. The sill contacts are apparently along zones of shearing and brecciation. The serpentine in these shear zones has been altered to buff, quartz-carbonate-mariposite rock, and is mineralized with cinnabar.

When examined, the only showing was a mineralized zone about 3 feet wide exposed in a trench. Within it most of the cinnabar was concentrated within a width of 3 inches, and consisted of bright red cinnabar associated with veins of chalcedonic quartz in quartz-carbonate-mariposite rock. Further discoveries are since reported to have been made.

Kwanika Group

(*See* Figure 11)

Reference: Armstrong, J. E.: Northern Part of the Pinchi Lake Mercury Belt, British Columbia; Geol. Surv., Canada, Paper 44-5, p. 11 (1944).

The Kwanika group of claims is on the west side of Kwanika Creek, and is accessible by trail, about 3 miles long, from Tsayta Lake. The lake is 130 miles by water and road, or 90 miles by air, from Fort St. James. The claims were staked by the Rottacker Brothers and associates in the summer of 1941, and were acquired under option by the Consolidated Mining and Smelting Company of Canada, Limited, in the autumn of the same year. Following a program of surface exploration and diamond drilling the option was relinquished, in 1942.

A belt of northerly trending Cache Creek limestone crosses Kwanika Creek at a sharp bend 2 miles above its mouth, and upstream diverges to the west. Thinly bedded, Takla group greywacke, argillite, and tuff are exposed along the creek above the bend. Tongues of the Hogem granodiorite-diorite batholith lying east of Kwanika Creek cut the rocks exposed along the creek, and the Pinchi fault zone crosses the creek at the bend. The limestone in the fault zone has been partly brecciated and altered to a buff-coloured, dolomitic limestone. North of the bend the fault zone is

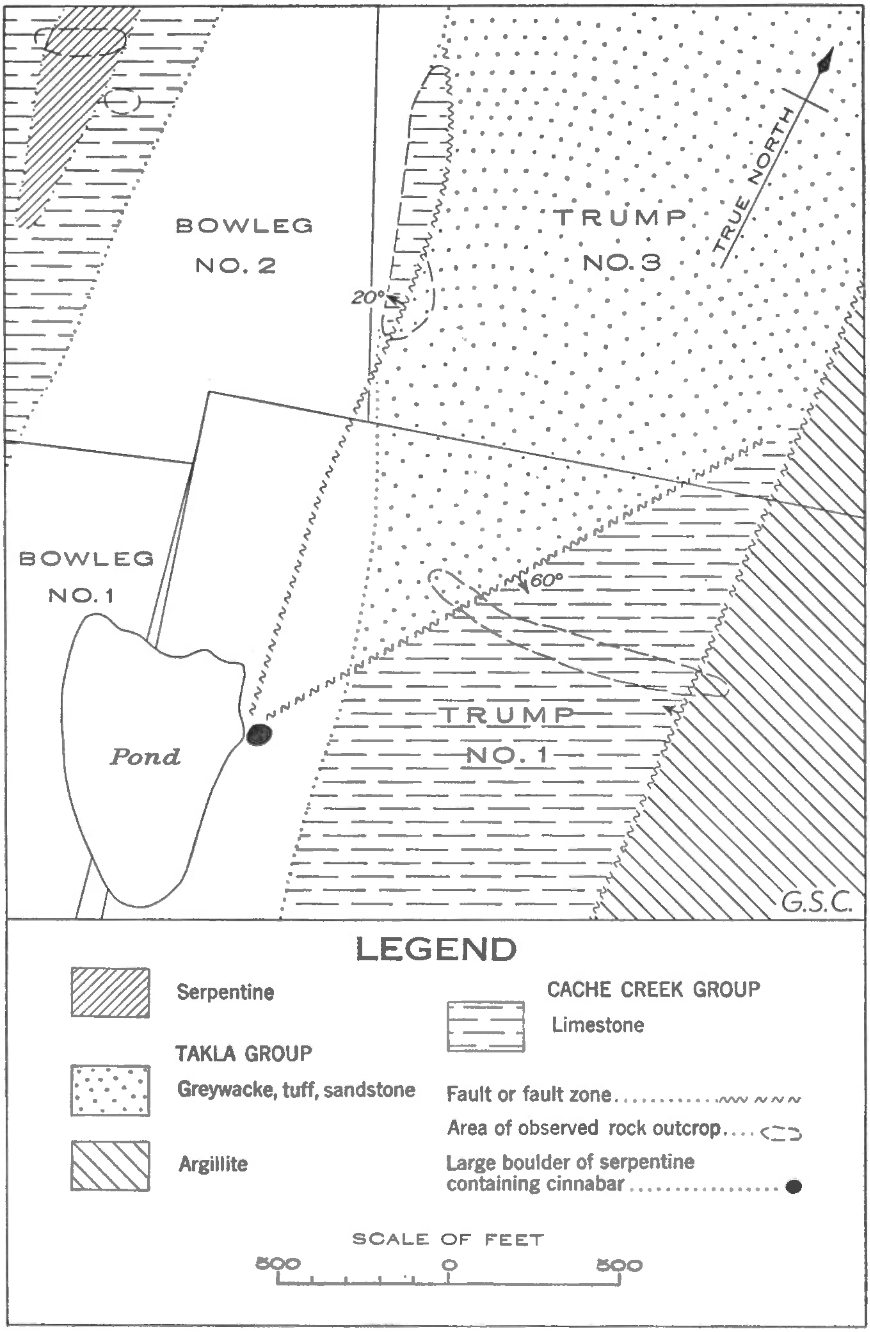


Figure 11. Geology of part of Kwanika and Bowleg groups (much of the geological information was obtained from diamond-drill records).

covered by at least 25 feet of drift, but probably marks the contact between Cache Creek rocks on the west and Takla rocks on the east. One diamond drill-hole crosses this fault contact. Takla group sandstone, greywacke, and tuff outcrop west of the Pinchi fault contact, in the southwest part of the Kwanika group on Trump Nos. 1 and 2 claims. Although no contacts are exposed, diamond drilling indicates that these Takla rocks occupy a triangular shaped fault block in Cache Creek limestone (*See* Figure 11).

A little cinnabar was discovered on Kwanika Creek about 4½ miles from its mouth. It occurs in a dolomite stringer, ¼ inch wide, traversing Takla argillite. The stringer lies about an inch from the contact of a narrow granodiorite sill that strikes north 5 degrees west, dips nearly vertically, and is exposed for 6 feet on the west bank of the creek. Surface work failed to uncover more cinnabar. About half a mile farther upstream, dolomite stringers, ¼ inch wide, containing realgar, native arsenic, and pyrite, occur in Takla argillite and greywacke. One-quarter mile above this showing another dolomite stringer contains specks of cinnabar. Arquerite, cinnabar, and native gold can be panned from the gravels of Kwanika Creek.

A boulder of carbonatized serpentine and limestone containing cinnabar in commercial quantities was found on the Trump No. 1 claim. It is at least 8 feet in diameter. Much diamond drilling in the vicinity of the boulder has encountered carbonatized serpentine, carrying a few specks of cinnabar, that may represent the source rock of the boulder. The altered serpentine lies between beds of Takla and Cache Creek rocks.

Victory Group

Reference: Armstrong, J. E.: Northern Part of Pinchi Lake Mercury Belt, British Columbia; Geol. Surv., Canada, Paper 44-5, p. 12 (1944).

The Victory group of claims joins the Kwanika group on the south, and was staked by the Consolidated Mining and Smelting Company of Canada, Limited. The Pinchi fault zone crosses the property from north to south. Brecciated and dolomitized Cache Creek limestone lies west of the fault zone, and Takla group sedimentary rocks and Omineca granodiorite to the east. Stripping carried out during the summer of 1942 failed to discover any cinnabar.

Bowleg Group

(*See* Figure 11)

Reference: Armstrong, J. E.: Northern Part of Pinchi Lake Mercury Belt; Geol. Surv., Canada, Paper 44-5, p. 11 (1944).

The Bowleg group of claims joins the Kwanika group on the west, and is owned by the Consolidated Mining and Smelting Company of Canada, Limited. Stripping and diamond drilling indicate that these claims are underlain by brecciated Permian limestone intruded by serpentine sills. No evidence of mineralization has yet been found.

Indata Lake Mercury Showing

(*See* Figure 12)

Reference: Armstrong, J. E.: Northern Part Pinchi Lake Mercury Belt, British Columbia; Geol. Surv., Canada, Paper 44-5, p. 12 (1944).

The Indata Lake mercury showing is on the east side of Indata Lake, about 1 mile from the south end. It may be reached by road from Fort St. James to the east end of Chuchi Lake (First Nation Lake), a distance of 75 miles, and thence by water up the Nation Lakes for an additional 40 miles. The property comprises nine claims, staked in the summer of 1940 by Messrs. D. and M. Rottacker and associates. The Consolidated Mining and Smelting Company of Canada, Limited, obtained an option on the group in the autumn of 1940, but relinquished it in the autumn of 1941 after doing some exploratory work.

Outcrops indicate that these claims are underlain almost entirely by blue-grey Cache Creek Permian limestone. Several small dykes and sills of serpentine cut the limestone. A major branch fault of the Pinchi fault zone extends along the eastern boundary of the group crossing claims F and A (*See* Figure 12).

A brecciated fault zone, 10 to 20 feet wide, is exposed on the Sunrise claim on the east shore of Indata Lake and contains the main cinnabar showing. The fault zone strikes north, dips west at about 70 degrees, and has been traced for 1,000 feet from the lake to where it disappears under 25 feet of boulder clay and gravel. It is offset for a few inches to 10 feet along a series of cross faults striking north 55 degrees east. At its north end the fault zone follows the contact of a serpentine dyke with limestone for 175 feet. Along the fault zone the normal blue-grey limestone has been changed to buff-coloured carbonate across a width of 30 feet. A chemical analysis of the carbonate shows a low silica, iron, and magnesium content. The serpentine dyke has also been altered across its entire width of 15 feet to a reddish buff, ankeritic carbonate with minor amounts of cherty material and green mica. The cherty material occurs in irregular nodules a few inches in diameter. Stringers of magnesite and of quartz, ⅛ inch to 2 inches wide, cut the altered dyke.

Most of the cinnabar occurs as scattered grains, either in the cherty fragments in the serpentine dyke or in similar fragments in the fault breccia, and is not sufficiently concentrated to constitute ore.

Indata Group

(*See* Figure 12)

Reference: Armstrong, J. E.: Northern Part Pinchi Lake Mercury Belt; Geol. Surv., Canada, Paper 44-5, p. 12 (1944).

The Indata group of claims is east of the Indata Lake mercury showing. The group comprises the Indata Nos. 1 to 6 claims, and is owned by the Consolidated Mining and Smelting Company of Canada, Limited. It may be reached by a trail about ¾ mile long from the south end of Indata Lake. Indata No. 4 claim straddles Rottacker Creek, and the others adjoin it to the north.

A fault strikes north 25 degrees west across Indata Nos. 1 and 4 claims and lies about 200 feet west of Indata Nos. 2, 3, 5, and 6 claims. Permian limestone occurs west of this fault. East of it Cache Creek ribbon chert

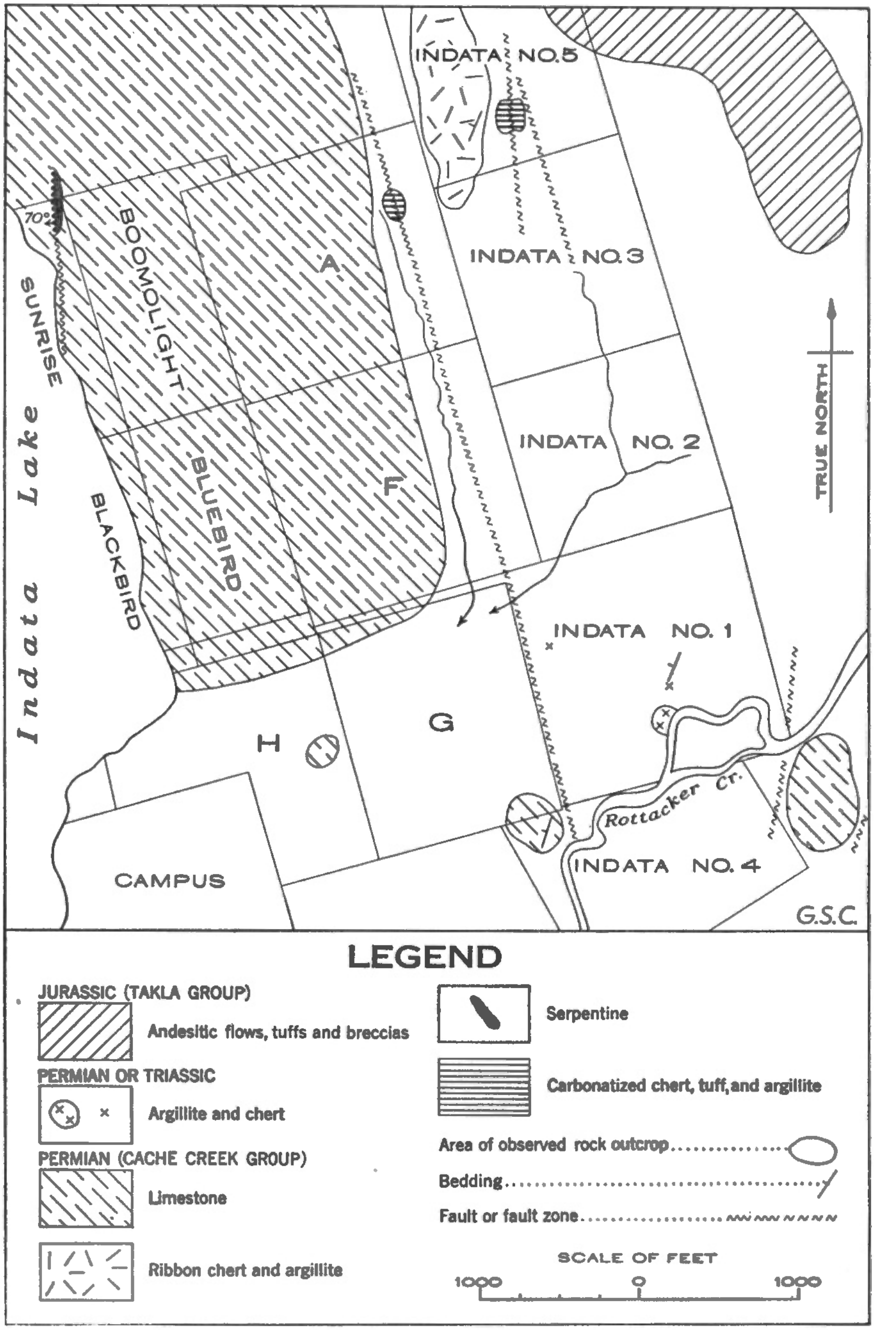


Figure 12. Geology in the vicinity of the Indata group and Indata Lake mercury showing.

and argillite outcrop on Indata No. 4 claim. Exposed on Indata No. 1 claim to the east of this fault are several small outcrops of argillite and chert of either the Cache Creek or Takla groups. On Indata No. 5 claim a second fault, striking north 15 degrees west and lying 800 feet east of the first fault, was observed. Both faults are marked by carbonatized and brecciated zones carrying specks of cinnabar. Jurassic lavas east of Indata No. 5 claim are believed to be separated from the Cache Creek argillite and ribbon chert on this claim by a fault trending north 25 degrees west. The Permian limestone exposed south of Rottacker Creek and east of the No. 4 claim has probably been faulted into its present position. Upper Triassic sedimentary rocks outcrop east of this limestone. All these faults probably form part of the Pinchi fault zone. Stripping, trenching, and diamond drilling, during the summer of 1941, failed to discover cinnabar in commercial quantities on the property.

Tchentlo Group

Reference: Armstrong, J. E.: The Pinchi Lake Mercury Belt, British Columbia; Geol. Surv., Canada, Paper 42-11, p. 18 (1942).

The Tchentlo group lies along the west side of the north arm of Tchentlo Lake; 35 miles by water plus 75 miles by road, or 70 miles by air, from Fort St. James. The claims were staked in the summer of 1940 for the Consolidated Mining and Smelting Company of Canada, Limited.

The showing consists of several large boulders and many smaller pieces of carbonatized serpentine containing cinnabar. The largest boulder is 11 by 7 by 6 feet. This float is contained in poorly stratified gravel, from 5 to 10 feet thick, resting on boulder clay. Stripping carried out during the summer of 1941 failed to locate the source of the cinnabar float. The bedrock exposed is Cache Creek argillite and greywacke.

Pinchi Lake Mercury Mine

References: Armstrong, J. E.: The Pinchi Lake Mercury Belt; Geol. Surv., Canada, Paper 42-11, pp. 12-15. Bainbridge, R.: Pinchi Lake Mercury Reduction Plant; Trans. Can. Inst. Min. Met., vol. 48, pp. 13-26 (1945). Dominion Bureau of Statistics: Report on Miscellaneous Metals in Canada, 1940; Dept. of Trade and Commerce, Dom. Bur. of Statistics, Min. Met., and Chem. Branch, Ottawa 1941, p. 18. Gray, J. G.: East Half, Fort Fraser Map-area, British Columbia; Geol. Surv., Canada, Paper 38-14, p. 9 (1938). Rice, H. M. A.: Unpublished maps and report. Stevenson, J. S.: Mercury Deposits of British Columbia; B.C. Dept. of Mines, Bull. 5, 1940, pp. 18-33.

INTRODUCTION

The Pinchi Lake mercury mine is situated in the Mercury group of claims, which comprises twenty-two Crown-granted claims and fractions on the north shore of Pinchi Lake. During the field season of 1937 cinnabar was discovered by J. G. Gray of the Geological Survey on what has since proved to be the main showing on the Mercury group. In May 1938, three claims, Mercury Nos. 1 to 3, were staked by A. J. Ostrem and Geo. Nielson, and ten claims, Dugout Nos. 1 to 8 and Chief Nos. 1 and 2, were staked by D. and M. Rottacker. Later in 1938 these thirteen claims were optioned by the Consolidated Mining and Smelting Company of Canada, Limited, who have since staked nine additional claims, Pinchi Nos. 1 to 9.

In June 1940 construction of a 50-ton reduction plant was completed, and smelting operations commenced. As the need for mercury at that time was very urgent, construction of a duplicate unit was begun immediately, and by January 1941 the plant was capable of treating 150 tons of ore daily. Construction of a larger unit was begun in the spring of 1941 and completed in November of the same year, bringing the total plant capacity to 500 tons a day. The need for mercury was still very urgent, and two additional units were installed, and by 1943 the plant was able to handle 1,200 tons of ore a day. In 1943 the Metals Reserve Board cancelled its mercury contract with the Company, and because of this and the extreme labour shortage the property was shut down in July 1944. During its operation, from June 1940 to July 1944, the Pinchi Lake mercury mine produced approximately 4,000,000 pounds of mercury, valued at about $10,000,000. The largest single year, 1943, witnessed a production of more than 1,670,000 pounds of mercury. The grade of the ore treated was reported to be between 0·5 and 0·75 per cent mercury.

The discovery showings are on the northeast side of Pinchi Lake on the top of a hill, called the "Mine Hill", about 700 feet above lake level and about 6 miles from the northwest end of the lake. The reduction plant is situated about 150 feet above the lake, allowing the ore to be extracted by adits to a depth of at least 550 feet. The property may be reached by a road, 29 miles long, from Fort St. James.

GENERAL GEOLOGY

(*See* Figure 13)

The hill on which the cinnabar showings are found is underlain by interbedded Permian ribbon chert, quartzite, schist, limestone, and minor greenstone of the Cache Creek group. The quartzite and ribbon chert form beds ½ inch to 2 inches thick, commonly minutely crumpled. Normally the beds are separated by thin partings of argillite, but near the mine the partings have been largely altered to mica, and the rocks are grey and brown, quartz-mica schists. Near faults, some carbonate has been introduced, and the rocks are quartz-mica-carbonate schists. Several bands of grey-green, quartz-glaucophane schist were observed to the west of the "Mine Hill". Limestone occurs in belts up to 600 feet thick. It is the normal, blue-grey variety, but along and near the faults has been partly to completely altered to buff weathering dolomite, and is partly silicified, the latter resulting in the formation of masses of white, cherty quartz throughout the limestone. Lenses of green, chloritic schist occur underground at the mine.

The hill north of the "Mine Hill" is underlain by Jurassic andesites of the Takla group. They are principally green to greenish grey rocks with phenocrysts of feldspar and pigeonite. The contact between the Permian and Jurassic series could not be observed here, as it is along a drift-covered draw north of the "Mine Hill". However, relations elsewhere along the mercury belt suggest it is a fault contact.

The Permian schists are intruded by several small bodies of altered serpentine, the largest about 600 feet in diameter. The least altered phases are dark olive-green rocks with the texture of coarse pyroxenites, but composed almost entirely of antigorite serpentine, which in turn has been

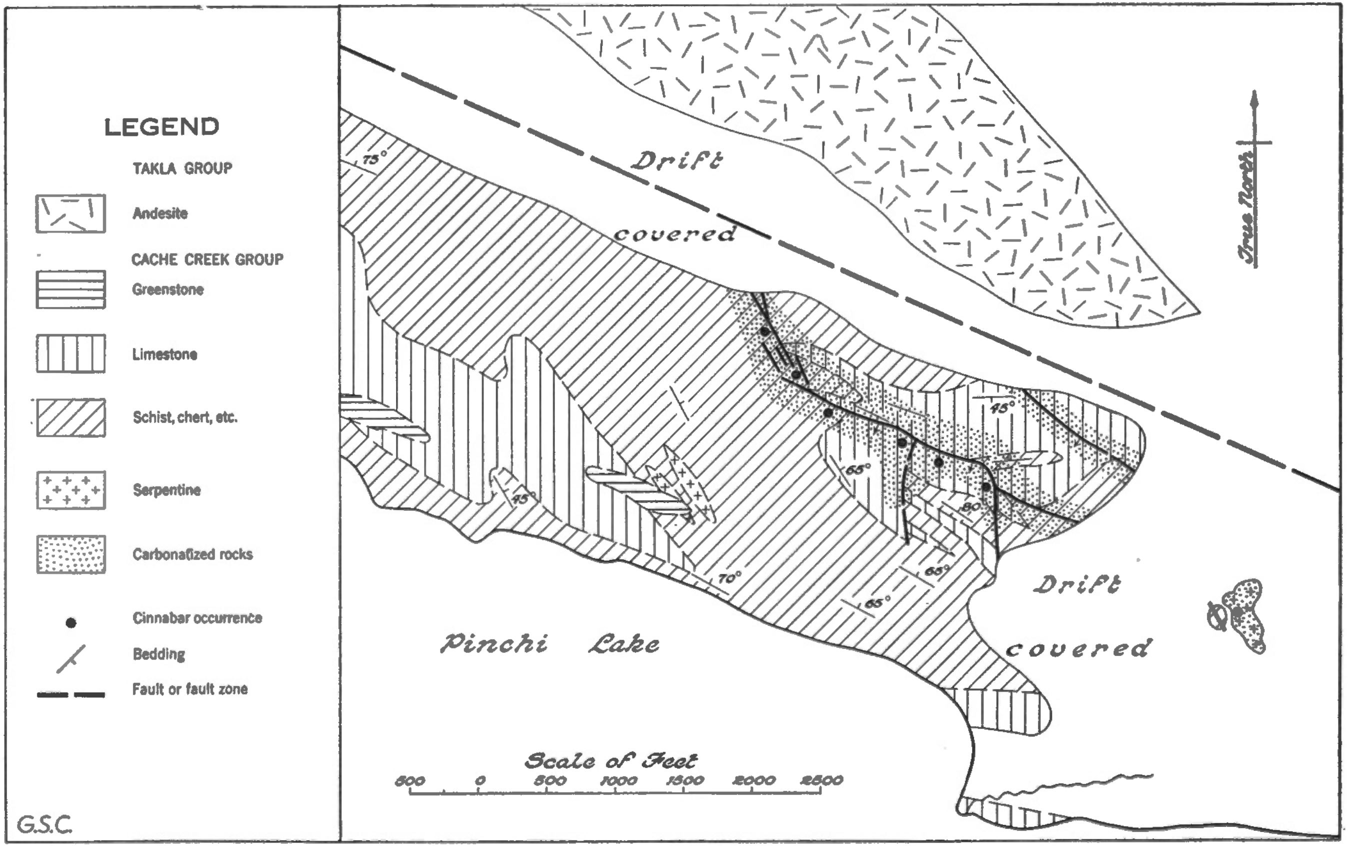
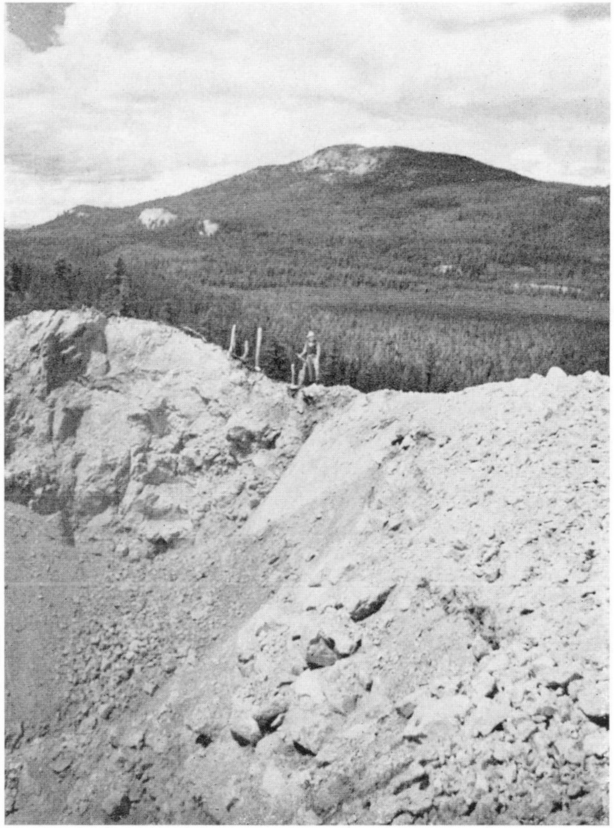


Figure 13. Geology in the vicinity of Pinchi Lake mercury mine.



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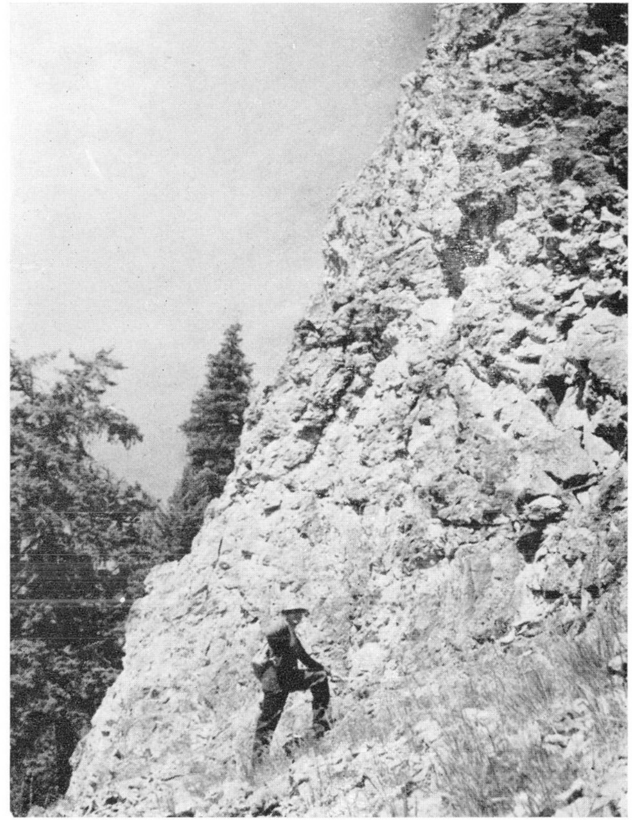
A. Pinchi fault zone at Pinchi Lake mercury mine. Face of south fault on right side of glory hole.



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B. Pinchi fault zone on south face of Murray Ridge. Rocks are magnesitic and ankeritic carbonates resulting from alteration of pyroxenite along fault zone.

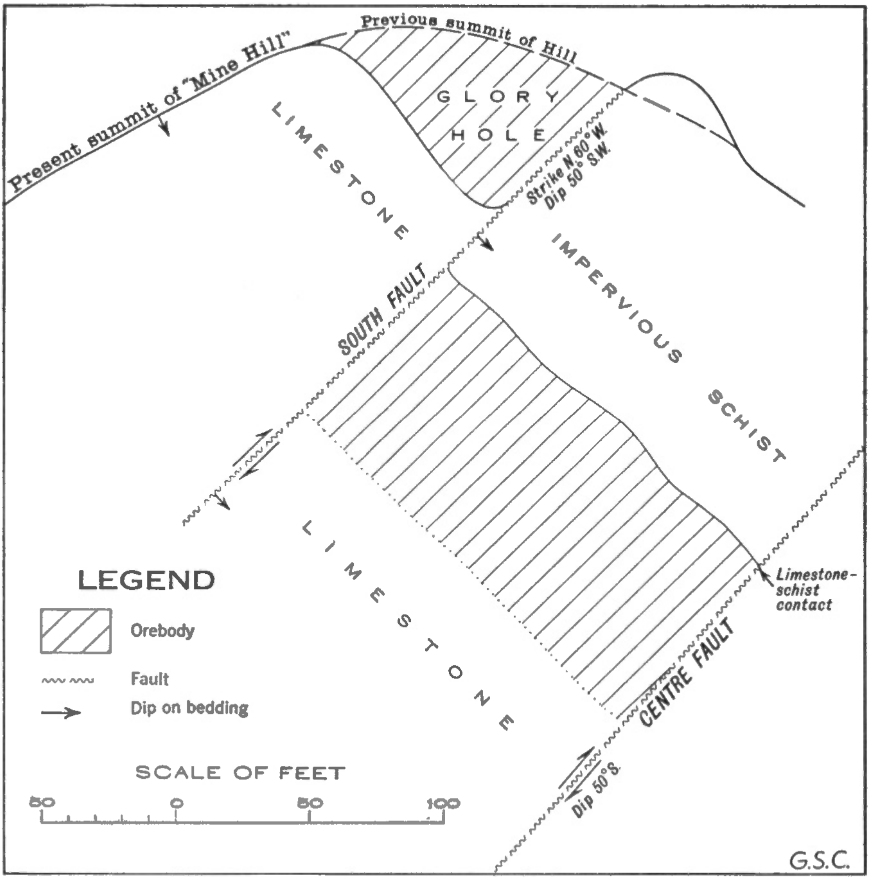
largely changed to buff- and cream-coloured, magnesitic and ankeritic carbonates, quartz, and green mica. All gradations from serpentine to carbonate rock may be observed.

West of the "Mine Hill" the Cache Creek schists and limestone are cut by two elliptical bodies of greenstone, each with an exposed area of 800 by 200 feet. They are composed largely of glaucophane, pigeonite, and clinozoisite.

STRUCTURAL GEOLOGY

(*See* Figures 13 and 14 and Plate V)

The structural geology as outlined below is based on observations made by the writer in the summer of 1941. Between 1941 and 1944 much



Fgure 14. Diagrammatic, geological section at Pinchi Lake mercury mine.

development was done underground, and the mine geologists have collected additional information on the structures, in view of which the following account may require some modification.

The Cache Creek strata have a general northwest strike and dip steeply northeast, but behave quite differently in the vicinity of the principal orebodies. The latter occur along or near northwesterly trending faults that cut folded Cache Creek rocks. The most important fault, called the "south fault", strikes north 60 degrees west and dips 50 to 70 degrees southwest, its trace following the crest of the Mine Hill. The "south fault" has been followed from the glory hole 1,600 feet southeast, where it is overlain by drift, and 900 feet northwest to where it appears to divide into an intricate group of closely spaced faults (*See* Plate V). This fault has been observed on all the levels of the mine, and along it the rocks are brecciated and silicified across a zone 4 to 30 feet wide. The brecciated zone is bounded by slickensided, slip-wall surfaces. The strata on the southwest side of the "south fault" form the southwest limb of a syncline dipping 60 to 80 degrees northeast and plunging to the southeast. They have been displaced upwards with respect to the beds on the northeast side of the fault, where the structure is less well known. A second fault, known as "centre fault", strikes approximately east, dips 50 degrees to the south, and is exposed on the 300- and 400-foot levels of the mine, from 100 to 200 feet northeast of the "south fault". The trace of this fault has not been found on the surface. A third main fault, the "north fault", is exposed near the base of the northeast side of the Mine Hill, about 600 feet northeast of the "south fault". It trends northwesterly, and is marked by a brecciated zone 50 feet or more wide. Two northerly striking branch faults were observed on the south face of the Mine Hill, and other branch faults underground. These faults all form part of the Pinchi fault zone, the northeastern border of which forms the Mesozoic-Palæozoic contact. Movement along the faults probably occurred prior and subsequent to ore deposition.

ECONOMIC GEOLOGY

Cinnabar is the only mineral known to occur in economic quantity in the mine. It is concentrated in breccia zones along the faults as well as in strata cut by the faults. The orebodies occur mainly in dolomitized limestone beneath bands of impervious schist, but some ore is found in the quartz-carbonate-mica schists. The limestone contains solution cavities that range in size from mere pits to openings several feet across. Most of the cinnabar occurs as veinlets and blebs filling pre-existing openings such as fissures, solution cavities, and interstices between grains and breccia fragments, and it is apparent that the grade of the ore increases in direct ratio to the porosity. However, there has been some replacement of the wall-rocks, especially limestone.

The known orebodies roughly parallel the bedding. They strike approximately northwest, dip to the northeast at 50 to 60 degrees, and are terminated down their dip by the northwesterly trending, southwesterly dipping faults. Their hanging-walls generally lie along a limestone-schist contact, the orebody in the limestone, and the schist acting as an impervious cap. The positions of the foot-walls appear to depend on assay values only. One orebody, which outcrops along the crest of the Mine Hill, is terminated about 100 feet down its dip by the "south fault", which dips southwesterly. Other orebodies occur between the "south" and "centre" faults and north of the "centre" fault (Figure 13).

Half a mile southeast of the main mine workings, an orebody occurs in a carbonatized and brecciated zone cutting a small body of serpentine.

The cinnabar is mostly the massive red variety, but some bright red, earthy cinnabar occurs in the upper part of the Pinchi Lake mercury mine, and crystallized cinnabar in the lower part. A little stibnite and scattered grains of pyrite have been found throughout the mine. The common gangue minerals are quartz and calcite. Most of the quartz is fine grained, but a few crystals were observed in open cavities. The quartz and cinnabar were deposited contemporaneously, but calcite formed before and after the cinnabar. In some specimens cinnabar may be seen filling interstices between calcite crystals and coating the crystals, whereas in other specimens cinnabar and calcite fill cavities in which it is quite evident that calcite was deposited first, then cinnabar and quartz, and finally calcite again. Alunite occurs in the mineralized limestones, and a few specks of barite were observed associated with the mercury deposit in the serpentine.

It is apparent that the Pinchi fault zone provided abundant channelways for the rising mineralizing solutions, which deposited cinnabar mainly in bands of limestone beneath bands of relatively impervious schist. The schists acted as a dam to the rising solutions, which spread out in the underlying limestone.

Murray Group

Reference: Armstrong, J. E.: The Pinchi Lake Mercury Belt, British Columbia; Geol. Surv., Canada, Paper 42-11, p. 18 (1942).

The Murray group of claims is situated south of Murray Ridge and west of the Fort St. James-Manson Creek road, about 6½ miles north of Fort St. James. The claims were staked in 1941 for the Consolidated Mining and Smelting Company. Several pieces of carbonatized serpentine containing cinnabar have been found on the property. The claims are overlain by 5 to 25 feet of boulder clay and gravel, and extensive stripping has not revealed the source of the cinnabar float. Wherever bedrock has been exposed it is Jurassic andesite of the Takla group.

Other Cinnabar Occurrences

Crystals of cinnabar were found in carbonatized serpentine outcropping on Mariposite Creek, and traces of cinnabar are reported in carbonatized serpentine outcropping on the lower part of Fall River.

Cinnabar is reported to have been found in the autumn of 1941 in carbonatized serpentine ½ mile east of Takatoot Lake, and claims were staked for the Consolidated Mining and Smelting Company of Canada, Limited. The property is along the Pinchi fault zone, but was not examined by the writer.

A few specks of cinnabar have been found in silicified Permian limestone about ½ mile east of the north arm of Tchentlo Lake in the Pinchi fault zone.

Specks of cinnabar occur along a carbonatized and silicified zone in the Permian schists about 4 miles northwest of the Pinchi Lake mercury mine. This zone apparently lies along a branch fault of the Pinchi fault zone.

A group of claims was staked by R. Baker and associates in Permian limestone about ½ mile east of Fort St. James. Cinnabar is reported to occur in the limestone.

A few small particles of cinnabar were observed in carbonatized rock along the Pinchi fault zone at the east end of Tezzeron Lake; along the south face of Pinchi Mountain; and on the southeast side of Pinchi Lake.

Several groups of claims, in addition to those already described, have been staked along the Pinchi fault zone, but to date cinnabar has not been found on them.

SILVER-LEAD-ZINC DEPOSITS

Kay Group

The Kay group of claims was staked in 1944, after the writer had completed the geological mapping of the area in which they are located; consequently, the showings were not examined, and the following information was kindly supplied by Dr. D. F. Kidd of Leta Explorations, Limited.

The Kay group is on the hillside west of the Bralorne Takla mercury mine, the main showings lying between elevations of 4,300 and 4,500 feet, and about 36 miles by truck road from Takla Landing. The claims were staked by R. McKee in 1944 and optioned to Leta Explorations, Limited, in 1945. After a program of surface development, including the driving of one adit, the option was dropped.

The claims are underlain mainly by northwesterly trending blue-grey Cache Creek limestone of Permian and probable Pennsylvanian age. A band of crushed argillite occurs near the showings, and several dykes of feldspar porphyry cut the limestone and argillite. The mineral deposits lie along a fault zone about 25 feet wide, which strikes 15 degrees west of north and follows approximately along a narrow band of crushed argillite. Dips along component faults in this zone vary from 60 degrees northeast to 75 degrees southwest. Evidence of mineralization has been traced along the strike for about 700 feet, the ore occurring in lenses of which the largest is several feet wide and at least 20 feet long. According to H. V. Warren[1] the ore is composed largely of metallic minerals, which are, in order of abundance, stibnite, jamesonite, arsenopyrite, sphalerite, pyrite, andorite, freibergite, native silver, quartz, and realgar. Some quartz and a little calcite are associated with them. For the rare mineral, andorite, Warren gives the following analysis:

	Per cent
Lead	20·89
Silver	9·18
Copper	1·45
Iron	2·07
Zinc	0·50
Arsenic	0·76
Antimony	41·07
Sulphur	21·83
Insoluble	1·83

1 Warren, H.V.: New Occurrences of Antimony and Tellurium Minerals in Western Canada; Contributions to Canadian Mineralogy, 1946, No. 51, University of Toronto Studies, Geol. Ser., pp. 71-72.

The assay results obtained on surface exposures were quite encouraging, as much as 100 ounces in silver a ton, and an appreciable gold content. Underground development, however, was disappointing, and assay returns much lower.

The workings consist of an adit about 320 feet long following the fault zone, and several surface trenches. Heavy sulphide deposits have been found at three places about 700 feet apart.

The fault zone crossing this property probably forms part of the Pinchi fault zone, and the mineral showings possibly originated from solutions ascending along it.

Black Hawk Group[1]

References: Armstrong, J. E., and Thurber, J. B.: Manson Creek Map-area; Geol. Surv., Canada, Paper 45-9, p. 18 (1945). Lay, Douglas: Northeastern Mineral Survey District No. 2; Ann. Rept., Minister of Mines, B.C., 1938, pp. 10-11.

A group of claims formerly named the Black Hawk lies west of Blackjack Gulch on the northwestern slope of Lost Creek Mountain. The property is reported to be owned by J. Vlasak. It is accessible by a wagon road that follows the flume from the Lost Creek placer gold property, and then by trail up Lost Creek Mountain to an elevation of 4,185 feet.

On this property at least nine veins, ranging in width from 15 inches to 5 feet, occur within a belt of fractured Cache Creek andesite 650 feet wide. Six veins strike northeasterly, with steep dips either to the southeast or northwest. One vein strikes west of north with a northeast dip, and the strike and dip of two other veins could not be determined from the exposures. The veins are mineralized with galena, sphalerite, pyrrhotite, and pyrite, and the wall-rocks are silicified and pyritized. A granodiorite batholith of the Omineca intrusions outcrops 1½ miles south of the showings.

An 18-foot adit, at an elevation of 4,435 feet, has been driven south 25 degrees west along an 18-inch quartz vein. At the portal the deposit carries much pyrrhotite and pyrite, with a small amount of sphalerite. According to Lay (1938, p. 11), a sample of selected pieces of mineral from a small pile at the portal assayed: gold, 0·02 ounce a ton; silver, 43·6 ounces a ton; copper, lead, and nickel, nil.

About 90 feet south 80 degrees west of the adit, at an elevation of 4,155 feet, a surface stripping, 21 feet long, exposes a quartz vein striking north 20 degrees west and dipping steeply northeast. This vein ranges from 3·5 to 5 feet wide and is well mineralized with pyrrhotite, pyrite, galena, and sphalerite. According to Lay, a sample across 5 feet of the best mineralized material assayed: gold, trace; silver, 40·8 ounces a ton; copper, nil; lead, 3 per cent; zinc, 3 per cent; nickel, nil. Another sample taken across 3·5 feet at a point 8 feet northwest of the last sample assayed: gold, trace; silver, 4 ounces a ton; copper, nil; lead, nil.

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[1] Examined by J. B. Thurber, Geological Survey, 1944.

The two veins described above yielded the highest assays. The other veins observed are mineralized chiefly with pyrrhotite and pyrite, and only in a few places yielded assays of more than an ounce or two of silver and a trace of gold to the ton.

Silver Island Showings

References: Armstrong, J. E.: West Half of the Fort Fraser Map-area, B.C.; Geol. Surv., Canada, Paper 37-13, pp. 19-20 (1937). Lay, Douglas: Northeastern Mineral Survey District No. 2; Ann. Rept., Minister of Mines, B.C., 1925, pp. A142-A143 (1926).

INTRODUCTION

The Silver Island Mining Company, now defunct, owned eight mineral claims, of which one, the Silver Island, covers the surface of the island of the same name, two others lie beneath Babine Lake, and the remaining five occur on the mainland on the south side of the lake. Silver Island is about 3,000 feet from the south shore and 10 miles from the east end of Babine Lake. The island is about 1,300 feet long, 750 feet wide, and has an elevation above the lake of 135 feet. A wagon road connects the south shore of Babine Lake with the settlement of Burns Lake, 27 miles to the southwest. All the showings and workings are on the island. The veins were developed by surface strippings and two drift adits from lake-level immediately above the high-water mark. No active work has been done on this property since the late twenties.

GEOLOGY

Silver Island is underlain by a dark green, Topley hornblende diorite and a light-coloured rhyolitic intrusion, each outcropping in about equal proportions. The rhyolite, probably of Tertiary age, occurs as a stock cutting the diorite, which is also intersected by numerous stringers of calcite.

The mineral deposits, fissure veins 1 to 6 inches wide, consist of tetrahedrite and minor amounts of argentite, native silver, galena, sphalerite, chalcopyrite, pyrite, malachite, and azurite in a gangue of ankerite, barite, and quartz. The fissures strike north 60 degrees west and dip about 45 degrees southwest. Two of them were explored by adits.

The following samples (Lay, 1925, p. 143) illustrate the grade of ore contained in the fissures:

Description	Gold	Silver	Copper	Lead	Zinc
		Oz. ton	Per cent	Per cent	Per cent
Selected sample of small bunch of ore, winze, No. 1 adit	Trace	243·6	3·0	Nil	3·0
Sample of picked ore, No. 2 adit, 1½ inches in width	Trace	693·6	8·0	Nil	3·0
Sample of country rock by diorite-rhyolite contact	Trace	9·2	Trace	Nil	2·0
Sample of best ore showing on surface over No. 1 adit	Trace	556·0	5·5	0·5	7·0

Taltapin Mining Company

References: Armstrong, J. E.: West Half of the Fort Fraser Map-area, B.C.; Geol. Surv., Canada, Paper 37-13, pp. 20-22 (1937). Galloway, J. D.: Northeastern Mineral Survey District No. 2; Ann. Rept., Minister of Mines, B.C., pp. 92-94 (1921). Kerr, F. A.: Mineral Resources along the Canadian National Railway between Prince Rupert and Prince George, B.C.; Geol. Surv., Canada, Paper 36-20, pp. 159-161 (1936). Lay, Douglas: Northeastern Mineral Survey District No. 2; Ann. Repts., Minister of Mines, B.C.: 1925, p. A143; 1926, pp. A145-A146; 1927, pp. C150-C152; 1928, pp. C177-C179.

INTRODUCTION

The property of Taltapin Mining Company, consisting of the Silver Fox and six other adjoining claims, is situated on Anderson Creek, 3 miles south of Babine Lake, and 25 miles by road northeast of the village of Burns Lake. The road for the first 12 miles from the lake is a good truck road; the remaining 13 miles is a wagon road. The principal showings are on the Silver Fox claim, and outcrop along the wall of a canyon 100 feet deep formed by Anderson Creek.

The company was organized in 1919, and active development work commenced late the same year and was continued intermittently for the next 10 years. The property was developed by means of trenches, two tunnels, and a shaft at least 110 feet deep, from which more than 100 feet of crosscuts were run. When examined by the writer the tunnels were caved and the shaft flooded, and much of the following information on the deposits is taken from published reports.

The main rock exposures are in a canyon, 100 feet deep, on Anderson Creek. There the walls of the canyon are mainly carbonatized and silicified, light to dark green, partly bedded, massive andesitic greenstones, and include some graphite schist. These rocks apparently represent a metamorphosed and altered phase of the greenstone division of the Cache Creek group. They are intruded by a medium-grained, grey granodiorite, probably a phase of the Topley intrusions of pre-Jurassic (?) age, although Kerr (1936, p. 161) believed it was a Tertiary granodiorite.

Dykes of dense, light grey rhyolite, of probably Tertiary age, cut the greenstones and granodiorite. Only one such dyke was observed near the showings, but they are more numerous to the north and east.

ECONOMIC GEOLOGY

The most favourable showings are on the Silver Fox claim where veins occur on both sides, and within 100 feet, of a tongue of granodiorite 200 feet or more wide. East and south of the claim, less favourable showings occur in roof pendants of andesitic greenstone, more than 200 feet in diameter, in the granodiorite.

Two sets of quartz veins are represented on the property, one striking northeasterly, and the other east. The east-striking veins are mostly barren, whereas those striking northeast carry the mineral deposits and dip at angles of 30 to 60 degrees. They are irregular veins, 2 inches to 4 feet wide, and consist of galena, sphalerite, chalcopyrite, and to a lesser extent pyrite and tetrahedrite, in a quartz gangue associated with a little white mica. They occur wholly within the greenstones. Small, pre- and post-mineral faults occur on the property.

A vein on the Silver Fox claim, known as the high grade vein, outcrops in the bed of Anderson Creek and on the wall of the creek canyon. It varies in width from 6 inches to 2 feet, strikes about north 30 degrees east, and dips 60 degrees to the northwest. According to Lay (1926, p. 146), a sample from this vein assayed: gold, trace; silver, 3·6 ounces a ton; lead, 3 per cent; zinc, 27 per cent; and copper, 1 per cent.

Three sparsely mineralized quartz veins occur 200 feet farther down the creek. They vary in width from 1 foot to 4 feet, and are from 10 to 20 feet apart. Two prospecting adits have been driven on these veins.

According to Lay, some diamond drilling was done to explore the high grade vein at depth, and he reported the following company statement (1928, pp. 178-179). "The diamond-drill with an inch core was sunk at an angle of 35°, and at a depth of 216 feet went through 7 feet of ore which assayed: gold, 0·03 oz. to the ton; silver 12·6 oz. to the ton; lead, 7 to 8 per cent; zinc, 2·4 per cent; also at a depth of 303 feet the drill went through the high grade ore appearing on Anderson Creek for 7 feet, which assayed: gold, 0·03 oz. to the ton; silver 77·2 oz. to the ton; copper 1·9 per cent; zinc 5·1 per cent."

Anderson Group

Reference: Armstrong, J. E.: West Half of the Fort Fraser Map-Area, B.C.; Geol. Surv., Canada, Paper 37-13, p. 23 (1937).

This group was owned by the late C. S. Anderson and associates, and is situated on the western slope of Taltapin Mountain at an elevation of 3,100 feet, about 2½ miles southeast of the Taltapin group.

The best showings are on the east wall of a ravine 100 feet deep. They consist of veins of quartz, 2 to 10 inches wide, containing galena, pyrite, and a little chlorite and white mica. These veins strike approximately north 30 degrees west. Above the canyon several veins of milky quartz, up to 5 feet wide, have been exposed by surface stripping. They strike about east, and show little evidence of mineralization except copper stains.

The veins occur in a roof pendant of well-banded greenstones of the Cache Creek group, which are carbonatized and silicified. These rocks strike south 10 degrees east and dip 10 degrees west. Although no exposures of the underlying intrusive body were seen in the ravine, outcrops of granite occur in the immediate vicinity. Grey augite andesite dykes cut both the granite and greenstone rocks, and were observed at different places on the property.

Golden Glory Group

References: Armstrong, J. E.: West Half Fort Fraser map-area, B.C.; Geol. Surv., Canada, Paper 37-13, pp. 23-24 (1937). Kerr, F. A.: Mineral Resources along the Canadian National Railway between Prince Rupert and Prince George, B.C.; Geol. Surv., Canada, Paper 36-20, pp. 159-161 (1936). Lay, Douglas: Northeastern Mineral Survey District No. 2; Ann. Repts., Minister of Mines, B.C.: 1927, p. 152; 1930, p. 146; 1940, p. 83.

The Golden Glory group, owned by W. Reed, R. H. Gerow, and A. Ostrem of Burns Lake, is situated on Gerow Creek, which flows into Decker Lake from the south, opposite the settlement of Decker Lake on the north shore. The property is about 1½ miles from the lake shore in a canyon more than 200 feet deep cut into the Hazelton volcanic rocks of the region. The mineral deposits on the property have been known for at least 35 years, and open-cutting and a little underground exploration have been done on them from time to time. However, when the writer examined the property in 1936, most of the old workings were caved, and only a surface examination was possible.

The bedrock in the vicinity of the showings consists of much oxidized and sheared andesitic flows and breccias of the Hazelton group, and a few small dioritic intrusions. Shear zones in these rocks strike northeasterly. The mineral deposits are in the shear zones, and include disseminated chalcopyrite and pyrite as well as several, small, very irregular, vein-like bodies of quartz. The latter are sparingly mineralized with chalcopyrite, galena, sphalerite, and pyrite, and have a maximum width of less than 2 feet. One small vein, striking north 20 degrees east, follows the creek for more than 100 feet. A second vein, exposed at the mouth of the adit at the south border of the Golden Glory No. 1 claim, is 22 inches wide at the surface, but is reported to be very irregular, and nowhere to exceed this width. Several assays of samples from these two veins show a good percentage of lead, zinc, and copper, but only a trace of gold and a few ounces of silver to the ton. According to Kerr (1936, p. 160), an assay of the altered volcanic rocks showed no gold or silver.

Samples collected by Lay (1940, p. 83) assayed as follows: (1) sample taken from 13 tons of mineralized material in a collapsed bin on the Golden Glory No. 1 claim: gold, 0·01 ounce a ton; silver, 2·9 ounces a ton; copper, 4·4 per cent; and (2) sample of pyritized diorite from the Hyland claim: gold, nil; silver, nil; copper, 0·2 per cent.

Silver Glance Claim

References: Armstrong, J. E.: West Half, Fort Fraser Map-area, B.C.; Geol. Surv., Canada, Paper 37-13, p. 24 (1937). Lay, Douglas: Northeastern Mineral Survey District No. 2; Ann. Rept., Minister of Mines, B.C., 1930, p. 146.

The Silver Glance claim is owned by J. C. MacLean of Burns Lake, and adjoins the Golden Glory group on the south. Geological conditions on the two properties are similar except that a rhyolite dyke cuts the volcanic rocks on this claim. A prospecting tunnel has been driven south 45 degrees west along a vein mineralized with galena, sphalerite, and chalcopyrite. The adit was flooded at the time visited (1936), but a 2-foot mineralized zone is reported in a crosscut 40 feet from the portal. According to Lay, a selected sample from this assayed: gold, 0·02 ounce a ton; silver, 3·1 ounces a ton; lead, 29·8 per cent; and zinc, 18·2 per cent. Pyrite occurs as specks scattered throughout the wall-rocks.

Mona

References: Armstrong, J. E.: West Half Fort Fraser Map-area, B.C.; Geol. Surv., Canada, Paper 37-13, pp. 25-26 (1937). Lay, Douglas: Northeastern Mineral Survey District No. 2; Ann. Rept., Minister of Mines, B.C., 1925, pp. 143-144.

The Mona property is situated on Deep Creek ½ mile from the Burns Lake-François Lake road. No active work has been done on it for several years.

Two prospecting adits and several open-cuts are reported to have exposed several veins in coarse-grained green andesite. In one open-cut a vein 1 to 2 feet wide and 10 feet long, has, on the foot-wall, 6 to 9 inches of galena and chalcopyrite, in a gangue of quartz, barite, and a little fluorite. Assays have been very low in precious metals.

Flag Group[1]

(*See* Figure 15)

References: Armstrong, J. E., and Thurber, J. B.: Manson Creek Map-area, British Columbia; Geol. Surv., Canada, Paper 46-9, p. 17 (1946). Lay, Douglas: Northeastern Mineral Survey District No. 2; Ann. Rept., B.C. Minister of Mines, 1938, pt. C, pp. 12-13.

The Flag group of four claims lies on both sides of Germansen River, 8 miles from Omineca River and ½ mile above the big bend where the course of the river changes from northeast to northwest (Figure 15). It was staked in 1944 by H. Porter and C. English of Manson Creek under a prospecting agreement with the Consolidated Mining and Smelting Company of Canada, Limited. The showings had been previously staked, but the claims, which were then known as the Motherlode, Flagstaff, and Vidi, had been allowed to lapse. In 1945, a program of assessment work was carried out on the property, but since then no work has been undertaken.

The bedrock exposed in the vicinity of the mineral showings consists of interbedded argillites and andesites of the Cache Creek group. These formations trend about north 55 degrees west and dip steeply southwest. Zones in the argillite have been carbonatized, silicified, and pyritized, and outcrops of quartz-carbonate-mariposite rocks occur to the southwest and northeast of the showings. Although the main trace of the Manson fault zone is believed to lie about ½ mile northeast of the property (*See* Figure 15), the altered zones in the argillites probably represent bedding shears or faults related to this fault zone.

Gold-bearing quartz veins have been explored along two carbonatized zones in the argillite. The veins occupy a system of fractures striking about north 35 degrees east at right angles to the bedding. They vary in width from 2 inches to 5 feet, and have a maximum length of 35 feet. Tetrahedrite forms about 2 per cent of the veins, and is also disseminated here and there in the wall-rocks. One stock-work of veins, about 35 feet by 100 feet, has been exposed in a pit, and selected samples from it assayed up to 0·19 ounce of gold and 37·1 ounces of silver a ton. A representative sample across veins and wall-rock averaged 0·006 ounce of gold and 0·6 ounce of silver a ton. Selected tetrahedrite samples from veins exposed by other workings yielded high gold and silver assays, but none of the veins is large enough to mine.

In addition to the tetrahedrite-bearing veins, an earlier set of barren quartz veins is exposed. These strike north 10 degrees west, dip 70 degrees northeast, and average 1 foot in width and 50 feet in length.

Farrell Property[2]

References: Armstrong, J. E., and Thurber, J. B.: Manson Creek Map-area, B.C.; Geol. Surv., Canada, Paper 45-9, pp. 16-17 (1945). Lay, Douglas: Northeastern Mineral Survey District No. 2; Ann. Rept., Minister of Mines, B.C., 1938, pt. C, p. 13 (1939).

The Farrell property, owned by C. Farrell of Manson Creek, lies on the east side of Germansen River about 3 miles above its mouth. Three

[1] Examined by J. B. Thurber, Geological Survey, 1944. Additional information supplied by E. Bronlund of the Consolidated Mining and Smelting Company of Canada, Limited.

[2] Examined by J. B. Thurber, Geological Survey, 1944.

quartz veins are reported to outcrop on these claims, but only one was examined during the summer of 1944. Information on the other two is

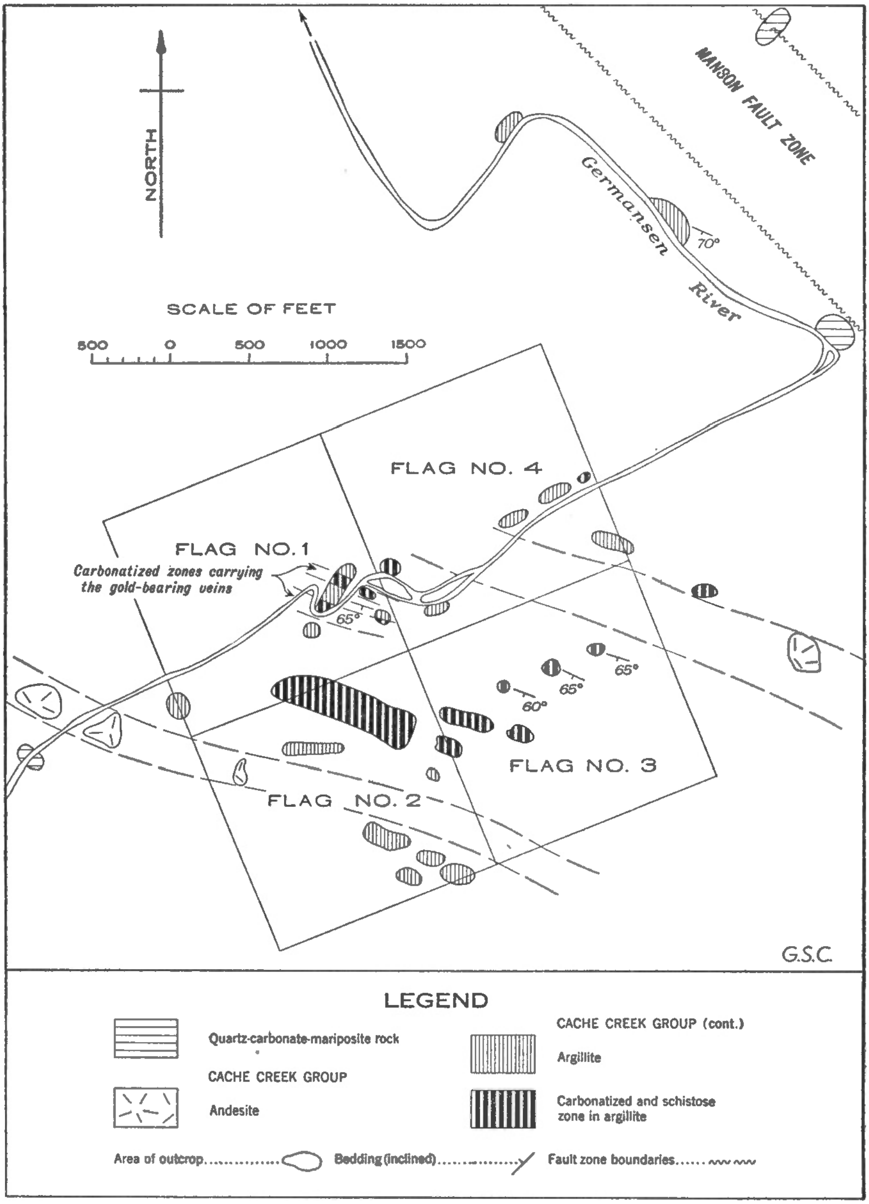

Figure 15. Geological plan of the Flag group.

taken from the Annual Report of the British Columbia Minister of Mines for 1938. The veins occur in partly carbonatized and silicified, sheared, green Cache Creek andesite. The shears strike northwest, and probably represent subsidiary movements related to the main Manson fault zone. The vein examined is 2 feet wide, strikes north 39 degrees west, dips steeply northeast, and is composed of milky white quartz mineralized with tetrahedrite, chalcopyrite, malachite, azurite, and free gold. A grab sample assayed: gold, 0·345 ounce a ton; silver, 0·66 ounce a ton. A sample across 2 feet assayed: gold, 0·8 ounce a ton; silver, 1·6 ounces a ton (Lay, 1939, p. 13). A sample from a small pile of ore taken from an open-cut on the vein assayed: gold, 0·32 ounce a ton; silver, 15·2 ounces a ton (Lay, 1939, p. 13). The other two veins vary in width up to 5 feet, and the best assay obtained showed: gold, 0·30 ounce a ton; silver 0·1 ounce a ton (Lay, 1939, p. 13).

Fairview Group[1]

References: Armstrong, J. E., and Thurber, J. B.: Manson Creek Map-area, B.C.; Geol. Surv., Canada, Paper 45-9, p. 16 (1945). Lay, Douglas: Northeastern Mineral Survey District No. 2; Ann. Rept., Minister of Mines, B.C., 1938, pt. C, p. 12 (1939).

The Fairview group of claims is on the east bank of Slate Creek about a mile above its mouth. In the summer of 1944 these claims were owned by Jack Mullen of Manson Creek.

The mineral deposit on the property comprises three lensy quartz veins and several stringers of quartz lying within a northwesterly trending shear zone in green, schistose andesite of the Cache Creek group. This shear zone is probably a subsidiary of the main Manson fault zone. Most of the shearing has been obliterated by later hydrothermal alteration of the andesite to massive, buff-coloured, carbonate-quartz-chlorite-mariposite rocks, across widths of 50 to 150 feet. These altered rocks grade into andesite on the northeast and serpentine on the southwest.

The most persistent quartz vein averages 1·5 feet in width for a length of about 200 feet. In its central part the vein is 6 feet wide. It consists of grey, vitreous quartz sparingly mineralized with chalcopyrite, tetrahedrite, and minor azurite, malachite, and pyrite. A sample of selected mineral from the best mineralized part of the vein assayed: gold, 0·28 ounce a ton; silver, 22·3 ounces a ton (Lay, 1939, p. 12). A grab sample from the vein assayed: gold, 0·02 ounce a ton; silver, 0·96 ounce a ton. Assays on the carbonate wall-rock yielded: gold, trace; silver, 0·03 to 0·10 ounce a ton. Two other veins with maximum widths of 9 and 12 feet respectively, but of unknown length, also outcrop on this property. They are composed of sugary white quartz and contain only minor amounts of sulphides and a trace of gold and silver.

Berthold Property[1]

Reference: Armstrong, J. E., and Thurber, J. B.: Manson Creek Map-area, B.C.; Geol. Surv., Canada, Paper 45-9, p. 17 (1945).

The Berthold claims lie ½ mile south of Boulder Creek, and are owned by B. Macdonald of Manson Creek. They are underlain by grey, argillaceous quartzite of the Wolverine complex intruded by a dyke of horn-

[1] Examined by J. B. Thurber, Geological Survey, 1944.

blende trachyte. The showing consists of a silicified fracture zone, 10 feet wide, mineralized with fine-grained pyrite and minor amounts of galena. The fracture zone is near a probable branch of the Manson fault zone. Assays indicate 0·01 to 0·06 ounce of gold and 6 to 13 ounces of silver a ton.

Erickson Property[1]

Reference: Armstrong, J. E., and Thurber, J. B.: Manson Creek Map-area, B.C.; Geol. Surv., Canada, Paper 45-9, p. 18.

The Erickson property is owned by P. Erickson of Manson Creek, and lies along Olson Creek, 2 miles above its mouth. The claims straddle a granodiorite-argillite contact. The argillite is also cut by aplite dykes up to 30 feet wide. About 400 feet north of the granodiorite contact two lenticular quartz veins, 8 and 16 inches wide respectively, occur in sheared argillite. They are sparsely mineralized with chalcopyrite and pyrite, and contain a little gold and silver.

Blackburn Property[1]

Reference: Armstrong, J. E., and Thurber, J. B.: Manson Creek Map-area, B.C.; Geol. Surv., Canada, Paper 45-9, p. 18.

Six miles up Gaffney Creek from the Manson road is a showing owned by H. Blackburn of Fort St. James. It consists of a pyritized fracture zone, up to 13 feet wide, in grey, cherty limestone of the Cache Creek group, and is reported to have yielded assays of several ounces of silver a ton.

Tezzeron Lake Veins[2]

Reference: Gray, J. G.: East Half, Fort Fraser Map-area, British Columbia; Geol. Surv., Canada, Paper 38-14, pp. 10-11.

A quartz vein is exposed on the north shore of Tezzeron Lake at a point 4½ miles from the west end of the lake. The vein outcrops at the lake edge, extends into the water, and may be examined only when the lake level is low. It is 2 feet wide and about 20 feet of its length is visible.

Fine-grained pyrite and arsenopyrite are disseminated along small fractures in the quartz, and a little galena and sphalerite was noted. An assay of a sample taken across the width of the vein indicated traces of gold and silver.

Considerable quartz float was noted on a low ridge 200 feet north of the outcrop of the vein on the lake shore, but no vein was seen on this ridge, and no sulphides were noted in the float.

The rocks in the vicinity are steeply dipping, thinly bedded, dark quartzites and slates of the Takla group, and a younger, dark green, fine-grained, massive andesite. The vein is in the andesite and considerable brecciation occurs along its walls. A few, barren stringers of quartz cut the andesite along the lake shore west of the vein.

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[1] Examined by J. B. Thurber, Geological Survey, 1944.
[2] Examined by J. G. Gray, Geological Survey, 1937.

Altered Serpentine Rocks

In view of the fact that prospectors had reported a gold content in the carbonate-quartz-mariposite and carbonate-talc rocks, altered Trembleur intrusions along shear zones, samples were submitted to the Bureau of Mines, Ottawa, for assay, and the following returns were received:

Sample No. 1. Carbonate-quartz-mariposite rock from the north slope of Mount Williams: gold, trace; silver, 0·12 ounce a ton.

Sample No. 2. Carbonate-quartz-mariposite rock from about a mile east of Mount Williams: gold, trace; silver, 0·01 ounce a ton; copper, trace; nickel, 0·07 per cent.

Sample No. 3. Carbonate-talc rock from the north shore of Trembleur Lake, 6 miles west of Middle River village: gold, trace; silver, 0·01 ounce a ton.

Sample No. 4. Carbonate-quartz-mariposite rock, high in quartz (75 per cent), from an outcrop 3 miles up Baptiste Creek: gold, 0·035 ounce a ton; silver, 0·07 ounce a ton; chromium, none.

Radio Gold Mines, Limited

References: Armstrong, J. E.: West Half of the Fort Fraser Map-area, B.C.; Geol. Surv., Canada, Paper 37-13, pp. 22-23 (1937). Kerr, F. A.: Mineral Resources along the Canadian National Railway between Prince Rupert and Prince George, B.C.; Geol. Surv., Canada, Paper 36-20, pp. 158-159 (1936). Lay, Douglas: Northeastern Mineral Survey District No. 2; Ann. Rept., Minister of Mines, B.C., 1933, p. 990.

The property of Radio Gold Mines, Limited, lies about 3 miles northeast of the Taltapin property. Work commenced in 1934 resulted in much surface trenching and in two shafts being sunk. These shafts were flooded at the time of examination.

The mineral showings occur at the contact of metamorphosed Cache Creek rocks (gneisses, schists, and banded foliated sediments) and a body of Topley diorite, which is intimately intruded by granodiorite. The contacts are indefinite and irregular, and throughout the area the Cache Creek rocks are cut by dykes and larger bodies of diorite, which in turn are cut by offshoots from the granodiorite body lying to the south.

Several types of showings are represented on the property. In the west, are irregular lenses of glassy quartz, up to 30 feet thick and 100 to 200 feet long, carrying a little pyrite, chalcopyrite, and molybdenite. Adjoining these quartz lenses are areas of rocks composed mainly of epidote, and up to 50 feet in diameter, which carry disseminated pyrite, magnetite, and glassy quartz, and a little intermixed chlorite, hornblende, pyrite, magnetite, specularite, and chalcopyrite. Elsewhere the metallic minerals are more scattered through the rocks.

South of the above showings a shaft is sunk on a quartz vein, which occurs in a hornblende-rich phase of the diorite. The shaft was flooded and could not be examined, but specimens on the dump showed diorite containing disseminations of bronze-coloured pyrite, epidote, magnetite, and quartz, and vein matter carrying minor amounts of pyrite, chalcopyrite, and molybdenite.

According to Kerr (1936, p. 160), several samples of the most highly mineralized rock from various sections of the property yielded, on assay, insignificant amounts of silver and gold.

Hiyou

Reference: Lay, Douglas: Northeastern Mineral Survey District No. 2; Ann. Rept., Minister of Mines, B.C., 1933, p. 99C (1934).

The Hiyou claim is owned by A. Ostrem of Burns Lake, and it situated near Bald Mountain, 5 miles northeast of Burns Lake.

The mineral showing consists of a pyritized granite porphyry dyke cutting pink granite. According to Lay, assays showed no gold or silver.

COPPER DEPOSITS

Duckling Creek Copper Showing[1]

The Duckling Creek copper showing lies between elevations of 5,800 and 6,700 feet on a ridge between the north and west forks of Duckling Creek. The west fork of the creek may be reached from Takla Landing by 40 miles of truck road to Old Hogem, and thence by 10 miles of trail to the creek.

The ridge between the creeks is underlain by medium- to coarse-grained, pink and green syenite and monzonite, which cut the nearby Omineca intrusions. The syenite and monzonite grade into one another, and are composed of varying proportions of pink and white orthoclase and plagioclase feldspar, augite, hornblende, and biotite. A well-developed gneissosity, striking nearly north and dipping vertically, was observed in places. Pegmatitic and quartz veins from 1 inch to 5 feet wide, and roughly parallel with the gneissosity, cut the syenite and monzonite. The pegmatites are composed of orthoclase, biotite, and quartz. All the rocks are much fractured.

Copper minerals were observed over an area about 500 feet wide by 1,800 feet long and through a vertical range of more than 600 feet. In this area the rocks are stained with malachite, and contain specks and small stringers commonly less than ¼ inch wide and 6 inches long of malachite, chalcopyrite, bornite, and pyrite. Most of the stringers lie along fractures or planes of gneissosity. A few grains of galena were noted. The quartz veins are well impregnated with copper minerals, but most of the pegmatite veins are not, although some contain pyrite. The entire showing would probably average less than 1 per cent copper and a few cents in gold a ton.

Nina Copper Showing[1]

Reference: Armstrong, J. E., and Thurber, J. B.: Manson Creek Map-area, B.C.; Geol. Surv., Canada, Paper 45-9, p. 19 (1945).

The Nina copper showing occurs near the summit of the peak north of the east end of Nina Lake, and is accessible to within 2 miles by a trail up Nina Creek to and beyond Nina Lake. The deposit is a mineralized zone, at least 8 feet wide, containing malachite and pyrite with minor azurite. It

[1] Examined by E. F. Roots, Geological Survey, 1944.

lies in a 200-foot band of sheared, carbonatized, silicified, and pyritized, interbedded argillite and andesite of the Cache Creek group. The mineralized zone is also much broken by faults and veined by quartz. A grab sample assayed 4·83 per cent copper and 0·005 ounce of gold a ton.

Klawli Copper[1]

(*See* Figure 16)

The Klawli copper property, which consists of eight claims owned by E. Kohse of Fort St. James, lies along a small creek flowing into Klawli River from the east about 8 miles above its mouth. The claims were originally staked in the twenties, and at that time were optioned to the Consolidated Mining and Smelting Company of Canada, Limited, who carried out a program of surface stripping and sank two shallow shafts

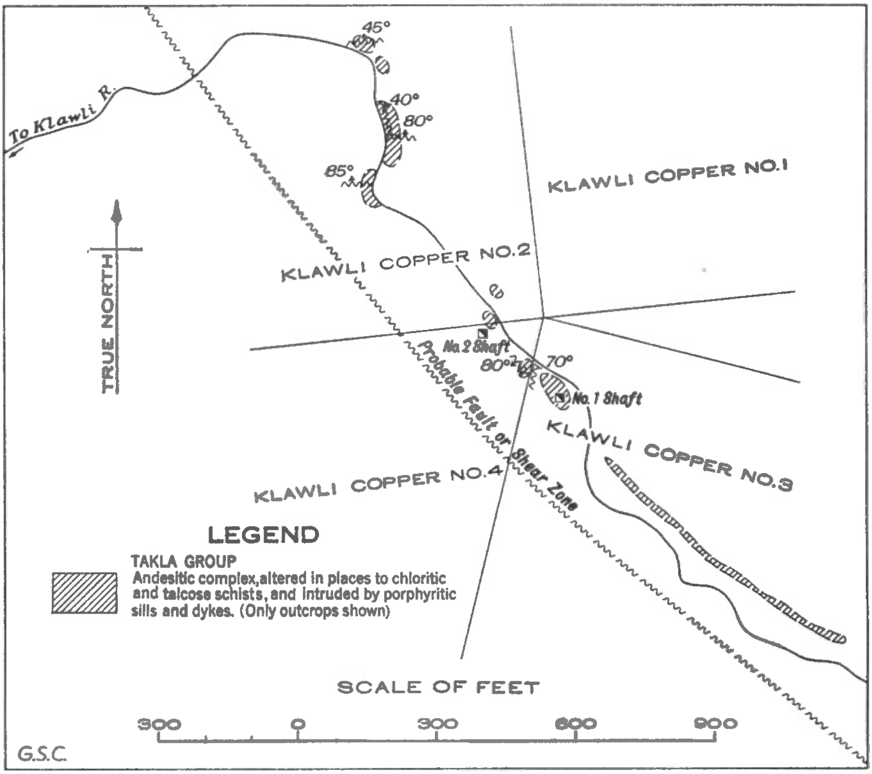

Figure 16. Geological plan of Klawli copper property.

before they dropped their option. The claims subsequently were allowed to lapse, but were restaked in 1944, and in the following year were acquired on option by the Geo. MacMillan interests of Toronto. In 1946, Quebec Gold

[1] Examined by J. B. Thurber, Geological Survey, 1944.

Mining Corporation took an option on this property, and undertook an extensive program of surface development and sampling before dropping their option.

The claims are underlain mainly by green Takla andesites, altered in places, particularly along shear zones, to chloritic and talcose schists. Quartz, feldspar, and grey andesitic porphyries, as least in part intrusive, are found in association with the andesites. The largest is more than 200 feet wide. A large body of granodiorite outcrops about 1½ miles south of the mineral showing. The andesites and porphyries are traversed by numerous small shears, many of which lie along andesite-porphyry contacts. A major, northwesterly trending shear zone is believed to cross the property 100 to 200 feet southwest of the Nos. 1 and 2 shafts.

The mineral showings consist of quartz-carbonate fissure veins and areas of mineralized andesite and porphyry, exposed at half a dozen places within a distance of 1,000 feet northwest of the No. 1 shaft. The widest area of mineralization is about 50 feet, the average being probably less than 20 feet. Most of the veins are 4 inches or less wide and only a few feet long, but several reach observed widths of 12 inches. Most of them are separated by 3 to 4 feet of wall-rock. The veins are abundantly mineralized with chalcopyrite, pyrite, and minor azurite and malachite and the same minerals are disseminated throughout the intervening wall-rock. Disseminated mineralization is most intense along small shears, especially where they traverse porphyry or lie along porphyry-andesite contacts. More than three hundred, 1-foot channel samples taken by Quebec Gold Mining Corporation averaged a trace of gold, less than 0·5 ounce of silver a ton, and less than 0·1 per cent copper. The two best channel samples averaged 0·15 ounce of gold and 4·7 ounces of silver a ton, and 2·6 per cent copper. A picked sample from a 2-inch vein assayed 0·41 ounce of gold and 35·34 ounces of silver a ton, and 6·71 per cent copper.

Three Star Group

References: Armstrong, J. E.: West Half, Fort Fraser Map-area, B.C.; Geol. Surv., Canada, Paper 37-13, p. 25 (1937). Lay, Douglas: Northeastern Mineral Survey District No. 2; Ann. Repts., Minister of Mines, B.C.: 1929, p. 181; 1930, p. 145.

This group is owned by V. Schjelderup, P. Sandnes, and K. Nysven, and is situated on Boo Mountain at an elevation of 2,900 feet, about 2 miles south of Palling station on the Canadian National Railway. The property was optioned to the Topley-Richfield Mining Company in 1929 and 1930. At that time considerable exploratory work was done, but little has been done since.

The rock, a dark green, sheared andesite of the Hazelton group, is traversed by shears trending north 80 degrees east, and dipping 85 degrees south. These have been mineralized, within a zone up to 20 feet wide and more than 300 feet long, by chalcopyrite, pyrite, and specularite, in a quartz gangue. The minerals form bands, varying from $\frac{1}{16}$ inch to several inches wide, and mineralized vugs in the andesite, which also carries scattered specks of pyrite.

A crosscut adit, 180 feet long and driven west of south, exposed 4 feet of well-mineralized quartz and andesite on the foot-wall, and 3 feet on the hanging-wall, with a sparsely mineralized zone between. No ore of commercial importance has yet been found.

Nechako Group

References: Lay, Douglas: Northeastern Mineral Survey District No. 2; Ann. Repts., Minister of Mines, B.C.: 1928, p. 180; 1929, p. 182.

The Nechako property was not visited by the writer and the following information is from published accounts by Lay.

The group, owned by A. Godwin, is situated on the south side of Nechako River about 3½ miles southeast of Fort Fraser, and is accessible by motor road.

The mineral deposit consists of small seams of chalcopyrite with a little malachite along a shear zone in granodiorite. The shear zone strikes north 65 degrees west and dips southwest at 65 degrees. A sample of selected mineral assayed: gold, trace; silver, 1 ounce to the ton; and copper, 4 per cent.

ANTIMONY DEPOSITS

Stuart Lake Antimony Mines, Limited[1]

(*See* Figure 17)

References: Lay, Douglas: Ann. Rept., B.C. Minister of Mines, 1929, p. 186. Gray, J. G.: East Half, Fort Fraser Map-area, British Columbia; Geol. Surv., Canada, Paper 38-14, 1938, pp. 7-8.

INTRODUCTION

The Stuart Lake antimony mine is situated on the southwest side of Stuart Lake about 10 miles west of Fort St. James. The property consists of ten claims and several fractions and is owned by Geo. E. Neilson of Vancouver. Originally the property was developed for antimony, but later its gold content was of primary interest.

The property was first staked in 1928, at which time it was called the McMullen group. Some development work was done by the original owners, but the claims were allowed to lapse, and the showings were restaked in 1938 by Geo. Nielson and A. Ostrem. Further development work was done in 1938 and 1939, and about 50 tons of sorted antimony ore was shipped. In 1939, an interest was acquired by V. Dolmage and R. H. Stewart of Vancouver, who optioned it to Pioneer Gold Mines of B.C., Limited. This company erected a well-equipped camp for about twenty men, and operated the property in 1940 by sinking an inclined shaft for 135 feet, and by drifting, surface stripping, and sampling. Their option was dropped late in 1940, and 36 tons of antimony ore, recovered as a salvage operation, was shipped. In 1941 the Consolidated Mining and Smelting Company of Canada, Limited, and in 1943 Leta Explorations, Limited, optioned the property for short periods and did some diamond drilling.

GENERAL GEOLOGY

(*See* Figure 17)

The claims on which the showings occur are underlain by northwesterly trending and steeply dipping, interbedded argillites, slates, quartzites, and

[1] Examined by H. M. A. Rice, Geological Survey, 1941.

greenstones of the Cache Creek group. The greenstones appear to comprise chloritized andesitic and dacitic lava flows, breccias, and tuffs. Diorite was observed in several places cutting the sedimentary formations.

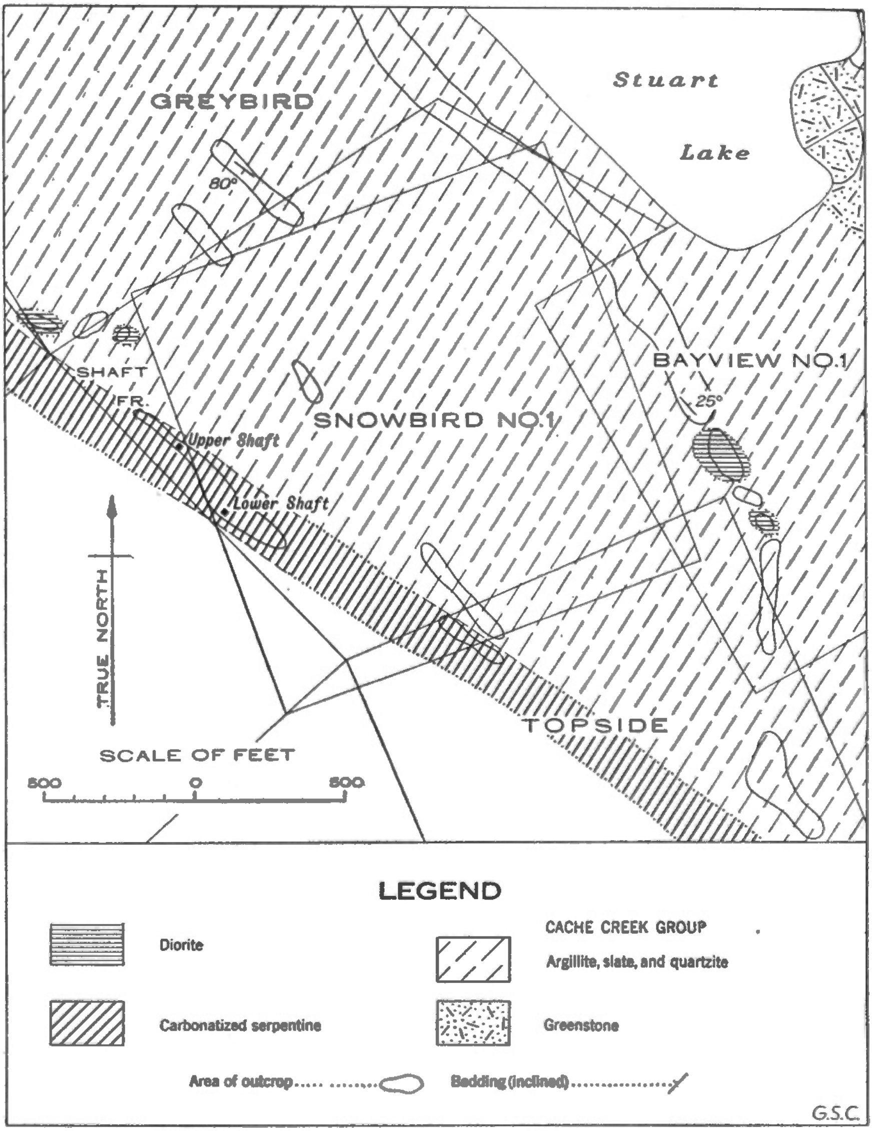

Figure 17. Geology in the vicinity of Stuart Lake antimony mine.

A zone of altered rocks, consisting mainly of cream-coloured, buff weathering aggregates of ankeritic carbonate, quartz, serpentine, and mariposite, and intersected by a network of quartz veins and lenses, crosses the property. This zone is about 150 feet wide, strikes northwesterly about parallel with the bedding of the Cache Creek formations, and dips from 40 to 50 degrees northeast. On the northeast side it grades into argillite, and on the southwest it is drift covered. At the surface it consists mainly of ankeritic carbonate, quartz, and patches of volcanic rock. In diamond-drill holes, much serpentine was encountered, and many specimens show carbonate replacing serpentine. Mariposite, an apple-green mica, is disseminated throughout the zone. Drill-holes indicate considerable brecciation along this zone. The origin of the breccias is doubtful; it has been suggested by some that they are fault breccias and by others that they are volcanic breccias. Although only a very cursory examination of the property was made by the writer, he believes that this band of carbonate rocks lies along a zone of faulting, shearing, and brecciation that provided channelways for later carbonatizing and mineralizing solutions, resulting in the rocks now exposed.

ECONOMIC GEOLOGY

Quartz veins and stringers mineralized with stibnite and pyrite occur in the carbonatized serpentine zone, chiefly near its hanging-wall side, and in the argillites on that side. The main showings consist of three, north-westerly trending veins in the carbonate zone and a northeasterly vein in the argillites.

The main 'vein' in the carbonate zone is exposed in the upper shaft (*See* Figure 17) and open-cuts for a length of 280 feet. Its width varies from 2 to 5 feet, but in places the quartz is split and occupies a greater width. Stibnite is the only mineral present in any amount, and generally forms bands or lenses along one or both walls. This 'vein' also carries a substantial amount of gold. It contains an ore shoot 95 feet long and at least 135 feet deep, averaging 0·25 ounce of gold a ton and 9·2 per cent antimony across 29 inches. Diamond drilling indicated that this ore shoot was closed at both ends; however, 300 feet to the northwest of the shoot a drill-hole cut 0·6 foot of quartz assaying 0·52 ounce of gold a ton, whereas intervening drill-holes revealed only a little gold. Southeast of this shoot the vein continues for 80 feet, of which the first 70 feet is sporadically mineralized, averaging 0·07 ounce of gold a ton and 4 per cent antimony.

A second 'vein' in the carbonate zone lies about 80 feet southwest of the main vein. It is exposed in outcrops and has been explored by several open-cuts. The showing consists of several intersecting quartz veins, none of which is much more than a foot or two wide, but which have an overall width of 10 to 15 feet. The vein matter is sparsely mineralized and the metal content is low.

The third 'vein' in the carbonate zone is exposed in the lower shaft. It consists of branch veins and lenses containing pods of stibnite along a strong fracture zone 2 to 6 feet wide. The values are very erratic and are not of commercial grade.

The quartz vein in the argillites lies along a northeasterly trending fracture. This vein carried a body of almost solid stibnite 30 feet long and averaging 4·1 inches wide. It was developed by an adit and open-cuts, and most of the antimony ore from this property was obtained from it.

Hand-sorted ore from this shoot assayed about 60 per cent antimony and 0·05 ounce of gold a ton. To the northeast of the ore shoot, the fracture zone has been followed by an adit without any indication of other orebodies.

CHROMITE DEPOSITS

Mitchell Mountains

Mitchell Mountains lie between Takla and Nation Lakes, and in their southern part are underlain by altered peridotite and dunite of the Trembleur intrusions. A trail about 15 miles long leads from near the outlet of Takla Lake to this area of ultrabasic rocks. During the field season of 1942, C. S. Lord of the Geological Survey of Canada prospected these ultrabasic rocks in search for chromite. Several deposits were found, and although none was considered to be of present commercial importance, three of them are worth recording. Their location is given relative to the mountain shown on the map as 6,790 feet in elevation, and which for convenience will be referred to as Chrome Peak.

SIMPSON CHROMITE DEPOSIT

The Simpson deposit is 1,600 feet west of Chrome Peak, and at an elevation of 6,330 feet (aneroid). It was discovered by a Geological Survey field party in 1940, and staked by Hunter Simpson and associates in the spring of 1941 under the name Alloy group. The chromite is exposed on a comparatively flat bench, about 25 feet wide, that juts out from the mountain side, which has an average slope of about 37 degrees.

The chromite occurs in an altered peridotite composed of varying amounts of olivine, serpentine, and talc. The olivine normally occurs in well-defined crystals, partly serpentinized, embedded in a talc-serpentine matrix. Some of the talc is observed replacing pyroxene crystals. The rock, which is dark grey-green, weathers to various shades of buff, pink, and yellow-brown, and is much fractured.

Ten small chromite lenses are exposed on a bench-like surface that trends southwest and dips 10 to 25 degrees southeast. This surface may represent a gently dipping fracture plane. The rock on this surface has weathered rusty brown to a depth of several inches. The chromite lenses probably form nearly flat slabs lying parallel with this surface. They are scattered throughout a length of 20 feet along a line trending about north and range in outcrop size from 3 inches in diameter to about 2·5 square feet. It is doubtful if any of these bodies extends to a depth of more than a foot or so.

Much of the chromite is hard, clean, bright, and massive. Some of it, near the borders of the lenses, is disseminated in the rock. A composite chip sample, collected from all the lenses, assayed: Cr_2O_3, 45·7 per cent; Cr, 31·3 per cent; Fe, 15·55 per cent; and Cr-Fe ratio, 2·01:1.

BOB CHROMITE DEPOSIT

The Bob deposit lies 6,100 feet north of Chrome Peak, at an elevation of 6,030 feet (aneroid) on the crest of a ridge that trends about north.

The bedrock is a massive, altered peridotite composed of olivine, serpentine, and talc similar to the rock observed on the Simpson deposit.

Ten chromite lenses are exposed over a length of 110 feet in a zone trending north 50 degrees west. The dip of the zone is not known. Outcrop dimensions of the lenses range from 1·5 feet by 0·2 foot to 4 by 3 feet. Parts of the lenses comprise massive metallic chromite, but other parts are about 50 per cent chromite occurring as ⅛ inch granules, and 50 per cent serpentine. A composite grab sample from the lenses of the southeast part of the zone assayed: Cr_2O_3, 28·6 per cent; Cr, 19·6 per cent; Fe, 17·1 per cent; and Cr-Fe ratio, 1·15:1. A similar sample from lenses of the northwest part of the zone assayed: Cr_2O_3, 31·2 per cent; Cr, 21·4 per cent, Fe, 14·5 per cent; and Cr-Fe ratio, 1·48:1.

IRISH CHROMITE DEPOSIT

The Irish deposit lies 22,000 feet north 30 degrees east from Chrome Peak, at an elevation of 5,480 feet (aneroid), a few hundred feet east of the top of a ridge that trends about north. So far as known, this is the largest chromite occurrence in the Mitchell Mountains area.

Bedrock is an altered peridotite composed of various proportions of serpentine, talc, and carbonate. The fresh rock is dark greenish grey, showing plates of talc. The rock weathers a reddish brown, with blotches of pink talc, and irregular fractures are common.

The chromite occurs as several irregular lenses distributed for a length of 68 feet along a line trending north 26 degrees west. The total outcrop area of these lenses is about 390 square feet, indicating about 50 tons of chromite per foot of depth. Parts of the chromite bodies are solid chromite, but other parts are disseminated ore, the chromite occurring in blebs up to ½ inch in diameter. The largest lens is 32·5 feet long, averages 8·8 feet wide, and contains 38·0 per cent Cr_2O_3 (average of ten channel samples). Seventeen channel samples were cut from several lenses, and the arithmetical averages of these are: length of channels, 5·5 feet; per cent Cr_2O_3, 35·6; per cent Cr, 24·3; per cent Fe, 10·7; Cr-Fe ratio, 2·30:1.

The chromite seems to occur as irregular lenses distributed at random in fairly uniform rock. The dips at the borders of the large lens at the north end of the deposit suggest that this lens is trough shaped, with a depth of only a few feet.

Middle River Range

Middle River Range, which lies southwest of Middle River, is underlain by Cache Creek formations invaded by Trembleur ultrabasic and Omineca granitic intrusions. The Trembleur intrusions consist of a serpentinized peridotite-dunite batholith underlying Mount Sydney Williams and several serpentinized peridotite-dunite sills outcropping between Mount Sydney Williams and Tsitsutl Mountain. During the field season of 1942, the writer and H. W. Little, of the Geological Survey of Canada, prospected these ultrabasic masses for chromite, and several deposits were found, although none was of apparent commercial size. These areas may be reached by a good pack-trail, which commences at Middle River near the mouth of Van Decar Creek, follows the creek to timber-line on the northeast slope of Mount Sydney Williams, and then leads northerly to Tsitsutl Mountain. The following descriptions are of the more important chromite deposits discovered.

TSITSUTL MOUNTAIN DEPOSIT

The Tsitsutl Mountain deposit is about 14,000 feet south of Tsitsutl Mountain, at an elevation of about 5,000 feet. It occurs in a rust-coloured, serpentinized dunite sill, and consists of a lens of almost pure chromite 5 by 7 feet in surface area. The walls of the lens are sharply defined and dip outward at 60 degrees. Elsewhere nearby are a few nodules of chromite 2 to 3 inches in diameter.

TILDESLEY CREEK DEPOSIT

The Tildesley Creek deposit is about 1 mile east of Tildesley Creek and 6 miles west of Mount Sydney Williams. It lies near the southwest end of a ridge at an elevation of about 4,500 feet.

The main occurrence consists of two small lenses of chromite, each about 2·5 by 5 feet in surface area, in a sheared, serpentinized dunite sill. These lenses are surrounded by lower grade material within a total area of, roughly, 7 by 22 feet.

MOUNT SYDNEY WILLIAMS DEPOSIT

The Mount Sydney Williams deposit occurs at an elevation of about 5,000 feet, 2 miles east of Mount Sydney Williams on the southeast slope of the long ridge that extends to Middle River.

At this locality a dunite body about 30 by 280 feet in surface area is exposed in the peridotite-dunite batholith. The whole body is mineralized, the average chromite content being from 3 to 5 per cent. A part of the dunite body, 7 by 30 feet in area, contains 6 to 9 per cent chromite.

MIDDLE RIVER RIDGE DEPOSIT

Middle River Ridge stretches long and high northeast from Mount Sydney Williams to within about 2 miles of Middle River. Near the end of this ridge, on the northeast slope at an elevation of about 5,000 feet, a chromite showing was found in an area of brown weathering, serpentinized dunite, which forms an irregular mass surrounded by peridotite. The best deposit consists of a lens of nearly pure chromite 8 by 5 feet in surface area. Sixty-five feet to the west a second lens of ore, 12 by 3 feet in area, contains 20 to 30 per cent chromite. The dunite adjoining these lenses contains 2 to 5 per cent chromite.

VAN DECAR CREEK DEPOSIT

The Van Decar Creek deposit occurs at an elevation of about 3,700 feet, a mile southeast of the forks of Van Decar Creek, and about 3 miles from Middle River. This is the best showing in the Middle River Range.

The chromite occurs as an irregular-shaped lens in serpentinized dunite. The main showing is 5 by 25 feet in area and contains at least 50 per cent chromite. Disseminated ore occurs at the south end of the lens.

About 1,000 feet southeast of this lens, a small body of dunite, about 3 by 40 feet in area, contains an average of about 10 per cent disseminated chromite.

MOLYBDENUM DEPOSITS

Stella Molybdenite Property

References: Armstrong, J. E.: West Half of the Fort Fraser Map-area, B.C.; Geol. Surv., Canada, Paper 37-13, pp. 27-28 (1937). Kerr, F. A.: Mineral Resources along the C.N.R., between Prince Rupert and Prince George, B.C.; Geol. Surv., Canada, Paper 36-20, pp. 163-165 (1936). Lay, Douglas: Northeastern Mineral Survey District No. 2; Ann. Repts., Minister of Mines, B.C.: 1927, pp. C152-153; 1928, pp. C179-180; 1929, p. 182; 1934, p. C13. Stevenson, J. S.: Molybdenum Deposits of B.C.; Dept. of Mines, B.C., Bull. No. 9, pp. 13-16 (1940).

INTRODUCTION

The Stella Molybdenite property consists of the Stella Nos. 1 to 4 mineral claims staked by C. H. Foote in 1927, and owned by Foote and associates of Fraser Lake and Endako. The property is situated about 5 miles southwest of Endako, a divisional point on the Canadian National railway. It may be reached from Endako by a motor road, which branches from the main Endako-Prince George highway at a point 3·5 miles east of Endako, for 3 miles southerly, and thence by a logging road westerly for 2 miles to a group of deserted camp buildings. From there a trail continues 6,700 feet westerly to the showings, which lie at an elevation of 3,450 feet. The workings consist of one adit, an inclined shaft, and several surface cuts, some of which never reached bedrock. When the writer visited the property in 1936, the showings were blanketed by 8 inches of snow, so that much of the following information was obtained from published reports.

GEOLOGY

The most important showings occur on two, east-west ridges 300 to 400 feet apart and at an elevation of 3,450 feet. These ridges are underlain by much fractured, pink, coarse-grained Topley granite, which outcrops only in a few places and is covered elsewhere by a thin mantle of soil, drift, and shattered rock. Molybdenite occurs as fine scales disseminated through the quartz veins and lenses, and to a lesser extent as impregnations in the granite close to the veins. In some places the molybdenite is weathered to the yellow oxide, molybdic ochre. Pyrite and hematite occur very sparsely in the deposit.

The veins strike from north 70 degrees east to south 80 degrees east and dip vertically to 60 degrees south. They range in width from 2 to 32 inches, and in length from a few feet to 8 feet, with the exception of the vein in the shaft, which has an indicated length of at least 75 feet.

Most commonly the veins have a ribboned structure caused by closely spaced films of very fine-grained molybdenite that parallel the walls of the vein.

The most important vein is the shaft vein on the Stella No. 2 claim. The incline has been sunk on a lenticular vein of quartz that strikes nearly east and dips 60 degrees south. The vein has a maximum width of 32 inches, and is reported to pinch to a few inches at the bottom of the shaft, which is 24 feet deep. A sample taken by Stevenson across the 32-inch width assayed 1·6 per cent molybdenite. In the hanging-wall the vein is bordered by a 2-foot zone of siliceous granite, which is badly broken by closely spaced, criss-crossing joints. Narrow, irregular stringers of quartz and molybdenite follow many of these joints. A 24-inch sample taken by

Stevenson across the siliceous granite zone assayed 0·7 per cent molybdenite. A much fractured granite on the hanging-wall side of this zone contains a little molybdenite across a width of 20 feet. Most of the mineral occurs in small lenses of quartz 1 to 4 inches wide.

At a distance of 50 feet from the shaft, down the south face of the ridge on the Stella No. 2 claim, a prospecting adit has been driven 30 feet, and cuts one molybdenite-bearing vein 12 inches wide. Another showing on this claim is 200 feet southeast of the shaft, and consists of three parallel, east-striking quartz stringers 2 to 6 inches wide.

On the Stella No. 3 claim, a vein about 6 inches wide has been exposed. Its strike is about the same as that of the others, and it dips north. Several other quartz-molybdenite lenses are known to occur on the property.

Scattered in the debris for 500 to 1,000 feet along each ridge are blocks of quartz that carry considerable molybdenite. These appear to be nearly in place, and range in size up to a maximum of 3-foot cubes. The soil in the vicinity of the showings is reported to assay as much as 1 per cent molybdenite.

Snowbird Group

The Snowbird group of five mineral claims joins the Stella group on the north. Several open-cuts have been made, but so far only barren quartz veins have been uncovered.

Savory Molybdenite

A little work has been done 3½ miles southwest of Savory on occurrences similar to those on the Stella group, but much less extensive.

Ling Lake Molybdenite

A. Ostrem has uncovered a pegmatite vein carrying flakes of molybdenite, 3 miles south of Ling Lake. The vein, which has an 8-inch centre of quartz and 2-inch borders of orthoclase, cuts coarse-grained, pink Topley granite.

TUNGSTEN DEPOSITS

Chuchi Tungsten Showing[1]

Reference: Armstrong, J. E., and Thurber, J. B.: Manson Creek Map-area, B.C.; Geol. Surv., Canada, Paper 45-9, p. 19 (1945).

The Chuchi tungsten showing lies 9 miles south of the east end of Chuchi Lake, at the contact of a small granitic stock with andesite of the Takla group. The deposit consists of scheelite, powellite, molybdenite, and chalcopyrite disseminated through a fracture zone at least 12 feet wide in silicified andesite at the granitic contact. Two grab samples assayed: 0·075 per cent WO_3; 0·015 per cent MoS_2; a trace of gold; and 0·70 ounce of silver a ton.

[1]Examined by J. B. Thurber, Geological Survey, 1944.

TIN-VANADIUM DEPOSITS

Tsitsutl Mountain Tin[1]

During the field season of 1942, J. Pataji, a prospector in the employ of the Geological Survey, discovered a vein of rhodonite on the north slope of Tsitsutl Mountain in the Middle River Range. Spectroscopic analyses indicated manganese, tin, vanadium, and cobalt, and as a result a group of claims was staked in the autumn of 1942. The Consolidated Mining and Smelting Company of Canada, Limited, optioned these claims in 1943, but dropped the option the same year when none of the above-mentioned metals was found in commercial quantities. The showing may be reached by a pack-trail about 20 miles long from Middle River.

The rhodonite vein occurs at an elevation of 5,500 feet in metamorphosed Cache Creek sedimentary rocks near the the contact of a quartz porphyry stock of possible Tertiary age. It strikes northwesterly, and has been uncovered at two places 24 feet apart. At the southeast end it is 18 inches wide and at the northwest end 24 inches wide.

The vein consists of about 70 per cent rhodonite, with 2 or 3 per cent arsenopyrite and a variable amount of calcite, garnet (spessartite), and ilmenite.

The Provincial Department of Mines assay office in Victoria reported on a sample of the rhodonite as follows: "Sample No. 1 contains manganese, tin, and zinc in amounts which suggest that the deposit may have commercial possibilities, particularly if samples can be obtained which contain a higher percentage of tin. No. 1 sample contained two- or three-tenths of one per cent tin." An assay on a specimen of rhodonite submitted to the Bureau of Mines, Ottawa, yielded 0·37 per cent zinc and 0·09 per cent tin. It was not assayed for manganese. H. V. Ellsworth of the Geological Survey examined specimens submitted to him and reported on them as follows: "Chemical tests showed the presence of appreciable amounts of manganese, cobalt, and vanadium, with a very little copper and hardly more than a trace of nickel. Further investigation showed that the source of the manganese, cobalt, and copper is the black material sparingly present in the rock. As the vanadium test was by fusion, I cannot say without further tests whether the vanadium is also in this material. The amount of cobalt is small, I should think no more than 0·5 per cent. However, as the cobalt, manganese, and copper can be readily extracted from the powdered rock by treatment with acid, it would perhaps be worth while to investigate the occurrence on the chance that it might be a very large deposit or that richer material might be found."

Specimens of the wall-rock submitted by the Consolidated Mining and Smelting Company of Canada, Limited, to the British Columbia Department of Mines indicated 0·65 per cent vanadium oxide.

The "black material" referred to by Ellsworth is probably ilmenite, and there can be little doubt that it is the source of some of the vanadium, cobalt, and nickel found in the assays.

[1]Examined by H. W. Little, Geological Survey, 1942.

MANGANESE DEPOSITS

Tead Property[1]

Reference: Gray, J. G.: East Half of Fort Fraser Map-area, B.C.; Geol. Surv., Canada, Paper 38-14, p. 6 (1938).

A deposit of manganese was discovered and staked in 1934 by Mr. B. Tead of Fort Fraser. It lies 1¼ miles due north of the second canyon on Nechako River below Fraser Lake, or 5½ miles northeast of Fort Fraser. The manganese occurs as pyrolusite and psilomelane, and lies in folded, cherty, Cache Creek quartzites that outcrop over an area of 4½ square miles in this region. These rocks trend northwest and normally dip steeply to the northeast.

On Tead's claim, the manganese oxides have been exposed in two places. A shaft has been sunk to a depth of 9 feet on the more important showings, and at the bottom of the shaft the oxides give way to sandy, yellow clay. The pyrolusite and psilomelane, with thin seams of sandy, yellow clay, form a small lens having a maximum width of 4 feet and a length of 10 feet. Manganese oxides are the only metallic minerals present. The purest material from the shaft is reported to assay 70 per cent manganese.

The second exposure of manganese is in a small open-cut 4 feet deep, 60 feet south of the shaft. At this point the rocks are mineralized across a width of 3½ feet, but the concentration of manganese is considerably less than in the shaft. Individual quartzite beds up to 2 inches in width have been almost completely replaced by manganese oxides.

Observations were made along the strike of the rocks north and south of the shaft and open-cut, but no evidence could be found to indicate that the two showings were continuous or that they extend any distance beyond where they are exposed. The rocks in the vicinity are stained on the surface with manganese oxide.

Godwin Property[1]

Reference: Gray, J. G.: East Half of the Fort Fraser Map-area, B.C.; Geol. Surv., Canada, Paper 38-14, pp. 6-7 (1938).

During the summer of 1936, Mr. Godwin, of Fort Fraser, and his associates discovered manganese oxides concentrated at a point about a mile northeast of Tead's property. The manganese oxides fill small, irregular fractures in Cache Creek rocks along the side and bottom of a small, steep-walled gully. The mineral concentration is greatest where there is the most fracturing, and in places small pockets contain ore of good grade. Trenching has been done in the vicinity of the gully, but has not indicated the presence of an orebody.

Indata Lake Manganese

Reference: Armstrong, J. E.: The Pinchi Lake Mercury Belt; Geol. Surv., Canada, Paper 42-11, p. 11 (1942)).

A vein of braunite (manganese silicate) and psilomelane (manganese oxide) occurs in Cache Creek limestone about 1 mile west of the south end of Indata Lake. The seam varies from a few inches to 2 feet wide and has been traced for 60 feet.

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[1]Examined by J. G. Gray, Geological Survey, 1936.

COAL DEPOSITS

Discovery Creek Coal

Coal occurs on Discovery Creek 4 miles from its mouth or 2 miles north of where the Aiken Lake tractor road crosses the creek. Discovery Creek, which flows southerly into Omineca River, may be reached by about 16 miles of tractor road, in reality a good pack-trail only, from Germansen Landing.

The coal is exposed on canyon faces along the creek. It occurs in what are probably upper Takla sedimentary strata, although no fossils were found in the coal measures and they are separated from fossiliferous Takla formations by drift. The section exposed in the vicinity of the coal measures is as follows:

	Thickness Feet
Conglomerate	20
Drift-covered	30
Coaly, sandy shale	20
Clay	3
Coaly, sandy shale with 6 inches of coal	4
Coaly sandstone	5
Coal	2·5
Interbedded shale and sandstone	1·5
Conglomerate	10
Shaly sandstone	5
Conglomerate	2·5

The beds strike approximately east and dip about 75 degrees south. The coal is very impure and lensy. The conglomerate is composed of boulders up to 1 foot across, although most are less than 6 inches in diameter, in a sandy matrix. They consist of black, cherty argillite, black argillite, greywacke, buff sandstone, grey quartzite, greenstone, and quartz. Most of them are lithologically similar to Cache Creek rocks.

About 500 feet upstream from the section just described more conglomerate is exposed, striking south 50 degrees east and dipping southwest 70 degrees. It contains 4 inches of poor coal.

Fraser Lake Coal[1]

References: Galloway, J. D.: Northeastern Mineral Survey District No. 2; Ann. Rept., Minister of Mines, B.C., 1921, p. 109. Gray, J. G.: East Half, Fort Fraser Map-area, B.C.; Geol. Surv., Canada, Paper 38-14, p. 14 (1938).

Several narrow coal seams are exposed in the large railroad cut at the east end of Fraser Lake. A company was organized in 1921 to investigate the occurrence, but after a little exploratory work the project was abandoned. The seams occur in Tertiary sedimentary beds overlain by basalt. They vary in thickness from 6 to 12 inches, but are mixed with much shale. The coal is of lignite rank, slacks very rapidly on exposure to the air, and is not suitable for commercial use; nor is the formation in which the coal occurs sufficiently extensive to contain any large deposit.

[1]Examined by J. G. Gray, Geological Survey, 1936.

ASBESTOS DEPOSITS

Mount Sydney Williams Asbestos

At the head of Van Decar Creek on the north slope of Mount Sydney Williams, a deposit of chrysotile asbestos occurs in a body of serpentinized peridotite. At the surface, a zone about 25 feet wide contains stringers of asbestos $\frac{1}{8}$ inch to $1\frac{1}{2}$ inches wide and from $\frac{1}{8}$ inch to 1 foot apart. Stringers $\frac{3}{4}$ inch or more wide may commonly be traced for about 25 feet. The asbestos consists of minute fibres arranged at an angle of 60 to 90 degrees to the walls, one of which at least is clearly defined. In a few stringers the fibres run from wall to wall without a break, but normally they meet at a parting, which in some stringers is parallel with the walls but commonly takes an irregular position. The whole zone contains approximately 5 per cent asbestos.

The fibre is brittle and of poor commercial quality, a feature due in part, no doubt, to injury sustained by surface alterations. The fact that it is brittle here does not mean that fibres elsewhere in the vicinity would also be brittle, as in the Eastern Townships of Quebec both types (brittle and flexible) are found in close proximity to one another.

Two miles northwest of the above showing, a deposit of tremolite asbestos was found. Three veins, each 4 to 10 inches wide and 200 feet apart, occur in a body of serpentinized peridotite. The veins could be traced for about 20 feet to where they disappeared beneath talus. The fibres in these veins extend from wall to wall, are very brittle, and are associated with some picrolite serpentine. This deposit is of doubtful commercial value, as it is small and the asbestos is of an inferior grade.

ASPHALTUM-PHOSPHATE DEPOSITS

François Lake

References: Ann. Rept., Minister of Mines, B.C., 1924, p. 101. Hanson, G: Prince Rupert to Burns Lake, B.C.; Geol. Surv., Canada, Sum. Rept. 1924, pt. A, p. 43 (1925). Poitevin, Eugene: A New Canadian Occurrence of Phosphorite from near François Lake, British Columbia; Geol. Surv., Canada, Contributions to Canadian Mineralogy, 1926, Bull. No. 46, pp. 2-12 (1927).

The writer examined a small deposit of asphaltum and phosphate minerals that occurs on the Collier Ranch 2 miles north of François Lake post office. At the time of examination nearly all the minerals had been removed for museum specimens, so much of the information contained herein is from the references cited.

The minerals are in a small, irregular vein, 4 to 12 inches wide, that outcrops at intervals for a distance of 100 feet. The vein lies almost horizontally and probably does not extend far in any direction. It consists of botryoidal phosphates associated with some asphaltum and andesite breccia.

The vein occurs in an amygdaloidal and vesicular andesitic flow, about 100 feet thick, that overlies sandstone and shale of Upper Eocene or Lower Oligocene age. It has the appearance of a layer between two lava flows rather than a filling of a fracture.

Nodules, from 2 to 8 inches in diameter, consist of botryoidal masses of phosphates in concentric layers, with an outer coating of black asphaltum, and, in most nodules, enclosing an angular fragment of andesite. Apparently the andesite had cooled and been fractured before the phosphates formed. In specimens from which the asphaltum had been removed, well-terminated quartz crystals, a few millimetres in length, encrust the outer surface of the phosphates.

According to Poitevin, the asphaltum is an asphaltic pyrobitumen, which he places in the narrow subclass of wurtzilite asphalt as well as in the broader class of native asphalt. The origin of these asphaltic pyrobitumens is usually ascribed to metamorphosis of petroleum.

The phosphates are collinsite and quercyite. Collinsite was first described by Poitevin, who named it after the late W. H. Collins, Director of the Geological Survey. Its properties, as determined by Poitevin, are as follows: composition, $P_2O_8Ca_2$ (MgFe).$2\frac{1}{2}H_2O$; triclinic; four cleavages; hardness, 3·5; specific gravity, 2·95; fusibility, 3; easily soluble in acids; colour, light brown, silky lustre; optically negative; 2V=80; $\alpha=1\cdot632$; $\beta=1\cdot642$; $\gamma=1\cdot657$.

Quercyite is a type of phosphate composed of an amorphous mineral and one or more crystalline minerals. It was identified by Poitevin on the basis that he found it to have the same chemical composition as the original material described by Lacroix under that name. He determined the following properties of quercyite: composition, $3CaO.P_2O_5.CaO.CO_2.H_2O$ $\frac{1}{2}CaF_2$; hardness, 4·5; specific gravity, 3·04. It is not fusible before the blow-pipe, but decrepitates violently, emitting a perceptible amount of volatile matter. $\alpha=1\cdot613$, $\beta=1\cdot626$, $\gamma=1\cdot629$. The chemical analysis suggests typical quercyite, which carries an appreciable amount of collophanite, whereas the microscopic examination indicates one definite mineral, which may be a new one.

PERLITE DEPOSITS

François Lake

Perlite is a rhyolitic volcanic glass containing absorbed water to the extent of 3 to 5 per cent by weight, but in such a way that it is not lost at temperatures below 105 degrees centigrade.

In 1876 G. M. Dawson of the Geological Survey reported that perlite outcropped at one locality on the north shore of François Lake (49, p. 86). The locality referred to by Dawson is about 2 miles east of the ferry landing. At the time of Dawson's survey perlite was of interest only as a petrographic curiosity, but in recent years it has become commercially valuable, being used after treatment as a light weight aggregate in wall plasters, gypsum board, acoustical tile, and cement products. In 1948 N. B. Davis, a mining engineer from Ottawa, became interested in the possibility of finding perlite in commercial quantity in Canada, and before proceeding to look for it in the field he undertook a thorough search of the publications of the Geological Survey. Noting Dawson's reference to perlite he went to François Lake, finding it in commercial quantity at the locality described.

Dawson described the perlite as follows: ". . . a rock, which might perhaps be called a spherulitic perlite, consisting of a yellowish feldspathic base, through which concretions like large and small shot are thickly scattered. The concretions are much harder than the matrix, and give it a curious appearance on weathering." In 1936 the writer noted the occurrence of spherulitic rhyolites in several places along and near François Lake and mapped them along with other acidic volcanic rocks of Eocene or Oligence age (pp. 73, 74).

N. B. Davis has supplied the writer with the following information on the deposit. The perlite at the lake shore is in the form of a smoky, glassy, lava flow 30 feet thick and having a dip of approximately 30 degrees to the west. On the weathered surface it has a grey, opaque appearance. It is overlain by a greyish white rhyolite and underlain by a dark brown rhyolite. Following the dip upwards from the lake shore it outcrops in a gully 200 feet above the lake and 1,000 feet back from the shore.

Analyses show it to contain a potash-soda ratio of approximately 1 to 1, low lime and magnesia, and as a result a very low melting point. Analyses of two samples from François Lake are as follows:

—	No. 1, at lake shore	No. 2, 1,000 feet from lake shore
	Per cent	Per cent
Silica	73·32	73·00
Alumina	11·91	12·34
Iron oxide	1·05	1·08
Lime	0·57	0·48
Magnesia	0·31	0·20
Soda	4·42	4·56
Potash	4·48	4·38
Moisture at 105° C.	0·23	0·14
Moisture above 105° C.	3·86	3·79
	100·15	100·07

When perlite is crushed to about minus 10 mesh plus 100 mesh it can be expanded in suitable heating chambers to about seven times its original volume.

CHAPTER VII

BIBLIOGRAPHY

(1) Alcock, F. J.: Zinc and Lead Deposits of Canada; Geol. Surv., Canada, Econ. Geol. Ser. No. 8, pp. 296-297 (1930).

(2) Anderson, R. A.: Fusulinids of the Granite Falls Limestone and Their Stratigraphic Significance; Research Studies of State College of Washington, vol. 9, No. 3, pp. 189-202 (1941).

(3) Armstrong, J. E.: West Half of the Fort Fraser Map-area, B.C.; Geol. Surv., Canada, Paper 37-13 (1937).

(4)———Northwest Quarter of the Fort Fraser Map-area, B.C.; Geol. Surv., Canada, Paper 38-10 (1938).

(5)———The Ultrabasic Rocks of the Fort Fraser Map-area (West Half), Northern British Columbia; Trans. Roy. Soc., Canada, 3rd ser., vol. XXXIV, sec. IV, pp. 21-32 (1940).

(6)———Fort Fraser (West Half), British Columbia; Geol. Surv., Canada, Map 631A (1941).

(7)———Geology of the Pinchi Lake Mercury Belt, British Columbia; Trans. Can. Inst. Min. Met., vol. XLV, pp. 311-323 (1942).

(8)———The Pinchi Lake Mercury Belt, British Columbia; Geol. Surv., Canada, Paper 42-11 (1942).

(9)———Northern Part of the Pinchi Lake Mercury Belt, British Columbia; Geol. Surv., Canada, Paper 44-5 (1944).

(10)———Smithers, British Columbia; Geol. Surv., Canada, Paper 44-23 (1944).

(11)———Hazelton, British Columbia; Geol. Surv., Canada, Paper 44-24 (1944).

(12)———Takla, British Columbia; Geol. Surv., Canada, Paper 45-6 (1945).

(13)———Geology and Mineral Resources of Northern British Columbia West of the Rocky Mountains; Geol. Surv., Canada, G.S. Bull. No. 5 (1946).

(14)———Takla, British Columbia; Geol. Surv., Canada, Map 844A (1946).

(15)———Aiken Lake, British Columbia; Geol. Surv., Canada, Paper 46-10 (1946).

(16) Armstrong, J. E., and Gray, J. G.; Fort Fraser (East Half), British Columbia; Geol. Surv., Canada, Map 630A (1941).

(17) Armstrong, J. E., and Roots, E. F.: Aiken Lake Map-area; Geol. Surv., Canada, Paper 48-5 (1948).

(18) Armstrong, J. E., and Thurber, J. B.: Manson Creek Map-area, British Columbia; Geol. Surv., Canada, Paper 45-9 (1945).

(19)———Prospecting Possibilities in Part of the Omineca Mining Division, British Columbia; Can. Min. Jour., vol. 66, No. 4, pp. 217-222 (1945).

(20) Armstrong, J. E., Thurber, J. B., and Lang, A. H.: Manson Creek, British Columbia; Geol. Surv., Canada, Map 876A (1946).

(21) Armstrong, J. E., and Tipper, H. W.: Glacial Geology of North-Central British Columbia; Am. Jour. Sci., vol. 246, May 1948, pp. 283-310.

(22) Armstrong, J. E., Tipper, H. W., and Hoadley, J. W.: Carp Lake, British Columbia; Geol. Surv., Canada, Paper 47-13 (1947).

(23) Bancroft, J. A.: Geology of the Coast and Islands between the Strait of Georgia and Queen Charlotte Sound, B.C.; Geol. Surv., Canada, Mem. 23 (1913).

(24) Bostock, H. S.: Geology and Mineral Deposits of Nickel Plate Mountain, Hedley, British Columbia; Geol. Surv., Canada, Sum. Rept. 1929, pt. A, pp. 198-252 (1930).

(25)———Hedley; Geol. Surv., Canada, Map 568A (1940).

(26) Bowen, N. L.: The Origin of Ultrabasic and Related Rocks; Am. Jour. Sci., vol. XXIII, pp. 89-108 (1927).

(27)———Evolution of Igneous Rocks; Princeton Univ. Press (1928).

(28)———Magmas; Bull. Geol. Soc. Am., vol. 58, pp. 263-280 (1947).

(29) Cairnes, C. E.: Coquihalla Area, British Columbia; Geol. Surv., Canada, Mem. 139 (1924).

(30)———Slocan Mining Camp, British Columbia; Geol. Surv., Canada, Mem. 173 (1934).

(31)———Geology and Mineral Deposits of Bridge River Mining Camp, British Columbia; Geol. Surv., Canada, Mem. 213 (1937).
(32)———The Shuswap Rocks of Southern British Columbia; Sixth Pac. Sci. Cong. 1939, Proc., vol. 1, pp. 259-272 (1940).
(33)———Kettle River Map-area, British Columbia; Geol. Surv., Canada, Map 538A (1940).
(34)———Geology and Mineral Deposits of Tyaughton Lake Map-area, British Columbia; Geol. Surv., Canada, Paper 43-15 (1943).
(35)———Hope Map-area, British Columbia; Geol. Surv., Canada, Map 737A (1944).
(36) Cairnes, D. D.: Preliminary Memoir on the Lewes and Nordenskiöld Rivers Coal District, Yukon Territory; Geol. Surv., Canada; Mem. 5 (1910).
(37) ———Portions of Atlin District, British Columbia; Geol. Surv., Canada, Mem. 37 (1913).
(38) Camsell, C.: Geology and Mineral Deposits, Tulameen District, B.C.; Geol. Surv., Canada, Mem. 26 (1913).
(39)———Exploration in the Northern Interior of British Columbia; Geol. Surv., Canada, Sum. Rept. 1915, pp. 70-75 (1916).
(40) Clapp, C. H.: Southern Vancouver Island; Geol. Surv., Canada, Mem. 13 (1912).
(41)———Geology of the Nanaimo Map-area; Geol. Surv., Canada, Mem. 51 (1914).
(42) Cockfield, W. E.: Nicola Map-area, British Columbia; Geol. Surv., Canada, Map 886A (1947).
(43) Cooke, H. C.: Thetford, Disraeli, and Eastern Half of Warwick Map-areas, Quebec; Geol. Surv., Canada, Mem. 211 (1937).
(44) Crockford, M. B. B., and Warren, P. S.: The Cache Creek Series of British Columbia; Trans. Roy. Soc., Canada. vol. 29, sec. IV, pp. 149-162 (1935).
(45) Daly, R. A.: North American Cordillera, Forty-Ninth Parallel; Geol. Surv., Canada, Mem. 38, pt. 1 (1912).
(46)———A Geological Reconnaissance between Golden and Kamloops, B.C., along the Canadian Pacific Railway; Geol. Surv., Canada, Mem. 68 (1915).
(47) Davis, E. F.: The Radiolarian Cherts of the Franciscan Group; Pub. Univ. of Calif. Dept. of Geol. (1918).
(48) Dawson, G. M.: Report on Explorations in British Columbia, chiefly in the Basins of the Blackwater, Salmon and Nechacco Rivers, and on François Lake; Geol. Surv., Canada, Rept. of Prog. 1876-77, pt. III, pp. 17-94 (1878).
(49)———General Note on the Mines and Minerals of Economic Value of British Columbia, with a list of Localities; Geol. Surv., Canada, Rept. of Prog. 1876-77, pt. V, pp. 103-149 (1878).
(50)———Report on an Exploration in the Southern Portion of British Columbia; Geol. Surv., Canada, Rept. of Prog. 1877-78, pt. IV (1879).
(51)———On a New Species of Loftusia from British Columbia; Jour. Geol. Soc., vol. 35, pt. 1, pp. 69-75 (1879).
(52)———Report on an Exploration from Port Simpson on the Pacific Coast to Edmonton on the Saskatchewan, Embracing a Portion of the Northern Part of British Columbia and the Peace River Country; Geol. Surv., Canada, Rept. of Prog. 1879-80, pt. B, pp. 1-142 (1881).
(53)———The Mineral Wealth of British Columbia; Geol. Surv., Canada, Ann. Rept. (new series) 1887-88, vol. III, pt. R, pp. 6-163 (1889).
(54)———On the later Physiographical Geology of the Rocky Mountain Region in Canada, with special Reference to Changes in Elevation and History of the Glacial Period; Proc. and Trans., Roy. Soc., Canada, vol. 8 (1890).
(55)———Report on the area of the Kamloops Map-sheet, British Columbia; Geol. Surv., Canada, Ann. Rept. 1894, vol. VII, pt. B (new series) (1896).
(56) Dolmage, V.: Finlay River District, B.C.; Geol. Surv., Canada, Sum. Rept. 1927, pt. A, pp. 19-41 (1928).
(57) Dunbar, C. O.: Neoschwagerina in the Permian Faunas of British Columbia; Trans. Roy. Soc., Canada, 3rd ser., vol. 26, sec. IV, pp. 45-50 (1933).
(58) Flint, R. F.: Glacial Geology and the Glacial Epoch; John Wiley and Sons (1947).
(59) Galloway, J. D.: Northeastern District No. 2; Ann. Rept., Minister of Mines, B.C., 1921, pp. G107-G110 (1922).
(60)———Northeastern District No. 2; Ann. Rept., Minister of Mines, B.C., 1924, pp. B101-B113 (1925).
(61)———Placer Mining in British Columbia; Dept. of Mines, B.C., Bull. No. 2, 1930, pp. 44-49 (1930).

(62)———Placer Mining in British Columbia; Dept. of Mines, B.C., Bull. No. 1, 1931, pp. 70-81 (1931).
(63) Gray, J. G.: East Half, Fort Fraser Map-area, British Columbia; Geol. Surv., Canada, Paper 38-14 (1938).
(64) Gunning, H. C.: Buttle Lake Map-area, Vancouver Island; Geol. Surv., Canada, Sum. Rept. 1930, pt. A, pp. 56-78 (1931).
(65)———Woss Lake, East Half, British Columbia; Geol. Surv., Canada, Paper 38-4 (1938).
(66) Haapala, Paavo; On Serpentine Rocks in Northern Karelia; Bull. de la Comm. Geol. de Finlande, No. 114 (1937).
(67) Hanson, G.: Prince Rupert to Burns Lake; Geol. Surv., Canada, Sum. Rept. 1924, pt. A, pp. 38-43 (1925).
(68)———Bear River and Stewart Map-areas, Cassiar District, B.C.; Geol. Surv., Canada, Mem. 159 (1929).
(69) Hanson, G., and McNaughton, D. A.: Eagle-McDame Area, British Columbia; Geol. Surv., Canada, Mem. 194 (1936).
(70) Hanson, G., and Phemister, T. C.: Topley Map-area, B.C.; Geol. Surv., Canada, Sum. Rept. 1928, pt. A, pp. 50-77 (1929).
(71) Hedley, M. S., and Holland, S. S.: Reconnaissance in the Area of the Turnagain and Upper Kechika Rivers, Northern British Columbia; Dept. of Mines, British Columbia, Bull. No. 12 (1941).
(72) Hess, H. H.: Hydrothermal Metamorphism of an Ultrabasic Intrusive at Schuyler, Va.; Am. Jour. Sci., 5th ser., vol. 126, No. 154, pp. 377-408 (1933).
(73)———The Problem of Serpentinization and the Origin of Certain Chrysotile Asbestos, Talc, and Soapstone Deposits; Econ. Geol., vol. 28, No. 7, pp. 634-637 (1933).
(74)———The Problem of Serpentinization; Econ. Geol., vol. 30, No. 3, pp. 320-325 (1935).
(75)———A Primary Peridotite Magma; Am. Jour. Sci., 5th ser., vol. 35, No. 209, pp. 321-344 (1938).
(76) Holland, S. S.: Lode-gold Deposits, Northeastern British Columbia and Cariboo and Hobson Creek Areas; Dept. of Mines, British Columbia, Bull. No. 20, pt. VI (1944).
(77) James, H. T.: Britannia Beach Map-area, British Columbia; Geol. Surv., Canada, Mem. 158 (1929).
(78) Johnston, W. A.: The Pleistocene of Cariboo and Cassiar Districts, British Columbia, Canada; Trans. Roy. Soc., Canada, vol. XX, sec. IV, pp. 137-147 (1926).
(79)———Geology of Fraser River Delta Map-area; Geol. Surv., Canada, Mem. 135 (1923).
(80) Johnston, W. A., and Uglow, W. L.: Placer and Vein Gold Deposits of Barkerville, Cariboo District, British Columbia; Geol. Surv., Canada, Mem. 149 (1926).
(81) Kelly, C. C., and Farstad, L.; Soil Survey of the Prince George Area, British Columbia; B.C. Dept. of Agric. in co-op. with Dom. Dept. of Agric., Rept. No. 2 B.C. Soil Survey (1946).
(82) Kerr, F. A.: Dease Lake Area, Cassiar District, B.C.; Geol. Surv., Canada, Sum. Rept. 1925, pt. A, pp. 75-154 (1926).
(83)———The Character of the Composite Coast Range Batholith in Northern British Columbia and Southeastern Alaska; Trans. Roy. Soc., Canada, 4th ser., vol. 26, pp. 305-316 (1932).
(84)———Glaciation in Northern British Columbia; Trans. Roy. Soc., Canada, 4th ser., vol. 28, sec. N, pp. 17-31 (1934).
(85)———Prospecting in the Northern Part of the Omineca District; The Miner, vol. 7, No. 2, Feb. 1934, pp. 52-54 (1934).
(86)———Manson River and Slate Creek Placer Deposits, Omineca District, B.C.; Geol. Surv., Canada, Sum. Rept. 1933, pt. A, pp. 9-29 (1934).
(87)———Mineral Resources Along the Canadian National Railway Between Prince Rupert and Prince George, British Columbia; Geol. Surv., Canada, Paper 36-20 (1936).
(88)———Quaternary Glaciation in the Coast Range, Northern British Columbia and Alaska; Jour. Geol., vol. 44, pp. 681-700 (1936).

(89)———The Physiography of the Cordilleran Region of Northern British Columbia and Adjacent Areas; Trans. Roy. Soc., Canada, 4th ser., vol. 30, pt. N, pp. 137-154 (1936).
(90)———Taku River, Cassiar District, British Columbia; Geol. Surv., Canada, Paper 45-30, prelim. map (1945).
(91) Lang, A. H.: Keithley Creek Map-area, Cariboo District, British Columbia; Geol. Surv., Canada, Paper 38-16 (1938).
(92)———Manson Creek, British Columbia; Geol. Surv., Canada, Paper 41-5 (1941).
(93)———Houston Map-area, British Columbia; Geol. Surv., Canada, Map 671A (1942).
(94)———Manson Creek, British Columbia; Geol. Surv., Canada, Paper 42-2 (1942).
(95) Lay, D. (1926-1939): Northeastern Mineral Survey District No. 2; Ann. Repts., Minister of Mines, B.C.: 1925, pp. A142-A145; 1926, pp. A144-A146; 1927, pp. C150-C153, C155-C160; 1928, pp. C177-C182; 1929, pp. C181-C182, C185-C187; 1930, pp. A143-A149; 1931, pp. A75-A76, A80; 1933, pp. A99-A100; 1934, pp. C13-C15; 1936, pp. C3-C16; 1938, pp. C3-C14.
(96)———Fraser River Tertiary Drainage-History in Relation to Placer Gold Deposits (Part II); Dept. of Mines, B.C., Bull. No. 11 (1941).
(97) Little, H. W.: The Ultrabasic and Associated Rocks of the Middle River Range, British Columbia; Doctorate Thesis, University of Toronto (1947).
(98) Lord, C. S.: McConnell Creek Map-area, British Columbia; Geol. Surv., Canada, Paper 46-6 (1946).
(99)———McConnell Creek Map-area, Cassiar District, British Columbia; Geol. Surv., Canada, Mem. 251 (1949).
(100) MacKenzie, J. D.: Geology of Graham Island, British Columbia; Geol. Surv., Canada, Mem. 88 (1916).
(101) Malloch, G. S.: A Reconnaissance on the Upper Fraser River between Fort George and Tête Jaune Cache; Geol. Surv., Canada, Sum. Rept. 1909, pp. 123-130 (1910).
(102) McConnell, R. G.: Report on an Exploration of the Finlay and Omineca Rivers; Geol. Surv., Canada, Ann. Rept. (new series) 1894, vol. VII, pt. C (1896).
(103)———Texada Island, B.C.; Geol. Surv., Canada, Mem. 58 (1914).
(104) McLellan, R. D.: Geology of the San Juan Islands; Univ. of Wash., Pubs. in Geology, vol. 2 (1927).
(105) Morice, A. G.: The History of the Northern Interior of British Columbia, 1660-1880; William Briggs, Toronto, Ont. (1904).
(106) Rice, H. M. A.: Nelson Map-area, East Half, British Columbia; Geol. Surv., Canada, Mem. 228 (1941).
(107)———Salmon Arm, British Columbia; Geol. Surv., Canada, Paper 46-7 (1946).
(108)———Princeton Map-area, British Columbia; Geol. Surv., Canada, Map 888A (1947).
(109) Ross, C. P.: Some Concepts on the Geology of Quicksilver Deposits in the United States; Econ. Geol., vol. 37, No. 6, pp. 439-465 (1942).
(110) Schuette, C. N.: The Geology of Quicksilver Ore Deposits; Calif. Jour. Mines and Geology, vol. 33, No. 1, pp. 38-50 (1937).
(111) Schofield, S. J.: The Geological Record of the Cordillera in Canada; Trans. Roy. Soc., Canada, 3rd. ser., vol. 17, sec. IV, pp. 79-103 (1923).
(112) Schofield, S. J., and Hanson, G.: Geology and Ore Deposits of Salmon River District, British Columbia; Geol. Surv., Canada, Mem. 132 (1922).
(113) Selwyn, A. R. C.: Journal and Report of Preliminary Explorations in British Columbia; Geol. Surv., Canada, Rept. of Prog. 1871-72, pp. 16-72 (1872).
(114)———Report on Exploration in British Columbia in 1875; Geol. Surv., Canada, Rept. of Prog. 1875-76, pp. 29-87 (1877).
(115) Stevenson, J. S.: Molybdenum Deposits of British Columbia; Dept. of Mines, B.C., Bull. No. 9, pp. 11-16 (1940).
(116)———Mercury Deposits of British Columbia; Dept. of Mines, B.C., Bull. No. 5, pp. 18-32 (1940).
(117) Thompson, M. L., and Wheeler, H. E.: Permian Fusulinids from British Columbia, Washington, and Oregon; Jour. Pal., vol. 16, No. 6, pp. 700-711 (1942).
(118) Thompson, M. L., Wheeler, H. E., and Hazzard, J. C.: Permian Fusulinids of California; Geol. Soc. Am., Mem. 17 (1946).

(119) Walker, J. F.: Geology and Mineral Deposits of Salmo Map-area, British Columbia; Geol. Surv., Canada, Mem. 172 (1934).

(120) Walker, J. F., and Cockfield, W. E.: Geology and Placer Deposits of Quesnel Forks Area, Cariboo District, British Columbia; Geol. Surv., Canada, Sum. Rept. 1932, pt. AI, pp. 76-144 (1933).

(121) Watson, K. Dep., and Mathews, W. H.: The Tuya-Teslin area, North British Columbia; B.C. Dept. Mines, Bull. 19 (1944).

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